TRANSACTIONS

of

the Wisconsin Academy of Sciences, Arts & Letters

Volume 80
1992

Transactions

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Transactions welcomes articles that explore features of the State of Wisconsin and its people. Articles written by Wisconsin authors on topics other than Wisconsin sciences, arts, and letters are also occasionally published.

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Transactions is a publication of the Wisconsin Academy of Sciences, Arts, and Letters, 1922 University Avenue, Madison, Wisconsin 53705-4099.

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Contents

The Ordeal of Being a Test Case: 1
In Quest of the Right to Practice Medicine in Wisconsin
Hania W. Ris

In 1949 the State Board of Medical Examiners denied a young, foreign-born medical doctor a license to practice medicine in Wisconsin, or even an opportunity to sit for the examination for the license. The fact that she was licensed to practice in two other states and had been on the faculty of two noted medical schools made no difference. But Hania Ris was different, and her account of her successful challenge of the Board's decision and procedure will intrigue scholars and general readers alike.

1988 Drought Impacts Among Wisconsin Dairy Farmers 21
John A. Cross

When a severe drought occurs in an area unused to this hazard, how are the farmers affected? John Cross divided the state into nine districts and examined specific drought-related problems. He also examined the question of why some farmers went out of business during this period. The conclusions contain surprises.

Distribution, Abundance, Larval Habitats, and Phenology 35
of Spring *Aedes* Mosquitoes in Wisconsin (Diptera: Culicidae)
Jeffrey W. Gilardi and William L. Hilsenhoff

The spring mosquitoes that are a nuisance in wooded areas of Wisconsin belong to the twenty-three species of *Aedes*. This paper summarizes previous studies in Wisconsin and examines new larval and adult *Aedes* collected in nine representative areas of the state. Two species were collected for the first time in Wisconsin.

Symbolism in the Cave of Montesinos 51
James T. Abraham

In a famous episode in *Don Quixote* the knight enters the legendary cave of Montesinos, where he has a strange dream about the enchanted inhabitants of the cave. This paper uses psychoanalytical theory to discuss the symbolism of the cave and the dream and what they reveal about the psyche of Quixote and perhaps Cervantes himself.

The Distribution of Franklin's Ground Squirrel in Wisconsin and Illinois 57
Timothy L. Lewis and Orrin J. Rongstad

Eastern populations of Franklin's ground squirrel have declined in the past two decades. The authors studied the range of this squirrel to determine whether a reduction in range accompanied the population decline.

That Eyes May Be Free: Mary North Allen Talks with *Transactions* Editor Carl Haywood 63

What started as conversation about photography between *Transactions* editor Carl Haywood and photographer Mary North Allen ended up covering much more. Readers will glimpse the complexity, intellect, and vision of one of Wisconsin's premier photographers.

The Photography of Mary North Allen 72

Community Response to Floodplain Relocation in Soldiers Grove, Wisconsin 87
Graham A. Tobin

The citizens' response to frequent flooding in Soldiers Grove was to relocate the downtown and several residential properties. This project is often cited as a successful example of multipurpose, community-sponsored planning. Although the relocation was effective in preventing most flooding, Graham Tobin raises questions about the social impact.

Depth, Substrate, and Turbidity Relationships of Some Wisconsin Lake Plants 97
Stanley A. Nichols

In his continuing studies of Wisconsin's lake plants, the author examines their tolerance for varying growing conditions. The information gathered will be useful in managing the state's lake plant resources.

Poetry 119

Poetry editor Bruce Taylor has selected poems from some of Wisconsin's well-known poets and some of our newer, most promising poets for inclusion in this volume.

First Report of Natural Bridges in Eastern Wisconsin 139
Richard A. Paull

Although natural bridges are well-known features in the Driftless Area of Wisconsin and adjacent states, none of these delicate landforms is documented in the recently glaciated region of Wisconsin. This paper describes natural bridges in two localities along the Silurian escarpment in eastern Wisconsin.

Live Capture Methods of Sympatric Species of Flying Squirrel 149
Thomas C. Engel, Michael J. Lemke, and Neil F. Payne

Standard methods of capturing other tree squirrels are not as effective for flying squirrels. The objective of this study was to determine the trapping success for sympatric species of flying squirrels relative to tree species, trap type, and the height of the trap in the tree.

Range Extension of Northern Flying Squirrels 153
Thomas C. Engel, Michael J. Lemke, and Neil F. Payne

The authors examine the range habitats of northern and southern flying squirrels. Their evidence extends the known range of the northern squirrels farther south into Portage County.

The Modern Spiritual Condition and the Ancient Wisdom of the *I Ching* 155
Claire E. Matthews

The *I Ching* or *Book of Changes* is an ancient Chinese manual of divination and wisdom. It preceded Confucius, who wrote commentaries on it. Later Carl Jung asserted his belief in its predictions. Claire Matthews presents a case for using the *I Ching* as a means of access to our own society's beliefs.

Distribution, Abundance, and Diversity of Mollusks (Bivalvia: Unionidae) from the Lower Chippewa River, Wisconsin 163
Terry Balding

For four summers the author collected mussels from the Chippewa River between Eau Claire and the Mississippi. Because freshwater mussels are a good ecological indicator of water quality, these raw data will be especially valuable as we monitor our environment during the next twenty-five to fifty years.

From the Editor

It was five years ago that I became editor of *Transactions*. It hardly seems that long, but my commitment of five years as editor is fulfilled, and this volume is my last. This has been a period of change in the activities of the Wisconsin Academy and in all its publications. But the great tradition of the Academy in providing a mechanism for collecting and preserving the creative, intellectual life of our state, and presenting that information to our citizens, has continued. It is a history in which the Academy justifiably takes pride, and it has been an honor to be associated, even for this short period, in the continuing process.

The changes in *Transactions* during the past five years were built on the groundwork established by previous editors, particularly Kathryn and Philip Whitford, whose dedication and work kept the journal alive. During my years as editor there have been a number of changes. Poetry and photography have been added as regular sections. In addition to regular issues, three special issues have been published: a history of the limnology program at UW–Madison (*Breaking New Waters*), a poetry anthology (*Wisconsin Poetry*), and a book on treaty rights (*Chippewa Treaty Rights*). There has also been started an occasional series that will result in at least two other publications. I am happy with these accomplishments, but they are not those of a single editor. Patricia Duyfhuizen and Bruce Taylor deserve much credit, and it is my pleasure to recognize their contributions and to thank them on behalf of all who have enjoyed the results of their work.

Bruce built the poetry section from an idea into one of the exciting places to sample the poetry of Wisconsin authors each year. It was Bruce who solicited and chose the poetry and then wrote the introduction to the special issue entitled *Wisconsin Poetry* (Vol. 79, No. 2), which has been extraordinarily well received. Bruce's poetry readings at the annual convention and around the state have done much to establish the Wisconsin Academy as one of the leaders in encouraging Wisconsin poets.

Our former Production Editor, Patricia Duyfhuizen, enabled us to expand our services to authors by increasing the level of professional scrutiny of the journal. Her advice, professional judgment, and dedication added immensely to the journal. And her work with student interns brought a level of professionalism that had not been available to previous editors.

When Patricia was unable to continue as Production Editor for this last volume under my editorship, *Transactions* was fortunate to find Jan Haywood to produce the current issue. Only those involved in publishing realize the seemingly unlimited number of mistakes possible in the process. The professional scrutiny and advice Jan has provided have continued the high quality of production our readers have come to expect. I am grateful to her for picking up the work on short notice and for doing so with good humor.

Virtually every piece of paper, telephone call, or message associated with *Transactions* for the past five years has been handled by Jan Kroll, a member of the Arts and Sciences staff at UW–Eau Claire. Perhaps only she and I realize her role in the success of this journal. She would, of course, dismiss it with "it's my job," but I know better and acknowledge her contributions with sincere gratitude.

The current volume of *Transactions* contains some absorbing articles. The lead essay is an examination of why a physician, licensed to practice medicine in two states and on the staff of two noted medical schools, would be denied a medical license by reciprocity or even an opportunity to sit for the examination to practice medicine in Wisconsin. Hania Ris' story is captivating. There are also the poetry section, an interview with Dresen Award–winning photographer Mary North Allen, along with a selection of her photographs, and articles on subjects as diverse as the impact of the 1988 drought on Wisconsin dairy farmers, lake plants, natural land bridges, spring mosquitoes, and ancient Chinese wisdom. And there is even more for the reader to discover.

Bill Urbrock becomes the new editor with the publication of this volume. All further correspondence, articles, and proposals should be sent to him at the address on the inside front cover.

Carl N. Haywood
Editor, 1987–1992

The Ordeal of Being a Test Case: In Quest of the Right to Practice Medicine in Wisconsin

Hania W. Ris

When my husband Hans Ris accepted an appointment as Associate Professor in the Department of Zoology at the University of Wisconsin–Madison in 1948, I was intrigued. That was the year *Life* magazine (6 September) ran its famous cover story identifying Madison, Wisconsin, as America's best place to live. Although I had an interesting and prestigious position as a pediatrician in the Cornell Medical School Department of Pediatrics, I looked forward to the move with anticipation. After diligently studying the *Life* article, I became even more enthusiastic. I learned that Madison, with a population of 80,000, had three lovely lakes, that the streets were lined with elms and maples, that its many parks were maintained with a very ample city appropriation. Its "intelligent and alert populace" had a literacy rate of 98%, and 17% had attended college. The schools had an excellent reputation, pertinent information for a couple expecting their first child in March 1949. Babysitters were easily available because of a large student population. The city had many cultural groups. The university supported several "artists in residence" including a painter as well as musicians. Drama was provided by the Lunts, who lived nearby and usually opened their new plays in Madison. The article even referred to the importance of the Madison League of Women Voters and its influence on civic decisions.

At the time of the University of Wisconsin offer we were living in New York City. My husband, a biologist, had been working in the field of cytology (structure, function, and pathology of the cell) at the Rockefeller Institute for Medical Research. I was working with Dr. May Wilson at the Children's Cardiac Clinic of New York Hospital as a Fellow in Pediatrics as well as teaching on the staff of Cornell University Medical School.


Photograph by Michael Kienith

Hania Ris today

Hania W. Ris, M.D., has been a member of the Department of Pediatrics, UW–Madison Medical School, for thirty-five years. She is a peace activist and champion of women's rights, reproductive rights, the prevention of teenage pregnancy, quality day care, and national health insurance. She writes newspaper and magazine features, as well as scientific papers. An abstract painter, she has had several one-woman exhibits.

Before my departure I had to certify my medical documents. To my amazement and amusement, I was warned by the physician in charge that I was moving to a "socialist state"!

In order to learn something about Wisconsin state politics, I read about "Fighting Bob" La Follette and his Progressive Party, which lost to the Democrats after the Second World War. Although La Follette had been dead for twenty years, his ideas of social reforms, including care of the unemployed and the elderly, had left permanent marks on Wisconsin. It was the first state to pass a workmen's compensation law, in 1932, and to prohibit child labor. Its law became a prototype for other states. La Follette also promoted the idea that the state government should use the university as its first resource and the university in turn should exert its influence on the entire state.

All this information added to our conviction that Madison would be an interesting and stimulating place to live and to raise a family. My husband was especially urged to accept the position by a friend and colleague, Charles Leonard Huskins, Professor of Botany at the university. A Canadian, he had been Professor of Botany at McGill University in Montreal until he moved to Madison in 1945. He and his wife Margaret and their three children befriended us and offered their home when we arrived in Madison in June 1949 with our three-month-old son, Christopher. The Huskins lived in a spacious older house on Vilas Avenue near the Vilas Zoo. We stayed with them a fortnight, and we could not have had a warmer and more gracious welcome. The Huskins remained our friends and wise advisors until their deaths in 1953.

In July 1949 we moved to the University Houses, built by the Wisconsin Alumni Association the previous year for faculty and families, and later given to the state. A generous gesture, but the architecture left something to be desired. Imagine a kitchen with one drawer and minimal counter space! As an ardent admirer of Frank Lloyd Wright, a native son of Wisconsin, I could never understand why the "Williamsburg" style of architecture had been chosen. But taking into account the prevailing housing shortage, we were grateful.

After getting settled I was ready to continue my pediatric work. In preparation for the move to Wisconsin, I had had the application form for medical licensing in Wisconsin completed and certified by the Board of Medical Examiners of Maryland in June 1949 for the purpose of licensure by reciprocity. I had been granted a license to practice medicine by the Maryland Board of Examiners in 1941, after passing on the first attempt what was considered a very rigorous examination, and after I had worked and studied in this country for only one and a half years. I had obtained my New York license to practice medicine in 1942 through reciprocity—a standing agreement between two state boards of medical examiners. Wisconsin and Maryland also had a reciprocity agreement, and I expected to obtain a Wisconsin license in the same way. I was therefore totally unprepared for what followed.

I submitted my duly certified application and my curriculum vitae to the Wisconsin State Board of Medical Examiners (hereafter

The new Dr. Ris, circa 1937

referred to as the Board). My vitae outlined my experience:

> 1937—Graduation with Doctor of Medicine degree from the Medical School of the University of Zurich, Switzerland.
>
> 1937–39—Assistant in Pediatrics at the Children's Hospital of the University of Zurich.
>
> 1939–40—Year's internship in Baltimore.
>
> 1940–41 and 1943–49—A total of seven years at the Johns Hopkins Pediatrics Department, including one year of work with Dr. Helen Taussig, cardiologist, the originator of the world-famous operation which corrected the defects in the hearts of "blue babies."
>
> 1942–43—Resident in Pediatrics, Children's Hospital, and Instructor of Pediatrics, University of Cincinnati Medical School.
>
> 1948–49—Assistant Pediatrician, New York Hospital, and Fellow in Pediatrics, Cornell University Medical School.

All of these positions required teaching of medical students. My experience included clinical work in syphilis and diabetes, and I had conducted several Well Baby Clinics for the Baltimore City Health Department. I also included letters of recommendation from prominent physicians with whom I had worked.

Round I

To my amazement, on 15 July 1949 all of my credentials were returned to me with the following arbitrary denial: "The Board of Medical Examiners of the State of Wisconsin is not licensing foreign graduates at the present time. It is hoped that within the not too distant future we will be able to get reports on the foreign schools which might enable us to license graduates of some of them."

To my further dismay, I learned that the State Board, at a meeting held in 1937, had adopted a policy of refusing any qualifying examinations for graduates of foreign universities, with the exception of graduates from approved Canadian schools. This ruling coincided with the immigration to the United States of a number of physicians threatened by racial and political persecution in Germany and other parts of Europe. Critics suggested that the Board's 1937 ruling was self-serving, aimed at eliminating competition and creating a monopoly under the guise of protecting the health of Wisconsin citizens. Other states had passed similar measures.

Some in government questioned the Board's action. I learned that in 1948, Wisconsin Representative Ruth Doyle had proposed a bill requiring the Board to provide any applicant denied the right to take the examination with written notification of the reasons for denial. It also provided that the Board be subjected to judicial review of its decisions in the same manner as other state boards and commissions. The purpose was to provide the applicant with an orderly procedure through the courts. It was blocked by the successful lobbying of both the Board and the Wisconsin State Medical Society (hereafter referred to as the Medical Society).

There is indisputable evidence that the Board was making exceptions to the 1937 ruling, however. In reviewing the minutes of the Board in 1989, I discovered, to my surprise, that it had allowed Dr. Harry Leeb, an American-born graduate of the University of Bern Medical School, Switzerland, to obtain his license. Although denied that right on his first appearance before the Board on 11 January 1938, Dr. Leeb was granted licensure at the Board's subsequent meeting on 27 June–1 July 1938, during which Dr. Leeb's case was discussed "at length" by Mr. Resh of the attorney general's office. A resolution was adopted unanimously that since Dr. Leeb had received his medical education at the University of Bern prior to the adoption of the 1937 ruling, and because of the "mistaken assumption based upon correspondence with the Board that the Board would recognize such a school," Dr. Leeb was permitted to take the examination. This resolution also stipulated that the permission would not extend to other graduates of foreign medical schools.

Additionally, the *Milwaukee Journal,* 5 December 1948, reported that an American-born, Swiss-trained physician had been licensed within the previous three years by the

Board, after passing an examination given especially for him.

Ironically, there was a shortage of physicians at the time in Wisconsin, as frequently reported in the *Milwaukee Journal* and other newspapers. Indeed, prior to our move to Wisconsin, I had been contacted in January 1949 by Dr. Amy Hunter, Director of Maternal and Child Health, Wisconsin Department of Health, who offered me a position contingent on my obtaining a license. She had written me after hearing from Dr. Leona Baumgartner, Director of the New York City Health Department, that I would be available for employment.

I responded to the notification of my rejection by the State Board with a letter dated 8 August 1949, pointing out that I had graduated from the University of Zurich in 1937, *before the war,* that the medical school was considered one of the best on the European continent, that I had had ten years of experience in the United States teaching in three leading medical schools, including Johns Hopkins, and that I was certified in 1944 by the American Board of Pediatrics, a national professional organization that certifies competence in the field.

The Board did not keep me long in suspense. In its 12 August 1949 reply, it stated: "It is a definite policy of the Board . . . at this time to grant no licensure to graduates of foreign schools other than Canadian." Following the second refusal, I asked for the privilege of appearing before the Board at its 10 January 1950 meeting. It met regularly only twice a year, in January and July. Permission was granted.

My presentation was factual and legalistic. I emphasized that the University of Zurich, from which I had graduated, was comparable to the American schools with which I was familiar: Johns Hopkins, Cincinnati, and Cornell. All my records, European and American, were available for review. I pointed out that the Board had, in 1925, licensed Dr. Karl F. Schlaepfer, a graduate of the University of Zurich Medical School and an American citizen. (I had become an American citizen in 1944.) Dr. Schlaepfer was practicing at that time in Milwaukee, and his licensure showed that the Board had already accepted Zurich as a reputable school.

In addition, I stated that I had been advised that my credentials could be submitted by the proper authorities for evaluation by Dr. Helen Dwight Reid, Chief, European Section, Division of International Educational Relations, Federal Security Agency, Office of Education, Washington, D.C. Dr. Reid had also advised me as follows: "The fact that you have been accepted for postgraduate training in American institutions and licensed in two other states should be helpful in obtaining recognition, if the State can make any exception to its general regulation." I informed the Board that I had been considered for a position with the State of Wisconsin Board of Health which called for a person with my pediatric training. I added to my previously submitted letters of recommendation one from Dr. Helen Taussig, the world-renowned child cardiologist with whom I had worked at Johns Hopkins from 1940–41, testifying to my character and professional competence and the reputability of the University of Zurich Medical School.

To my continuing dismay and growing sense of unreality, I was once again denied the right to be admitted for examination for licensure to practice medicine in Wisconsin. The three and a half nonchalant lines in the Board's minutes hardly reflect the impact that this decision had on my life: "Dr. Hania Ris, graduate of the University of Zurich, Switzerland, in 1937, appeared. She answered questions asked by the Board members relative to her professional education and history, following which she was informed that her application was temporarily, at least, refused. Dr. Ris left the meeting."

Inner politics of Board and Medical Society

In the course of preparing for my 10 January 1950 meeting with the Board, I had been advised by a respected senior pediatrician, Dr. Horace Tenney of Madison, to consult with two officers of the Medical Society. I found Mr. C. H. Crownhart, attorney and secretary of the Society, and Mr. Tom Doran, Society employee, both courteous and willing to advise. It was my impression that they were sympathetic to my plight and interested in my obtaining the license. As members of a professional organization dealing with the public, they appeared to be concerned about the image the Medical Society was projecting.

By contrast, the State Board was a legal body; its eight members (seven physicians and one osteopath) were appointed by the governor for a period of four years. I learned that Dr. C. A. Dawson, the powerful secretary of the Board and a homeopath, had run for the office of lieutenant governor. When Dawson was defeated, Governor Goodland appointed him to serve as secretary of the Board of Medical Examiners. The remaining seven members of the Board were appointed at Dr. Dawson's suggestion.

All the members of the Board, with the exception of the osteopath, were members of the Medical Society and active in its affairs. Since the Board and the Medical Society always presented a united front before the legislature in matters such as the Medical Practice Act, in the eyes of the public they were not differentiated. It is germane to note that the Medical Society had always been a conservative body, cautious in endorsing new ideas.

A letter from the past sheds light

In my recent search—some thirty-four years after my original request for licensure—for documentation indicating covert deliberation regarding my case, I found nothing other than my original application in my file or under various headings such as "Foreign Graduates," at the Historical Society Archives or in the office of the State Board. My written testimony presented to the Board, various documents submitted, the Board's correspondence with the Council of Medical Education of the American Medical Association (AMA) and with the University of Zurich Medical School, and the correspondence between my attorney and the Board cannot be found even at the office of the Board. But my file at the Medical Society (not available to the public) contained, among other informative documents, a letter by C. H. Crownhart, secretary of the Medical Society. This letter was sent to me in 1984 by courtesy of Mr. Earl Thayer, at the time secretary of the Medical Society. A consultation in 1989 with the attorney general's office revealed that it should have been part of the public documents of the State Board. It was either suppressed or overlooked, to my detriment.

Crownhart's letter of 23 November 1949 was addressed to Dr. H. H. Christofferson of Colby, Wisconsin, a member of the Board, a member of the Council of the Medical Society, and its president-elect. It was written six weeks before my 10 January 1950 hearing before the Board. Three and one-half pages, single-spaced, the letter was a legal attack on the Board's position against licensing foreign graduates in general, and its refusal to license me in particular.

Mr. Crownhart pointed out that he did not recall any instance in which there was a divergence of opinion between the Medical Society and the Board. When, in 1948, "Assemblywoman Ruth Doyle, along with other legislators interested in the problem of the foreign graduate, brought in a proposal to amend the law to make it easier for these people to qualify, the State Board and the State Society saw eye to eye on the effect of that bill. As a matter of fact the Secretary of the State Board and the Secretary of the State Medical Society appeared at the hearing and explained the problem." Both secretaries must have been very persuasive in defending the status quo; the bill did not pass.

However, Mr. Crownhart also pointed out in his letter that before the Board adopted the 1937 ruling against admitting graduates of foreign medical schools to examinations, the graduates of such schools could apply and their credentials would be verified. As a result, there were many foreign-educated physicians practicing in Wisconsin. Then Mr. Crownhart cited my case, emphasizing that

I had graduated from the University of Zurich in 1937 before the war, that I had had ten years of postgraduate training in this country in addition to teaching in three medical schools, and that I was accredited as a specialist by the American Board of Pediatrics and was a member of national medical societies. Furthermore, he noted that I was being considered for appointment in one of the state agencies on the basis of my credentials and recommendations.

"It is my feeling," Mr. Crownhart continued in his letter,

> that the odds are about even that this particular situation may ultimately result in wide public knowledge of her problem. . . . It seems to me that the public would feel that this woman was entitled to the examination. As a matter of fact they would feel that even if her school of graduation should have been inferior to American schools in the type of training offered, that her subsequent training as an intern and as a resident, and her acceptance on the teaching faculty of several schools would have overcome whatever deficiencies she might have had from her academic training.

Mr. Crownhart continued:

> I have read the Medical Practice Act many times. As I have told the Board I, as an attorney, fail to find in it authority under which the Board may adopt any blanket rule. The burden of proof is, undoubtedly, upon the applicant. I would not question that for one minute, but unless the Board considers the application and the applicant's qualifications and gives that individual an opportunity to fulfill the burden that is upon her or him, it seems to me that the Board has failed to follow the spirit or the letter of the law.

Unaware of this letter as I was for forty years, I could not have known at the time what an advocate I had—a competent attorney in an official position at the Medical Society who was cognizant of the political scene.

My case gains notoriety, or "Can't Examiners Examine?"

Indeed my 10 January 1950 appearance before the Board generated a great deal of publicity, accurately reported, and all of it critical of the Board. Europeans traditionally eschew publicity; I was crushed! I was to grow more accustomed to and more grateful for the press as my case was championed over the following year on the editorial pages of the *Capital Times*, the *Wisconsin State Journal*, the *Milwaukee Journal*, and the *Milwaukee Sentinel*. Headlines were often bluntly critical of the establishment: "The State Board of Medical Examiners Continues to Operate a Closed Shop," "Medical Monopoly Still Upheld," "The State Board of Medical Examiners Continues Its Stubborn Policy," and "Can't Examiners Examine?" It is hard to remember any other such instance when these four newspapers, with their otherwise divergent opinions, acted in such unison.

During this period of publicity the Board cited cases in defense of its policies. Another physician, Dr. Ralph Smith, a graduate of Edinburg Medical School and formerly a professor in Canada, was denied a license to practice in Wisconsin. He was later found to be a drug addict.

Another case was that of a Dr. Dubin. In 1930 he had presented himself as a graduate *cum laude* of Maximilian University in Wurzberg, Germany. He was permitted to write the examination eight times, with failure each time. It was later discovered that he had never actually graduated from Maximilian University and that by a special dispensation he had been permitted to take an examination and present a doctoral thesis.

I was confronted with this case of forgery when I was referred by some prominent Wisconsin physicians to an administrator associated with the Wisconsin State Laboratory of Hygiene in the hope that he might intervene in my behalf. It was devastating for me to have this prominent administrator insinuate that my own veracity might be questionable.

In a similarly distressing encounter, a highly placed medical educator told me that academic medicine would be closed to me forever because of the publicity, that one does

They Denied Licenses To Physicians

Members of the state board of medical examiners, which has denied Wisconsin licenses to a number of foreign-educated physicians, are shown here as photographed at a recent meeting. Left to right, they are: Front row—Dr. C. A. Dawson, River Falls, secretary; Dr. E. W. Miller, Milwaukee; Dr. H. H. Christofferson, Colby; and Dr. F. C. Murphy, Eau Claire; rear row—Dr. J. W. Smith, Milwaukee, board president; Dr. A. F. Ruffio, Kenosha; Dr. Alvin G. Koehler, Oshkosh; and Dr. J. W. Prentice, Ashland.

From the Capital Times, *17 February 1950. Courtesy of the State Historical Society of Wisconsin.*

not go public with such complaints in the United States and especially in Wisconsin. I informed him that I myself had been perturbed by the publicity and explained that I had no control over it. He indicated doubt about this, and ironically an editorial critical of the Board appeared in the *Capital Times* the next evening.

I was not surprised that support for my plight was not coming from physicians in private practice, but this prejudiced treatment from physicians in academic medicine was unsettling. I was told that Dr. Amy Hunter, who had offered me the state position on the basis of my credentials, tried to intervene and for her efforts was rebuffed by her superior in the State Health Department. I grew desperate.

A confidential source within the Medical Society staff who began advising me about this time informed me that several physicians, members of the Medical Society, had gone to the Governor and asked him to intervene. But Dr. Dawson, secretary of the Board, had anticipated their move and presented my case to the Governor in a fashion that made him believe the Board would be breaking the law by granting me a license, an interpretation that distorted the law. I was also told that several physicians hoped I would take my case to court. But none of them had the courage to protest the restrictive policy openly.

The biggest blow to my morale was a press release issued by the Medical Society unconditionally endorsing the Board's policy against licensing foreign graduates. In response to criticism by the media, the Medical Society, on 18 February 1950, issued a news release commending the State Board for acting in "good faith in the matter of reviewing qualifications of those educated in foreign countries." It complimented the State Board for being a moving factor in initiating a study of foreign medical schools by the AMA. At that time, thirty-eight schools had been approved, but Swiss schools had not as yet been evaluated. To counteract any suspicion of prejudice, the Medical Society added that the "Board consists of highly respected individuals, many of whose immediate forebears come from foreign countries."

If the State Board had done any "fence-building," of which it was accused, the news release continued, it had done so only "to protect the health of the people of this state . . . through the legislative and judicial processes." Yet this was the very process that had been described privately by Mr. Crownhart, the Medical Society's attorney, as a failure "to follow either the spirit or the letter of the law."

But the communique opened one door, namely, that the Board would "*continue* [emphasis added] in the future to receive applications from graduates of schools not as yet formally qualified." (Yet I had been denied this right when I had appeared before the Board in January 1950, only five weeks earlier.) The applicant would have the burden of proof to demonstrate that "he was trained under the same general conditions as are required of those attending the medical school of the University of Wisconsin."

This statement gave me some hope. Ironically, during that time many European and American medical academics were critical of the quality of institutions such as the University of Wisconsin Medical School. For instance, at Wisconsin the Department of Pediatrics was part of Internal Medicine and did not become independent until 1957. Similarly, the Department of Psychiatry did not become independent from the Department of Neurology until 1956. In contrast, the Department of Pediatrics of my medical school at the University of Zurich was headed by the world-renowned Professor Guido Fanconi. I had also been privileged to study under Professor W. R. Hess, Director of the Physiological Institute of the University of Zurich, who received the 1949 Nobel Prize in Medicine and whose work greatly enhanced physiologic and psychiatric thinking throughout the world. American physicians used to come to Zurich for postgraduate training and to work with such other famous department chairpersons as Professor Guido Miecher (dermatologist and venerealogist), Professor Hans Rudolf Schinz (roentgenologist), and Professor Otto Naegeli (hematologist). The departments of pediatrics in which I had trained in this country for ten years prior to seeking the Wisconsin medical license were also independent; the Department of Pediatrics at Johns Hopkins had been independent since 1914.

One other hopeful note in the Medical Society release was its endorsement of a proposal that the Board consider "such additional training as an applicant may have acquired since coming to this country." (The Board never acted on this endorsement in my case.)

In response to this press release, the *Milwaukee Journal* printed an editorial entitled "Whitewash for Doctors' Fence" on 20 February 1950. It attacked the policy of the Board in protecting its selfish professional interests: "Doctors of unquestioned ability and repute have been arbitrarily barred from examination in Wisconsin by a policy of the Board which was never imposed by the legislature, courts or public. Communities and institutions in need of those doctors have been denied them—by the Board and by nobody else."

Yet Mr. Crownhart, secretary of the Medical Society, defended the Board's actions in a letter responding to this editorial which was published in the *Milwaukee Journal* and reproduced in the *Wisconsin Medical Journal,* March 1950. It seems impossible to reconcile this public statement with his letter sent to Dr. Christofferson in November 1949.

A steady source of encouragement

While battling what seemed a no-win situation, I contacted my former teacher and mentor, Dr. Edwards A. Park, recently retired and former chairman of the Department of Pediatrics of the Johns Hopkins Medical School. Though others helped, I am convinced that his tireless one and one-half year interventions with the AMA were crucial to my obtaining my license to practice medicine in Wisconsin.

Dr. Park, a nationally and internationally renowned pediatrician, became my steady source of encouragement. At age seventy-one he took it upon himself to fight my battle with youthful vigor. He wanted to know every detail of my dealings with the Board. I wrote lengthy letters to him to which he always responded promptly, frequently after consultation with individuals who he thought might help. This correspondence became a useful reference for documenting my case (and was recently accepted by the Johns Hopkins Medical Archives to broaden the profile of Dr. Park).

In his comforting letter to me after the Board's second refusal to recognize my application, Dr. Park wrote on 25 January 1950: "May I say that I was incensed at your treatment by the examining Board in Wisconsin. . . . I am sure you will receive your license, the examining Board will not dare refuse it after their exposure by the press. They will probably wait long enough to save their face." Dr. Park wrote me on 8 March 1950: "The whole affair makes me ashamed of my country and particularly ashamed of the medical profession." In a letter dated 22 March 1950 he informed me: "*Time* [magazine] has written that they will accept a letter from me on your case in Wisconsin." At the urging of Dr. Donald G. Anderson, secretary of the Council to the House of Delegates of the AMA, Dr. Park postponed sending this letter in order to allow Dr. Anderson to intervene in my behalf. On 11 April 1950 Dr. Park wrote to me again noting his request to Dr. Anderson and further explained, "I hesitate to take too open a part for the reason that I am anathema, having headed the protest against organized medicine. By some I am regarded as having communistic leanings."

Round II

In response to the Board's statement that it would accept new evidence from the applicants as to the reputability of their medical schools, I resubmitted my credentials on 5 April 1950 to Dr. Dawson, secretary of the Board. It included the enumeration of every lecture, every course and laboratory exercise, certified by the Zurich Medical School. I also sent a money order for fifty dollars to cover the reciprocity fee with Maryland, for which, as I was told by Dr. Dawson, I was to be eligible, once the reputability of the Zurich Medical School was established. I also asked him to consider my application at the forthcoming meeting on 19 April 1950.

I accompanied my application with a letter from Dr. Marion Sulzberger, an American-born U.S. citizen, a world-renowned dermatologist and allergist who was at the time professor and chairman of the Department of Dermatology and Syphilology at the Post-Graduate Medical School, New York University. He had graduated from the University of Zurich Medical School in 1926, just eleven years prior to my graduation. He had written several textbooks and more than a hundred articles and had contributed greatly to his fields of expertise. I could not have had a better testimony to the reputability of the University of Zurich Medical School. Indeed, some of my teachers were the same as those of Dr. Sulzberger. At the time I was a student, Dr. Sulzberger had returned to Zurich for postgraduate training. How could the Board ignore these facts?

Providing another written testimony was Professor Karl Meyer, a Swiss native and

Professor of Experimental Pathology at the University of California Medical Center–San Francisco.

My application, dated 5 April, was acknowledged by Dr. Dawson on 10 April 1950. His letter stated that although the one-day meeting of the Board on 19 April would have a heavy agenda, "I shall present your application in its entirety to the Board at that time." When I did not hear from Dr. Dawson within the following two weeks, I wrote him on 6 May to inquire about the action the Board had taken in my case. Dr. Dawson replied on 10 May saying that the matter of foreign graduates had not been considered. He added, "The fact of the matter is that no change in the policy regarding foreign graduates is possible at this time inasmuch as no addition has been made to the list of the approved schools issued by the AMA." This statement reversed the Board's alleged public change of policy that it would honor the right of the applicant to prove the reputability of the school of graduation. It became clear to me that the Board's intention was not only to stall but to deny me the license permanently.

Dr. Dawson also mentioned in his letter that the next meeting of the Board would be held in Milwaukee on 11–13 July 1950; if I wished to appear I should let the Board know, and they would notify me as to place and time of my appearance. On 17 May I wrote Dr. Dawson to confirm my interest, adding: "Undoubtedly, you have by now reviewed the standing of the Medical School of the University of Zurich in the prewar period [on the basis of documents I submitted]. . . . If there is any further evidence that you would like to have presented to prove that . . . the University of Zurich Medical School . . . provided training equivalent to the Medical School of the University of Wisconsin, I will make every effort to obtain such evidence."

I had been warned by my confidential source at the Medical Society that since Dr. Dawson withheld information and communication from other members of the Board, I should distribute a copy of each communication to every Board member. This was still a world without photocopy machines. If I did not advance my medical career during this interim, I certainly did advance my secretarial and paralegal skills.

The warning was not idle. I did not hear from Dr. Dawson until I wrote him again on 3 July, this time sending a copy to each member of the Board. The time constraint was nerve-wracking and intimidating. Had I missed the semiannual meeting, I would have had to wait another six months. Dr. Dawson responded with a letter dated 5 July 1950 giving me an appointment for 12 July at 2 P.M. at the Pfister Hotel in Milwaukee. There was no response to my inquiry as to whether the Board wished to have additional documents to prove the reputability of my medical school.

Approval of Swiss medical schools

By 1949, the year my fight for licensure began, the problem of licensing foreign graduates had assumed national and political dimensions. A report by the Council on Medical Education and Hospitals to the delegates of the AMA on 6 June 1949 recognized these dimensions: "In the past fifteen years more than 10,000 foreign trained physicians have migrated to the United States and it may be expected in the years ahead that at least 1,000 foreign medical graduates will be coming to this country annually." The Council recognized that the state licensure boards had no way by which to evaluate foreign medical schools, and consequently some excluded all foreign medical graduates, while others admitted all foreign graduates to their examination for licensure. (In 1949 only twelve state medical examining boards admitted foreign graduates to examinations for licensure.) The Council proposed that the House of Delegates empower it to evaluate foreign medical schools, which it did.

In preparing to appear before the Board I learned that on 24 June 1950 the Council on Medical Education and Hospitals of the AMA approved five Swiss medical schools, including that of the University of Zurich. Again my confidential source told me that Dr. Dawson would try to suppress this information in order to prevent me from obtaining the license and to justify his original refusal.

I contacted Dr. Donald G. Anderson, Secretary of the AMA Council, and asked him to notify Dr. Dawson about the Council's decision. Dr. Anderson kindly obliged on 8 July by letter. On 7 July I received a wire from the Council of the AMA informing me of the Board's notification. Dr. Park's correspondence with Dr. Anderson on my behalf had paved the way to this unprecedented cooperation.

But there was a problem lurking in the Council decision. In its evaluation of the Swiss medical schools, the Council of the AMA had reviewed their status *after 1940,* at which time a new degree was introduced for non-Swiss citizens: *Akademische Zeugnis* or the *Certificat d'Etudes Médicales* (Certificate of Medical Studies). The only degree available to non-Swiss citizens like myself at the time of my graduation in 1937 had been the M.D. degree, which the Council of the AMA did not approve. The Council also approved a second degree, the Swiss Federal Diploma, for which only Swiss citizens were eligible. At the time of my study in Switzerland I was a Polish citizen, although I later became Swiss through marriage.

The AMA recommendation specified that the requirement for both approved degrees was at least eight semesters of study. I was in my tenth semester when I passed the examination for my M.D. degree and thereafter completed three additional semesters of postgraduate study. I took the same courses and lectures required of the Swiss students eligible for the Federal Diploma.

Immediately following my degree in 1937 I was granted a position as Assistant in Pediatrics at the Children's Hospital of the University of Zurich, working under the renowned pediatrician, Professor Guido Fanconi. I performed the same duties as my Swiss colleagues holding the Federal Diploma. I held this position for two years before coming to the United States in March 1939, and I had a statement from Professor Fanconi attesting to these facts. In spite of this evidence of my training, I surmised that the Board would use the AMA evaluation as a weapon against me. I did not err.

On the advice of my confidential source, I engaged a lawyer. My fortunate choice was James Doyle, who later became a federal judge and was married to Assemblywoman Ruth Doyle.

The date of my appearance before the Board on 12 July to defend my case was fast approaching. On 8 July an important letter was written by Dr. Kenneth McDonough, Associate Professor of Pediatrics, University of Wisconsin, to Dr. J. W. Smith, president of the Board:

> Dr. Ris has made rounds and attended staff meetings at the Wisconsin General Hospital in Madison during the past year. I have been impressed with her intelligence, her knowledge of medicine in general, and her understanding of pediatrics, the field in which she is particularly interested and for which she has excellent training. We also have the opportunity to know her professionally and believe that she will make a fine practitioner. She will render a valuable service to the community and state.

On the crucial day, I drove with my attorney to Milwaukee. I did not plan to have him appear with me at the meeting unless there was nothing further to lose. Dr. Park feared that having me represented by a lawyer might antagonize the Board. Members of the press representing major Wisconsin newspapers were also present.

I spoke and supplemented my oral presentation with two concise written statements. One addressed itself to the reputability of the University of Zurich Medical School and the other to the approval of the Swiss medical schools in general. I specifically explained why I could not possess the Certificate of Medical Studies. It seemed so simple. This particular degree was introduced in 1940, and I had graduated in 1937.

The Board at first denied knowledge of the AMA's approval of the University of Zurich Medical School. When I showed them the wire from the AMA stating that the Board had been notified, its response was that the AMA's letter was not official, because the approval had not yet appeared in print in the *Journal of the American Medical Association.*

Though some members of the Board asked questions during my forty-five–minute appearance, the attorney for the Board, John W. Davison, questioned me most often. After the futile battle, I asked to be represented by my counsel. Davison agreed. Though the presence of James Doyle appeared not to antagonize the Board, it simply continued to stall. My attorney suggested that the Board should send my credentials for evaluation to the Council on Medical Education and Hospitals of the AMA and that the Board afford me opportunity to present my case personally to the Council. The Board appeared to accept this suggestion. When my attorney asked for a written confirmation of this agreement at the conclusion of the meeting, the Board's attorney stated that this request might anger the Board. There is no evidence that the Board ever sent my credentials to the AMA. This is no surprise since my attorney told me after the meeting that he had never seen such a disorganized state body as the Board of Medical Examiners. Most of the time, he observed, they did not seem to know what they were discussing.

The following are the "postmortem" minutes of the 11–13 July 1950 Board meeting as they relate to my case:

> The Dr. Hania Ris case was reviewed briefly by Mr. Davison, having been announced by the President as the first order of business. Dr. Ris had previously requested permission to attend the meeting, and she was admitted to it at this time. Mr. Spaulding of the *Milwaukee Journal,* and a reporter from the *Milwaukee Sentinel,* were also present. Dr. Ris made a short statement to the Board and answered several questions put to her by the members. Dr. Ris then requested that her attorney, Mr. James Doyle, Madison, be admitted to the meeting, and her request was granted. Mr. Doyle attempted to clarify Dr. Ris' position on the matter of recognition of Swiss schools, particularly the University of Zurich, and the matter of her diploma.
>
> The Board did not take any formal action on the matter of Dr. Ris' application, and indicated to her that nothing further could be done until a decision had been reached by the Council on Medical Education of the American Medical Association. Dr. Ris and Mr. Doyle left the meeting.

Following the meeting, Dr. J. W. Smith, Board president, spoke to me privately. He said he had tried to convince the members of the Board to grant me a license but they would not listen. He apparently wanted me to reassure him that he had been fair to me.

The Council on Medical Education and Hospitals of the AMA and the Executive Council of the Association of American Medical Colleges officially reported their approval of the University of Zurich Medical School on 14 July 1950, three days after my appearance at the Board meeting. My attorney, James Doyle, sent a written reminder on 25 July to Davison, the Board's attorney (as well as precautionary copies to all members of the Board), to send my credentials for evaluation to the AMA Council as per agreement. In the letter Mr. Doyle pointed out that the language of the AMA report of 14 July was almost identical to the language of the letter from Dr. Anderson of the AMA Council that had been in the possession of the Board at the 11 July meeting.

It was not certain that the Board would honor its agreement even after an article appeared in the *Milwaukee Journal* on 30 July 1950 stating that the Board intended to send my records to the Director of the Swiss Health Bureau for evaluation. The article added that the Board might consider it necessary to send my records to the AMA Council for interpretation after the Swiss director's reply had been received. In order to avoid further unnecessary delays, my attorney requested, in a 31 July 1950 letter, that the Board send my credentials simultaneously to Switzerland and the AMA Council. Mr. Doyle also asked to receive a copy of the letter the Board was to send to the Swiss Health Bureau and requested to be informed which of my records had been sent. There was no response to Mr.

Doyle's letters of 25 July and 31 July until he sent a written reminder on 7 August.

The Board's attorney responded on 9 August: "The case of Dr. Ris has been brought to the attention of the Director of the Swiss Health Bureau. To date none of the records has been sent to Switzerland. It may be necessary to do so in the future. At the present time I am not able to furnish you with a copy of the Swiss correspondence." We were at a loss to understand what objection there could be to our request to see the Board's correspondence with the Director of the Swiss Health Bureau. The disconcerting explanation was that the Board had not included my records, even though the basic controversy centered around the duration and character of my study.

The delays continued. On 17 November the Board requested a copy of the regulation sent me by the Dean of the University of Zurich Medical School, defining the eligibility for obtaining the Certificate of Medical Studies introduced in December 1940. "If I find it necessary to obtain this information from Switzerland," warned the Board's attorney, "it may take several weeks." I had, however, already submitted this six-page, single-spaced document in the original and with a translation at my 12 July 1950 appearance before the Board!

I learned not to underestimate the Board's creative stalling tactics. This same letter from the Board requested certified copies of my marriage license. Records from 20 November 1950 show that the Board's attorney requested the marriage certificate "in order to definitely establish the identity of the applicant." This request was made sixteen months after my original application for the license and after my two appearances before the Board! I found it insulting. My attorney was appalled.

The 1950 document spelling out why the Board needed my marriage license epitomized the Board's tortuous rationale against licensing me. It referred to a new course introduced by the Swiss Medical Schools in 1940 leading to a Certificate of Medical Studies, equivalent to the course leading to the Federal Diploma. Noted the Board's attorney: "Dr. Ris would have been eligible for this course had she been attending school at the time. The fact that she was not able to enroll in this course for the reason that it was not offered at the time can in no way be held against her, but neither can the Board be criticized because of her inability to do so." However ridiculous the reasons, it became clear that the Board hoped above all that its rationalizations would preserve its credibility with the public over this issue.

The reply of the Swiss Director of Health to questions submitted by the Board was necessarily general in nature, because the Board had not included my individual records despite our urging. Later, after I had sent the records myself and the Swiss director had reviewed them, he concluded that I had taken more courses, lectures, and clinics than required for admission to the examination for the degree of Doctor of Medicine; that, in fact, I had received the same training as Swiss citizens then received; and that I would have been admitted to examination for the Certificate of Medical Studies, if such examination had existed at the time.

Round III

News of the Board's refusal on 11 July to grant me the right to take an examination for licensure reached Dr. Park at his vacation cottage in Canada. In a letter dated 13 August this dignified and gentle human being expressed his profound outrage: "I am incensed over the action of the WI. Licensing B'd. . . . I have again written to Dr. Anderson [secretary of the AMA Council]. If this does no good I shall consider getting Dr. Weech and Levine to unite with me in some publicity. [Dr. Weech was chairperson of Pediatrics, University of Cincinnati Medical School, where I worked in 1942–43. Dr. Levine was chairperson of the Department of Pediatrics, Cornell University Medical School, where I worked in 1948–49.] I shall not give up. . . . I am filled with shame that you should be treated so."

My other champions, the Wisconsin press, meanwhile continued to advocate my licensure. In fact, the source of our information about the Board's contemplated action was often newspaper articles. An article of 6 October 1950 indicated that the Board said I would be notified of the meeting and permitted to present my case to the Board on 10 January 1951. I was glad to read this, since I had not been personally notified.

A *Capital Times* editorial on 9 October again defended my case: "Dr. Ris is a distinguished member of the profession . . . but here in Wisconsin the political fuddy-duddies who dominate the Board of Medical Examiners and whose competence is far inferior to that of Dr. Ris are allowed to sit in judgment of her case." Referring to the critical shortage of physicians, the editorial urged the passage of a bill introduced by U.S. Representative Andrew Biemiller of Wisconsin to provide federal aid to medical schools, a bill which it accused the AMA lobby of "knifing in Congress." This federal aid was deemed imperative by deans of the major medical schools "to insure even the barest minimum of doctors for future civilian and military needs," noted the *Capital Times*. President Harry Truman had termed the bill "the most vital health legislation before Congress" ("Washington Merry-Go-Round," syndicated column by Jack Anderson and Fred Blumenthal, *Capital Times*, 18 August 1950).

At the end of November I received a long letter from Dr. Park outlining a strategy to enlist the aid of Dr. Anderson of the AMA Council. Dr. Park intended to visit Dr. Anderson in Chicago and to "be guided of course by his advice, provided his advice appears to me in your interest and wise." He planned to seek Dr. Anderson's consent to send my credentials to the AMA Council for adjudication, and mailed him records of my educational qualifications and reports of the Board's action. In late December Dr. Park counseled me to write Dr. Anderson directly asking for the adjudication before the AMA Council, if the licensing Board would be willing to refer my records. Warning me not to mention his name, Dr. Park suggested that I try to secure a wise physician-advisor in Madison to guide me step by step so as to avoid political mistakes. No one was willing to take an open stand in what had become a controversial issue.

In another letter from Dr. Park on 27 December, just two weeks prior to the Board's meeting on 10 January 1951, he indicated that he had written Dr. Anderson "that if the Board did not grant your request at their approaching meeting, . . . I could no longer restrain myself. . . . I should not be surprised if Dr. Anderson exerted some pressure on the Board, for he said to me over the telephone, 'Let's wait and see what they do on January 10.' . . . He expressed a belief that they would pass 'Hania' on that date . . . if they fail to pass Hania on that date, he [Dr. Anderson] would recommend some action."

Dr. Park also wrote of the possibility of seeking publicity to expose the Board's refusal to license me, perhaps consulting the *New York Times* or the *Washington Post*. In his strategy letter of 29 November, he had written: "It might be possible to create enough sentiment in Wisconsin so that the Board would be forced out." I do not think Dr. Park realized the political power of the Board.

Meanwhile, the communications between my attorney, James Doyle, and the Board's attorney, John W. Davison, accelerated. Between 12 July and 31 October there were seven such exchanges. In November they exchanged ten letters; in December thirteen, in addition to a number of telephone calls. There were always delays in Davison's answers to my attorney's letters, in spite of the fact that we were critically short of time. For instance, the letters from the Swiss authorities evaluating my credentials dated 15 August and addressed to the Board were not forwarded to us until 15 November, in spite of several earlier requests. And at this late juncture the Board asked me to translate the documents!

Another example of delay and harassment: On 29 November my attorney requested that the record of my two semesters (1942–43) in the Graduate School of the University of

Cincinnati, which was in the possession of the Board, should become part of my official record. Although the "record book" with entries constituted an "official transcript" as the term is commonly used, the Board's attorney now insisted that we obtain a certified copy of the official transcript from the university. We complied.

On 12 December my attorney reminded Davison that the Board now possessed two documents verifying that my studies at the University of Zurich had included more semesters and more courses than required for the Certificate of Medical Studies, which was now approved by the AMA Council. (These were from Dean F. Schwarz, of the University of Zurich Medical School, and from Dr. P. Vollenweider, Director of the Federal Health Department.) My courses of study would have entitled me to examination for the Certificate of Medical Studies had such a certificate been offered at the time I completed my studies. Furthermore, Mr. Doyle reminded the Board that I had taken the same medical courses as those taken by Swiss citizens then entitled to examination for the Federal license.

Mr. Doyle wrote: "I assume that any previous uncertainty has now been dispelled by the AMA Council's formal approval of the Medical School of the University of Zurich, coupled with the unequivocally favorable evaluation of Dr. Ris' credentials. . . . Dr. Ris will very much appreciate your early advice as to the time and place in January at which she will be expected to appear before the Board on her application for licensure by reciprocity."

But the Board was not yet willing to accept defeat. Davison stated in a 14 December reply that the two documents mentioned by my attorney were in the process of being translated. Translation was hardly the obstacle this implied. The records were, after all, in German, not Sanskrit, and were only two pages long.

Attorney Davison's letter continued: "It appears to me that the facts which you anticipate being included in the letters from [the University of Zurich] . . . could be very easily established by procuring from the University of Zurich the course of study required for a Certificate of Medical Studies and an official transcript of Dr. Ris's credits. If a comparison of these two documents reveals that she has taken all of the courses required for a certificate of medical studies, it would seem that that particular question would be definitely answered."

They were asking for documents they already had! They had possessed, since 1949, the official transcript of my credits and had had the official documents from Switzerland concerning courses required for the Certificate of Medical Studies since 11 July 1950.

Previously the Board had agreed it was willing to rely on the direct evaluation of the Swiss authorities. Apparently it had intended to honor this only if the result was detrimental to my record. Now the Board was proposing a different procedure and adopting new criteria less than a month before the meeting where my professional future was to be decided; I could not interpret this in any way other than that the Board had been acting in bad faith.

On 26 December the Board's attorney called my attorney to solicit his help in making a comparison of my courses with those required for the Certificate of Medical Studies. On 27 December Mr. Doyle made the comparison using two parallel columns. I came off with flying colors. Yet at this late date I still had not been granted permission to appear before the 10 January 1951 meeting of the Board.

On 27 December my attorney wrote a two-page letter to Dr. J. W. Smith, president of the Board (with copies to members of the Board and its Council), summarizing my one and a half year struggle for licensure. Mr. Doyle pointed out that I was entitled to be informed without delay whether the Board would grant me permission to appear at its upcoming meeting.

This was the last document in my own and attorney James Doyle's files of my case. What followed must have been transacted over the telephone because of time constraints.

I was told I would be permitted to appear before the Board on 10 January 1951 to take the oral examination for licensure by reciprocity. Dr. Edwards Park, my advocate, awaited the outcome anxiously. Dr. Anderson of the AMA Council wired Dr. Park on 5 January:

> Your letter of January 3 just received. Have telephoned Dr. Christofferson, chairman of the Wisconsin Board, who assured me without reservation that Dr. Ris will receive exactly same type of oral examination as that given to all physicians seeking licensure in Wisconsin by reciprocity. Written examination was waived for her as it is for other candidates for reciprocity to spare unnecessary ordeal. I feel confident that Dr. Christofferson will insure Dr. Ris a fair examination. [signed:] Donald G. Anderson MD.

Round IV: I Am Finally Licensed

My appearance before the Board was summarized in the rather anticlimactic language of the 10 January 1951 minutes of the Board: "Dr. Hania Ris, applicant number 25, was ushered into the room. Dr. Ris' application has been reviewed again in the light of letters from the school from which Dr. Ris graduated, giving information that she had received the same education and had taken the same examination as those students who had received the accepted degree following which she left the room."

My name appeared later in the minutes among the list of candidates receiving the Wisconsin license by reciprocity. After one and a half years of painful negotiation with the State Board of Medical Examiners, I finally experienced one humane act. In mid-January 1951 I received a letter from Dr. C. A. Dawson (erroneously dated 13 January 1950 instead of 1951), stating: "Knowing you are naturally anxious as to the outcome of your examination, I am telling you confidentially that you were successful. . . . The list of all newly licensed physicians will be furnished shortly." The first congratulatory call came from Mrs. Edwin B. Fred (Rosa), the wife of the president of the university, who had kept in touch with me throughout the struggle. Her support was typical of the non-medical community.

It is ironic, however, that the State Board of Medical Examiners likely was not following the 1937 law when they denied me a license to practice medicine in Wisconsin. In a February 1991 Legislative Reference Bureau legal opinion, Mr. Barry J. Stern, legislative attorney, indicates the following:

> In my opinion, while the board appears to have had the authority under the 1937 law to adopt a policy of accepting an application for examination for licensure to practice medicine from any graduate of a foreign medical school that was classified in the American Medical Association (A.M.A.) rating, the board did not appear to have the authority under that law to accept an application from a foreign graduate *only* if the applicant was a graduate of one of the A.M.A. classified schools. On its face, the 1937 law, which required an applicant to have a diploma from a "reputable professional college approved and recognized by the board," would appear to have required the board to provide a foreign applicant who was a graduate of a school that was not classified by the A.M.A. with an opportunity to show that his or her school was reputable. [Personal correspondence, 4 February 1991]

Of course, the saga of my quest for licensure in Wisconsin does not end on the date of 10 January 1951. I paid a considerable price for being a test case, in addition to the price of being a woman challenging the medical establishment. I had many experiences as a *persona non grata;* one incident stands out.

While awaiting the decision of the Board, I attended clinical conferences held regularly at the University Hospital. At one conference, a prominent professor of gastroenterology approached me during a lecture and said: "You have to leave, you did not register." There were approximately forty participants in the room, which had a large capacity. I knew I was not displacing anybody by my presence, but I received a public rebuke because of my controversial status.

Four decades later, the professor's command still rings in my ears. However, at an Alumni Conference reception in 1981, some thirty years after the episode, the same professor, then approaching ninety years, came up to me, shook my hand and then kissed it (which was quite unusual for someone without a European background), and said, "I had to do what I have done." "I forgive you," I replied.

It is true that the struggle to be recognized for my professional credentials and expertise, to have the right to practice medicine in the state of Wisconsin, left some personal scars. But there were rewards in winning the battle, not just for me but for the many foreign physicians who followed.

Aftermath: The Status of Foreign Graduates

Since the conclusion of my personal battle, Wisconsin laws pertaining to foreign-educated applicants have been liberalized. The law of 1957 provided that if an applicant had graduated from a foreign medical school that was not approved or recognized by the Board, but had postgraduate training in this country substantially equivalent to training at the University of Wisconsin, the Board might admit the applicant to examination. However, this law allowed no more than twenty-five licenses a year to be granted under such conditions, and the ruling was to expire in 1961. After that date the fixed quota of foreign medical graduates who could be licensed each year was increased to fifty. In 1969 the Board started to rely selectively on examinations conducted by the Educational Council for Foreign Medical Graduates. Since 1970 Wisconsin law has governed the licensure of graduates of foreign medical schools under provisions similar to those of 1957 but without the limitation to fifty licenses annually.

In the opinion of Mr. Earl Thayer, who was employed by the Medical Society from 1947 to 1957 as public relations person, later serving as assistant secretary (1957–70) and as secretary of the Society (1970–87), my test case forced the Board to rethink and revise its policy and to accept the AMA Council's approval of some foreign medical schools. In the years 1930 to 1949, among active physicians in Wisconsin who were counted in a five-year period (Wisconsin Division of Health, Center for Health Statistics), the number of foreign graduates ranged between 6 (0.7%) and 44 (5.1%). Between 1950 and 1954 the number of foreign graduates increased to 140 (16.2%) (I was the first contributor to this increase), and in the years 1955–60 it increased to 218 (25.3%).

The Woman Question

What role, if any, did the fact that I was a woman play in the Board's attitude? I have never been sure. My perception, no doubt, was colored by almost a decade of earlier positive working experiences in friendly, congenial atmospheres where colleagues, professors, and administrators had gone out of their way to be helpful. The first time I experienced discrimination was when I came to Madison.

One authority is persuaded that being a woman and being aggressive were pivotal factors. Being aggressive was a positive trait in the world of men, but it was negative when applied to women. Mr. Earl Thayer, the Medical Society's respected secretary, recently told me that he had been appalled at the way the Board operated not only in my case but in general. He said I had been viewed as "aggressive" and the Board had hoped its tactics would discourage me.

The general lack of recognition and respect given to women in medicine was certainly a factor in my struggle to gain the right to practice medicine in Wisconsin, but perhaps it is illustrated even more clearly by a job offered to me in 1951 in Milwaukee. I was the mother of a fourteen-month-old infant at the time and had no private transportation, which prohibited my commuting. Nevertheless I was offered a position by the Bureau of Maternal and Child Health for the City of Milwaukee, which is about eighty miles from Madison. At first it was suggested that I hitch a ride daily with a truck driver at truck stops! Although I have never been conventional, I rejected that idea. It was then suggested that I take a bus which left daily from Watertown, Wisconsin, at 6:30 A.M. and arrived in Milwaukee at 7:45 A.M. "In other words, it is only necessary for you to find transportation from Madison to Watertown [a distance of about thirty miles] to make your daily journey here possible." This kind of sacrifice was expected of a woman physician in the 1950s: a willingness to sacrifice her motherhood, her child, her personal life, for the privilege of having a position in the field of public health. These suggestions would have been less shocking and more amusing had they not come from a woman physician who was herself a promoter of maternal and child health.

Women have had to persevere in an arena and during times when medicine was considered male territory. Statistics bear this out. At the time I received my licensure, in 1951, there were 204 women physicians (5.5%) in Wisconsin, compared to 3,492 male physicians. In 1960 the percentage went down to 4.5% (3,833 males, 183 females). It has risen steadily since that time: 5.9% in 1978, 7.4% in 1980, and 9.9% in 1984, the last year for which statistics are available (Department of Health and Social Services, Center for Health Statistics).

But even today there are relatively few women in medical academia. In 1981 women constituted only 17% of all medical school faculty. Few women chair medical school departments, and few are in leadership positions in professional organizations. A case in point is the American Academy of Pediatrics, which was established in 1930, and now has a membership of 37,000 (25% of whom are women). Only in 1986 did a woman, Dr. Betty Lowe, become a member of the nine-person Executive Board. The Academy's first woman president, Dr. Antoinette Eaton, became vice-president and president-elect in 1989, by a majority vote of the Academy membership.

"Living the Good Life"

While public health medicine appealed to me, I turned to a much more reasonable and agreeable alternative. My family and I looked for a house in Madison that could lend itself to combining living quarters with a physician's office, where I could practice without outside pressures and spend as much time with each patient as necessary. We found such a house, surrounded by large trees, at 2306 Van Hise Avenue, across the street from West High School before its expansion. This work arrangement was rather unusual in Madison but quite common in the East. I would have preferred an academic position or an association with an obstetrician in an office, but this was unrealistic; I was still perceived as too controversial and too much a risk for close professional associations such as these.

Many of our friends, university teaching staff, people whom I came to respect and admire, entrusted me with their children. As a pediatrician, I later became a specialist in adolescent medicine, and then part-time medical director of a school for delinquent girls. I developed a comprehensive, multidisciplinary health program for the underprivileged young women, which led to clinical research in the field of sexually transmitted diseases and to the position of medical director of all Wisconsin state correctional institutions under the jurisdiction of the Department of Health and Social Services, Division of Health. Prevention of teenage pregnancy through sex education and the elimination of legal barriers to control of reproduction for teenagers and adults has been an important part of my activities.

Despite the dire predictions that I would be barred from academic medicine forever, since 1956 I have been a member of the University of Wisconsin Medical School faculty and am currently a Clinical Professor of Pediatrics. I have published a number of professional articles, mainly in the field of sexually transmitted diseases in young adults.

Of course, since *Life* magazine's 1948 article about "The Good Life in Madison, Wisconsin," many things have changed. Nevertheless, I have enjoyed my forty years as a Madison resident immensely and would still contend that it is one of the best places in America to live. My fondness for Madison is probably even stronger because I had to fight for the right to make it my home, to be able to practice my profession without discrimination; I have always believed that is the right of every American citizen. My perseverance has been amply rewarded.

Acknowledgments

It should be obvious to the reader that I did not persevere without a great amount of encouragement and support. The press of Wisconsin championed my case with numerous articles, and without its airing of the issues my efforts would have been far more difficult. The late James Doyle, my attorney, exhibited incredible skill and patience in dealing with the machinations of the Board of Medical Examiners. He contributed greatly to bringing my case to a successful resolution.

I wish to reserve a special place to celebrate the late Dr. Edwards A. Park, physician, scientist, champion of medical care for the poor, early supporter of Medicare and Medicaid, and devoted friend. Dr. Park championed my cause out of his intense commitment to human decency, fairness, and justice. He was among the first to oppose the AMA's conservative policy regarding social health issues. In his teaching and by the example he set, he instilled in people the importance of the search for knowledge, the pursuit of truth, honesty, and high standards in all aspects of life. He published over a hundred articles, and until his death in 1969 at age ninety-one, his expertise was sought by authors of scientific publications. Much of the material needed to reconstruct the events described in this article came from the voluminous correspondence I had with Dr. Park, who obtained confidential information and advice from many individuals.

1988 Drought Impacts Among Wisconsin Dairy Farmers

John A. Cross

Abstract. *Drought such as occurred throughout the American Midwest during 1988 was an unusual experience for Wisconsin's farmers, who lost half their hay and corn crops. Dairy operators, who represent nearly half of the state's farmers, faced added hardships in maintaining their herds in face of feed shortages and rising feed prices. This paper reports the findings from a survey of Wisconsin dairy farmers concerning the drought impacts and the adoption of various drought mitigation measures. The consequences of the drought were most severely felt by farmers already experiencing a variety of economic stresses. Although three-quarters of the dairy farmers reported receiving federal drought assistance payments, 73% of these farmers would have survived without such relief. Farmers are pessimistic about future drought occurrences.*

Drought is a frequent and ever-present hazard for farmers tilling subhumid and semiarid lands and has been most studied within such environments (Hurt 1981; Rosenberg 1978; Saarinen 1966; and Warrick 1975). Although the rare drought events within normally humid environments have received less attention, the impacts of unusual drought occurrences can be highly significant and are worthy of study. This paper reviews the impacts of the 1988 summer drought upon dairy farmers in Wisconsin. At the time of the drought, 45% of Wisconsin's 81,000 farmers were engaged in dairying, leading the nation in milk production.

Drought conditions were felt throughout Wisconsin during the summer of 1988, when "43% of the area of the contiguous United States was in the severe or extreme drought category" (Trenberth, Branstator, and Arkin 1988). In Wisconsin the drought resulted in the loss of approximately half of the state's hay and corn (maize) crops. During the winter and spring of 1989 dairy farmers faced not only the consequences of these feed losses, but also the possibility of continuing drought conditions. This paper summarizes findings from a survey concerning the impacts of the 1988 drought at a time many dairy farmers would be expected to be experiencing hay and feed grain shortages resulting from the substantially diminished 1988 harvest. The 1988 drought provided an excellent opportunity to study drought impacts, mitigation, and perception among the population of a normally humid environment that has rarely had to deal with such a hazard.

John A. Cross is an associate professor and chair of the Department of Geography at the University of Wisconsin–Oshkosh. His other recent publications have dealt with geographic literacy, natural hazards, and the Dairy Termination Program in Wisconsin.

Funding for the research survey was provided by a grant from the Natural Hazards Research and Applications Information Center of the University of Colorado, Boulder, through their quick-response research program. Any opinions, conclusions, or recommendations expressed in this paper are those of the author and do not necessarily reflect the view of the Hazards Center or its funding agencies.

1988 Drought Conditions

Extreme drought conditions, as defined by the Palmer Index (Fig. 1), occurred in six of Wisconsin's nine agricultural reporting districts during the summer of 1988 (*Weekly Weather and Crop Bulletin* 1988). Precipitation from April through August 1988, as shown in Figure 2, was the lowest recorded in ninety-three years of records in both southwestern and southeastern Wisconsin, with three additional districts recording their second or third driest growing seasons. Rainfall was particularly deficient in May and June, with a Milwaukee weather station reporting a two-month total of 0.99 inch and Green Bay recording 0.73 inch—11.6% of normal (U.S. Department of Commerce 1988). Abnormally hot temperatures accompanied the drought, with six of Wisconsin's nine agricultural reporting districts reporting their highest June through August mean temperatures in records dating back to 1895 (U.S. Department of Commerce 1989b). Although a portion of eastern Wisconsin received substantial rainfall in August and September, over half of the state experienced an annual precipitation shortfall of at least six inches, with the southwestern corner of Wisconsin receiving fifteen inches below normal precipitation (Clark 1989a).

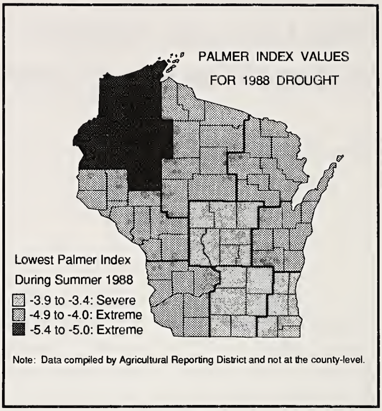

Figure 1

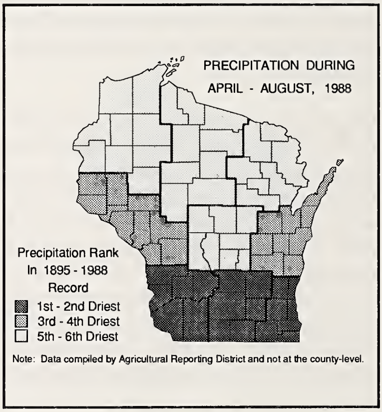

Figure 2

The 1988 corn harvest was 60% below the 1987 harvest, alfalfa hay was down 45%, other varieties of hay were off 44%, and oats were down 54% (Wisconsin Department of Administration 1989). Furthermore, because 1987 harvests had fallen from even greater 1986 harvests as a result of less severe drought conditions in 1987, the 1988 harvests of alfalfa hay and corn were 46% and 36%, respectively, of their 1986 harvests. Although the tonnage of corn silage harvested in 1988 was down only 2%, this was accomplished by a doubling of the harvested acreage, largely an effort to salvage wilted cornfields that had been planted for grain (Wisconsin Agricultural Statistics Service 1988 and 1989). Unfortunately, because of its lower protein content, the substitution of such corn silage for alfalfa without additional protein supplements reduced milk production (Howard and Shaver 1988).

The dollar value of the 1988 hay harvest exceeded that of the 1987 harvest by 18.2% because of the shortage and rapidly escalating prices. Indeed, hay prices doubled or tripled, with the price of top-grade alfalfa hay reaching $250 per ton. Price increases failed to keep pace with lost production for other crops. For example, the cash value of the corn harvest was down by 48.9%, and the oat harvest generated 25.5% less revenue than in 1987 (Wisconsin Agricultural Statistics Service 1988 and 1989). However, higher commodity prices were not advantageous to most Wisconsin dairy farmers. They normally consume their crop on their farms, and the higher prices simply translated into higher costs of feeding their herds to stay in business (Rodefeld 1988a).

Drought-induced crop losses were not uniformly distributed across Wisconsin, with the western and southern portions of the state reporting the greatest declines in production between 1987 and 1988 (Fig. 3). For example, in Polk County the 1988 corn crop was 17.8% of the 1987 harvest, and in Marathon County—the state's foremost milk producing county—the corn crop was only 24.5% of the previous year's harvest. Although the decline in alfalfa production (Fig. 4) was not as dramatic as the drop in the corn harvest, similar spatial patterns of crop losses were noted, with the greatest drought losses occurring in the north central, northwestern, and southernmost portions of Wisconsin.

Press reports during the winter and early spring of 1989 painted a bleak picture of conditions facing Wisconsin dairy operators. Large proportions of farmers had either exhausted their feed or were expected to do so before their next harvest. A Wisconsin Agricultural Statistics Service survey in early November 1988 determined that 14% of the state's livestock farmers (dairy, cattle, and hog) expected to have exhausted their hay by January, 42% by March, and 74% would be out of hay by May. Grain or grain concentrate supplies were expected to be similarly expended (*Wisconsin Farm Reporter* 9 November 1988). Wisconsin's hay stocks in December 1988 were down 3.9 million tons from December 1987 (Rodefeld 1988b). Replacement of this lost hay and haylage statewide was estimated to cost from $600 to $700 million, and replacement of corn stocks was estimated between $200 and $400 million (Wisconsin Department of Administration 1989).

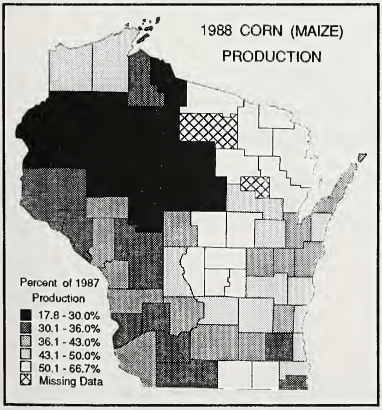

Figure 3

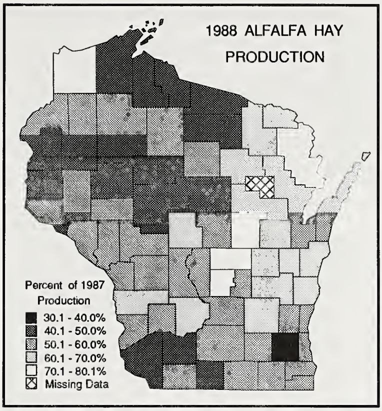

Figure 4

Weather conditions during the winter and spring of 1989 caused further concern at the same time dairy farmers were facing feed shortages. Freezing rains (rather than snow) during January 1989 had seriously damaged the alfalfa fields (Clark 1989b). Precipitation during the spring of 1989 was well below normal, with many areas by early May having received less precipitation since the beginning of the year than in 1988 (U.S. Department of Commerce 1989a). The 6 May

1989 Palmer Index (*Weekly Weather and Crop Bulletin* 1989) indicated that severe drought was occurring in southwestern Wisconsin, moderate drought was present in central Wisconsin, and mild drought was present in five of the state's other seven agricultural reporting districts.

Methodology

Concerns about how Wisconsin dairy farmers had managed to deal with the drought-induced hay and feed grain shortages during the winter and spring of 1988–89 and about these farmers' vulnerability to future stress—drought and otherwise—prompted the survey of Wisconsin dairy farmers that provided most of the data reported in this paper. An eight-page questionnaire was mailed on 4 May 1989 to 506 dairy operators throughout the state. The initial mailing of the questionnaire, accompanied by a cover letter and a business reply envelope, was followed six days later by a reminder post card. This card thanked participants and encouraged recipients to complete and return the survey. Farmers not responding to the initial survey were mailed a second copy of the questionnaire, a new cover letter, and a second business reply envelope on 24 May 1989. Completed surveys were received from 283 farmers, representing 57% of the eligible members of the sample who received the survey.

Farmers receiving this survey were selected by a stratified systematic sampling procedure from an early April 1989 Wisconsin Department of Agriculture listing of the 35,611 dairy operators whose herds had had the Brucellosis Ring Test, which is required quarterly for all commercial milk producers. The sampling was designed to select 1.2% of the dairy operators in the six largest agricultural reporting districts. In the remaining three districts, which would have fewer representatives, an additional 1–2% of the farmers were selected so that district-to-district comparisons could be made. In addition, a short survey was sent to agricultural extension agents throughout Wisconsin requesting data on their observations of farmers in their various counties.

Impacts of 1988 Drought

The 1988 drought had numerous impacts upon Wisconsin's dairy farmers, including substantial crop losses, losses of income, and shortages of hay and feed grains, together with a wide assortment of economic stresses (Table 1). Some even lost their farms.

Crop losses and feed purchases

Crop losses led to a cascade of drought impacts for Wisconsin's dairy farmers. The Wisconsin State Agricultural Stabilization and Conservation Service in late August 1988 es-

Table 1. Impacts of the 1988 drought

"Indicate to what degree (if any) you have experienced the following as a result of last summer's drought?"

Condition	*Strongly felt*	*Moderately felt*	*Slightly felt*	*Not felt*
	%	%	%	%
Decrease in gross farm income	27.0	29.2	23.2	20.6
Decrease in net farm income	39.1	27.8	20.3	12.8
Increase in farm indebtedness	19.6	18.1	23.1	39.2
Shortages in hay or alfalfa	49.8	24.3	13.9	12.0
Problems with corn toxicity	3.5	5.8	12.7	78.0
Bank foreclosure threat	3.5	4.3	6.7	85.5
Greater need of off-farm income	14.9	19.8	20.6	44.7
Sale of lands or farm equipment	3.5	6.9	6.9	82.7

timated statewide crop losses of 50% for both hay and corn (U.S. Department of Agriculture 1988). Crop yields for 1988, as reported by dairy farmers responding to my survey, were close to these estimates, with their hay/alfalfa harvest averaging 45% of normal and their corn crop averaging 50% of normal. When surveyed in May–June 1989, only 37% of the farmers indicated they had "sufficient feed grain supplies to last until the next harvest."

Purchases of hay or alfalfa hay had been made by 62% of the dairy operators between September 1988 and May 1989, and 72% had purchased feed grains. Statewide, 75.5% of Wisconsin's dairy operators reported making purchases of either hay or feed grains, with the proportion ranging from 68 to 83% of the farmers in the various agricultural reporting districts. In a normal year, over 40% of the surveyed farmers buy neither hay nor feed grains. Purchases of hay and feed grains during 1988–89 averaged $14,616, with a median purchase cost of $9,000. The mean cost of these purchases in a normal year averaged $6,733 with a median cost of $2,000. The greatest increase in hay and feed purchases was reported by dairy farmers in southwestern Wisconsin.

Changing feed, reducing herd size

Farmers also took a variety of other actions (Table 2) to mitigate the feed shortages. For example, 35% changed the type of feed given to their animals, 22% reduced the amount of feed, and 38% of the respondents reduced the size of their herds. Conversely, 27.8% of the survey respondents were able to increase their herd size.

Farmers most likely to reduce the size of their dairy herds were located in central Wisconsin (where over half took this action), as well as the southwestern, northeastern, and south central Wisconsin regions. With the exception of southwestern Wisconsin, which experienced the greatest precipitation deficits in 1988, districts where dairymen were less likely to purchase feed supplies were those most likely to have reductions in herd size. Farmers in east central, west central, and southeastern Wisconsin (42 to 50%) were most likely to change the type of feed given to their herds, while those in northeastern and south central Wisconsin were least likely (18 to 23%). Reduction of the amount of hay or feed grains fed to the dairy cows was reported by over 30% of the dairymen within central, southwestern, and southeastern Wisconsin, while fewer than 14% of the dairymen within

Table 2. Actions taken because of hay or feed grain shortages

	Percent of dairy farmers taking action			
Agricultural reporting district	*Purchasing hay/feed*	*Reducing herd size*	*Changing feed type*	*Reducing amount fed*
	%	%	%	%
Northwest Wisconsin	80	37	27	10
North central Wisconsin	83	28	31	14
Northeast Wisconsin	68	45	23	14
West central Wisconsin	69	36	44	19
Central Wisconsin	70	51	33	30
East central Wisconsin	79	29	50	24
Southwest Wisconsin	82	46	36	32
South central Wisconsin	70	44	18	22
Southeast Wisconsin	77	23	42	31
State total	75.5	37.5	34.9	21.9
Adjusted state total*	76.0	37.9	34.9	21.6

*Because Wisconsin's dairy farmers are not evenly distributed among the nine agricultural reporting districts, this total was calculated by weighting the responses from each district by the proportion of Wisconsin's dairy farms that operate in that district.

the northern third of the state put their herds on short rations.

Drop in farm income

Net farm income was down for the majority of the dairy farmers, yet for better than one in ten, income was above average. When asked an open-ended question, "Your net income (from all sources) for 1988 was about what percent of normal?" one-quarter of the farmers indicated 100% or more (Table 3). Dairy farmers reporting above normal income—with some reporting their best year ever—typically had substantial hay supplies carried over from 1987. Conversely, 11% reported net incomes of 50% or less of normal, with the mean net farm income being 84.5% of normal (median was 90%). These estimates are similar to those of the agricultural extension agents, who estimated that average income was 89% of normal. Although one out of seven of the agents estimated that the average farmer within his or her county earned a greater than normal income, in none of the agricultural reporting districts was the average net income (either mean or median), as reported by the farmers, greater than 90% of normal. The greatest departures from normal were reported by dairy farmers in central and southwestern Wisconsin.

Sixty-seven percent of the dairy farmers surveyed indicated that decreases in their net farm income were strongly or moderately felt, an even larger proportion than those farmers reporting decreases in gross farm income (56%, Table 1). Half of the farmers indicated that shortages in hay or alfalfa were "strongly felt," with an additional 24% claiming these shortages were "moderately felt." Nevertheless, increases in farm indebtedness as a result of the drought were strongly or moderately felt by only 38% of the farmers. Drought-induced bank foreclosure threat was strongly or moderately felt by 8% of the dairy farmers, and the sale of lands or farm equipment was similarly felt on 10% of the farms. Thirty-five percent of the farmers indicated that a "greater need of off-farm income" was strongly or moderately felt.

Table 3. Change in net farm income from normal during 1988

"Your net farm income (from all sources) for 1988 was about what percent of normal?"	%
0–50% of normal	10.7
51–75% of normal	19.1
76–89% of normal	16.8
90–99% of normal	29.0
100% of normal	13.7
101–200% of normal	10.7

Spatial differences in "strongly felt" impacts of the drought were noted (Table 4). Farmers in southwestern, central, and east central Wisconsin were most likely to report strongly felt shortages of hay or feed grains. Decreases in both gross and net farm income were most frequently reported in northeastern, central, and southeastern Wisconsin, all areas where dairy operators had faced above average economic stresses and declines in the previous decade (Cross 1989). Dairymen in the central Wisconsin region were significantly more likely to have strongly felt increases in farm indebtedness, while farmers in the north central, west central, and central agricultural reporting districts were most likely to have a greater need for off-farm income. Although these spatial patterns are not entirely consistent, farmers in central Wisconsin consistently reported above average levels of concern about all the potential drought impacts.

Drought-induced declines in both gross and net incomes, shortages of hay and feed grains, and increased indebtedness were experienced by a broad spectrum of Wisconsin dairy farmers. No differences in drought impacts were noted among the farmers based upon the age of the farmer, the number of years as farm operator, farm acreage, size of dairy herd, the farmer's land tenure status, or whether the farm was a grade A or grade B operation. On the other hand, the responses of the farmers to the shortages of hay and feed supplies were related to a number of these characteristics (Table 5). For example,

Table 4. Impacts of the 1988 drought in Wisconsin's agricultural reporting districts

Agricultural reporting district	*Percent of dairy farmers indicating that the condition was "strongly felt" as a result of the summer 1988 drought*				
	Shortage of hay/ alfalfa	*Decreased gross income*	*Decreased net income*	*Increased farm debt*	*Need of off-farm income*
	%	%	%	%	%
Northwest Wisconsin	43	29	37	18	8
North central Wisconsin	46	32	39	19	22
Northeast Wisconsin	38	41	54	19	14
West central Wisconsin	50	10	36	19	19
Central Wisconsin	64	39	47	32	21
East central Wisconsin	54	26	38	18	16
Southwest Wisconsin	65	21	28	21	14
South central Wisconsin	46	15	31	8	7
Southeast Wisconsin	33	37	44	21	4
State total	50.0	26.9	39.0	19.6	14.9
Adjusted state total*	51.1	24.7	37.2	18.8	15.2

*Because Wisconsin's dairy farmers are not evenly distributed among the nine agricultural reporting districts, this total was calculated by weighting the responses from each district by the proportion of Wisconsin's dairy farms that operate in that district.

Table 5. Significant relationships between dairy farmer characteristics and responses to drought-induced hay/feed shortages

Farmer characteristics	*Farmer responses*			
	Purchase hay/feed	*Reduce herd size*	*Change feed type*	*Reduce feed amount*
Age of farmer	.00977	NS*	.04195	.09128
Years of farm operation	.00387	NS	.01902	.01837
Farm acreage	NS	NS	NS	.03218
Farm ownership	NS	NS	NS	.06011
Herd size	.02114	.03078	NS	NS
Drop in net farm income	.06239	.00777	.05057	.07215
Off-farm income	.02173	.06594	NS	NS

*NS indicates chi-square not significant at .1000 significance level.

farmers most likely to have already purchased hay or feed grains as a result of the drought were the youngest, those with lower net incomes, those with the largest number of cows, and those with off-farm incomes.

Drought Relief

Wisconsin dairy farmers were asked to evaluate the importance of various factors in helping their farms financially survive the 1988 drought and its aftereffects. The two most important factors were government drought relief payments and increased milk support prices, cited as "very important" by 44 and 41% of the farmers, respectively. Personal savings were cited as "very important" by 26% of the dairy operators, bank credit by 22%, and off-farm income by 17%. Crop insurance payments were "very important" to only 8% of the surveyed farmers.

Several federal and state government programs provided assistance to Wisconsin farmers. Lands in the Conservation Reserve Program and Conservation Use (set-aside) program were opened to both grazing and haying. State-owned lands and highway right-of-ways were opened to haying. Additional federal funds were authorized to purchase ground beef, assuring that dairy farmers who liquidated their herds could do so with a reasonable market for their cows. A scheduled drop in the federal milk support price was postponed, and support prices were increased. Property tax credits and a guaranteed loan program for farmers were approved by the state (Richards 1988; Wisconsin Department of Administration 1989). The largest relief program was provided by the U.S. Disaster Assistance Act of 1988, which authorized compensation to farmers with crop losses exceeding 35% of normal production. In general, farmers received no compensation for their first 35% of lost production, were compensated at 65% of the target price (approximately the pre-drought average market price) for the loss of 36 to 75% of their harvest, and 90% of the target price for the loss of 76 to 100% of production. Thus, the program did not "prevent farmers from experiencing substantial declines in their incomes" (Jones 1988).

Financial assistance through the Disaster Assistance (Drought Relief) Act was reported by 75% of the Wisconsin dairy farmers surveyed, a greater proportion than those who reported that this assistance was either "important" or "very important" in helping their farm financially survive the drought. Thirty-seven percent indicated that these drought relief payments were the primary source of funds for their hay and feed grain purchases. Thirty-five percent relied primarily upon their farm income (milk check) or withdrawal of funds from their savings to purchase hay or feed. Thirteen percent borrowed funds from banks or other financial institutions.

Seventy-three percent of the surveyed dairymen who received drought relief payments indicated that they would have been able to remain in the dairy business even without the aid. In contrast, Wisconsin agricultural extension agents estimated that without the drought relief payments only 9% of the dairy farmers would succumb. Dairymen in southeastern, south central, and west central Wisconsin expressed the greatest confidence that they would have survived without any drought relief payments. Conversely, dairy farmers in the central, east central, and north central agricultural reporting districts were least confident about their ability to have survived the drought without drought relief payments. In central Wisconsin only 53% felt they would have survived without the payments.

If we consider only those farmers who received drought relief payments, these payments were most significant in the survival of Grade B dairy farms, the farmers with off-farm income or employment, those farmers who reported that decreases in net farm income were moderately or strongly felt, and the farmers reporting the greatest hay and corn crop losses in 1988. Indeed, 41% of the dairy farmers receiving drought assistance who had lost over two-thirds of their hay/alfalfa crops doubted their ability to survive without those payments (Table 6).

Drought relief payments and other federal and state benefits, estimated at $565 million for Wisconsin farmers, covered approximately 37% of feed expenses and lost cash crop revenues of Wisconsin farmers. Thus, Wisconsin farmers (both dairy and crop) had estimated uncompensated losses averaging over $11,000 each (Wisconsin Department of Administration 1989). Since even a year before the drought 16% of all Wisconsin farms (a total of 12,800 farms) were considered by the U.S. Department of Agriculture to be experiencing "extreme financial stress," for many farmers such losses were unbearable. Furthermore, Rodefeld (1988) indicated, "Many farmers who survive the coming winter will have high levels of stress in future years because of their higher debt loads and tighter cash flows from this year's drought."

Loss of Dairy Farms

Statewide, an estimated 960 farmers had already terminated their dairy operations by

Table 6. 1988 hay/alfalfa crop loss and ability of drought relief recipients to survive without payments*

	Hay crop as percent of normal harvest		
	0–33%	*34–50%*	*51–100%*
Would survive without payment	41 (58.6%)	74 (77.9%)	40 (90.9%)
Would not survive/ doubtful without payment	29 (41.4%)	21 (22.1%)	4 (9.1%)
Totals	70 (100.0%)	95 (100.0%)	44 (100.0%)

*Chi-square = 16.010, 2 degrees of freedom, significance = .00033.

early May 1989 as a direct result of the 1988 drought, based upon estimates of county-level agricultural extension agents. Between March 1988 and March 1989 the total number of commercial herds in Wisconsin dropped by 1,351, a decline of 3.7% (Wisconsin Agricultural Statistics Service 1988 and 1989). Thus, the drought would appear to be the leading cause of herd losses. Between March 1989 and March 1990 Wisconsin lost another 1,768 dairy herds, a decline of 5%. However, to keep these losses in perspective, we should note that the number of dairy operations in Wisconsin fell by 9.8% (a total of 4,026 herds) between 1986 and 1988 (40% were participants in the Dairy Termination Program) and fell by 19.2% between 1982 and 1988 (Cross 1989). Although the annual loss between March 1988 and March 1989 was smaller than within the previous few years, many agricultural extension agents felt in May 1989 that it was still too early to determine the total number of casualties from the 1988 drought. Hence, many dairy farmers ceasing operations between 1989 and 1990 should also be considered victims of the drought.

The distribution of the losses of dairy farmers between 1988 and 1989 (Fig. 5) was similar to that over the previous half decade (Cross 1989), with a few notable exceptions. For example, above average declines were noted in several counties of northwestern Wisconsin and in central Wisconsin, simply continuing trends that existed before the drought. On the other hand, the above average losses during 1988–89 in several southwestern Wisconsin counties (notably Grant and Iowa) are in sharp contrast to their considerably below average declines between 1981 and 1988. Losses in dairy herds between 1989 and 1990 more closely parallel long-term pre-drought trends (Fig. 6), which saw the greatest declines in northern Wisconsin, parts of central Wisconsin, and near the Milwaukee metropolitan area in southeastern Wisconsin.

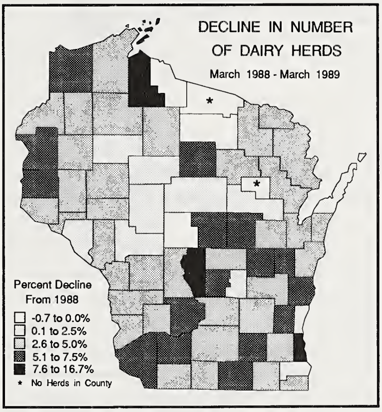

Figure 5

Vulnerability to continued drought stresses

A third of the dairy farmers surveyed indicated that, if there was a drought during

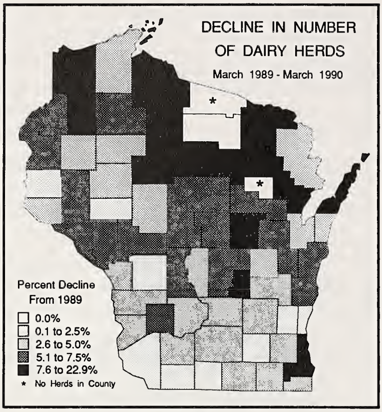

Figure 6

the summer of 1989, they would no longer be in business by the spring of 1990. (Although five of Wisconsin's nine agricultural reporting districts received less average district-wide precipitation in 1989 than in 1988, strategically spaced rainfall spared most crops [Naber 1990].) However, 7% of the surveyed farmers did not expect to still be in business the next year, even if rainfall amounts were normal during the summer of 1989. Furthermore, 29% of the dairy farmers affirmatively answered the question, "Would you like to sell your farm?" This was particularly prevalent throughout the northern third of Wisconsin, where 40% of the dairy farmers wished to sell. It should be noted the entire northern portion of the state saw the highest rates of farm abandonment over the past decade and the greatest participation rates in the Dairy Termination Program (Cross 1989).

Farmers who expressed the greatest concern about their vulnerability to continued drought were typically those with smaller than average farm acreages, with below average herd sizes, and with Grade B operations (Table 7). Thus, farmers most threatened by the drought were the same group the Wisconsin Dairy Task Force (1987) had identified even before the drought as having the bleakest chance of economic survival because they both lacked economies of scale and could not "afford relatively expensive new technologies." Strong statistical relationships were noted between the farmers' expectations that they could survive a 1989 drought and their crop losses (especially corn) in 1988 and the adequacy of their hay and feed grain supplies (Table 8). Those farmers who indicated they did not expect to still be in business—drought or no drought—by 1990 were generally the oldest, with the greatest number of years as farm operators, and with smaller than average herd sizes. However, those expecting to quit had suffered drought-

Table 7. Significant chi-square relationships between drought vulnerability of farmers and characteristics of farmers

Farmer characteristics	*Could survive drought in 1989*	*Could survive without drought relief payment**	*Wish to sell farm*
Age of farmer	NS†	NS	.01089
Years of farm operation	NS	NS	.08401
Farm acreage	.06472	NS	NS
Farm ownership	NS	NS	.039
Herd size	.00177	NS	NS
Herd grade (A/B)	.00881	NS	NS
Drop in net farm income	.01891	.00909	.07437
Off-farm income	.03370	NS	NS

*All respondents were asked this question, both those who had and those who had not received any drought relief payments.
†NS indicates chi-square not significant at .1000 significance level.

Table 8. Significant chi-square relationships between 1988 drought impacts and future vulnerability of dairy operations

Drought impacts from 1988	*Could survive drought in 1989*	*Could survive without drought relief payment*	*Wish to sell farm*
Hay crop losses	.06337	.00001	NS*
Corn crop losses	.00392	.00424	.00923
Adequacy of hay supplies	.00000	.00000	NS
Adequacy of feed supplies	.00084	.00164	.05057
Increased farm indebtedness	.00004	.00000	.06922
Feed/hay purchases	.09500	.00112	NS

*NS indicates chi-square not significant at .1000 significance level.

induced crop losses and feed and hay shortages that were no different than the remaining farmers.

Drought Mitigation for 1989

Many dairy farmers made no efforts to mitigate possible drought losses in 1989, although virtually all Wisconsin dairy farmers had suffered crop losses in 1988 and 70% expected a drier than normal 1989 growing season. Nevertheless, crop insurance coverage expanded, and nearly half the farmers took some action to reduce future drought losses.

Crop insurance

Crop insurance to cover drought losses had been obtained by only 8% of the surveyed dairy farmers in 1988, although 36% had obtained insurance to cover hail losses. For their 1989 crop season, 51% of the dairy farmers reported that they either had or would obtain crop insurance to cover drought losses. Such a low figure is surprising because multi-peril crop insurance was required of drought relief recipients who lost at least 65% of their crops as a condition for receiving their payments (U.S. Public Law 100-387, Section 207). Nevertheless, 16% of the surveyed farmers whose hay and corn crops were both under 35% of normal—but who still had received drought assistance—had not purchased drought (or multi-peril) insurance. Furthermore, several other respondents obtained only minimal crop insurance coverage because of its cost. Although the legal requirements mandating multi-peril insurance in exchange for drought assistance did not receive universal compliance, dairy operators with the largest crop losses (whether or not they received financial assistance) were significantly more likely to obtain drought insurance for the next year.

Crop planting

The 1988 drought prompted 42% of the dairy farmers to make changes in their crop planting plans for 1989. Farmers in northwestern, north central, and east central Wisconsin were significantly more likely to report these changes. Numerous changes in cultivation techniques and crops were undertaken, although only a few farmers mentioned changes in plowing/planting dates, reduced tillage, or fertilizer and herbicide usage.

Farmers with the greatest acreages were most likely to report making changes in their crop planting plans for 1989. Likewise, younger and middle-aged farmers were significantly more likely to report making changes than the older farmers (those over sixty years of age). On the other hand, the land tenure status of the farmers, the size of the farmer's dairy herd, and whether the herd was a Grade A or Grade B operation were not statistically related to crop planting changes. The decision to make changes in crop planting plans was significantly related to both the farmers' perceptions of the likelihood of drought during the summer of 1989 and their perception that drought possibilities are a problem in Wisconsin.

The prominence of hay/alfalfa, corn, and oat production on Wisconsin dairy farms remains unchanged following the drought. Ninety-five percent of the surveyed farmers reported planting corn in 1988, and 94% intended to grow corn in 1989. Similar proportions produced hay and/or alfalfa. Oats were cultivated on 73% of the dairy farms in 1988, the same proportion that planned to grow oats in 1989. However, a slightly greater amount of crop diversification was planned for 1989, and the proportion of farms producing many of the lesser grown crops increased. For example, dairy farmers planting sudan grass increased from 9.6% in 1988 to 13.3% in 1989 and sorghum from 5.2% to 7.3%.

Irrigation is a rarity on Wisconsin dairy farms. Only 3.2% of the surveyed farmers had irrigation systems in place before 1988, with an additional 1.4% installing systems during 1988. Only two (of the 283 farmers responding to the survey) planned to install an irrigation system during 1989. Statewide, only 250 of Wisconsin's 81,000 farms installed emergency surface water irrigation systems during the summer of 1988 (Wisconsin Department of Administration 1989).

Conclusions

The drought of 1988 has provided us with a unique opportunity to study drought perceptions and drought mitigation among farmers who have rarely dealt with this hazard. Drought is but one of many conditions that threaten the livelihood of Wisconsin dairy farmers. When asked to evaluate drought and a variety of other problems, farmers more frequently mentioned everyday economic concerns as being major problems than any natural hazard, including drought, hail, and flood. Indeed, milk support prices were considered a major problem by 53% of the farmers, property taxes by 51%, and drought by 36%. Only 9% of the farmers ranked drought possibilities as the single most important problem facing dairy farmers in their Wisconsin county, compared with 45% who cited either milk support prices or wholesale milk prices.

The final toll of the 1988 drought upon Wisconsin's dairy farmers will take years to tally fully. However, between March 1988 and March 1990 Wisconsin lost 3,119 dairy operations, an 8.4% decline. The economic stresses caused by the drought-induced diminished feed stocks and high hay and feed grain prices were somewhat mitigated by increased milk production per cow, rapidly escalating milk prices, and drought relief payments. The greatest stresses of drought did not necessarily occur in those areas experiencing the greatest meteorological drought or crop losses, but in areas where farmers were already under economic stress, and thus lacking in the resilience to respond successfully to another threat. In this respect, Wisconsin dairy farmers are no different from farmers in Mexico, where Liverman (1990) made similar observations. For many Wisconsin dairy farmers, high debt loads remain, only increased by the stresses of the drought.

Wisconsin dairy farmers are generally pessimistic about the possibility of future droughts. Another drought, as severe as the 1988 drought, is expected within ten years by nearly half of the farmers surveyed (Cross 1990). If predictions of climatologists about climatic warming because of the Greenhouse Effect are accurate (Schneider 1989), Wisconsin farmers must learn to deal with an increasingly capricious environment. Although the Greenhouse Effect cannot be blamed for an individual drought such as that during 1988, "the greenhouse effect may tilt the balance such that conditions for droughts and heat waves are more likely" (Trenberth, Branstator, and Arkin, 1988). We should remember what we have learned from this drought experience, which nationally was overshadowed only by the droughts of the 1930s and 1950s. Indeed, we should not forget the advice of Miewald, who wrote after another drought, "If we learn nothing from the current drought, then it may be said that the worst impact is no real impact at all" (1978).

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Distribution, Abundance, Larval Habitats, and Phenology of Spring *Aedes* Mosquitoes in Wisconsin (Diptera: Culicidae)

Jeffrey W. Gilardi and William L. Hilsenhoff

Abstract. *In 1988 10,651 larval and 1,612 adult* Aedes *were collected in nine representative areas of Wisconsin during the spring and early summer; an additional 3,146 larvae were collected during the spring in 1989 and 1990. From these collections and previous studies we determined the distribution, relative abundance, larval habitats, and probable phenology of the twenty-three species of* Aedes *that breed in water from melting snow and early spring rainfall.* Aedes decticus *and* A. euedes *were collected for the first time in Wisconsin. Adult longevity and flight ranges were also studied.*

In May and June Aedes stimulans *was the predominant mosquito biting humans in central and southern Wisconsin, while* A. communis *and* A. punctor *were the most important pests in the north. Adults of* A. vexans *were late spring pests in most areas in 1988 but were absent in 1989 and restricted to west central Wisconsin in 1990. Adults of* A. canadensis, A. excrucians, A. fitchii, *and* A. provocans *were minor pests in most areas of the state but were abundant locally. Adults of* A. cinereus *were troublesome biters in woodland areas throughout Wisconsin.*

Almost every year in May and June mosquitoes become a nuisance in wooded areas throughout Wisconsin. This problem is created by females of twenty-three species of *Aedes* that breed in temporarily flooded areas, which have resulted from snowmelt and early spring rains. The mosquito nuisance is especially severe after heavy snowmelt and/or heavy rains. Adults of these spring *Aedes* mosquitoes have a limited flight range and tend to remain in areas near larval development sites. Most are relatively short-lived, and after June, mosquitoes that have emerged in spring are rarely a nuisance.

Fifty-three species of mosquitoes are known from Wisconsin; twenty-eight of them are *Aedes*. All adult mosquitoes probably feed on floral nectar and other plant liquids (Grimstad 1973), but only females take blood meals. Females of some species feed on reptiles and amphibians, others prefer birds, but those of at least forty species, including all *Aedes*, readily attack humans and other mammals. This study was undertaken to determine the distribution, relative abundance, larval habitats, and nuisance potential of each species of *Aedes* that emerges during the spring and to summarize previous studies of these species in Wisconsin.

Larvae of all *Aedes* in Wisconsin develop in areas that are temporarily inundated with water, ranging from small cavities, holes, and depressions to marshes, ponds, bogs, and swamps. They also develop in fluctuating margins and intermittent shallow areas of more permanent habitats. Areas included in this

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Research supported by the College of Agricultural and Life Sciences, UW–Madison, and by Hatch Research Project 3050.

study fall into six categories: (1) marshes, primarily open areas vegetated with cattails (*Typha*) and/or sedges and rushes (*Carex, Eleocharis, Scirpus*) and associated plants; (2) *Sphagnum* bogs and swamps, usually with leatherleaf (*Chamaedaphne calyculata*), tamarack (*Larix laricina*), and/or black spruce (*Picea mariana*), and with water often limited to isolated pockets; (3) woodland pools surrounded by coniferous and/or deciduous trees, with a layer of leaf litter, and without aquatic vegetation; (4) drainage ditches without associated aquatic vegetation; (5) grassland pools surrounded by non-woody vegetation and without aquatic vegetation; and (6) temporary to semipermanent ponds with aquatic vegetation.

Species of *Aedes* in Wisconsin can be divided into two groups, both of which overwinter as eggs. The first group has a single generation each year, with eggs entering an obligatory diapause that is terminated by exposure to several weeks of cold winter temperatures. In Wisconsin this group includes *A. abserratus, A. aurifer, A. communis, A. decticus, A. diantaeus, A. euedes, A. excrucians, A. fitchii, A. flavescens, A. grossbecki, A. implicatus, A. intrudens, A. provocans, A. punctor, A riparius,* and *A. stimulans*. Hatching of eggs is related to flooding from snowmelt and rain and also to warming in March and early April; it may be delayed in heavily shaded areas and in habitats that remain relatively cold.

The second group consists of species whose eggs also hatch in the spring, but these species are capable of having additional broods throughout the warm months of the year. Additional eggs hatch each time the habitat is reflooded after it has become dry. This group includes *A. atropalpus, A. campestris, A. canadensis, A. cinereus, A. dorsalis, A. hendersoni, A. nigromaculis, A. spencerii, A. sticticus, A. triseriatus, A. trivittatus,* and *A. vexans*. Some of these species may have only one brood in some northern locations. *Aedes nigromaculis* (Ludlow, 1907) and *A. trivittatus* (Coquillett, 1902) were not studied because their larvae develop in late spring or summer. Also not studied were *A. hendersoni* Cockerall, 1918 and *A. triseriatus* (Say, 1823), which breed in tree holes and artificial containers, and *A. atropalpus* (Coquillett, 1902), which develops in rock pools.

While several studies of mosquitoes have been carried out in Wisconsin, the relative abundance, statewide distribution, and larval habitats of species of spring *Aedes* have remained poorly known. Dickenson's monograph (1944) provided the first account of Wisconsin mosquitoes, listing thirty-eight species. It was followed by Allen's summary (1950) of Wisconsin mosquito studies and his preliminary survey of species in the University of Wisconsin–Madison Arboretum. He documented the only statewide survey of adult mosquitoes, which was conducted in twenty-three counties by the Wisconsin State Board of Health in 1941; univoltine species of *Aedes* were poorly represented in this survey because many counties were sampled only in mid or late summer. More recently, Siverly and DeFoliart studied larvae (1968a) and adults (1968b) in northeastern Wisconsin, significantly contributing to our knowledge of spring *Aedes*. A study by Porter and Gojmerac (1970) identified *A. stimulans* as the most important pest in Point Beach State Forest, Manitowoc County, and another study (Gojmerac and Porter 1969) compared pest species of Point Beach State Forest with those of Wyalusing State Park, Grant County, where *A. communis* group species and *A. vexans* predominated. Amin and Hageman (1974) identified *A. stimulans* and *A. vexans* as important springtime pests in southeastern Wisconsin. Other studies that included county records or other information pertinent to this study were carried out by Ryckman (1952), Patel (1959), Thompson (1964), Thompson and Dicke (1965), Thompson and DeFoliart (1966), Loor and DeFoliart (1970), Wright and DeFoliart (1970), Wright et al. (1970), Grimstad (1973), and Kardatzke (1979).

The bionomics of mosquitoes, including almost all species of *Aedes*, was summarized by Carpenter and LaCasse (1955) for North America and by Wood, Dang, and Ellis (1979) for Canada. Several previous studies in Wisconsin also provided ecological information, especially those by Siverly and DeFoliart (1968a, 1968b). Additional information on larval ecology in nearby states and provinces appeared in Owen (1937), Barr (1958), and Price (1963) for Minnesota; Knight and Wonio (1969) for Iowa; Ross (1947) for Illinois; Matheson (1924), Irwin (1942), Obrecht (1949, 1967), Beadle (1963), and Wilmot, Henderson, and Allen (1987) for Michigan; Christensen and Harmston (1944) and Siverly (1959) for Indiana; Venard and Mead (1953) for Ohio; and Beckel and Atwood (1959) and Steward and McWade (1960) for Ontario. In our "Account of Wisconsin Species," which follows, these references are not cited unless the information differs from our findings.

Methods and Materials

Study areas

Larval and adult *Aedes* populations were surveyed in nine approximately 24-mile-square areas defined by Billmyer (1971) in conjunction with a survey of Wisconsin stoneflies (Fig. 1). These areas were selected as representative of Wisconsin based on topography, geology, soil types, vegetation, and climate. Study areas were located as follows:

Northern: North of T47N, R4–7W in Bayfield and Ashland counties.

Northwestern: T37–40N, R15–18W in Burnett and Polk counties.

Northeastern: T36–39N, R15–18E in Florence, Forest, and Marinette counties.

North central: T33–36N, R2–5E in Lincoln, Oneida, Price, and Taylor counties.

West central: T23–26N, R11–14W in Buffalo, Dunn, and Pepin counties.

East central: T15–18N, R19–22E in Calumet, Fond du Lac, Manitowoc, and Sheboygan counties.

Central: T16–19N, R7–10E in Adams, Marquette, and Waushara counties.

Southwestern: T9–12N, R1E–3W in Crawford, Richland, and Vernon counties.

Southeastern: T2–5N, R14–17E in Jefferson, Rock, Walworth, and Waukesha counties.

Larval collections

Using a long-handled 350-ml dipper, Gilardi collected mosquito larvae from twenty to thirty sites in each study area on two dates between 4 April and 19 May 1988 (Gilardi 1990). The first set of collections was made when most larvae were early instars. The second set was made just prior to, or coinciding with, the first appearance of adults. Larvae were not present in all localities when the first collections were made, and many sites had dried up before they were sampled again. Five dips were taken from each site on each collection date. Each dip was taken from a different area within the site because numbers and species composition may vary with location (Service 1976). Because larvae submerge when disturbed, they were allowed one minute to return to the surface following a disturbance of the habitat (Hocking 1953) before each sample was collected. Larvae were reared to the fourth instar and pupae were reared to adults to facilitate species identifications.

Ten sites in each area were selected for additional larvae collections by Hilsenhoff in 1989 and 1990. Collections were made just prior to first emergence in 1989 (18 April–10 May) and somewhat after first emergence in 1990 (25 April–8 May), with ten dippers of larvae or a maximum of fifty larvae being collected from each site. Identifications of larvae and adults were based on keys and descriptions by Barr (1958) and Wood, Dang, and Ellis (1979). Voucher specimens are in the University of Wisconsin Insect Collection.

Adult collections

Gilardi (1990) also collected adult mosquitoes with an aspirator during the daytime from 6 June to 21 July 1988 as they attempted to feed. Although the propensity to feed in daylight varies among species, effective biting responses were obtained by collecting in heavily vegetated areas where mosquitoes rest during the day, and by disturbing vegetation before obtaining samples. Two sets of collections were taken. The first

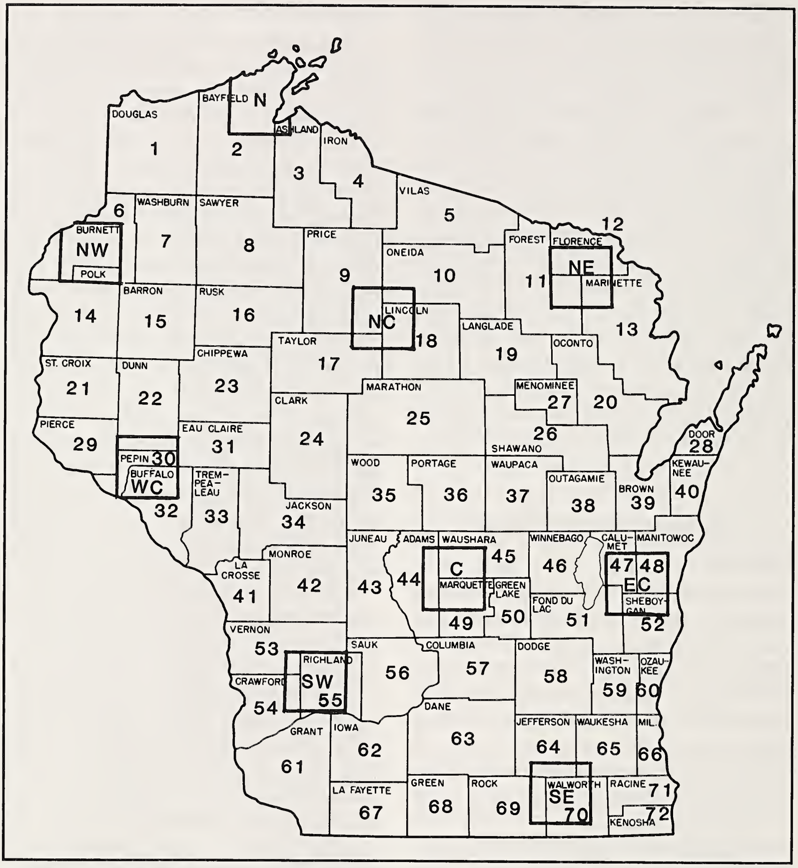

Figure 1. *Nine approximately 24-mile-square study areas selected to be representative of Wisconsin (Billmyer 1971), with a number for each county.*

set approximated peak adult populations. The second was obtained five to six weeks later. Collections were made for a ten-minute period at ten previously identified breeding sites within each study area and also at locations one to five miles from all known breeding areas. Mosquitoes were collected from all areas of the body that could be reached with an aspirator; the head and back were protected with a repellent.

Because female adults of several species of *Aedes* cannot be readily identified after more than a few days of flight, some were often identified only to species group. Two groups are typically recognized for species in this region. The *A. stimulans* group includes the following band-legged species: *A. euedes, A. excrucians, A. fitchii, A. flavescens, A. riparius,* and *A. stimulans*. The *A. communis* group includes the following black-legged species: *A. abserratus, A. cinereus, A. communis, A. decticus, A. diantaeus, A. implicatus, A. intrudens, A. provocans, A. punctor,* and *A. sticticus*.

Results and Discussion

Weather

Prior to the study period in 1988, precipitation ranged from near normal to more than 40% below normal. An early thaw occurred and was followed by cold temperatures, which may have affected the larvae of some species. Kardatzke (1979) determined that larvae of *A. abserratus, A. communis, A. diantaeus, A. provocans,* and *A. punctor* may appear during early thaws in northern Wisconsin and Michigan but subsequently become vulnerable to refreezing. James (1962) documented mortality of *A. provocans* larvae trapped in ice following a thaw in Ontario.

The 1988 study period was characterized by unusually warm temperatures and the onset of a record drought. Small or shallow breeding areas remained dry, and an unusually large proportion of habitats dried before larval development was completed. The spring of 1989 was very dry, and some sites that had been sampled in 1988 contained no water. Very warm temperatures and melting snow in mid-March of 1990 caused an early hatch of *Aedes* larvae, but unseasonably cold temperatures followed, retarding larval development. The onset of very warm weather during the last ten days of April accelerated development and caused rapid pupation and emergence of mosquitoes in most study areas. As a result, larvae of early emerging species were missed or underrepresented at some sites. Except for the northeastern study area, which remained very dry, water levels in 1990 were similar to those in late April of 1988.

Collections

A total of 10,651 larvae and 1,612 adults were collected in 1988, representing twenty of the twenty-three species of spring *Aedes* known to occur in snowmelt habitats in Wisconsin. Included were the first collections of *A. euedes* within the state. The 1988 collections are summarized in Tables 1 and 2. Larval collections from ten selected sites in each area numbered 1,546 in 1989 and 1,600 in 1990, which compares to 1,658 (total adjusted for differences in collecting procedures) from the same sites in 1988 (Table 3). The 1989 samples included the first records of *A. decticus* in Wisconsin.

Species distributions

Crossing the state diagonally is a region of climatic and ecological transition that is reflected in a tension zone of varying width between two major floral regions, the Northern Hardwood-conifer province and the Oak-prairie Province (Curtis 1959). *Aedes communis, A. decticus, A. diantaeus, A. euedes, A. implicatus,* and *A. intrudens* are boreal in Wisconsin, and the southern limit of their range apparently parallels this floral tension zone. Ranges of *A. aurifer, A. canadensis, A. cinereus, A.dorsalis, A. fitchii, A. flavescens, A. sticticus, A. stimulans,* and *A. vexans* encompass the entire state. *Aedes abserratus, A. campestris, A. excrucians, A. provocans, A. punctor, A. riparius,* and *A. spencerii* are probably also present throughout Wisconsin, but may reach their southern limit in southern Wisconsin or northern Illinois. *Aedes campestris, A. provocans,* and *A. riparius* have not been reported from Illinois. *Aedes grossbecki* is represented in Wisconsin by a single specimen from Dane County, which probably represents the northwestern limit of its range.

Geology and soil type also influence the distribution of mosquitoes. Two sections in the Central Lowlands Geomorphic Province of the United States are represented in Wisconsin (Hole 1976), the Wisconsin Driftless Section in the southwestern part of the state, and the Great Lakes Section elsewhere. Mosquito breeding was confined primarily to floodplain marshes and pools in the Wisconsin Driftless Section (southwestern and west central study areas), which limited somewhat the diversity of species collected. Larval habitats were more varied and numerous in the Great Lakes Section (all other study areas). Paleozoic bedrock is present in nearly all areas except a southern extension of the Canadian Shield into the northern third of the state.Certain northern species of *Aedes* were

Table 1. Larvae and collection sites (in parentheses) for species of *Aedes* collected from nine 24-mile-square areas of Wisconsin in the spring of 1988

Species	*Northern*	*North-western*	*North central*	*North-eastern*	*West central*	*Central*	*East central*	*South-western*	*South-eastern*	*Total*
abserratus	1 (1)	31 (6)	37 (14)	20 (7)	2 (1)	23 (4)	2 (2)	1 (1)	6 (2)	123 (38)
aurifer	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	1 (1)	1 (1)
canadensis	40 (6)	16 (4)	48 (6)	14 (6)	94 (4)	39 (4)	20 (4)	280 (9)	28 (5)	579 (48)
cinereus	14 (7)	73 (18)	106 (14)	12 (7)	44 (7)	12 (6)	28 (10)	5 (1)	32 (8)	326 (78)
communis	5 (2)	0 (0)	0 (0)	162 (11)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	167 (13)
diantaeus	1 (1)	0 (0)	5 (1)	10 (4)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	16 (6)
euedes	0 (0)	0 (0)	0 (0)	1 (1)	0 (0)	1 (1)	5 (3)	0 (0)	0 (0)	7 (5)
excrucians	22 (4)	13 (7)	61 (11)	73 (15)	24 (7)	399 (14)	62 (16)	53 (10)	20 (5)	727 (89)
fitchii	1 (1)	3 (2)	4 (3)	30 (4)	7 (3)	71 (5)	2 (2)	7 (5)	4 (3)	129 (28)
flavescens	0 (0)	0 (0)	0 (0)	0 (0)	1 (1)	1 (1)	0 (0)	0 (0)	1 (1)	3 (3)
implicatus	1 (1)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	1 (1)
intrudens	0 (0)	4 (3)	1 (1)	30 (7)	1 (1)	2 (1)	0 (0)	0 (0)	0 (0)	38 (13)
provocans	33 (9)	41 (6)	65 (13)	337 (17)	48 (8)	347 (19)	39 (9)	37 (4)	37 (5)	984 (90)
punctor	1 (1)	3 (3)	29 (10)	118 (11)	1 (1)	10 (2)	1 (1)	3 (1)	4 (1)	170 (31)
riparius	0 (0)	2 (2)	4 (2)	2 (1)	0 (0)	2 (2)	0 (0)	0 (0)	1 (1)	11 (8)
spencerii	3 (2)	2 (2)	2 (1)	2 (1)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	9 (6)
sticticus	1 (1)	1 (1)	5 (2)	1 (1)	14 (3)	1 (1)	2 (1)	3 (2)	0 (0)	28 (12)
stimulans	5 (1)	45 (1)	1 (1)	22 (9)	633 (13)	2,510 (18)	397 (18)	344 (12)	533 (15)	4,490 (88)
vexans	1,006 (7)	1,365 (23)	23 (4)	2 (2)	239 (10)	11 (7)	12 (3)	16 (5)	168 (8)	2,842 (69)
Totals	1,134 (21)	1,599 (30)	391 (30)	836 (28)	1,108 (20)	3,429 (27)	570 (24)	749 (21)	835 (25)	10,651 (226)

Table 2. Adults and collection sites (in parentheses) for species of *Aedes* collected at known breeding sites in nine 24-mile-square areas of Wisconsin in 1988

Species	*Northern*	*North-western*	*North central*	*North-eastern*	*West central*	*Central*	*East central*	*South-western*	*South-eastern*	*Total*
abserratus	0 (0)	0 (0)	6 (2)	0 (0)	0 (0)	3 (1)	0 (0)	1 (1)	12 (2)	22 (6)
aurifer	5 (1)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	5 (1)
campestris	1 (1)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	1 (1)
canadensis	0 (0)	0 (0)	7 (2)	2 (1)	0 (0)	6 (3)	7 (4)	1 (1)	2 (1)	25 (12)
cinereus	28 (5)	34 (5)	80 (6)	9 (3)	88 (6)	54 (5)	233 (9)	11 (3)	46 (6)	583 (48)
communis group	0 (0)	1 (1)	13 (3)	4 (2)	0 (0)	0 (0)	21 (7)	0 (0)	0 (0)	39 (13)
excrucians	6 (1)	1 (1)	1 (1)	4 (1)	0 (0)	2 (2)	20 (9)	0 (0)	6 (4)	40 (19)
fitchii	2 (1)	0 (0)	4 (2)	11 (2)	1 (1)	11 (5)	53 (9)	0 (0)	7 (3)	89 (23)
provocans	85 (8)	0 (0)	119 (5)	12 (4)	2 (1)	24 (6)	6 (3)	0 (0)	0 (0)	248 (27)
stimulans group	3 (2)	1 (1)	3 (2)	2 (2)	27 (5)	152 (10)	235 (10)	43 (5)	33 (6)	499 (43)
vexans	2 (2)	13 (6)	0 (0)	0 (0)	33 (4)	10 (6)	0 (0)	1 (1)	2 (2)	61 (21)
Totals	132 (10)	50 (10)	233 (10)	44 (10)	151 (10)	262 (10)	575 (10)	57 (10)	108 (10)	1,612 (90)

associated with the latter area (Wood, Dang, and Ellis 1979).

Larval phenology

Based on larval collections and rearing, the order of appearance of fourth instar larvae approximated the following sequence: (1) *A. spencerii;* (2) *A. implicatus, A. intrudens, A. provocans;* (3) *A. communis, A. diantaeus, A. punctor, A. sticticus, A. stimulans;* (4) *A. abserratus, A. aurifer, A. excrucians, A. euedes, A. flavescens;* (5) *A. canadensis, A. fitchii, A. riparius;* (6) *A. cinereus, A. vexans.* Larval development of most species was synchronized, with nearly all members of a given species entering the fourth instar within a week or less in the same region. Exceptions were *A. cinereus* and *A. vexans,* which often had staggered emergence periods.

The central sandy uplands and plains, and northern loamy uplands and plains, respond quickly to seasonal warming (Hole 1976). Larval development in these regions was considerably advanced relative to development on other soils.

Adult dispersal

Aedes canadensis, A. cinereus, A. excrucians, A. fitchii, A. provocans, A. stimulans, and *A. vexans* were frequently collected within two miles of known breeding sites. Collections at greater distances did not occur for *A. excrucians* and were infrequent for the other six species. These observations are similar to reports of *Aedes* flight ranges by Jenkins and Hassett (1951), Neilsen (1957), Burst (1980), Washino (1984), and Joslyn and Fish (1986), although many workers have cited much greater flight ranges for *A. vexans* during the summer. Horsfall et al. (1973) indicated that dispersal varies with environmental conditions and may be thwarted in *A. vexans* populations that emerge in the spring before evening temperatures are conducive to flight.

Table 3. Larvae of each species of *Aedes* collected from ten selected sites in each of nine 24-mile-square study areas in 1988, 1989, and 1990

Species	*Year*	*N*	*NW*	*NC*	*NE*	*WC*	*C*	*EC*	*SW*	*SE*	*Total*
abserratus	1988	1	13	5	4	0	9	1	1	0	34
	1989	3	23	35	6	0	0	2	0	0	69
	1990	5	18	58	42	0	0	0	0	0	123
aurifer	1988	0	0	0	0	0	0	0	0	1	1
	1989	0	0	0	0	0	0	0	0	0	0
	1990	0	0	0	0	0	0	0	0	0	0
canadensis	1988	23	8	24	1	0	3	0	44	0	103
	1989	0	2	41	0	0	0	0	0	0	43
	1990	61	0	22	0	0	0	18	7	0	108
cinereus	1988	7	28	2	6	7	0	7	5	1	63
	1989	3	44	9	7	3	1	1	0	0	68
	1990	43	19	66	0	3	0	5	0	1	137
communis	1988	2	0	0	51	0	0	0	0	0	53
	1989	100	0	19	58	0	0	0	0	0	177
	1990	9	0	0	9	0	0	0	0	0	18
decticus	1988	0	0	0	0	0	0	0	0	0	0
	1989	0	0	4	2	0	0	0	0	0	6
	1990	0	0	0	0	0	0	0	0	0	0
diantaeus	1988	1	0	5	5	0	0	0	0	0	11
	1989	3	0	3	0	0	0	0	0	0	6
	1990	6	0	0	5	0	0	0	0	0	11
euedes	1988	0	0	0	0	0	0	1	0	0	1
	1989	0	0	0	0	0	0	0	0	0	0
	1990	0	0	0	1	0	0	6	0	0	7
excrucians	1988	17	4	27	33	17	66	23	15	11	213
	1989	64	7	7	61	4	10	8	4	1	166
	1990	131	84	18	19	0	36	27	2	0	317
fitchii	1988	1	1	1	0	4	50	1	2	0	60
	1989	5	0	0	4	0	20	7	1	2	39
	1990	11	13	4	9	2	18	18	0	0	75
flavescens	1988	0	0	0	0	0	1	0	0	1	2
	1989	0	0	0	0	0	0	0	0	0	0
	1990	0	0	0	0	0	0	0	0	0	0
implicatus	1988	1	0	0	0	0	0	0	0	0	1
	1989	0	0	0	0	0	0	0	0	0	0
	1990	0	0	0	0	0	0	0	0	0	0
intrudens	1988	0	0	1	2	0	2	0	0	0	5
	1989	4	0	0	0	0	1	0	0	0	5
	1990	0	0	0	0	0	0	0	0	0	0
provocans	1988	16	18	31	38	28	76	12	2	18	239
	1989	88	7	64	132	0	48	0	0	0	339
	1990	24	28	30	39	0	24	0	0	0	145
punctor	1988	1	0	7	5	0	8	0	3	0	24
	1989	10	0	20	12	0	0	0	0	0	42
	1990	4	1	70	65	0	0	0	0	0	140

Continued on next page

Table 3—*Continued*

Species	*Year*	*N*	*NW*	*NC*	*NE*	*WC*	*C*	*EC*	*SW*	*SE*	*Total*
riparius	1988	0	1	0	0	0	1	0	0	0	2
	1989	0	0	0	0	0	0	0	0	0	0
	1990	0	0	0	0	0	0	0	0	0	0
spencerii	1988	1	0	2	0	0	0	0	0	0	3
	1989	0	0	0	0	0	0	0	0	0	0
	1990	0	0	0	0	0	0	0	0	0	0
sticticus	1988	0	0	0	0	3	0	0	0	0	3
	1989	0	0	0	0	0	0	0	0	0	0
	1990	0	0	0	0	0	0	0	0	0	0
stimulans	1988	5	0	1	18	152	201	94	55	51	577
	1989	27	0	0	5	87	210	167	22	68	586
	1990	14	8	0	0	23	157	112	84	58	456
vexans	1988	0	210	20	0	15	1	9	7	1	263
	1989	0	0	0	0	0	0	0	0	0	0
	1990	0	0	0	0	61	1	0	1	0	63
Totals	1988	76	283	126	163	226	418	148	134	84	1,658
	1989	307	83	202	287	94	290	185	27	71	1,546
	1990	308	171	268	189	89	236	186	94	59	1,600

Adult longevity

Because drought prevented additional broods of multivoltine spring *Aedes* in 1988, this study provided an unusual opportunity to identify persistent components of spring populations. The second set of adult collections yielded *A. aurifer, A. campestris, A. cinereus, A. stimulans* group, and *A. vexans*. *Aedes stimulans* group adults are frequently reported to persist into August and occasionally September. Carpenter and Nielsen (1965) reported a seventy-two–day biting period for *A. campestris,* and Horsfall et al. (1973) concluded that the typical lifespan of spring generation *A. vexans* females is about seventy-two days. At the opposite extreme, the nuisance potential of *A. provocans* was offset by its brief adult lifespan. Adult collections of this species were primarily a measure of how recently it had emerged in a given area. Wood, Dang, and Ellis (1979) noted that adults of this early species were seldom seen in Canada after other spring *Aedes* had emerged.

Account of Wisconsin species

***Aedes abserratus* (Felt and Young, 1904)** = *Aedes implacabilis* of authors before 1954, except Walker, 1848. County records (Fig. 1): 2, 6, 9, 11–13, 18, 32, 45, 48,* 49, 51, 52, 55, 63,* 64, 65,* 69. (Asterisks indicate published records only.)

Aedes abserratus was fairly common statewide. Larvae were almost always associated with *Sphagnum* in swamps, bogs, shrubby marshes, and woodland pools. Larvae developed in essentially the same habitats occupied by *A. punctor,* but *A. abserratus* larvae were more prevalent in sandy regions, and *A. punctor* larvae were more prevalent in and around *Sphagnum* bogs. Other researchers also noted the association of larvae with *Sphagnum* among shrubs or trees.

***Aedes aurifer* (Coquillett, 1903).** County records (Fig. 1): 2, 13,* 17,* 18,* 35,* 43,* 46,* 51,* 52,* 57,* 61,* 63,* 70.

This statewide species is apparently rare in early spring breeding sites in Wisconsin. In 1988 a single larva was collected from a large, open cattail pond in the southeastern study area, and five adults were collected near a small woodland lake in the northern study area. Other studies in Wisconsin resulted in the collection of a limited number of specimens. Breeding sites reported from nearby states and provinces include permanent and semipermanent bodies of water, cranberry bogs, river-overflow areas, woodland pools, and roadside habitats, with larvae frequently being collected away from shoreline areas.

***Aedes campestris* Dyar and Knab, 1907.** County records (Fig. 1): 2, 52,* 63.*

Aedes campestris is apparently rare in Wisconsin in the spring; it may occur more commonly in the summer. A single adult was collected in the northern study area from a row of trees surrounded by open farmland. This species was found during three surveys in Dane County and was represented by only three specimens in the State Board of Health General Survey (Allen 1950). Elsewhere in the United States and Canada, it was usually found in open areas; larvae were reported to develop in alkaline prairie pools, especially those with a high organic content.

***Aedes canadensis* (Theobald, 1901).** County records (Fig. 1): 2, 5,* 6, 9, 11–13, 17,* 18, 22, 30, 34,* 35,* 37,* 45,* 46,* 48,* 49, 52, 55, 56 (unpublished), 57,* 58,* 63,* 64, 69, 70, 71,* 72.*

This species was fairly common statewide. Larvae were most abundant in woodland seepage pools in the south and boggy areas in the north but also occurred in sedge-cattail marshes. Many researchers in nearby states to the south of Wisconsin noted that woodland pools, especially those associated with streams, are a preferred habitat. Others in northern states and provinces noted an association with *Sphagnum*.

The limited number of adults that were collected may be attributed to the wide range of hosts that are attractive to this species. Limited biting activity was also noted in Wisconsin by DeFoliart (1967), and Carpenter and LaCasse (1955) observed that this species is seldom a pest in the eastern half of its range, even when present in considerable numbers. Several authors have noted that adults often feed on turtles (Crans 1964; Hayes 1965; Nolan, Moussa, and Hayes 1965; DeFoliart 1967; Crans and Rockel 1968). Nevertheless, adults are known to readily attack humans, and they may be an important pest in some areas of Wisconsin, most notably in woodland seepage areas.

***Aedes cinereus* Meigen, 1818.** County records (Fig. 1): 1,* 2, 4,* 5,* 6, 7,* 9, 11–14, 17,* 18, 19,* 22, 23,* 30, 32, 34,* 35–37,* 39,* 41,* 43,* 44, 45,* 48,* 49, 51, 52, 55, 57,* 58,* 61–63,* 64, 65, 66,* 69, 70, 71,* 72.*

Larvae were fairly common in a wide variety of habitats but were mostly found in sedge and cattail marshes or in bogs. They were especially common in the northern, northwestern, and north central study areas. Often several instars were present at the same time, indicating a staggered emergence. The wide variety of larval habitats was noted previously in Wisconsin and by many workers in nearby states and provinces.

Adults attacked readily throughout the day in woodlands, where they were often encountered in considerable numbers. This species was identified as a pest throughout Wisconsin in the State Board of Health General Survey (Allen 1950); it was the second most numerous species biting humans in Iowa County (Loor and DeFoliart 1970).

***Aedes communis* (De Geer, 1776).** County records (Fig. 1): 2, 5,* 9, 11–13, 18, 35,* 48,* 63,* 72.*

This boreal species is an important pest of the Canadian Shield. Larvae were collected only in the northern, north central, and northeastern study areas, where they were the predominant or only species in certain sites. They occurred only within soils of loamy uplands and plains. Here they were found in vernal ponds, mostly in woodlands and partially shaded areas, and along margins of swamps and leatherleaf bogs. Larvae were especially common in 1989; they were much less common in 1988 and 1990. Rapid drying of habitats in 1988 and possible emergence before completion of sampling in 1990 may have contributed to lower numbers of larvae in these years. Siverly and DeFoliart reported this to be the most numerous species in larval collections from Forest County (1968a), and the second most abundant spring mosquito in adult collections from five northeastern counties (1968b). Workers in nearby states and provinces reported *A. communis* larvae from habitats similar to those described above and also noted that they often occur exclusively or nearly so in large numbers. Irwin (1942) found that larvae were particularly abundant in rapidly drying pools and shallow habitats in central Michigan; Gjullin et al. (1961) indicated that adults frequently emerged just before larval habitats in Alaska had dried.

***Aedes decticus* Howard, Dyar, and Knab, 1917.** County records (Fig. 1): 12, 18.

In 1989 six larvae were collected in northeastern Wisconsin from two sites that contained *Sphagnum*. They represent the first records of this species for the state. Four larvae were found in an open leatherleaf bog; the other two were collected from a spruce-tamarack swamp. In the western Great Lakes region other studies associated larvae of this relatively rare species with *Sphagnum*.

***Aedes diantaeus* Howard, Dyar, and Knab, 1917.** County records (Fig. 1): 2, 8,* 9, 11,* 12, 13, 18.

This boreal species occurred uncommonly in northern Wisconsin. Larvae were collected from margins of swamps or from pools in alder (*Alnus*) thickets and were usually associated with *Sphagnum* and alders and almost always with larvae of *A. punctor*. Siverly and DeFoliart (1968a) identified a productive breeding site in Forest County where larvae occurred in stump holes "formed by cedar and hemlock windthrow." They also obtained modest numbers of adults from five northeastern counties (1968b). Prior to their study this species was represented in Wisconsin by a single adult from Sawyer County (Smith 1952). Other studies in our region associated larvae with *Sphagnum* pools and alders or woodland pools.

***Aedes dorsalis* (Meigen, 1830).** County records (Fig. 1): 19,* 63,* 64,* 72.*

Aedes dorsalis adults may emerge later than those of most species of spring *Aedes* in Wisconsin, where they have usually been collected in small numbers, mostly during the summer. No specimens were collected in this study. In other states and provinces larvae of this species were reported to occur in alkaline and saline pools and also in ponds that are rich in organic matter. Outside of the prairie region larvae were usually associated with industrial wastes.

***Aedes euedes* Howard, Dyar, and Knab, 1917** = *Aedes barri* Rueger, 1958. County records (Fig. 1): 11, 13, 49, 51, 52.

Aedes euedes larvae were found only in the northeastern, central, and east central study areas, where they were uncommon. Seven were collected in 1988 and seven more in 1990. These are the only records of this species from Wisconsin. Larvae were collected in association with cattail marshes containing scattered ash trees (*Fraxinus*) or from rather open pools adjacent to woodlands. Wood, Dang, and Ellis (1979) associated larvae with large open marshes having dense accumulations of decomposing sedges and cattails. Wilmot, Henderson, and Allen (1987) reported larvae from several woodland pools in Michigan, while Price (1963) found larvae in nearly all habitats he sampled in northern Minnesota.

***Aedes excrucians* (Walker, 1856).** County records (Fig. 1): 2, 4,* 6, 7,* 9, 11–14, 18, 28,* 30, 39,* 41,* 42,* 44, 45, 48,* 49, 51, 52, 55, 57,* 58,* 63,* 64, 65, 66,* 68,* 69, 70, 71,* 72.*

Aedes excrucians larvae were common in all study areas and occurred in more different sites and habitats than larvae of any other species. They were almost always found in association with larvae of other species and usually were not the dominant species. The relatively ubiquitous larvae were most common in marshes and margins of swamps. It was the most abundant larva that Siverly and DeFoliart (1968a) collected in Lincoln County, where it occurred in unshaded grassy pools and ditches. In nearby states and provinces all researchers reported larvae from a variety of habitats.

***Aedes fitchii* (Felt and Young, 1904).** County records (Fig. 1): 2, 4,* 5,* 6, 7,* 9, 11–14, 18, 19,* 22,* 28,* 30, 35,* 37–39,* 43,* 44, 45, 48,* 49, 51, 52, 55, 57,* 58,* 63,* 64, 65, 66,* 69, 70, 71.*

Larvae of *A. fitchii* were fairly common statewide. They were almost always associated with larvae of *A. excrucians* and/or *A. stimulans* and were never the dominant species in collections. Larvae were most common in marshes but also occurred in drainage ditches, woodland pools, and margins of swamps and bogs. Siverly and DeFoliart (1968a) reported that *A. fitchii* larvae occurred in a wider range of habitats than *A. excrucians* in northeastern Wisconsin. Other researchers in our region found that larvae inhabited mostly marshes and rarely were associated with *Sphagnum*.

Although *A. excrucians* outnumbered *A. fitchii* in larval collections, the opposite was true in adult collections. This may be partially attributed to the greater propensity of *A. fitchii* to invade woodlands, where biting counts were made. In addition, since adults of *A. fitchii* emerge later than those of *A. excrucians*, they would have experienced less mortality prior to the collection of adults in June and July.

Aedes flavescens **(Müller, 1764).** County records (Fig. 1): 2,* 5,* 32, 43,* 49, 60,* 63,* 65,* 69, 72.*

This species was rare in our study. It was reported to be sporadic over most of its range and common only in prairies (Wood, Dang, and Ellis 1979). Three larvae were collected in the southern half of the state, one from a woodland pool, another from a cattail pond, and the third from a glacial kettle. Siverly and DeFoliart (1968b) collected a single adult from northeastern Wisconsin. In other areas of the western Great Lakes region larvae were associated with grassland pools and marshes, cattail ponds, and by Irwin (1942) with woodland pools.

Aedes grossbecki **Dyar and Knab, 1906.** County record (Fig. 1): 63.*

Aedes grossbecki is represented in Wisconsin by a single adult from the University of Wisconsin–Madison Arboretum (Thompson and DeFoliart 1966). This southern woodland species was reported to be common in southern Illinois and rare northward (Ross 1947; Ross and Horsfall 1965).

Aedes implicatus **Vockeroth, 1954 =** *Aedes impiger* of authors before 1954, except Walker, 1848. County records (Fig. 1): 2, 9 (unpublished), 11,* 48.*

Aedes implicatus is apparently a rare boreal species in Wisconsin. In the northern study area a single adult was reared from a pupa that was collected from a marsh that contained willows and was next to a stream. Siverly and DeFoliart, who first reported this species in Wisconsin, obtained a single larva from a coniferous woodland stump hole in Forest County and one adult nearby (1968a); they also collected one adult from an unspecified location in northeastern Wisconsin (1968b). Porter and Gojmerac (1970) reported small numbers of adults emerging from woodland pools in Point Beach State Forest, Manitowoc County. In Colorado, Smith (1965) found larvae in "small shallow pools left by receding streams and shaded by willow thickets"; Wood, Dang, and Ellis (1979) obtained large numbers of larvae from a similar habitat in Ontario. Other workers found larvae mostly in temporary woodland habitats and *Sphagnum* bogs.

Aedes intrudens **Dyar, 1919.** County records (Fig. 1): 2, 5,* 6, 9 (unpublished), 11–13, 18, 28,* 30, 44, 48,* 49, 63,* 72.*

Larvae were rare, but those that were collected were found in all types of habitats except ditches. The varied larval habitat was also noted by other researchers in our region, with *Sphagnum* bogs and woodland pools the most frequently mentioned habitats.

Aedes provocans **(Walker, 1848) =** *Aedes trichurus* (Dyar, 1904). County records (Fig. 1): 2, 6, 9, 11–14, 18, 30, 32, 44, 45, 49, 51, 52, 55, 64, 70.

Aedes provocans larvae were very common in all study areas. Although they were collected most frequently from marshes and woodland pools, larvae were rather common in all types of habitats that were sampled, especially open, temporary sites such as grassy ditches and grassland pools. In northeastern

Wisconsin, Siverly and DeFoliart (1968a) associated larvae with grassy pools. The varied nature of the larval habitat was also reported in studies in nearby states and provinces.

Aedes punctor **(Kirby, 1837).** County records (Fig. 1): 2, 5,* 6, 9, 11–13, 18, 30, 35, 45,* 48,* 49, 52, 55, 57,* 65,* 69.

Larvae of *A. punctor,* an important pest of the boreal forest, were common in the north central and northeastern study areas and uncommon elsewhere. They were the most numerous larvae in the northeastern study area, and also in the study by Siverly and DeFoliart (1968a) in northeastern Wisconsin. Among species we commonly collected, *A. abserratus* and *A. punctor* were most often coincident in larval habitats; *A. punctor* larvae appeared in more than three-fourths of the sites known to be inhabited by larvae of *A. abserratus*. During a seven-year study in Minnesota, Price (1963) observed that *A. punctor* larvae occurred in all habitats that had yielded *A. abserratus* larvae. While larvae were collected from a variety of habitats, they most frequently occurred in *Sphagnum* bogs and, to a lesser extent, in woodland pools with *Sphagnum*. Most researchers in nearby states and provinces mentioned that larvae were associated with *Sphagnum* and shrubs or trees. The exception was Steward and McWade (1960), who found larvae in Ontario in virtually all types of standing water, most commonly in woodland pools.

Aedes riparius **Dyar and Knab, 1907.** County records (Fig. 1): 6, 9, 12, 28,* 43,* 45, 49, 51,* 63,* 64, 65.*

Aedes riparius is apparently rare in Wisconsin. Only four specimens were found in the State Board of Health survey (Allen 1950). Larvae were collected in small numbers from several habitats but most frequently were found in marshes. Researchers in nearby states and provinces also collected larvae mostly from marshes that frequently contained some scattered trees or shrubs, or had trees along their margins.

Aedes spencerii **(Theobald, 1901).** County records (Fig. 1): 2, 5,* 6, 9, 12, 13,* 32,* 51,* 52,* 58,* 63,* 69.*

Aedes spencerii is apparently uncommon in Wisconsin. A few pupae were collected in northern areas during the first set of larval collections in 1988; in 1989 and 1990 adults had probably emerged before larval collections were made. All pupae were collected from open habitats, including grassland pools, a sedge marsh, a *Sphagnum* bog, and a small pond. In adjacent states larvae were reported from grassland pools, marshes, and bogs. Wood, Dang, and Ellis (1979) indicated that this species has been underrepresented or overlooked in several studies because of its early appearance, noting that pupae were present when larvae of other spring *Aedes* were about half grown.

Aedes sticticus **(Meigen, 1838).** County records (Fig. 1): 2, 6, 11, 18, 30, 32, 35,* 42,* 48,* 49, 52, 55, 67.*

Larvae develop throughout the state primarily in floodwater pools along streams. Although rare in this study because of the drought in 1988, *A. sticticus* larvae may become exceptionally numerous near streams after unusually heavy snowmelt and/or rain. It was identified as a pest in Manitowoc County (Porter and Gojmerac 1970). Adults were collected in considerable numbers in Wood County (Wright et al. 1970) and in five northeastern counties (Siverly and DeFoliart 1968b).

Cook, Bodine, and Wermerskirchen (1974) studied the biology of this species in the Twin Cities area just west of Wisconsin. Eggs were laid along the periphery of flooded areas and accumulated in river floodplains and bottomlands during intervals between extensive floods. They remained viable for several years under drought conditions and hatched after flooding. In Canada, Wood, Dang, and Ellis (1979) observed that *A. sticticus* populations are almost always associated with *A. vexans,* but that the converse is seldom true "because *A. vexans* develops in summer rainpools after local flooding, whereas *A. sticticus* requires extensive flooding, which only follows widespread excessive precipitation."

Aedes stimulans **(Walker, 1848).** County records (Fig. 1): 2, 4,* 5,* 6, 11–14, 18, 19,* 22, 28,* 30, 32, 37,* 39,* 44, 45, 47, 48,* 49, 51–53, 55, 57–59,* 61,* 63,* 64, 65, 66,* 69, 70, 72.*

Larvae of *A. stimulans,* the most numerous species in this study, were found in a variety of habitats but were collected most frequently and in largest numbers from marshes, temporary ponds, and woodland seepage pools, including river valley sites. Some ditches and grassy pools near marshes also harbored large populations. In other studies larvae were most often associated with woodland pools. In Minnesota, however, Owen (1937) mentioned grassland pools as a preferred larval habitat, while Price (1963) observed that they prefer marshes but often occur elsewhere.

Adults were the most important nuisance in central and southern Wisconsin in May and early June, but they were uncommon in much of the north. Siverly and DeFoliart (1968a) noted a virtual absence of this species in northeastern counties. A similar pattern is evident in other studies in this region. Wood, Dang, and Ellis (1979) associated large populations south of the Ottawa area with paleozoic sediments, and the general scarcity northward with the Precambrian Shield, implicating acidity as a possible limiting factor. The largest collection of larvae from the four northern study areas in 1988 (outnumbering all other northern collections combined) was taken from a site in the northwestern study area that is not on the Precambrian Shield.

Aedes vexans **(Meigen, 1830).** County records (Fig. 1): 2, 5,* 6, 9, 11, 13, 14, 17,* 18, 22, 29,* 30, 32,* 34,* 35,* 37–39,* 41,* 42,* 44, 46,* 47, 48,* 49, 50,* 51, 52, 53,* 54,* 55, 56–58,* 61–63,* 64, 65–68,* 69, 70, 71,* 72.*

Aedes vexans, the most important pest mosquito during the summer and fall in most areas of Wisconsin, was a variable component of spring populations. It was the second most abundant species in larval collections in 1988, larvae were absent in 1989, and larvae were numerous only in the west central study area in 1990. This was probably the result of more extensive flooding of habitats by early spring rains in 1988. Adults, however, were found in small numbers in 1988 because many habitats dried before larval development was completed. Larvae were collected from all types of habitats, but more than 85% were found in marshes and grassland pools, and only about 1% were from woodland pools and *Sphagnum* bogs. Shallow, open, grassy depressions were identified as primary breeding areas by workers in nearby states and provinces. However, Horsfall et al. (1973) and Wood, Dang, and Ellis (1979) observed that woodland habitats can also harbor large populations.

Larvae were collected most frequently and in largest numbers within areas containing sandy or loamy soils, which corroborates findings in other states (Horsfall et al. 1973). Siverly and DeFoliart collected substantial numbers of larvae (1968a) and adults (1968b) in parts of a five-county area in northeastern Wisconsin that were dominated by such soils. Horsfall et al. (1973) indicated that this species is very local or absent in northern Michigan wherever black-legged species such as *A. communis* and *A. punctor* are abundant. A predominance of *A. communis* group species and scarcity of *A. vexans* were evident in most larval collections by Siverly and DeFoliart (1968a).

Possible additional species

Aedes pionips **Dyar, 1919.** This univoltine northern species was reported from Itasca State Park, Minnesota (Barr 1958; Price 1963), Isle Royale, Michigan (Cassani and Newson 1980); and Ontario (Wood, Dang, and Ellis 1979). It was reported to be common in the boreal forest region and rare or local southward.

Aedes pullatus **(Coquillett, 1904).** Earlier reports of *A. pullatus* from Michigan by Irwin (1942) were questioned by Barr (1958) and Wood, Dang, and Ellis (1979), and because of their distance from established records and an apparent lack of more recent material, they were discounted by Darsie and Ward (1981). However, based on unpublished data of Wagner and Newson from 1971, Cassani and Newson (1980) reported *A. pullatus* from six counties in the northern half of Michigan. Other records show an unusual disjunct distribution of this univoltine species in northwestern and northeastern North America, which may be a result of glacial history (Wood, Dang, and Ellis 1979).

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Symbolism in the Cave of Montesinos

James T. Abraham

The episode of the Cave of Montesinos in *Don Quixote* has become one of the most analyzed and interpreted incidents in modern literary history. Most critics agree that it is the crucial moment in the work because, as Gethin Hughes states, "We witness the confrontation of two worlds in Don Quixote's mind—the chivalric and the real" (112). The novel takes a different direction after Don Quixote resurfaces and tells the story of his "grande adventura de la cueva de Montesinos." This is the only adventure that Don Quixote faces alone, so it gives us the best opportunity to study his psychological state. By analyzing the dream, we can better understand Don Quixote's madness. This paper discusses the symbols and their meanings in the dream and the significance of the dream itself.

Sigmund Freud wrote in his book, *The Interpretation of Dreams,* that all dreams have meaning. The meaning of a dream can be interpreted through the symbols that appear in the dream itself. The incident in the Cave of Montesinos is rich in symbolization. In the dreamwork Don Quixote descends into a legendary cave and encounters a beautiful landscape and crystal palace. He meets several famous characters, all demonstrating bizarre behavior. Upon seeing his enchanted mistress, the knight is elated but confused by her actions. Finally Don Quixote ascends back into the "real" world only to find his friends criticizing the cave, the adventure, and Don Quixote himself. Analyzing dreams and their significance is part of the psychoanalytic process developed by Freud around the turn of the century. Psychologists today still use the guidelines set down by Freud to analyze dreams. The ideas presented in this paper suggest possible explanations for the dream and even Quixote's madness by using psychoanalytical theories.

The first symbol we encounter is the cave itself. Don Quixote is familiar with the legend surrounding the cave and insists on stopping at it on his way to Barcelona. He wants to descend into the cavern and see "si eran verdaderas las maravillas que de ella se decían por todos aquellos contornos (if they were true, the wonders that were spoken of the cave in those parts)" (Cervantes, *Don Quixote,* 435). Before entering the cave, Don Quixote must chop his way through thick brush to find the entrance and fend off bats, owls, and other nocturnal birds. Quixote has intense drive and needs to experience what the cave holds. He is not afraid of his destiny and is, in this case, actively pursuing his future.

The cave itself is "a maternal symbol that excites curiosity" (Becker, 149). It is a positive symbol because caves were often used as oracles. In the pastoral novel of Spain, the cave was the entrance to the underworld. According to Frederik de Armas, caverns were "the source of power of magicians, wisdom of prophets and inspiration of poets" (Armas, 337). They were used to communicate with the dead. Carl Jung believed the cave represents the unconscious. Cervantes did not use caves in his pastoral novels because of

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their demonic connotations but reversed his fear in *Don Quixote* and *La cueva de Salamanca.*[1] The use of a cave by Cervantes signals something very important. In this case, the cave symbolizes a mystical realm in the unconscious mind of Don Quixote where he can come in contact with the souls of his fallen brethren and chivalric heroes from an age regrettably now past.

This magical place where knights live is known to Alonso Quijano only through the books of chivalry that have driven him mad. The old man's love and belief in the Age of Chivalry, yet total lack of experience in it, mirror in reverse his adventures. In the novels of chivalry, the aspiring knight learned of rules and codes of conduct to be followed by all in order to establish order amidst chaos. But *El Caballero de la Triste Figura,* upon putting on armor and accepting the charge of knighthood, has come to learn that being a knight is not an easy endeavor. He is battered and trampled, disgraced and dishonored. Needing rest and a return to the code of chivalry, Quixote sets out on a pilgrimage to the cave of Montesinos. But the cave is much more than just another place to explore. He seeks in the maternal symbol a return to his novels, to security, to the womb. This is evident when Don Quixote resurfaces and begins to tell his story. Sancho, solidly fixed in the "real" world of the novel, calls the cave a pit. Don Quixote becomes enraged and demands that Sancho and the scholar not call it a pit. With great emotion, he chastises them saying, "Dios os lo perdone, amigos; que me habéis quitado de la más sabrosa y agradable vida y vista que ningún humano ha visto ni pasado (God forgive you friends because you have taken me from the most pleasurable life that any human has seen or experienced)" (Cervantes, *Don Quixote,* 438). On the surface Quixote may be defending the honor of his mother since the cave is a maternal symbol. However, I believe he is really defending his entire chivalric world and the fact that it exists. No part of his "world" may be put into question because it is founded on such unsteady ground that it could easily be toppled.

Deeper into the symbolism, we can look at the bell that Don Quixote forgets to put on. The bell is a symbol of reality and his link to the world outside the cave. It is proof that he is moving in the flesh and blood world of reality. If he had been wearing the bell, Sancho and the scholar would surely have yanked him back into reality when it stopped making a sound, thus ending any possible adventure. Without it, however, the knight is free to roam in the unknown and experience all the "maravillas" of the cave. He is free to step out of reality and explore the world of fantasy.

Another symbol that is part of the old knight's entrance into the cavern is the rope used to lower him. Becker states that a rope represents the sexual act (84). The smooth walls of the cave represent erect bodies according to Freud (109). Therefore, Don Quixote's descent by means of a rope, past the smooth walls of the cave, symbolizes what Don Quixote knows little about—sex. The effect is to emphasize the fact that Don Quixote is breaking new ground with respect to the world of his heroes and his own sexuality.

Once inside the cave, Don Quixote sees a beautiful place that only nature could create. He is not sure whether he is asleep or awake but soon convinces himself that he has all his faculties. Could the knight be in paradise? I believe so, at least the paradise that the knight Don Quixote de la Mancha has envisioned. The beautiful landscape emphasizes the idyllic nature of the dream. In this ideal land, Quixote spies a crystal castle. Crystal represents the self (Becker, 154), and here Don Quixote is looking into a mirror. He sees himself as a majestic, strong, and royal personage equal to his ideals. He has created in his mind the perfect reincarnation of himself and his beliefs.

Soon after creating his heaven, Quixote meets its first inhabitant, the old Montesinos. The knight describes Montesinos as "vestido con un capuz de bayeta morada, que por el suelo le arrastraba, ceñíale la cabeza una gorra milanesa negra, y la barba, canísima, le pasaba de la cintura (He was clad in a long mourning cloak of purple baize, which trailed upon the ground; over his shoulders and breast he wore a kind of collegiate tippet of green satin, his hoary beard reaching below his girdle)'' (Cervantes, *Don Quixote,* 439). Is this the image of God in Don Quixote's mind? Not exactly. Becker says kings or queens represent parents (85); Montesinos represents Don Quixote's father. Quixote further proves this when he says, ''El continente, el paso, la gravedad y la anchísima presencia, cada cosa de por sí y todas juntas, me suspendieron y admiraron (His mien, his gait, his gravity, and his goodly presence each singly and conjointly filled me with surprise and admiration)'' (Cervantes, *Don Quixote,* 439). Just as a child respects his parents, Don Quixote looks up to Montesinos and respects him.

Montesinos has been analyzed by many critics, and all have found different things about him strange. He is a figure from medieval Spanish ballads in the region of La Mancha. Carrol B. Johnson, in his book, *Madness and Lust,* remarks that although Montesinos is dressed in a scholarly way, he does not know all the answers. He does not know how to disenchant all the people in the cave or whether he used a ''daga'' (dagger) or a ''puñal buido'' (dirk) to take out his friend Durandarte's heart. Even more startling to Quixote is the fact that Montesinos is not familiar with the beautiful Dulcinea (163). Johnson interprets these uncertainties as Don Quixote's own or, much more likely, as those of his father (163). Just as a rebellious teenager believes that his parents do not know what is best, Don Quixote questions Montesinos.

A theme discussed by E. C. Riley is the absurdity of Montesinos. The picture given us of Montesinos does not fit the image of a great knight. He is holding a rosary with beads the size of chestnuts and ostrich eggs. He does not evoke awe or fear as a great knight of his time would but rather appears ridiculous. Further highlighting the absurdity of Montesinos is the fact that his best friend, Durandarte, was to have had a heart that weighed two pounds.[2] Riley writes, ''These ridiculous details puncture the fabric of his (Don Quixote's) chivalric vision'' (142). He believes these elements are meant to mock Don Quixote and his principles (142). They emphasize the ridiculous nature of the dream and the old knight himself.

Soon after meeting Montesinos, Don Quixote asks the old man if the legend surrounding the removal of his best friend's heart is true. Montesinos answers ''yes,'' and the fact that there is a question about the dagger leaves us to wonder about its significance. The knife is a masculine symbol. The appearance of a masculine element within the womb causes much fear in Don Quixote. Johnson believes the dagger symbolizes Quixote's fear of castration and the castrating female (167). This symbol is a manifestation of his inability to interact with women and probably stems from an unresolved problem in the Oedipal stage of his childhood (Johnson, 167).

Next, Don Quixote meets the zombie Durandarte. Named for Roland's sword, he is Don Quixote's image of the ideal knight. Johnson believes Durandarte is identifiable to Don Quixote because they are both knights and both have hairy, bony hands that show great strength. Don Quixote identifies with him but is afraid when he realizes that Durandarte is no longer a powerful knight. Because Durandarte and a sword are so closely related, Johnson associates Durandarte to the phallus through symbolization (164). The fact that Durandarte is a ''sword-phallus rendered useless by bloody mutilation'' (Johnson, 164) points to impotency. Because Durandarte and Quixote are essentially the same, Durandarte's impotency points to fears of impotency in Don Quixote. Johnson goes as far as to say that this element of impotency ''bring[s] together some of the most pervasive themes of Don Quixote's psychic life, with some of the most deep-seated fears about himself and his manhood'' (164).

The first female character that the knight encounters is the noble woman, Belerma. Quixote describes Belerma as clad in black, with a slightly up-turned nose and a large mouth with colored lips. Johnson sees three different themes in the character of Belerma. First, he believes that she represents all the older women in Quixote's life—his mother, his grandmother, and others (165). The allusions to the age and sensuality of Belerma are signs of an Oedipal attraction in the knight's past. Next, there is a relationship between Belerma and Dulcinea since Belerma is to Durandarte what Dulcinea is to Don Quixote, mainly the object of courtly love (164). Belerma, according to Johnson, represents the reason for his dysfunction, something from his childhood that has forced him to create Dulcinea (167). Finally, because they both have bad teeth and are sexually inoperative,[3] Don Quixote and Belerma are identifiable as one (Johnson, 168). Belerma was a legendary beauty, but when Don Quixote sees her he is disappointed and disillusioned. Hughes sees the symbolism and applies it to Dulcinea. She believes that it means if Belerma can be made ugly, through enchantment, so too can his beautiful Dulcinea (110). It is important to remember that Don Quixote's picture of the enchanted Dulcinea is the ugly maid Sancho pointed out to him. The image of ugliness through enchantment bolsters Quixote's belief in the existence of an enchanted world and its need for his help.

Separately, each of these people has major significance. Is there any significance to the three being together? Johnson believes there is. He states, ''All three of the chivalric characters are projections of different aspects of our hero himself'' (167). This idea fits with Freud's theory of condensation; that is, many unrelated elements may come together in a dream. All share nearly the same age and the fact that their lives are at a standstill (Johnson, 167). The three inhabitants of the cave are sentenced to live forever in legend, while Don Quixote, although still part of the ''real'' world, takes time out from the continuing action above ground to join them in fantasy below ground. By joining the three characters into one, we complete the psychic picture of the bent knight. Montesinos, according to Johnson, projects a number of intellectual insecurities. Durandarte projects Quixote's fear of castration and impotence, and Belerma reflects his fear of aging (167). Throughout the dream, Quixote is analyzing himself and struggling with questions that run deep into his psyche.

Finally, Don Quixote comes face to face with the ''incarnation of his chivalric world'' (Hughes, 109), Dulcinea. She is with two other damsels and runs away at the sight of the great knight. One of the damsels soon comes back and asks if Don Quixote might lend Dulcinea six *reales*. He has only four, but gives them to her anyway. Johnson believes the money represents Dulcinea's sexual needs and Quixote's prowess (158). The fact that he is unable to give her the total of six *reales* once again symbolizes his fears of impotency and capability of loving his mistress. Hughes believes the monetary aspect destroys Don Quixote and his chivalric world (112). The money is not part of the chivalric code and thus proves that this world cannot and does not exist. It is this event that later (on his deathbed) permits Don Quixote to accept Sanson Carasco and the priest. Dulcinea's simple request for money shows him that his ideals are fantasy, and he cannot survive in the current age of realism.

By looking at the entire episode of the Cave of Montesinos, we can get a good look at Don Quixote's psychological state. Perhaps the best picture comes not from a psychoanalyst, but from one of Spain's great authors, Miguel de Unamuno. Donald Palmer, in his article entitled, ''Unamuno, Freud and the Case of Alonso Quijano,'' points to Unamuno's book *Vida de Don Quijote y Sancho*[4] as the first psychoanalytical account of Don Quixote (243). In fact, Unamuno and Freud were contemporaries, and Unamuno's book was published while Freud was doing his major work on psychoanalysis. In the book, Unamuno discusses sublimation. Freud defines sublimation as "the sexual trend abandoning its aim of obtaining a component of reproductive pleasure and taking on another which is related genetically to the abandoned one but is itself no longer sexual" (Brill, 179). Palmer reports that Unamuno believed Quixote repressed his amorous feelings for his teenage maid and, after letting the repression boil for twelve years, finally went mad. Claiming that aspects of higher culture come from sublimations of repressed instinctual drives (Brill, 215), Freud does not condemn this sublimation as evil but calls it "a triumph of spirituality over the senses" (Brill, 217). Quixote's quest for the pure, the noble, and the chivalric is the outcome of his sublimation of amorous feelings. His need to contact past heroes is just another manifestation of his repressed desires. Although hiding a dark secret, he retains his honor and dignity (at least in his own eyes). Johnson agrees with this idea, stating that Don Quixote has repressed his feelings for his niece from "just below conscious to deep unconscious level" (156).

Another plausible explanation for the dreamwork in Don Quixote's dream is the theory of wish fulfillment. Freud writes: "A dream is a (disguised) fulfillment of a (suppressed or repressed) wish" (Brill, 57). Quixote has been struggling with the enchantment of his damsel since Book I, Chapter 10, when Sancho invented her. Hughes believes the dream allows him to solve the problem of Dulcinea's enchantment (108) through wish fulfillment. Don Quixote's wish for a land where the laws of chivalry are upheld and adventure involving his damsel is obvious in the dream. He identifies with all the people in the dream world, and his supreme chivalric act would be to disenchant all its inhabitants. This theory rationalizes the dream as merely an escape into fantasy land for the gallant knight, thus having no psychological value other than to manifest his aspirations.

The final explanation for this episode is that it is a look into the psyche of Cervantes himself. Becker states, "The work of art and, even more, dreams in works of art have been considered as confessions of the artist's unconscious personality, his affective conflicts and especially his sexual complexes" (103). He outlines how dreams may be used in literature. First, the author may use the dream explicitly to further the main theme in the work. Second, he may use the dream implicitly as an invisible support system for the structure of the work. Applying this theory to *Don Quixote,* we might say Cervantes uses Don Quixote's lunacy explicitly to satirize the Chivalric Age. The dream, once again, reinforces the madness of the old knight and the absurdity of the Chivalric novel. Implicitly, however, the dream creates a picture of the reasons for Don Quixote's madness. It subtly shows us that Don Quixote is not just mad but that there are concrete reasons for his condition. He has suppressed his amorous desires for all the women he has ever known and now must deal with all the repercussions. He struggles relentlessly against tremendous obstacles. It is sad that Don Quixote will never know love, but it is noble that he will fight until death to keep the hope for it alive.

Endnotes

[1]Miguel de Cervantes, "La cueva de Salamanca," in *Entremeses de Miguel de Cervantes Saavedra,* ed. Adolfo Bonilla y San Martín (Madrid: Asociación de la Librería de España, 1963).

[2]The legend of the day stated that the size of a man's heart is directly proportional to his bravery.

[3]Belerma was postmenopausal and Don Quixote impotent.

[4]Miguel de Unamuno, *Vida de Don Quixote y Sancho Según Miguel de Cervantes Saavedra, Explicada y Comentada por Miguel de Unamuno* (Madrid: Renacimiento, 1928).

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The Distribution of Franklin's Ground Squirrel in Wisconsin and Illinois

Timothy L. Lewis and Orrin J. Rongstad

Abstract. *Eastern populations of Franklin's ground squirrel* (Spermophilus franklinii) *have declined in the past two decades. We studied the current range of this squirrel in Wisconsin and Illinois to determine whether a reduction in range accompanied the population decline. We contacted 236 biologists in Wisconsin and Illinois by mail and telephone to determine the extent of recent sightings. We found a range extension in northwestern Wisconsin but a range reduction in southwestern Wisconsin and northwestern Illinois. Several possible explanations for the range reduction are discussed.*

A growing body of evidence indicates that in recent years the number of Franklin's ground squirrels has declined at the eastern extent of its range (Van Petten and Schramm 1972; Panzer 1986; Johnson 1988). We studied the distribution of this squirrel in Wisconsin and Illinois to determine its current range.

In Indiana Franklin's ground squirrel was listed as a "species of special concern" (Panzer 1986). Recent trapping work in Indiana indicated a substantial reduction in the ground squirrel's distribution (Johnson 1988). At least two reintroductions of Franklin's ground squirrel in Illinois have succeeded in countering this decline (Van Petten and Schramm 1972; Panzer 1986). In Wisconsin the squirrel is currently managed by the Bureau of Endangered Resources.

Franklin's ground squirrel is reclusive, hibernating from late September until April each year (Sowls 1948; Panzer 1986), and is strictly diurnal. Thus it may spend 90% of its life below ground (Sowls 1948). Its habitat is native prairie, brushy borderlands, fence rows bordering cropland and railroad tracks, or marshland edges (Cory 1912; Sowls 1948; Jackson 1961).

This squirrel's natural range was almost exclusively in the tall- and mid-grass prairie region (Hall 1981; Hall and Kelson 1956). The general range of the squirrel has not changed much in recent times, although De Vos (1964) reported a slight range extension along the Indiana-Michigan border, and Anderson (1947) reported a range extension in Manitoba. De Vos (1964) attributed the extension along the Indiana-Michigan border to human-influenced disturbances. Smith (1957) attributed the Manitoba extension to climatic changes.

The Franklin's ground squirrel has probably always been an uncommon species in Wisconsin and Illinois. The squirrel is more abundant farther west in Minnesota, the Dakotas, and north into the plains of Canada. Wildlife biologists in the eastern range of the squirrel feel that the abundance of the ground squirrel has declined during the past twenty years. This survey was conducted to deter-

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mine whether there have been any changes in the ranges found in Wisconsin and Illinois.

Methods

We identified wildlife biologists and state park naturalists as the people most likely to be familiar with the Franklin's ground squirrel. In October 1986 we surveyed each biologist by mail and by follow-up telephone interview about recent and past ground squirrel sightings. In the past, sightings were often recorded because of the squirrel's destructive role as a nest predator (Sowls 1948; Sargeant et al. 1987). Each biologist was asked to report any Franklin ground squirrel sightings made in the past ten years.

In Wisconsin we contacted all 68 Department of Natural Resources wildlife biologists and managers, as well as 4 U.S. Fish and Wildlife biologists at Horicon National Wildlife Refuge. In Illinois we contacted 22 of 25 wildlife managers and all 6 natural heritage biologists. In addition, we wrote to each state park supervisor or naturalist at Wisconsin's 61 state parks and recreation areas, the Illinois Department of Conservation's 71 state parks and recreation areas, and 4 forest preserve districts. A sample of nonrespondents was made to determine nonresponse bias.

Information on Franklin's ground squirrel was also solicited from the general public through wildlife managers, radio programs, and personal contacts in areas where Franklin's ground squirrels were previously found. Most such sightings reported by the public were other small mammals; however, several sightings were later confirmed by personal observation. Each potential sighting location in Wisconsin was visited and livetrapping attempted at five locations.

Results

We received 70 responses from 126 biologists (many responded jointly) of the 236 biologists originally surveyed. Follow-up telephone calls to 15 nonrespondents indicated nonresponse was due to lack of sightings to report.

Wisconsin

The Franklin's ground squirrel was reported in 14 of 72 counties in Wisconsin. There were 35 sightings reported for 28 locations (Fig. 1). Concentrations of squirrels

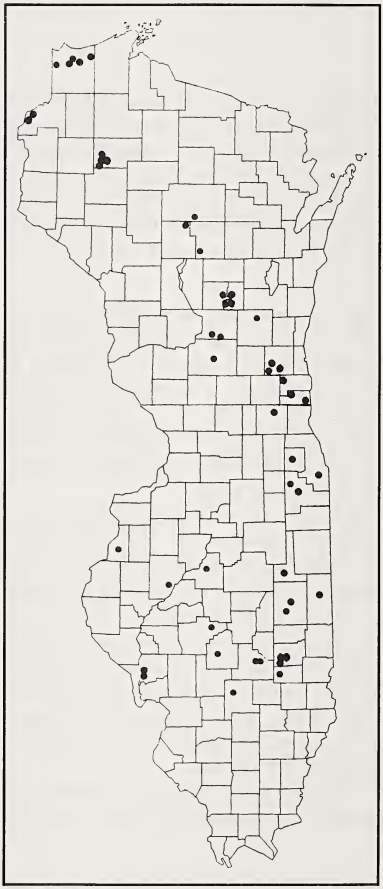

Fig. 1. *The reported locations of Franklin's ground squirrel sightings by Illinois and Wisconsin biologists for 1985 and 1986. Note the lack of sightings in the unglaciated southwest portion of Wisconsin and northwest Illinois.*

were found in Douglas, Burnett, and Rusk counties in northwest Wisconsin, and in Waukesha, Racine, and Kenosha counties in southeastern Wisconsin, as well as thinner groupings in between in an area ranging from Marathon County to Dodge County. In addition, one Franklin's ground squirrel was observed during trapping near Horicon National Wildlife Refuge, and two were collected in northwestern Douglas County.

Illinois

Franklin's ground squirrels were reported in 22 locations in 16 of 102 counties in Illinois (Fig. 1). Squirrels were reported in the northeast in Cook, DuPage, and Will counties. All other sightings were in a band of central counties from Henderson and Green counties to Ford, Vermilion, Coles, and Champaign counties. Squirrel range in Illinois showed no new extensions; no sightings were reported in northwestern Illinois, contiguous to an area of southwestern Wisconsin where there were no squirrels.

Discussion

Wisconsin

Cory (1912) listed the range of Franklin's ground squirrel in Wisconsin as southern and western Wisconsin. His map (Fig. 2A) depicted the range from Burnett County southeast to Walworth County, west of Lake Michigan on the Illinois border. No specific sightings were listed.

Hall and Kelson (1956) drew the range line closer to Lake Michigan in the southeast, including Racine and Kenosha counties, south of Milwaukee (Fig. 2B). They listed only one specific sighting in Wisconsin, at Lake Delavan, and relied on sightings in Minnesota and Illinois to place the range line in Wisconsin.

Jackson (1961), dealing specifically with Wisconsin mammals, as had Cory (1912), listed 32 sightings and museum specimens dating from pre-1900 to 1960. Jackson's range for the Franklin's ground squirrel (Fig. 2C) is the most accurate to that date,

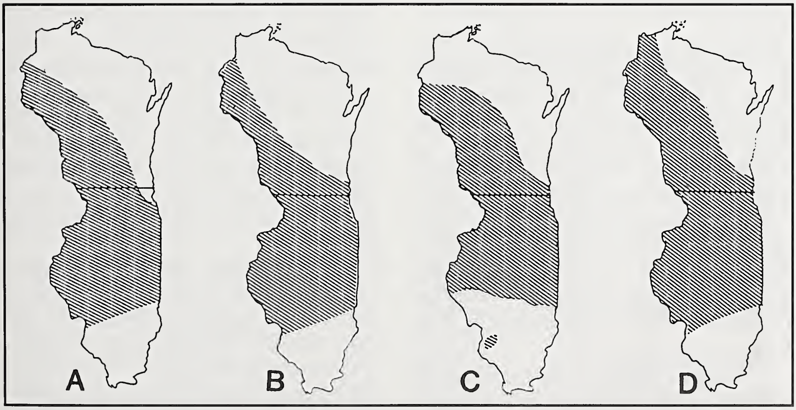

Fig. 2. *The historical distribution of the Franklin's ground squirrel in Illinois and Wisconsin. Figure A shows the early distribution in both states according to Cory (1912). Figure B shows the distribution according to Hall and Kelson (1956). Figure C gives the Illinois distribution of Hoffmeister and Mohr (1957) and the Wisconsin distribution after Jackson (1961). Figure D shows the most recent range estimates for both states as given by Hall (1981).*

based upon museum specimens and sightings from authorities. He confirmed the range described by Hall and Kelson (1956) in Racine and Kenosha counties with actual records and moved the northwest range more southerly to Polk County, just south of Burnett County.

Hall (1981) revised the 1956 range map in Wisconsin (Hall and Kelson 1956) in light of Jackson's 1961 work and one additional sighting in Hibbing, Minnesota, and one in Duluth. Using no records from Wisconsin, Hall estimated the range to extend north in northwest Wisconsin into Douglas County (Fig. 2D). We found five Franklin's ground squirrels, including two livetrapped, for Douglas County, verifying Hall's 1981 range estimate. All of the Wisconsin ranges listed are close to the tension zone described by Curtis (1959).

Illinois

Cory (1912) placed the range of the Franklin's ground squirrel in Illinois as the entire northern two-thirds of the state except Lake County in the far northeast (Fig. 2A). His southern line ran from Madison to Clark counties.

Hall and Kelson (1956) established the range 80 km farther south based on one sighting in St. Clair County (Fig. 2B). They also included one sighting in Lake County in the northeast. Hall (1981) did not modify his earlier range map (Hall and Kelson 1956) after twenty-five years (Fig. 2D).

Hoffmeister and Mohr (1957) were more conservative with their range line (Fig. 2C). Their line of known locations was farther north from Adams County to Vermilion County, with a disjunct population in St. Clair County.

Our results tended to follow a line from Madison County to Clark County in the south, though sightings were reported from St. Clair County. There were no sightings in northwest Illinois contiguous with the area in southwestern Wisconsin that had no recent Franklin's ground squirrel sightings.

Changes in distribution

It appears from our distributional data that Franklin's ground squirrels have a relatively stable range in Wisconsin and Illinois. However, we found no sightings in southwestern Wisconsin or northwestern Illinois, where a few squirrels had previously been reported (Jackson 1961).

Illinois naturalists familiar with Franklin's ground squirrel think it has declined over the past thirty years, although precise data are lacking. Jim Grude of the McHenry County Conservation Department attempted to trap ground squirrels in the county but found none during the summers of 1986 or 1987 (pers. com.). Van Petten and Schramm (1972) wrote twenty years ago of the "increasing rarity" of Franklin's ground squirrel in Illinois. Many of the responses to our survey also included comments suggesting the loss of squirrels, or at least the perception of loss from decreased frequencies of sightings. In order to counter the decline in Illinois, Van Petten and Schramm (1972) in Knox County and Panzer (1986) at the Markham Prairie have with some success attempted reintroduction into the former range.

There are several reasons that the Franklin's ground squirrel may no longer be found in southwestern Wisconsin. The squirrels may never have been common in the unglaciated portions of Wisconsin and Illinois. This area is covered by a thin layer of unconsolidated material less than fifty feet thick, and often only inches thick. Erosion can be severe and could create a problem with burrow construction.

Land-use changes seem to be a primary candidate for causing a decline, as suspected in places in Minnesota as early as 1892 (Herrick). Sowls (1948) related a comment from C.C. Furniss that the squirrel "appears to be retreating before the advance of agriculture." Van Petten and Schramm (1972) blamed cultivation, mowing, and grazing for the decline of Franklin's ground squirrel. However, Cory (1912) felt the squirrel was not greatly affected by the cultivation of land.

The general loss of prairie habitat alone may not be entirely responsible for the decline. The Franklin's ground squirrel is often locally abundant while nearby areas have none (Jackson 1961). Recent trappings in the plains of Canada by A. Sargeant revealed small concentrations of the squirrel isolated by large areas without them, despite apparently homogeneous habitats (pers. com.).

Isolation of these "islands" could easily lead to long-term numerical declines. Newmark (1987) found that over 40% of all species of lagomorph, carnivore, and artiodactyl (12 species) found in western national parks have become extinct. The loss of park species was attributed to the loss of mammals on adjacent lands, isolating the park populations. The populations within the park were smaller, less stable, and isolated from potential recolonizers. Habitat fragmentation in agricultural areas could similarly isolate ground squirrel populations.

Another factor contributing to a decline may be that the populations are cyclic. Erlien and Tester (1984) noted a ten-year cyclic population pattern in Franklin's ground squirrel that they linked to predator shifts during cyclic lows in the snowshoe hare population. Sowls (1948) noted a six-year cycle at Delta, Manitoba, that he attributed to climate, infertility, and disease. Normal cyclic declines in fragmented populations could eliminate some populations even though habitat is suitable, and the isolation would prevent reoccupation, leading to a general decline. However, the apparent decline in Franklin's ground squirrels at the eastern extent of the range has been noted for more than twenty years, and farther south than other cyclic populations. There seems to be no macroclimatic change that could exclude the squirrels from the area, as they are found farther south in Illinois, farther north into Canada, farther east into Indiana, and farther west into Illinois, Iowa, and the Dakotas.

Further work on site-specific changes in habitat should be done to examine changes over time in areas that may have lost or gained Franklin's ground squirrels. Also necessary are studies of reproductive success and survivorship.

Acknowledgments

We would like to thank the many biologists in Illinois and Wisconsin for their cooperation with this research, and S. Craven, R. Guries, and an anonymous reviewer for comments. Support for this study was provided by the Max McGraw Wildlife Foundation, the University of Wisconsin–Madison College of Agricultural and Life Sciences, and the University of Wisconsin–Madison Graduate School.

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That Eyes May Be Free: Mary North Allen Talks with *Transactions* Editor Carl Haywood

In 1990 the Wisconsin Academy of Sciences, Arts, and Letters established the Dresen Award in memory of David Dresen, longtime photographer with the University of Wisconsin Photo Media Center.

Mary North Allen was the first recipient, and the award was presented at the Academy's annual meeting held at UW–Platteville. Looking at the photographs, I was intrigued with the question, "What are Mary North Allen and her work about?" After the awards luncheon I sought her out to talk about the possibility of publishing some of her photographs in *Transactions,* perhaps with an interview regarding her work and her view of photography. A year later we met for the interview at the Academy meeting at UW–Superior. I thought it would be a relatively easy assignment, but that was before I knew Mary North Allen. After talking to her for hours, listening to the tapes, and reading transcriptions, I found the results complex and subtle. Months of correspondence have followed, with telephone discussions for clarifications, and Mary has put her answers in writing, but the answer to my question remains elusive. As with so many things, the interview published here does not do justice to the complexity and richness of one of Wisconsin's remarkable people. The purpose will have been served if the reader comes to see the beauty in both the person and her work. What started out as an assignment has become a joy, and it is my hope to share that with our readers.

Transactions: When we talk about "photography," what idea or definition comes to mind?

MNA: On a simple level photography is a way of making pictures by bringing light together with a light-sensitive surface. A camera is a light-tight box containing a device for holding film. Opposite the film is a hole through which the light can pass. For opening and closing the hole a cork would do or a piece of electrician's tape. All the stuff you pay so much money for is there to let you control exactly how the light will enter the camera and impinge upon the film. But most people buy cameras with automatic controls to coordinate the various actions. Some of us prefer to do our own coordinating.

The light entering your camera is, of course, not pure light. What enters the camera is light that is reflected from the surfaces in front of the camera. The configuration of light and shadow which impinges on the film is thus a reflection of the *surface appearance* of what's in front of the camera. But surface appearance changes every hour of the day, every time a cloud passes, every season of the year.

Although the camera is often figuratively described as an "eye," it cannot see the way a person sees. The purpose of photography, in most cases, is that you want to share with somebody your *interest* in what you are seeing. The camera is just a box. It has no way of knowing about your interests.

Transactions: In our discussions you have often used the words "seeing" and "vision." Do these have special meaning in your approach to photography?

MNA: Vision is more than reception of raw data, more than identification, more than seeing enough to avoid bumping into things. Vision is a thought process, interrelated with all of mind's activity, with all our formal and experiential learning, and with all the baggage, both essential and superfluous, that we all carry. A configuration of various intensities and wave lengths of light impinging upon the retina of our eyes generates nerve impulses that travel the optic nerve to enter an intricate network of thousands of brain cells. Herein lies the intuitive part of the visual process—what the photographer depends upon.

I believe that each person's vision is as unique to that particular person as his or her voice. We recognize the voice of a friend whom we haven't seen for years. But how can any of us know our friend's vision—or our own vision—unless we communicate it in some way? And my way is to make something—to create a photograph.

Transactions: Have you always had this sense of seeing or did something in your background develop it?

MNA: I am one of those who can't draw, or so I always thought. When I was a child in rural New York State, there was no art taught in the local schools. Nor was there music, except for a singing class, for which the teacher screened us in first grade. He determined that roughly half of the pupils were listeners, not singers. Through twelve grades we sat while others sang.

We lived on a farm and I played in the woods. I waded in a clear, clean, sparkling brook. In my trusty oatmeal carton I collected flowers and pretty stones, twigs of interesting shape, colored leaves, hemlock cones, wild strawberries and blackberries and raspberries (a patch of white raspberries grew by the remains of an old stone wall where trees met the upper field) and beechnuts, if I could get them ahead of the squirrels. When I lugged my treasures home, my mother didn't scold about the holes in the knees of my stockings or my hair ribbon tattered with briars. Instead, she admired my precious findings and listened to my tales of adventure. It was imaginative, inventive play.

After public schools I majored in biology at Mills College, then washed laboratory glassware at Hopkins Marine Station, where I marvelled at intertidal fauna and studied microbiology. Biology appealed to me as a new way of seeing the living earth I felt so close to.

In 1946 I came to Wisconsin with my husband, who was for thirty years professor of botony at the University in Madison. We raised three children on a farm near Mt. Horeb. I had long been interested in photography and in the 1960s decided to study it seriously. I entered the UW–Department of Art, where I was fortunate to work with George Gambsky, who taught photography and who himself had been a student of Minor White.

In biology I had been asked, "On the basis of what observations do you draw your conclusions?" There was some important difference in the seeing I was now learning to practice. I was engaged in yet another kind of learning, another mode of thinking new to me. Gambsky was reminding us that making a photograph is sending a message. "Don't you think you ought to know what sort of messages you are sending?" We would sit in class, in long, concentrated silence, looking at our own and each other's prints, before anybody spoke up.

The photographer has to grasp what Cartier-Bresson called the "precise moment," when all elements of your picture come together, and this can only be done intuitively. Only later, when studying prints, can you assess the message content.

In 1971 I hung my first one-person show. I was already past fifty, but I had finally found the right work for me. I was elated to discover that there is such a thing as grasping a concept aesthetically, that image-making opens a whole new approach to understanding. Above all, I had the joyful feeling that some part of me that had been totally neglected was coming to life. I'm still learning, along with my students, many of whom have experienced a similar liberation themselves.

Only after several more decades did it dawn on me that the driving question of my life has been to make sense of the dilemmas of being human, the paradoxes that have been puzzling me as long as I can remember, and that this is the stuff of art—all the arts. The arts are of and for all of us, and in simpler eras they played essential roles in daily living.

It is photography as an art form that particularly interests me. There are countless other applications of photography, from X ray to remote sensing to advertising, about which I know very little.

For ten years I taught photography with the UW–Extension, which for much of that time had one of the best photography programs in the country, with more than a dozen instructors under the direction of Tom McInvaille. In 1985, after Tom had left and the peak of that excellence had passed, I resigned to found CAMERA WORKS, making my home into an independent center for photographic study.

In the CAMERA WORKS program beginners do an intensive eight-week sequence of structured assignments that enable them to see with their own eyes how the technical adjustments they have made influence their images. The basic building block of photography is the one-stop difference in exposure. Making a series of photographs of the same subject with a one-stop difference, they see how change in the intensity of light looks and how it alters relationships between the objects in the picture. At one end of the series, detail in the shadows is more visible; at the other end, detail in the highlights. Often there are several acceptable possibilities, and the photographer must make a choice: What will be revealed, what will remain hidden?

From experiments with light, students go on to learn about depth of field as they work on problems of making a two-dimensional picture out of the three-dimensional world. Finally they work on problems of making a still photograph out of the hustle and bustle of a world endlessly in motion.

Encouraged to be aware of the design elements all around them, and to see with their own eyes, students apply the discipline of the photographic craft to whatever they see in their daily lives. They begin to discover new worlds on their own doorsteps. Sometimes in class we all spark each other. We stretch ourselves. We outdo ourselves, and we're all amazed at the photographs that emerge.

CAMERA WORKS has been enormously successful as a pedagogical experiment. I found that I love teaching, and I've come to see teaching as inseparable from learning. Take the problems of teaching depth of field. It is hard to find words for speaking of relationships in space, as distinct from the measurement of distance. There was the hockey coach still mystified after two class sessions. Well, I venture, sometimes he must be watching just one player, and other times he must watch the movements of several. How does he get just one in focus for one picture, and then for another picture get several players in focus all at once? Right away he sees the problem, and I have a new way of presenting it.

I tell a family story to illustrate the complexities of thinking spacially. Many years ago we took our children to Niagara Falls. Here we are standing at the top of the cliff. I am getting nervous at the height, wanting to get away before somebody falls. Suddenly the four-year-old, all excited, is pointing to the boatload of people at the bottom of the falls. "Look at all the little people!" he exclaims.

A small child, in the habit of looking up at adults towering above him, has found some adult-type people who are the size of his little fingernail—what a discovery! Somewhere along the line we learn to use that illusion of diminished size as a measure of distance. But we are not aware we ever learned it until a child shows us.

Vision is not a simple mirroring of the world. It's a capability we have to learn to use. As I study the responses of students to my assignments. I realize that I am not clear enough in what I ask of them. As I search for ways to clarify my class presentations, writing and rewriting assignments, I gradually see the problems more clearly and in larger perspective. How the camera functions in relation to light, in relation to space, in relation to time—those camera functions become more understandable when I realize that vision has got to do with seeing things in relation to one another—brighter/darker, nearer/farther, stationary/in motion. I think about people functioning in relation to light, to space, to time. Thinking "in relation to" is different from thinking absolutes. Visual thinking, with its own logic, known as design, supplements, complements, enriches all of mind, all of living.

Half way through the foundation course at CAMERA WORKS I can begin to detect that some students have a strong sense of form, some a subtle sense of timing, some a feel for color—capabilities they probably did not know they had. I have watched countless people free their vision from the blinders of stereotype, but there is absolutely no predicting who is going to do well in photography.

Transactions: Is photography what we see, a representation of something, or does it mainly connect us with something we have experienced?

MNA: A simplistic answer is ''all of the above.'' If you want to consider the question in depth, you have to ask whether ''what we see'' is physical world or mental construct. I have ideas about this, but I'll leave the discussion to others more qualified.

We can use photographic materials and processes in whatever way suits our purposes, and the results will bear some resemblance to whatever the camera is pointed at. The critical question then is the kind of resemblance and how it relates to your purpose: What is your interest in your subject?

You can use words to write a government document, a business letter, a sonnet, or a shopping list. So with photography. There are so many applications of photographic materials and methods that I cannot possibly speak for all. To me photography is a means of representing a person's vision/perception of a subject.

Transactions: If you see photography connected with vision/perception, do you also see it as a symbol, like language?

MNA: Yes, the photograph is a symbol in that it stands for or represents. The photographer learns technical basics as tools for building images with some sort of message content. When I speak of symbol, I do not mean just the flag or the cross. I refer to symbol systems and all the various carriers of message that human beings have devised: spoken and written words, numbers, music, dance, theater, as well as all the visual arts.

A photograph is, after all, a two-dimensional object, an emulsion on paper. But it can bear a powerful illusion of the three-dimensional world we walk around in. In a sense all representation is illusion. I sometimes think that a photograph is much like theater. It condenses. It intensifies. It demands the willing suspension of disbelief.

In an anecdote told about Picasso, a villager, finding the master in his garden, approaches him with a question, ''Why don't you paint a woman the way a woman really looks?''

''How does a woman really look?'' asks Picasso.

The man takes from his pocket a snapshot. ''Here, this is how a woman looks. This is my wife.''

Picasso looks intently, points to the photograph and asks, ''This really is your wife?''

''Oh, yes, that's my wife.''

''She's rather small, isn't she? And flat?''

Other creatures communicate (we are just beginning to learn how extensively), but we are the ones who have devised the elaborate, complex symbol systems we think with—and thereby structure the worlds we inhabit. It is a peculiar predicament we human creatures have made for ourselves, trying to live in physical world and symbolic world simultaneously. Here we sit at the junction, Janus-like, looking both ways: we *are* the joining, the transforming link our genius and our exquisite vulnerability.

I like to think of the first woman drawing the first picture on the wall of a cave. I can see her bursting with need . . . need to share more than food and shelter . . . need . . . to share vision. Suddenly she picks up a charred stick, rubs it against the rock, and out flows form. Need and capability and tools and vision, enhancing each other, evolving together . . . ; today we can scarcely separate the strands.

Transactions: Is what the woman produced "truth"? It is often said that cameras never lie.

MNA: That is like saying that words never lie, or statistics never lie. It is not the symbol system or technological device that does or does not speak truth. It is the human being. People can lie in any language, with or without technological device, if lying is their intent.

Often, I think, we confuse logical types. It is important to distinguish between authenticity, raw data, factual information, literal content, subliminal content, verbal interpretation. A photograph does not necessarily have any verbal equivalent. You can talk about it in words, but that is interpretation. Is the picture on your driver's license a "true" picture of you? A teenager may want to be photographed to look like the most recent celebrity. The teenager's parents and grandparents won't think photographs of themselves are "good pictures" if their warts show. Convention dictates that a studio portrait will make you appear attractive in accord with current fashion. Whether it reveals anything of your personality or character is another question. When a studio photographer uses lighting, makeup, retouching, etc., to make you look the way you would like to look, when this is carried a step further to create fantasy for marketing shirts, shoes, beer, or candidates for public office, she/he is following conventional procedures. Is this lying? Wherein does truth abide?

It is not the mechanical equipment, but the skill and hard work of the photographer that make portraits and ceremonial photographs look the way we expect them to. The photographer has to work fast, ever alert to include all elements necessary for a coherent image, and to exclude all distractions. The last time I photographed a wedding is a fine example of the hazards awaiting any photographer who suffers a momentary lapse of concentrated attention. Just before the ceremony I came upon a great scene—the bride and her mother conferring with the judge in a hallway. I failed to notice that behind them was a door slightly ajar. I failed to observe evidence that somebody back there was using the phone. My flash picked up the white telephone cord and suspended it, shiny-bright and droopy, from the nose of the mother of the bride.

Transactions: You appear to be saying that a photographer creates something from her/his vision. How would the vision of the observer relate to the photograph?

MNA: The viewing of a photograph can be as complex as human vision. It is possible to return again and again to a truly memorable image and experience anew the thrill of discovery. Just as words, used to write legal or scientific documents or stories or poetry or lists, will be read with differing expectations, so with photography. Most images invite interpretation. Some require interpretation by specially trained analysts. Others are adventures in seeing.

In 1979, as part of an Extension photography instructors exhibit, I tried an experiment which I called "Participatory Photography." Along with two of my photographs I provided a little book in which viewers were invited to write comments. The photographs I used are the first two in the collection that follows. I hope readers will take time to look at these two photographs and then make their own observations before reading further. Here are samples of what exhibition visitors wrote:

> "Not too different—both couples appear financially secure. One couple waits and the good things come to them. The other goes out to get the good things and has to work for them."
>
> "Two well-to-do couples. Right: Self-made hard-working couple proudly posing before their home."
>
> "I think they are my grandparents."
>
> "The beauty of old age—especially the beauty of relationships that have lasted a long time. My grandmother used to say, 'This is the last for which the first was made.' "
>
> "Old age is not worth the price of admission."
>
> "At age 52—AMEN!"
>
> "The hell you say—I know. I'm 67 and I love it."

"The secret of old age is dying young at the last possible moment."

"They look so unhappy."

"In the final analysis we are all alone. That is the bottom line."

"Pictures are grey just like the people."

"The photos are ten years old. Do you want to talk them to death? It seems time to make some new ones, Mary."

"Good work should be shown and reshown."

"It is a relief to see some pictures of the elderly as opposed to glossy-color photos of young models."

"The first one is great. If I knew why, it wouldn't be art, would it?"

"Left: Not paying attention to each other—space between them has an uncomfortable feel to it. Right—together."

"It's interesting, the man walking behind the woman."

"Left: Unhappy situation because of female dominance."

"Unhappy for whom?"

"What dominance?"

"I hadn't even realized that the two people in the left photo were supposed to be together!—chilling comment on marriages of too-long standing."

"Do you know, for sure, that they're together?"

"The two people are not actually a couple."

"Left: The action and viewing angle are interesting."

"Left: Crop the picture more at top and left side to cut out extra people."

"Extra people are vital to composition. They balance the photograph."

"No, they unbalance."

"It's easy to read too much into these pictures, but again it's fun to think about them. It's good for the imagination."

"In the end, it seems appropriate to note that not only are the photographs themselves interesting and enlightening, but that the comments and reflections of others add greatly to the overall growing experience of the work. It should be added that this book, as a growing statement on art, is actually a living and growing example of art. For our perceptions and reflections are as significant a part of our experience as any tangible physical items.—Thomas R. G—"(last name illegible)

"It's interesting how much people tell about themselves when they comment on the photos. I found the comments much more interesting than the photos."

"Comment on the comments: Most people seem to have lost the gift of 'just looking' at an image without (at least subconsciously) naming it, interpreting verbally, editorializing, or otherwise bogging it down with words.—JT Beers"

I had selected these two photographs not because I thought they are the finest, but because of their potential as a pair. The photograph on the left I took as I was sitting on the steps of the National Gallery in London, watching people, wondering where they came from, where they were going, who they might be. It is an example of image seen intuitively, caught on the instant.

The photograph on the right: I had asked the Grabandts, retired grocer and his wife of Verona, Wisconsin, whether I might photograph them. They chose to present themselves exactly as they appear.

Transactions: So the photograph of the strangers is just an image without any intended meaning or message; the viewer has to bring meaning to it?

MNA: Two people can be seen in each photograph, but the message content is not the same. One photograph clearly questions, while the other presents a statement. Format and structure contribute to the sense of doubt of the one, the certainty of the other. The juxtaposition of the two pictures reinforces this difference. Each photograph has become part of the context in which the other is seen. Viewers did not find much to say about the one on the right; the picture has said most of what there is to say. Did you notice how many of the comments were attempts to answer implied questions that viewers read into the picture on the left?

Transactions: Does this experiment rule out the possibility that a picture can contain a universal idea? Can it have anything in common with all people?

MNA: Are you asking whether by means of photography a universal idea might be given some form accessible to all people? I think that is asking a bit much for any medium. Between the message sent and the message received "falls the shadow."

Everyone is born and dies and in between experiences troubles and satisfactions. It is not difficult to take a picture that refers to the commonality of human experience, on some level. More often than not, the effect is to trivialize. A photography student taking a picture of a beautiful sunset discovers that the result is not automatically a beautiful image. A sensitive photographer who has witnessed and photographed a terrible event, such as an act of war, will be painfully aware that the photograph does not come anywhere near conveying the full sense of tragedy.

I believe that the true archetype lies very deep. The more profound, the more difficult to transform into profound image. I think that all great art arises from experience felt so deeply that the artist feels compelled to labor to give it form.

Viewer response will vary from individual to individual and culture to culture. Occasionally a work breaks barriers, and the image becomes part of cultural heritage. This can happen in photography. Almost everyone knows Dorothea Lange's "Migrant Mother."

I well remember the first time I saw an original Edward Weston print, a Minor White, a Cartier-Bresson. For full appreciation of fine photographs, people need to have access to original prints. The subtleties are lost in reproduction for publication unless the very finest book papers are used and the very finest printing methods, all of which are expensive. Fortunately, it is now possible to see original prints in many galleries, and I urge everyone to go and to take time looking. If you have never seen exhibition quality prints, you may be surprised to discover what a photograph can be.

Transactions: Michael Brenson, in a review of "An Uncertain Grace, the Photographs of Sebastaio Salgado," said that the photographer had, in fact, and I'm quoting, "turned African tribesmen and women into Biblical kings and queens." And he went on to talk about the emotion and energy in the photographs of the people. Does his conclusion incorporate your earlier point about what the viewer brings to the photograph? How can Brenson conclude that the photograph has changed, even metaphorically, a tribesman into a king? He implies that the photograph creates nobility.

MNA: I'm glad that you mentioned Salgado. He is one of the greats, one of those who tie me to humanity on a very deep level. Salgado came from Latin America where he had seen at first hand terrible poverty. He became an economist, but decided that nothing would be done about poverty until the world moved beyond thinking of poverty as an abstraction and the poor as statistics. Instead of supposing that anybody living under degrading conditions must be despicable, Salgado felt that human beings who manage to survive appalling circumstances without losing self-respect must have great inner strength. That is the quality Salgado sensed and made visible.

It is the rare artist who can give form to human suffering endured with spiritual strength. Only a person of great conviction would even try. Salgado has not given up hope for humankind. And, he has succeeded brilliantly in bringing his vision to the rest of us. His photographs are powerfully beautiful. The reviewer was reminded of Biblical kings. I am reminded of the writings of Elie Wiesel and Viktor Frankl. Same fundamental archetype expressed in different forms.

Transactions: If I showed you my photograph of my grandparents, you could evaluate it technically. When I look at it, I bring to it a set of memories and experiences profoundly different from yours. Can we ever bridge this space? Can there be any common understanding?

MNA: The way you phrased the question brings to mind a student I had in class a dozen years ago. Every photograph was, for him, evidence of this or that lens or gadget, and nothing more. I labored the entire semester to find ways to encourage him to see the image, and eventually he did. Of course, technical decisions influence the way a picture looks, but concern for technique should never obscure vision.

Sometimes the photographic technology of the time has an influence we need to take into account when we look at old pictures. Were all those stern ancestors of a century ago really humorless people? Probably they were not greatly different from us today. You are observing the consequences of photographic materials and equipment now obsolete. Films were slow, lenses were slow. Portrait studios were equipped with head rests and other props so that people could hold still for up to several minutes. You might like to try photographing your next family reunion that way and see how you look and how it feels.

I had grandparents too, and I am a grandparent. I might look at your picture and say, "Hmm, Carl looks like his grandfather. Or, grandmother has keen eyes. Interesting dress she is wearing . . ." I don't have to share your family memories to enjoy looking at your picture and to pick up information about those two people.

I have included in this volume several photographs that might be considered of the family album type. Readers of *Transactions* are likely to find the pictures accessible, even though they have no acquaintance with the people photographed.

Outside the family, such memorabilia may be of great interest to cultural historians and social anthropologists who are wanting evidence of living habits and customs of ordinary folk. There is a scholarly journal called *Visual Anthropology,* and John Collier's classic book of that title is now back in print. Recently I received Robert Levine's book, *Images of History,* in which he discusses criteria for historians to use in determining authenticity of a photograph as document and for evaluating content.

Transactions: What about the other pictures you have chosen to include in these pages? I can see that many are about nature, but they don't look quite like most of the nature photographs I have seen. How do people respond to your photographs?

MNA: A forester making pictures for a field guide for trees would be certain that criteria for identifying species were clearly visible in his photographs. A plant pathologist would make sure that disease symptoms in trees were clearly visible. Their photographs would not look like mine, nor will the romantic nature pictures of vacationers and departments of tourism. All of these photographs are related to nature, but there the similarity ends.

I've been inquisitive for as long as I have memory. The life of being human presents dilemmas. I keep trying to reconcile it with the life of living earth. The older I grow, the less confident I am of easy answers or ultimate answers. Not surprisingly, my photographs raise questions, tweak the imagination, and, I hope, set viewers to wondering. When my intuitive vision is working, the resulting photographs might speak some poetic truth. I believe that is possible, but I do not know.

The woodland pictures came out of a deeply troubled time in my life. I didn't know it then, but the making of those photographs, in helping me to see my life in a larger context, was an act of affirmation.

I walk in the woods until some sight compels my attention. *Attention* . . . I surrender, becoming completely absorbed in seeing . . . spaces shaped by light and shadows and by trees . . .

In the last dozen years I have moved from exploring light and spaces to exploring motion and color: intensity and wave length, passage of time. I have been tinkering with color ever since a UW–Art Department course in color theory. Color photography simply requires use of a film that is sensitive to the full spectrum of visible light, but I wanted to use color to structure the image as a painter would, for making visible what I could see in mind's eye—an interplay of life processes and human experience. I wanted the added factor of interacting color. Thinking color is different from thinking monochrome. It took quite a few years of experimenting before I began to get the sort of imagery I wanted.

I am envisioning all this in multidimensional forms for which I know no words. I have been reading systems theory and chaos theory. I'm imagining the joys and terrors of ordinary lives of ordinary folk flowing and ebbing like river currents joining and separating, mixing and rejoining, slowly wearing channels through soil, through rock, through improbable time.

I'm wading in a little stream, so shallow that rocky bottom colors show, a bit of sunlight catches a ripple, an autumn leaf floats by . . . I come in with a close-up lens on a little red rock barely breaking surface . . . I drop a pebble, the current shifts . . . I slow down the shutter, reflections pull out like taffy . . . I am eliminating any key to scale. The craft remains disciplined while result becomes deliciously unpredictable.

I'm a child playing; the old oatmeal carton has turned into a camera. I've got treasures to share with kindred spirits.

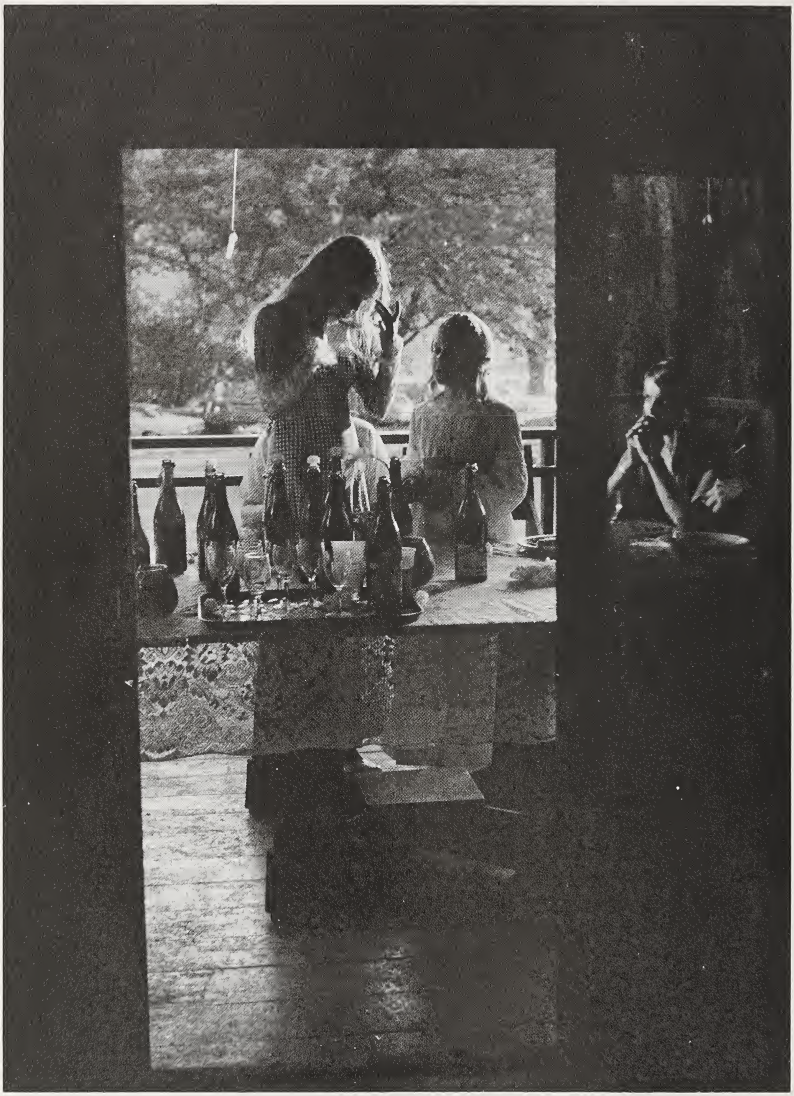
My work is an attempt to see eye to eye with other human beings. All I ask is an honest response. If one person sees a lament for vanishing forests and another itches for a chainsaw, so be it.

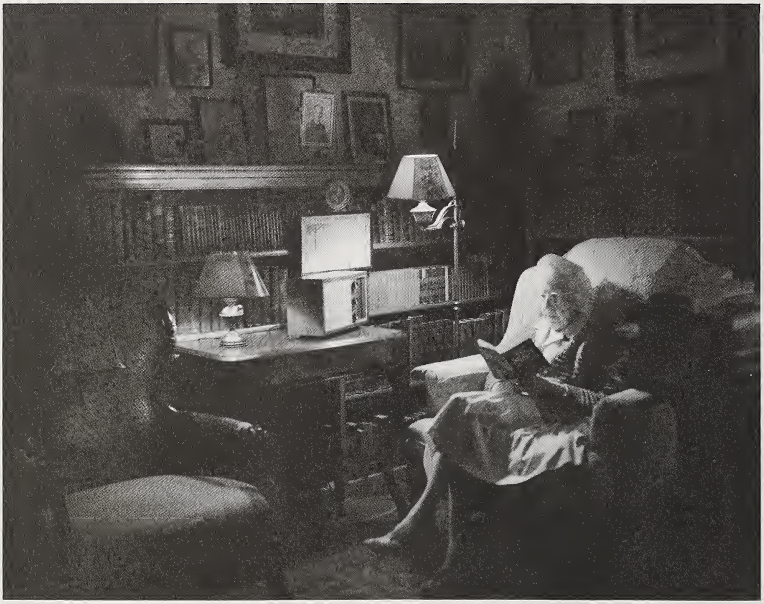
A visiting professor from Japan looked long, without words, and took home several tree prints.

A farmer from southwest Wisconsin, unknown to me, saw one of my color photographs on the wall of the Johnston Gallery in Mineral Point. Later he told me that the picture jumped right out of the frame.

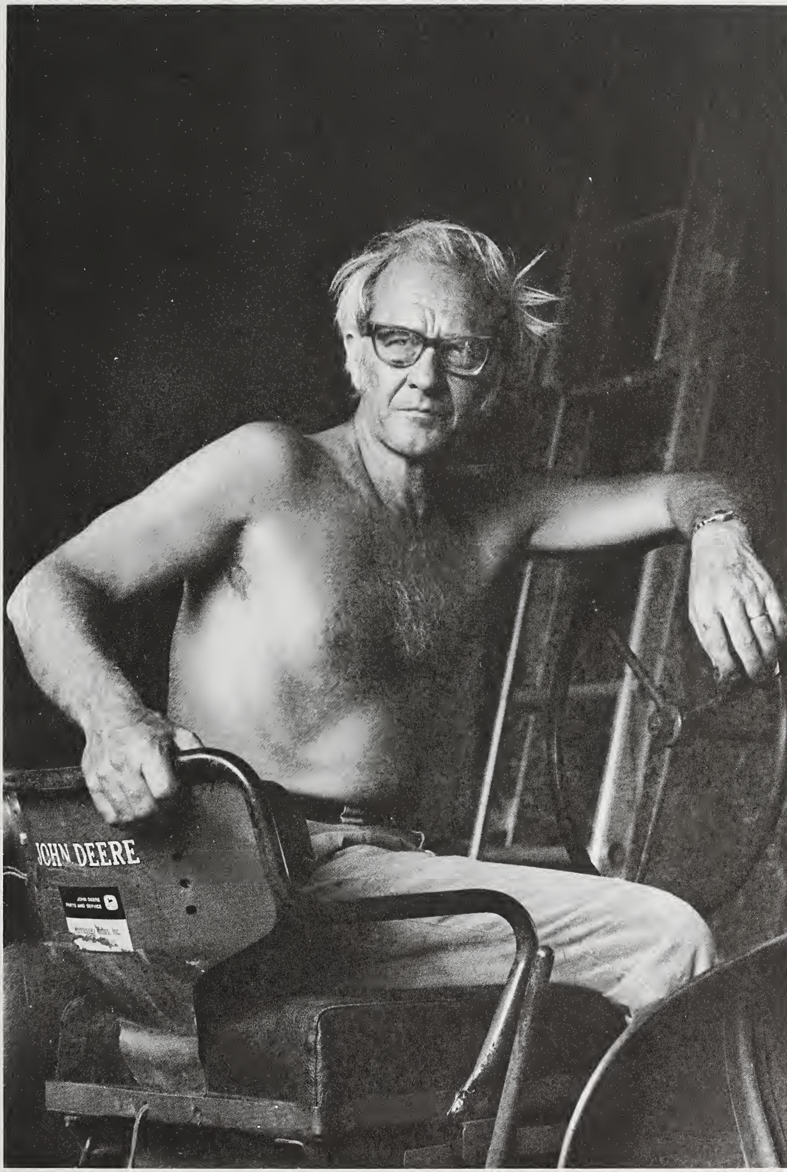
To see eye to eye with another human being is rare.

The Photography of Mary North Allen






HAIL
HERBIE!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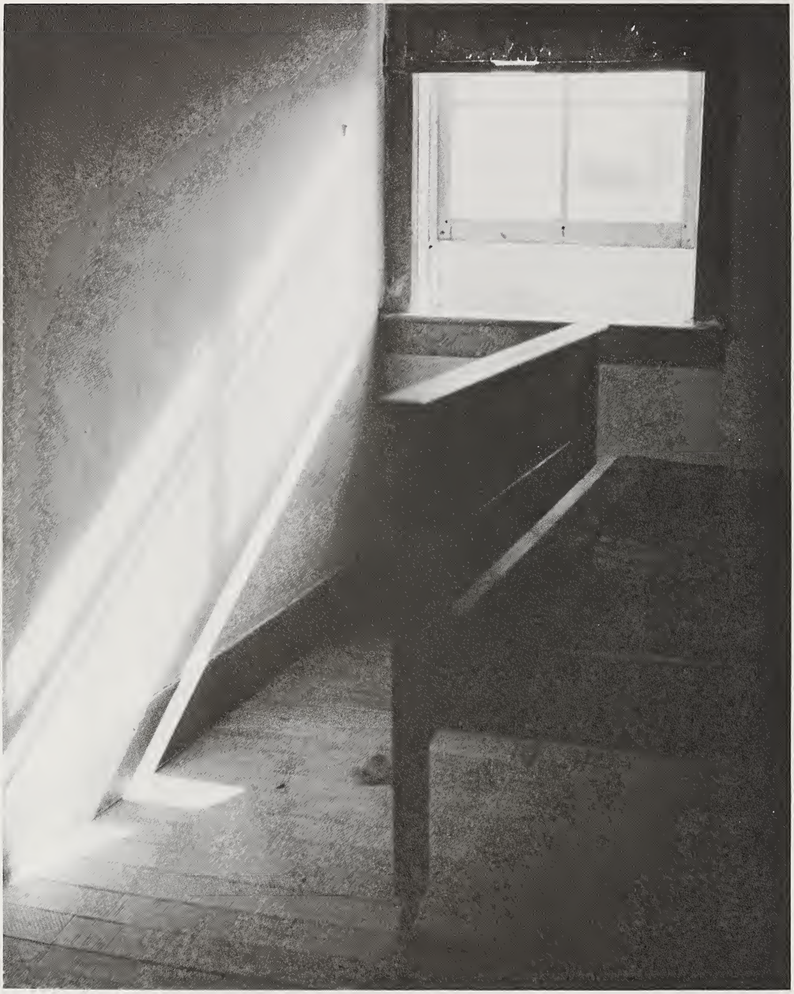

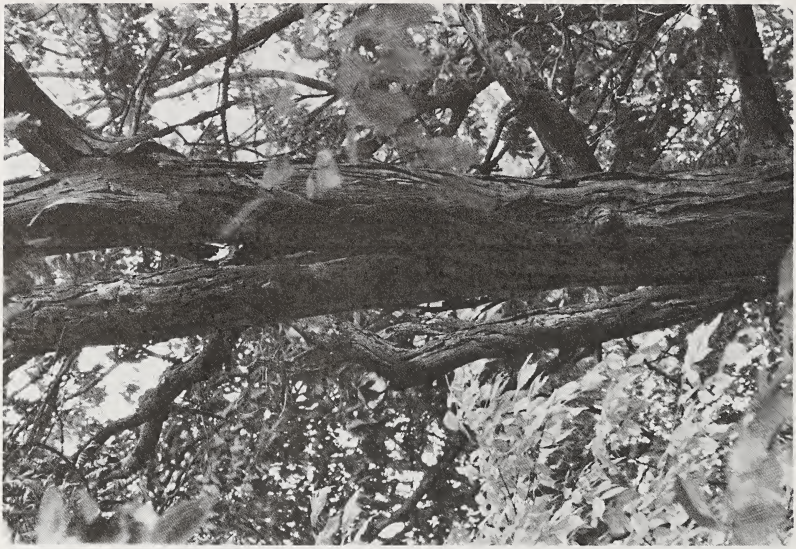

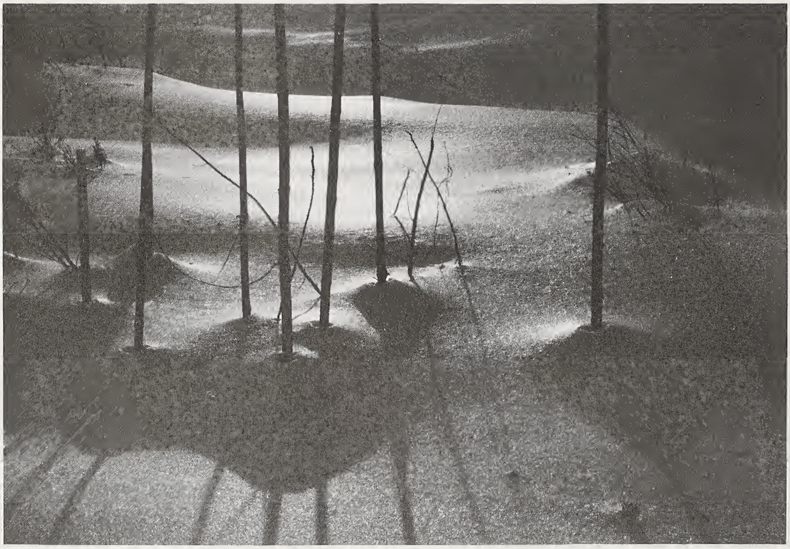

Community Response to Floodplain Relocation in Soldiers Grove, Wisconsin

Graham A. Tobin

Abstract. *The Soldiers Grove downtown relocation project is often cited in the hazards literature as a successful example of multipurpose, community-sponsored planning. Frequent flooding has been alleviated and the local economy stimulated. Nevertheless, spatial changes in the physical structure of the community suggest that social impacts should be examined. It was hypothesized that unforeseen problems arising from the relocation project could lead to a degree of disillusionment. A questionnaire survey of residents revealed that views were mixed. Conflicts have arisen because of perceived inequalities in the distribution of benefits accruing from the relocation. Additionally, internal dissatisfaction has disrupted community spirit. However, Soldiers Grove remains a model for community involvement and has been successful in many respects, although further lessons regarding spatial planning can be learned from this project.*

The relocation of Soldiers Grove, Wisconsin, is frequently cited as a successful example of multipurpose, community-sponsored planning. The stimulus for the project was a recurring flood problem exacerbated by a declining local economy. The plans included the complete removal and relocation of the downtown business district, the razing of several residential properties, flood proofing of other structures, and the incorporation of building ordinances zoning the new town for solar energy. In terms of flood alleviation, the project has been highly successful. The old downtown area now boasts a park and recreational facilities. However, the social impacts of the project have not been addressed. This research, therefore, looks at residents' opinions of relocation now that all major components of the project have been completed.

The flood hazard literature includes a number of examples of small-scale projects in which real estate property has been relocated out of the floodplain. Shawneetown, Illinois, for instance, is often presented as a "planning" failure since ultimately a portion of the town opted to remain at the old site (Murphy 1958). It is interesting to note that the new Shawneetown is now more prosperous than the decaying remnants of the old community. More recently, as the emphasis on flood alleviation has broadened to incorporate a greater range of nonstructural measures (Dzurik 1979), other attempts at partial relocation have been made. These have usually involved local residential areas subject to frequent or catastrophic flooding, rather than downtown business districts. A few examples include the following: Arnold, Missouri (U.S. Water Resources Council 1981); Robindale and Nelson, Pennsylvania; Clinchport, Virginia; Tulsa, Oklahoma; Rapid City, South Dakota (U.S. Department of Housing and Urban Development 1978); and Prairie

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du Chien, Wisconsin (Miller et al. 1983). However, none of these involved the comprehensive planning and community initiatives that were pursued in Soldiers Grove.

The Soldiers Grove Relocation Project

Soldiers Grove, along with several other communities situated on the Kickapoo River, had experienced severe flooding on eight occasions in the twentieth century. The U.S. Army Corps of Engineers' response was to begin construction on a storage dam at La Farge, thirty-six miles upstream from Soldiers Grove, and to plan levee systems for several communities. Building of the dam started in 1969, and levee plans were presented to the community in 1974 (U.S. Army Corps of Engineers 1975). Since the dam would protect only 9% of the hundred-year floodplain area in Soldiers Grove, the levee system was considered an essential component of the project. However, the high costs of the levees and the large annual maintenance charges forced Soldiers Grove to look for alternative solutions. Furthermore, in 1977, President Carter imposed a moratorium on water projects, which stopped dam construction and left the Kickapoo communities without any flood protection. By this time, substantial capital investment had already been made in the project (Tobin and Peacock 1982).

The declining economic base of the town accentuated the need for a major planning initiative if the community were to survive. Consequently, the flood alleviation project grew to include major socioeconomic changes incorporating several different goals: (1) to eliminate the flood problem, (2) to enhance local employment opportunities, and (3) to stimulate the local economy. The main thrust of the project entailed moving the central business district to a safer location out of the floodplain. In addition, plans were made to create further recreational facilities by converting the old downtown area into a park and erecting a community center in the new town. The project called for a general revitalization of Soldiers Grove. For detailed accounts of development, timing, and implementation of the relocation project, see Becker (1983); David and Mayer (1984); National Science Foundation (1980); and Tobin and Peacock (1982).

The flood hazard literature has often touted the Soldiers Grove relocation plan as a significant advance in floodplain management. For example, the successful relocation of property away from flood-prone areas has been commented on by Becker (1983) and by the U.S. Department of Housing and Urban Development (1978). Others have described the economic advantages accruing to the community (David and Mayer 1984) and the energy savings from the solar zoning ordinance (Jenson and Fantle 1979). The comprehensive planning initiated and undertaken by the local community has been praised by various authors (Becker 1983; Pierce and Hagstrom 1978; *Time* 1981; Tobin and Peacock 1982). Some criticisms have been raised, but generally these have focused on failings of federal government programs to make any long-term commitment to the locally sponsored project rather than on specific community-related problems (National Science Foundation 1980). Similar thoughts on appropriate mixes of local, state, and federal involvement are echoed in the Interagency Task Force on Floodplain Management report (FEMA 1986).

In many ways relocation has been worthwhile. The community clearly benefits from projected savings from flood losses and current economic enhancement. The population of Soldiers Grove grew from 530 in 1978 to 622 in 1980 (U.S. Department of Commerce 1982), although there has been little change in recent years, according to local officials. The community tax base, however, has increased by two million dollars (David and Mayer 1984). The economic success of the project, therefore, seems well established. However, what has not been seriously addressed is the impact the relocation plan may have had on the local population. What do residents of Soldiers Grove think of the project? In what ways has it affected daily living? The literature suggests that residents were overwhelmingly supportive of the original relocation plan, and this aspect has often been cited as a reason for the apparent success (Pierce and Hagstrom 1978). To what extent is this true now that relocation has been completed? This paper examines some of the social impacts of the relocation project on the population of Soldiers Grove through a consideration of residents' perceptions.

Research Questions

It was hypothesized that residents of Soldiers Grove would perceive the relocation plan as socially beneficial to the community. The project was locally initiated and hence demonstrated all the characteristics of self-determination necessary to "guarantee" some degree of success (Hoggart and Buller 1987). However, it was further hypothesized that some internal conflicts would materialize between groups as the distribution of costs and benefits was gradually realized. Hoggart and Buller, for instance, warn against assuming that rural communities constitute homogeneous populations with uniform ideologies. In particular, the physical separation of the business district from the larger residential areas might be expected to present problems, especially to the elderly and those without adequate transportation.

Apart from age and location of residence, other factors thought to influence perceived satisfaction with the relocation project included household income, gender, level of education, and years of residence in the community. In the literature, there is ample evidence that such socioeconomic traits play important roles. Youmans (1977) suggested that the elderly rarely benefit from development projects and invariably carry any increased costs associated with transportation difficulties. Since the elderly are also often women in the lower income groups, they can be severely disadvantaged by community changes. In addition, attitudinal contrasts often exist between the elderly, who frequently look toward the past, and younger residents, who are usually more forward-looking. In other words, if benefits have accrued exclusively to local businesses, that is, the economic elite of Soldiers Grove, then others may now express some dissatisfaction with the relocation project.

Methodology

A personal, door-to-door questionnaire survey was conducted of Soldiers Grove residents in August 1988. A stratified random sample of households was surveyed such that a representative proportion was drawn from each residential area within the community. At the time of the 1980 census, the town had a population of 622, which included 249 households (U.S. Department of Commerce 1982). Of this population 54% were female, 77% were adults, and 37% of the adults were over sixty-five years of age. The survey strategy called for interviewing one adult from each of the randomly selected residences. Eighty-five interviews were successfully conducted with three rejections. An estimated accuracy rate for the overall survey, based on the response/no response rate, was plus or minus 1.5%, using the formula proposed by Moser and Kalton (1971).

The questionnaire was designed to elicit opinions on three aspects of the relocation plan and accumulate socioeconomic information on the residential population. The first set of questions required respondents to assess Soldiers Grove as a place to live in an attempt to determine community "spirit." The second set was used to examine the perceived impacts of the relocation plan on various aspects of the community, and the third set focused specifically on the flood hazard.

Data were analyzed using standard statistical techniques including chi-squared and simple frequency counts. Some recoding of raw data was undertaken to organize responses into larger groups. For instance, income was aggregated into three categories: less than $10,000, $10,000 to $20,000, and over $20,000. These were used to determine whether any significant differences existed among the responses of different groups within the community. Independent variables included residential location, age, sex, number of years lived in Soldiers Grove, level of education, and household income. Except where otherwise stated, a probability level of .05 was used to determine significantly different responses.

Characteristics of Respondents

The survey sample consisted predominantly of elderly people, with nearly 50% over the age of fifty-five years and only 7% under twenty-five years. Most respondents had lived in Soldiers Grove for some time; the modal category was over twenty-five years (46%). Thirty-two percent of the respondents had moved to the town since the last flood in 1978, but only 15% since final decisions were made regarding the relocation plan (Table 1). It was expected that this combination of age and length of residence would contribute to a good understanding or awareness of the problems faced by the community and how the relocation strategy had sought to accommodate various interests.

Several other socioeconomic characteristics were collected. Sixty percent had graduated from high school, and nearly 15% had a college-level education. Reported household income for 1987 confirmed the generally low-income nature of the community that had been reported in the earlier studies (U.S. Senate Oversight Hearings 1975, 7149). Forty-nine percent of reporting households had incomes lower than $10,000 and 24% more than $20,000. As might be expected, level of education was positively related to income and inversely correlated with age of respondent. Consistency with the census data was maintained across the sexes with 58% of respondents being female.

Location of residence within Soldiers Grove was considered important, since the plan had resulted in distinct spatial changes to the physical structure of the community. In particular, the relocation of the downtown business district was expected to present transportation difficulties for the majority of residents. Initially, five areas were determined, but these were later regrouped to reflect proximity to the new downtown (Table 1). Most of the respondents resided in two areas, the Flats, which was flooded in 1978, and the Hill. These residential areas are immediately adjacent to the area that formerly housed the old central business district but are approximately 1.2 and 1.5 miles from the new town. A substantial number of respondents also lived in areas around Church Street and Pine Street. These two were somewhat closer to the new business district, less than 1 and 0.75 mile, respectively. Finally, very few respondents actually lived in the new town. The flooding that inundated the town in 1978 not only created problems for

Table 1. Characteristics of respondents

	N	%		*N*	%
Age			Education level		
Less than 35 years	15	17.9	Some high school	33	39.8
36 to 55 years	27	32.1	High school graduate	24	28.9
Over 55 years	42	50.0	Community college	14	16.9
Sex			College/graduate	12	14.5
Male	36	42.4	Residential location		
Female	49	57.6	New town	11	12.9
Income			The Flats	24	28.2
Less than $10,000	32	48.5	Hill	15	17.6
$10,000 to $20,000	18	27.3	Pine Street	22	25.9
Over $20,000	16	24.2	Church Street	13	15.3
Length of residence					
Up to 10 years	27	31.8			
11 to 25 years	19	22.4			
Over 25 years	39	45.9			

the businesses but also caused extensive damage throughout the Flats and parts of the Pine Street area.

Results

(1) Community spirit

As a general introductory question, respondents were asked to rate Soldiers Grove as a place to live on a scale from poor to excellent (Table 2). Of those responding, 75% rated the town satisfactory or better and only 5% as poor. There were no significant differences between responses based on the independent variables.

Two further questions required respondents to be more specific regarding perceived "community spirit." Participants were asked to assess the level of community spirit in Soldiers Grove both currently and in the pre-move period (Table 3). Opinions on the status of community spirit indicated a distinct decline. Whereas 31% rated pre-move community spirit in the highest category, this figure fell to 7% for the current situation. Similarly, the proportion rating community spirit as little or none rose from approximately 13% to 35%. These responses were significantly different. In 1988, therefore, residents perceived a downturn in community spirit in Soldiers Grove following implementation of the relocation plan. While this is not conclusive proof that social conditions had deteriorated, since selective memory is probably playing a role here, it is an indication at least that not everyone is entirely happy with current community affairs.

Perception of community spirit produced significantly different results based on independent variables of household income and age of respondent. There was a tendency for those with the highest incomes and to some extent those in the youngest age group (this latter variable was significantly different at the .1 level) to perceive a lower level of community spirit than others (Tables 4 and 5). Not surprisingly, it was found that those respondents who rated Soldiers Grove less favorably as a place to live also perceived little current community spirit.

(2) Impacts of the relocation project

Nearly 70% of the respondents thought that problems associated with the relocation plan outweighed any advantages. Contrary to previous findings described in the literature review, those in the oldest category (over fifty-five years) were less likely to report problems than those in the two younger age groups (significantly different at the .1 level, Table 6).

Since more specific information on the perceived impacts of the relocation project would help define the problems, participants were asked to respond to a series of questions related to service utilities such as water, electricity supply, and garbage collection; quality of the neighborhood environment; access to public facilities and businesses, including libraries, banks, and grocery stores; and

Table 2. Rating of Soldiers Grove as a place to live

	N	%
Poor	4	4.8
Fair	17	20.5
Satisfactory	26	31.3
Good	32	38.6
Excellent	4	4.8
Missing	2	

Table 3. Perceived community spirit*

	Pre-move		*Post-move*	
	N	%	*N*	%
A little/none	8	12.5	29	34.9
Good	36	56.3	48	57.8
Great/excellent	20	31.3	6	7.2

*X^2 = 19.08, 2 degrees of freedom, p = .001.

Table 4. Perceived community spirit (1988) by household income*

	<$10,000		$10–20,000		>$20,000	
	N	%	*N*	%	*N*	%
A little/none	7	22.6	4	23.5	9	56.3
Good/excellent	24	77.4	13	76.4	7	43.8

*X^2 = 6.212, 2 degrees of freedom, p = .05.

Table 5. Perceived community spirit (1988) by age*

	<36 years		36–55 years		>55 years	
	N	%	*N*	%	*N*	%
A little/none	6	40.0	13	48.1	9	22.5
Good/excellent	9	60.0	14	51.9	31	77.5

*X^2 = 5.074, 2 degrees of freedom, p = .1.

Table 6. Views on the relocation plan by age*

	<36 years		36–55 years		>55 years	
	N	%	*N*	%	*N*	%
Perceived problems	13	86.7	20	80.0	24	60.0
Perceived advantages	2	13.3	5	20.0	16	40.0

*X^2 = 5.146, 2 degrees of freedom, p = .076.

personal finances (Table 7). The perceived impact on public services and utilities was predominantly in the no change category (67%), although there was a large minority (23%) who perceived that service facilities had declined with implementation of the project. Those respondents who had perceived little or no spirit in the community were more likely to perceive a negative impact on services from the relocation plan (significance level .1). The distribution of responses regarding impact on neighborhood environment was more varied, but still nearly 50% perceived no change. However, a large proportion of respondents (36%) felt that the relocation project had enhanced neighborhood quality. Similar results were apparent for impact on personal finances. Over 65% perceived no change due to the relocation plan. It was noticeable, however, that no one from the new town area perceived any detrimental effect on their personal finances.

The greatest negative effect of the relocation plan appears to have been the impact on access to public and private facilities. Forty-seven percent of respondents believed that access had got worse since the relocation plan was implemented. However, 22% thought the opposite. Responses from different areas within Soldiers Grove were significantly different (Table 8). Residents living in the new town were more likely to perceive either no change or some improvement in access, whereas those living in the area farthest from the new business district (the Flats and Hill area) were most likely to see increasing problems with access. This question generated the most open-ended comments from participants, many of whom complained about the distance to stores and the general lack of focus of the community.

The relocation project has had a recognizable impact on the businesses of Soldiers Grove. Both David and Mayer (1984) and

Table 7. Perceived impact of the relocation project

	Services		*Environment*		*Access*		*Finances*	
	N	%	*N*	%	*N*	%	*N*	%
Greatly improved	0		3	3.6	3	3.7	0	
Improved somewhat	9	10.7	27	32.5	15	18.5	10	12.0
No change	56	66.7	41	49.4	25	30.9	54	65.1
Somewhat worse	15	17.9	8	9.6	24	29.6	17	20.5
Much worse	4	4.8	4	4.8	14	17.3	2	2.4
Missing	1		2		4		2	

Table 8. Perceived impact on access by residential area*

	New town		*Flats/Hill*		*Pine/Church*	
	N	%	*N*	%	*N*	%
Improved/no change	7	70.0	14	36.8	22	66.7
Worse access	3	30.0	24	63.2	11	33.3

*X^2 = 7.619, 2 degrees of freedom, p = .022.

Becker (1983) have described the changes that actually occurred during implementation of the project. Eight businesses were lost, including a restaurant, grocery store, meat locker plant, laundromat, three bars, and the local newspaper, while there were seven gains, a restaurant/hotel, dental clinic, real estate agency, craft store, pharmacy, an insurance office, and an expansion to a nursing home. On the other hand, there was a net gain in permanent jobs of 46.5 (Becker 1983). The number of persons employed in the business district increased from 66 full-time equivalent jobs to 123. Residents' perception, however, was one of decline; 76% believed the number of businesses had fallen. There was a significantly different response based on length of residence in Soldiers Grove. Those residents new to the community were more likely to perceive no change or an increase in the number of businesses operating in Soldiers Grove (Table 9). This response may reflect the gradual growth and change in emphasis of the new businesses. Many basic commercial enterprises were replaced by those related to secondary services. It was also noticeable that residents in the new town were more likely to perceive an improvement than residents from other parts of town.

Respondents were also asked to comment on the relative success of remaining businesses (Table 10). Twenty-nine percent believed that businesses were poorer than before the move compared to 41% who perceived that they were more successful. Once again, respondents living in the new town perceived greater success than other respondents (significantly different at the .1 level).

(3) Flood hazard

Sixty-six percent of respondents indicated that flooding was no longer a problem for Soldiers Grove. This is a high negative response rate and certainly does not reflect the serious nature of the flood hazard. Parts of the residential community are still prone to inundation, and public facilities, roads, sewers, etc. will suffer periodically from flooding. A failure to maintain old levees in the area could also increase the incidence of flooding in lower parts of the new parkland. Nevertheless, this is a typical reaction, and the hazard literature is full of discussions focusing on the "false sense of security" generated by implementing alleviation projects (Burton, Kates, and White 1978).

The Soldiers Grove relocation plan had been developed and financially supported to

Table 9. Perceived number of businesses by length of residence*

	<10 years		11–25 years		>25 years	
	N	%	*N*	%	*N*	%
Increased/no change	11	42.3	2	10.5	6	15.8
Decreased numbers	15	57.7	17	89.5	32	84.2

*X^2 = 8.093, 2 degrees of freedom, p = .02.

Table 10. Perceived success of local businesses

	N	%
Very successful	5	6.0
Somewhat successful	29	34.9
Okay	25	30.1
Somewhat poor	17	20.5
Very poor	7	8.4
Missing	2	

a large extent by the local community. In light of this direct experience, two questions were asked regarding responsibility toward flooding (Table 11). Financial responsibility for correcting flood problems was placed primarily on the federal government (72%) and secondly on state government (47%). Local sponsorship of adjustments to flooding was suggested by only 25% of the respondents. In this question respondents were permitted to nominate more than one option. These results conflict with what actually occurred in Soldiers Grove, where local financial commitment amounted to a substantial share of total costs. However, some explanation is forthcoming from the next question: Who should take responsibility to oversee flood control work? Here the response pattern was different. While 51% still believed the federal government should be held responsible, significant groups supported state (38%) and local (45%) control. These results indicate that respondents would like a greater role by the federal government financially but would also like to retain some control over what is actually undertaken in the community.

As a final analysis respondents were asked their opinions on completion of the La Farge dam several miles upstream from Soldiers Grove. This dam had been shelved by the Presidential moratorium on water projects in 1977 even though it was almost complete and approximately fifty million dollars had already been spent on it (Tobin and Peacock 1982). During discussions on the relocation project the lack of protection offered by the dam had been used as a strong argument for an alternative project for Soldiers Grove. In spite of this, 64% of respondents believed that the dam should be completed, 14% said no, and the rest (22%) did not know. Significantly different responses were found between the sexes. Males were overwhelmingly in favor of completing the dam, whereas females were less likely to express an opinion.

Discussion and Conclusions

The response of residents in Soldiers Grove to the relocation plan can be explained by current thinking on rural communities. Not surprisingly, given the degree of change,

Table 11. Responsibility for flooding

	Financial		Work control	
	N	%	*N*	%
Federal government	54	72.2	41	51.3
State government	35	46.7	31	38.3
Local authorities	19	25.3	36	45.0
Private individuals	10	18.3	8	10.0

problems have arisen following implementation of the project. In particular, there is a consensus that community spirit is not good. Over 25% rated the town as only fair or lower as a place to live. This attitude was particularly evident amongst those younger residents of the town. Furthermore, respondents perceive an inequality in the distribution of costs and benefits accruing from the project. Residents are now paying the costs of business revitalization. The spatial disassociation prevalent within the community is especially troubling for many individuals. Consequently, more attention needs to be addressed to these questions before Soldiers Grove can be cited as the "planning ideal" (David and Mayer 1984) or model for small community floodplain planning (Tobin and Peacock 1982).

It is clear that residents came to accept the idea of major change in the community and gradually overcame any fears and uncertainty about the future. Undoubtedly, residents perceived many gains in comparison with few losses from relocation, which pushed the project toward the certainty end of the scale (Becker 1983, 38). The severe nature of the flood hazard (combined with a timely reminder of flooding in 1978) and the declining economic base of the community must have been powerful incentives to accept this radical change. These stimuli may not be found in other communities contemplating such drastic action.

Residential opinions on authority involvement could be explained within the context of the theoretical structure described earlier. The Soldiers Grove relocation project involved a high level of local commitment and support and hence was perceived as a successful planning venture. Criticisms were generally leveled at the federal government for its vacillating policies and intermittent funding (Hirsch 1980; National Science Foundation 1980). Given the high local contribution to funding and the difficulties in obtaining money from other sources, it is not surprising to see respondents requesting greater federal financial commitment. At the same time, many residents wished to maintain strong local control over any projects, thus retaining an element of self-determination in community affairs.

The socioeconomic elite in Soldiers Grove had been responsible for developing the relocation project in the first place. The local newspaper and several businesses had taken very active roles in promoting the acceptance of the project (Becker 1983, 20). This also conforms to the theoretical structure described at the beginning of the paper, with local leaders taking the initiative. It was very much a locally inspired project that retained local control, but this has also generated conflict within the society. The heterogeneity of groups within the community has led to differences of opinion about the perceived success of the project.

While the community tended to present a united face to the problems confronting Soldiers Grove, it is clear that some internal conflicts now exist. Many residents are dissatisfied with the relocation project and see it as destroying the spirit, or sense, of community. Results of the questionnaire survey showed that residents are not entirely happy with how benefits have been distributed. Many residents perceive costs to have been borne by all the community, especially regarding the changing physical structure of the town. Most residents now must drive to the new downtown for groceries, for instance. Consequently, while the basic cost-benefit analysis for the relocation plan was favorable (David and Mayer 1984), attention should also be devoted to particular gainers and losers of the project.

In conclusion, the relocation project in Soldiers Grove has not been the solution to all the community's problems. Certainly, there have been economic gains, and flood losses should no longer devastate the town. However, the social costs have also been high, and it remains to be seen whether Soldiers Grove can recapture or develop a sense of community that at present appears to be lacking. The structural changes in use of space throughout the town have clearly had repercussions on the community. The planning process in Soldiers Grove, therefore, can continue to serve as a model for other communities, but it may also serve as an example of the need to monitor carefully social implications of such changes.

Acknowledgments

This research was supported in part by an Undergraduate Research Opportunities Grant awarded to Heidi Kroening by the University of Minnesota. Heidi Kroening was instrumental in administering the questionnaire survey.

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Depth, Substrate, and Turbidity Relationships of Some Wisconsin Lake Plants

Stanley A. Nichols

Abstract. *The depth distribution and substrate and turbidity preferences are described for 78 aquatic plant taxa found in 68 Wisconsin lakes. In general it was found that 1) taxa numbers decrease with increasing depth; 2) taxa richness is not different between substrate types; 3) many species are restricted to shallow water, while others are broadly tolerant of water depth variation; 4) the depth distribution of many species is skewed towards shallow water; 5) the maximum growth depth for many species is highly variable; 6) there is a significant linear relationship between water clarity and maximum depth of plant growth; and 7) water clarity, water depth, turbidity tolerance, and substrate preference influence species association.*

Water depth, substrate, and turbidity are important factors affecting the growth and distribution of aquatic plants in lakes (Spence 1967; Swindale and Curtis 1957; Pearsall 1920; Barko, Adams, and Clesceri 1986; Lind 1976; Dale 1981). Shallow-water plants may be limited by mechanical damage from ice, waves, or fluctuating water levels; deep-water plants may be restricted by light penetration, temperature, or nutrients. Turbidity decreases light penetration and acts selectively, favoring species more adapted to turbid conditions. Nutrient concentrations, texture, amount of organic matter, and siltation rate are some substrate parameters that influence plant growth and distribution. Water depth, turbidity, and substrate are interrelated. Increasing water depth decreases soil particle size, turbulence, and light (Spence 1967).

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Is is difficult to describe habitat preferences without detailed ecophysiological studies of individual species. Variations in life cycle, morphology, physiology, and reproduction determine how a species relates to the aquatic environment. Detailed life history and ecophysiological studies are available for relatively few, usually nuisance, species (Nichols and Shaw 1986).

The depth, substrate, and turbidity preferences of 78 species of submergent, emergent, and floating-leaved plants in 68 Wisconsin lakes are described in this paper. Specifically, the depth range where species were found; the species preference for habitats described by substrate, water depth, and turbidity; and the species response to various substrate-depth habitats are described. In addition, growth and distribution of species in Wisconsin lakes are compared to responses at other geographic locations. This information is useful for conducting further ecophysiological studies of individual species and for management purposes.

Methods and Analysis

Between 1975 and 1983 detailed macrophyte surveys were completed for 68 Wisconsin lakes. The lakes were sampled by Wisconsin Department of Natural Resources (WDNR) field staff or by private consultants for the WDNR Office of Inland Lake Renewal (OILR). The primary purposes of the surveys were to design lake management strategies or to collect benchmark limnological data.

The lakes represent a broad range of Wisconsin lake types with regard to geographic distribution (Fig. 1), water chemistry (Table 1), and human impact. Physical and chemical data for each lake were collected during macrophyte sampling or were collected earlier as part of surface-water resource inventories for each county.

Field methods

To assure geographical coverage of a lake, the surveyors selected sampling points using a grid system. Grid size and the number of sampling points per lake varied with lake size, i.e., larger lakes contained more sampling points on a larger grid.

At every sampling point water depth was measured to the nearest 0.1 m, and substrate was categorized as being hard (type 1: sand or gravel) or soft (type 2: silt, muck, or flocculent). All plants within a circle 2 m in diameter around the sampling point were recorded and were assigned a 1 to 5 density rank based on the criteria established by Jessen and Lound (1962). Unknown species were collected and sent to the Wisconsin Geological and Natural History Survey for identification. Plant identification followed Fassett (1969). Specimens were then sent to the University of Wisconsin–Madison herbarium as voucher specimens.

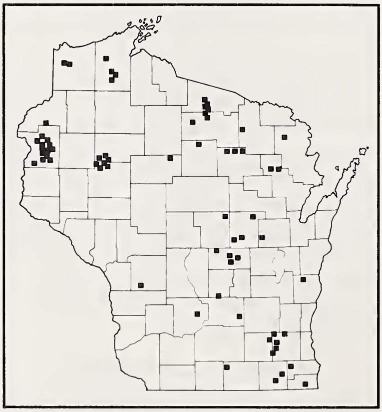

Figure 1. *Location of sampled lakes*

Analysis

Because the study is meant to determine where plants grow, only quadrats with plants were analyzed. Due to differing water clarities, plant depth for some analyses is expressed as a percentage of the maximum depth at which plants grew in each lake. Depth classes of 0–25%, 26–50%, 51–75%, and 76–100% of maximum growth are reported as depths 1, 2, 3, and 4.

Data were analyzed using standard descriptive statistics, boxplots, chi-square, analysis of variance, correlations, and linear regression (SAS Institute 1985; Lotus Development Corporation 1985). Because more information is available about common species than about rare ones, different levels of analysis were necessary.

Results

Species occurrence and habitat richness

A total of 123 plant taxa were found in the 68 lakes. The numbers of taxa are nearly the same for the two substrate types but declined with relative depth (Table 2). The decreasing taxa number with increasing depth was expected. The similar number of taxa for both substrates was not expected.

The similarity of species occurrence was also compared for each depth-substrate class. This was done by calculating the relative frequency of species occurrence for each depth-substrate class from information provided in Table 3. The classes were compared using the similarity index $2W/A+B$ (Bray and Curtis 1957). The vegetation in the shallow-water, hard-substrate habitat (i.e., depth 1, substrate 1) was least similar (i.e., most dissimilar) to

Table 1. Limnological characteristics of sampled lakes

Lake name	County	Total alkalinity	pH	Specific conductance at 25° C	Secchi	Area	H_2O >3m	H_2O <1m	Quadrats sampled	Depth of maximum plant growth	Biotic influence
		mg/l $CaCO_3$		umhos/cm	m	ha	%	%		m	
Allequash Lake	Vilas	39	7.8	87	3.1	172.5	25	12	135	4.8	
Amnicon Lake	Douglas	24	6.6	56	1.8	172.5	4	15	123	3.6	
Anodanta Lake	Bayfield	90	6.8	238	2.5	10.5	15	15	225	3.9	
Apple River Flowage	Polk	126	7.2	264	2.1	258.8	0	20	190	3.6	
Ashippun Lake	Waukesha	220	8.4	500	2.4	34.0	50	4	231	6.1	
Balsam Lake	Polk	84	7.2	186	2.4	831.9	25	10	188	4.5	Algae
Bear Lake	Oneida	31	7.0	70	3.1	126.4	20	5	123	4.2	
Bear Paw Lake	Oconto	21	6.8	71	3.1	19.8	0	10	100	3.0	
Big Butternut Lake	Polk	83	7.2	186	2.4	153.1	0	20	87	4.0	Algae
Big Hills Lake	Waushara	105	8.6	252	2.1	53.9	0	0	36	2.4	
Black Otter Lake	Outagamie	194	7.3	412	0.9	30.4	0	10	75	2.7	
Blake Lake	Polk	108	6.8	340	1.5	122.3	0	25	50	2.7	
Bone Lake	Polk	122	6.8	194	3.1	721.3	20	15	105	3.9	
Cary Pond	Waupaca	148	8.3	315	2.9	10.5	0	10	111	2.1	
Cedar Lake	Polk	125	7.8	225	1.5	448.3	15	15	228	2.7	
Chain Lake	Chippewa	37	6.8	120	4.3	189.5	50	8	48	3.2	
Chute Pond	Oconto	100	7.9	230	1.5	168.9	0	20	134	3.0	
Clear Lake	Rusk	88	7.0	156	4.0	38.5	59	7	70	5.0	
Clear Lake T39 R7 S16	Oneida	10	6.8	27	5.9	342.6	85	3	134	7.8	
Como Lake	Walworth	180	8.2	417	2.4	383.1	0	20	160	1.4	
Decorah Lake	Juneau	53	8.6	137	0.9	42.1	0	40	117	2.6	
Devil's Lake	Sauk	21	7.2	99	5.2	151.1	75	4	221	3.6	Algae
Dowling Lake	Douglas	22	6.3	56	1.5	62.4	0	25	24	2.1	
Ennis Lake	Marquette	201	8.2	339	1.7	10.1	15	10	294	3.6	
Enterprise Lake	Langlade	30	7.0	44	1.2	204.5	7	10	102	3.1	
Frank Lake	Vilas	10	7.1	29	3.1	57.1	10	6	24	5.2	
George Lake	Kenosha	103	9.9	253	0.3	23.9	0	50	62	1.8	Carp, algae
Half Moon Lake	Polk	89	6.6	122	3.4	234.5	35	9	142	5.0	
Half Moon Lake T47 R8 S17	Bayfield	47	7.4	74	3.1	42.1	0	30	100	2.6	
Helen Lake	Portage	110	7.7	281	3.4	31.6	0	15	165	4.8	

Continued on next page

Table 1—*Continued*

Lake name	County	Total alkalinity	pH	Specific conductance at 25° C	Secchi	Area	H_2O >3m	H_2O <1m	Quadrats sampled	Depth of maximum plant growth	Biotic influence
		mg/l $CaCO_3$		umhos/cm	m	ha	%	%		m	
Island Lake	Rusk	65	7.0	82	3.1	213.0	35	9	84	4.2	
Lazy Lake	Columbia	214	9.2	373	1.2	65.2	0	40	58	2.4	Carp
Leota Lake	Rock	250	7.8	641	0.3	16.6	0	25	24	1.5	Carp, algae
Little Arbor Vitae Lake	Vilas	55	7.8	120	2.1	215.9	20	6	128	5.1	Algae
Little Elkhart Lake	Sheboygan	133	8.5	246	2.1	21.9	1	10	190	4.5	
Long Lake T20 R09 S17	Waushara	54	8.5	120	0.9	18.2	0	85	69	1.5	
Long Lake T32 R8 S8	Chippewa	42	7.2	97	4.9	429.3	55	5	46	1.8	Crayfish
McCann Lake	Rusk	68	6.8	94	2.7	53.9	21	26	94	3.3	
Mid Lake	Oneida	49	6.5	113	1.5	87.1	0	25	103	3.3	
Moon Lake	Marinette	79	6.8	200	4.4	39.3	15	15	73	4.8	
Mount Morris Lake	Waushara	136	8.4	239	2.7	66.0	5	5	188	5.1	
Mud Hen Lake	Burnett	85	8.4	174	3.4	228.0	30	30	159	4.2	
Muskellunge Lake	Lincoln	32	6.4	76	3.4	64.4	5	15	111	3.3	
Oconomowoc Lake, Upper	Waukesha	221	8.0	488	2.4	17.4	0	10	117	4.1	
Okauchee Lake	Waukesha	139	8.9	287	5.5	480.7	40	5	348	5.2	
Ottawa Lake	Waukesha	265	7.8	462	2.3	11.3	0	10	338	5.1	
Pearl Lake	Waushara	123	8.5	208	4.9	37.3	65	2	198	6.0	
Perch Lake T45 R7 S5	Bayfield	8	6.0	28	3.1	28.4	45	8	146	5.1	
Pigeon Lake	Waupaca	191	8.2	388	1.8	66.0	0	0	139	3.3	
Pike Lake	Polk	130	7.4	271	2.3	64.4	15	15	130	6.0	
Pine Lake	Waukesha	139	8.5	360	3.3	284.7	80	5	118	5.4	
Pine Lake	Forest	35	7.6	90	3.7	676.4	0	20	224	3.9	
Pine Lake	Chippewa	17	5.8	26	4.6	106.1	75	4	122	5.0	
Post Lake, Upper	Langlade	48	7.2	95	0.9	306.6	0	20	96	2.7	
Pretty Lake	Waukesha	155	8.4	400	2.4	25.9	10	35	57	4.5	
Prong Lake	Vilas	5	6.6	20	4.5	12.2	47	8	133	5.4	
Rib Lake	Taylor	65	6.8	156	1.2	129.6	0	40	136	3.3	Algae
Rolling Stone Lake	Langlade	77	7.7	142	2.1	272.2	0	0	106	3.6	
Round Lake	Polk	94	8.4	160	1.6	411.1	0	25	124	3.6	
Silver Lake (Anderson) T22	Waupaca	180	8.5	367	1.5	13.0	0	12	75	2.3	

Continued on next page

Table 1—*Continued*

Lake name	County	Total alkalinity	pH	Specific conductance at 25° C	Secchi	Area	H_2O >3m	H_2O <1m	Quadrats sampled	Depth of maximum plant growth	Biotic influence
		mg/l $CaCO_3$		umhos/cm	m	ha	%	%		m	
Tahkodah Lake	Bayfield	9	6.8	15	2.7	61.6	0	15	9	1.2	
Tichigan Lake	Racine	244	8.2	842	0.6	458.9	8	32	30	1.8	Carp, algae
Town Line Lake	Chippewa	9	6.0	35	1.3	19.4	15	10	152	4.0	
Twin Lake, North	Polk	129	7.0	263	1.9	54.7	0	25	148	6.0	
Twin Lake, South	Polk	135	7.2	279	1.5	30.0	0	25	145	3.0	
Vienna Lake (Honey)	Walworth	315	8.1	670	0.3	17.8	0	30	23	1.2	Carp
White Ash Lake	Polk	93	7.0	284	1.2	62.0	0	25	46	2.4	
White Ash Lake, North	Polk	113	7.4	175	2.0	48.2	0	25	131	2.7	

other stands (Table 4). The shallowest water was the least similar of all the depth classes. There was little difference in similarity between hard and soft substrates.

Taxa with fewer than ten total occurrences, taxa identified only to the generic level except for *Chara* spp. and *Nitella* spp., and free floating species such as *Lemna* spp. and *Wolfia* spp., which have little relationship to depth and substrate, were eliminated from further consideration. *Ceratophyllum demersum* was the most common species. It occurred in 34% of the quadrats and in two-thirds of the lakes. All species with more than two hundred occurrences are common aquatic plants in Wisconsin. All occurred in at least 10% of the lakes. Many of the less common species are either emergent, or they are found in bogs or extremely hard- or extremely soft-water lakes. They have the most restricted habitat requirements.

Depth distribution and maximum depth of growth

The maximum depth of any macrophyte was 7.8 m in Clear Lake, Oneida County. Clear Lake also had the greatest secchi disk reading (Table 1). A least-squares regression of $2.12 + 0.62\,X$ describes the linear relationship between maximum growth depth and secchi depth in these lakes (Fig. 2). There is a significant positive correlation between the two factors ($r = .58$, $N = 68$, $p < .001$). A maximum growth depth versus secchi disk regression was calculated for lakes where a charophyte (*Chara* sp. or *Nitella* sp.) occurred in the deepest quadrat. This regression was not significantly different from the regression in which only non-charophytes were found in the deepest quadrat.

The linear relationship between the maximum depth of growth and secchi depth was tested for the 43 species that occurred in five or more lakes (Table 3). A significant positive correlation ($p < .05$) was found for 13 species (Table 5). *Eriocaulon septangulare* showed the strongest correlation, and all but one of the species showing correlation were submergent.

Table 2. Distribution of taxa by relative depth-substrate class

	Relative depth (% of maximum)				
Substrate	*0–25%*	*26–50%*	*51–75%*	*76–100%*	*Total taxa*
Hard	105	89	81	44	114
Soft	107	100	64	61	113
Total taxa	120	112	88	64	
Grand total taxa =	123				

Boxplots (Fig. 3) show the depth distribution of individual species with ten or more occurrences. The species are arranged in descending order of median depth. More than 75% of all plants were found in less than 3 m of water. *Chara* spp. was found at 7.8 m, the maximum depth for any species. It also occurred over the broadest depth range. *Najas flexilis* followed closely behind *Chara* with a maximum depth of 7.5 m. Both species had a broad outlier range. *Nitella* spp. had the greatest median depth and the greatest depth for the 75% quartile. *Myriophyllum heterophyllum, M. farwellii,* and *Isoetes macrospora* had the broadest depth range when outliers were not considered.

Species common in deep water were also found in shallow water, but species common in shallow were often not found in deep water. Generally speaking, species with shallow median depths are emergent species. However, *Potamogeton foliosus, P. oakesianus,* and *P. vaginatus* are submerged species with a shallow median depth.

The maximum depths of plant growth for 46 species were compared to literature values (Sheldon and Boylen 1977; Wilson 1941; Schmid 1965; Denniston 1921; Lillie 1986; Lind 1976). Twenty-three species were found at a greater maximum depth in other lakes (Table 6), including six species that were found at greater maximum depth in a later study of Devil's Lake (Lillie 1986). Some differences in maximum depth probably relate to limnological conditions and others to the sampling technique used to establish maximum depth (see Spence, 1967, for a discussion of problems related to determining maximum depth of growth).

Various depth statistics were tested, using correlation analysis, to determine how useful they might be for predicting the sequential order of maximum growth depth in a lake (i.e., in a lake with a given flora, which species will have the deepest maximum depth of growth, the second deepest, and so forth). The statistics tested were median depth, the trimmed maximum depth (i.e., the maximum depth or the maximum depth not considering outliers, whichever is the most shallow), the maximum depth, the median of the maximum depth for species that occurred in five or more lakes, and the median of the maximum depth/secchi disk for species that occurred in five or more lakes (Table 6). Based on median correlation values, the best predictor of the sequential order of maximum growth depth is median maximum depth (Table 7). Median depth and median of maximum depth/secchi ratio predicted maximum depth order nearly as well. Maximum depth was the poorest predictor of maximum depth order. On the average, all methods were better at predicting maximum depth order for Wisconsin lakes than for non-Wisconsin lakes.

Substrate and depth preference

Substrate and depth preferences were tested using a chi-square analysis on species occurrence. The hypothesis tested was that the distribution of a species is not significantly different from the distribution of all vegetated quadrats (Table 8).

Because each species acts as an individual, significant variation from the all-species distribution is expected. More interesting and informative are how and to what degree each species varies. A *Z* score of (observed/

Table 3. Number of species occurrence

	Substrate 1				Substrate 2						
Species	*Depth 1*	*Depth 2*	*Depth 3*	*Depth 4*	*Depth 1*	*Depth 2*	*Depth 3*	*Depth 4*	*Occurrence of turbid water*	*No. lakes occurring*	*Association of turbid water**
Brasenia schreberi	64	25	2	0	163	134	32	13	146	16	+ + +
Carex aquatilis	0	0	0	0	11	0	0	0		1	Nocalc
Ceratophyllum demersum	147	287	130	67	440	759	655	387	663	45	+ + +
Ceratophyllum echinatum	2	1	0	0	10	9	2	1		1	Nocalc
Chara spp.	299	204	32	20	378	318	194	112	105	36	− − −
Cyperus engelmannii	0	0	0	0	3	2	4	1		1	Nocalc
Dulichium arundinaceum	28	2	0	0	33	10	0	0	42	11	+ + +
Elatine minima	8	4	0	0	0	0	0	0		2	Nocalc
Eleocharis acicularis	21	9	4	0	8	5	7	4	24	12	+ + +
Eleocharis palustris	5	7	2	1	2	3	1	0		3	Nocalc
Eleocharis robbinsii	6	6	1	0	2	39	19	6		3	Nocalc
Elodea canadensis	81	117	67	38	246	414	271	150	342	46	+ + +
Eriocaulon septangulare	22	12	3	0	8	10	0	0	0	6	− − −
Gratiola aurea	8	5	0	0	0	0	0	0		1	Nocalc
Heteranthera dubia	97	59	12	3	100	115	54	39	123	26	+ + +
Isoetes echinospora	4	3	3	0	7	17	1	0		3	Nocalc
Isoetes macrospora	8	28	9	2	1	6	5	3		3	Nocalc
Leersia oryzoides	0	0	1	0	1	8	1	0		1	Nocalc
Lobelia dortmanna	8	10	0	0	0	0	0	0		3	Nocalc
Megalodanta beckii	17	23	6	0	55	53	11	1	2	9	− − −
Myriophyllum exalbescens	52	101	37	16	108	300	297	90	148	28	− − −
Myriophyllum farwellii	0	1	1	0	28	43	17	8		1	Nocalc
Myriophyllum heterophyllum	2	67	7	1	25	30	12	2		2	Nocalc
Myriophyllum spicatum	26	47	44	32	69	158	79	37	77	9	− − −
Myriophyllum tenellum	13	13	0	0	0	3	1	0		2	Nocalc
Myriophyllum verticillatum	89	86	46	15	158	230	92	21	28	12	− − −
Najas flexilis	226	184	45	9	171	296	144	106	248	42	− − −
Najas gracillima	0	3	3	2	0	0	4	1		2	Nocalc
Najas marina	2	1	1	0	19	45	21	3		3	Nocalc
Nitella spp.	4	6	10	8	14	37	33	28	28	12	Nonsig

Continued on next page

Table 3—*Continued*

Species	Substrate 1 Depth 1	Substrate 1 Depth 2	Substrate 1 Depth 3	Substrate 1 Depth 4	Substrate 2 Depth 1	Substrate 2 Depth 2	Substrate 2 Depth 3	Substrate 2 Depth 4	Occurrence of turbid water	No. lakes occurring	Association of turbid water*
Nuphar advena	1	3	2	0	11	48	6	3	13	5	Nonsig
Nuphar variegatum	62	54	9	9	208	200	36	11	105	39	– –
Nymphaea odorata	53	37	9	2	107	120	34	5	160	17	+ + +
Nymphaea tuberosa	57	19	2	2	271	161	23	13	102	26	Nonsig
Polygonum amphibium	14	0	0	0	75	16	4	0	47	6	+ + +
Pontederia cordata	26	20	1	2	61	49	3	1	18	20	– – –
Potamogeton amplifolius	35	92	25	14	108	274	108	53	138	44	Nonsig
Potamogeton berchtoldii	15	24	14	8	7	24	14	9	33	5	+ +
Potamogeton crispus	41	43	23	10	87	97	58	36	105	18	+ + +
Potamogeton diversifolius	2	0	0	0	17	29	6	0		2	Nocalc
Potamogeton epihydrus	10	1	1	1	14	23	5	2	10	12	Nonsig
Potamogeton filiformis	0	5	3	2	4	6	11	1		3	Nocalc
Potamogeton foliosus	23	8	4	0	77	51	56	29	96	9	+ + +
Potamogeton gramineus	98	89	21	16	51	79	37	19	100	24	Nonsig
Potamogeton illinoensis	33	23	3	0	58	55	20	8	17	15	– – –
Potamogeton natans	62	42	4	0	134	95	16	0	70	28	Nonsig
Potamogeton nodosus	21	9	1	0	8	18	0	2	24	6	+ + +
Potamogeton oakesianus	0	0	0	0	16	3	0	0		2	Nocalc
Potamogeton obtusifolius	0	1	0	0	6	8	0	0		2	Nocalc
Potamogeton pectinatus	87	84	13	3	150	162	119	55	151	32	Nonsig
Potamogeton praelongus	21	24	16	2	100	215	184	64	47	21	– – –
Potamogeton pusillus	8	18	4	2	99	105	30	11	123	15	+ + +
Potamogeton richardsonii	80	155	45	23	71	196	112	71	172	31	Nonsig
Potamogeton robbinsii	29	78	48	38	90	204	97	109	146	20	Nonsig
Potamogeton strictifolius	18	9	0	0	15	13	3	0		2	Nocalc
Potamogeton vaginatus	15	2	0	0	52	7	3	2		2	Nocalc
Potamogeton vaseyi	1	0	0	0	1	5	6	1		2	Nocalc
Potamogeton zosteriformis	115	159	67	33	247	401	282	112	246	41	– – –
Ranunculus longirostris	7	3	0	0	6	8	3	0	6	9	Nonsig
Ranunculus reptans	7	13	0	0	0	1	2	0		2	Nocalc

Continued on next page

Table 3—*Continued*

Species	Substrate 1				Substrate 2				Occurrence of turbid water	No. lakes occurring	Association of turbid water*
	Depth 1	Depth 2	Depth 3	Depth 4	Depth 1	Depth 2	Depth 3	Depth 4			
Ranunculus trichophyllus	5	0	2	0	4	4	0	0		3	Nocalc
Sagittaria graminea	2	0	2	0	8	3	0	0		3	Nocalc
Sagittaria latifolia	9	0	0	0	21	2	3	0	10	9	Nonsig
Sagittaria rigida	3	0	0	0	15	7	1	0	11	5	+ + +
Scirpus americanus	5	1	0	0	11	12	1	0		4	Nocalc
Scirpus validus	97	62	2	1	175	18	0	0	11	26	– – –
Sparganium angustifolium	2	2	1	0	4	0	1	0		3	Nocalc
Sparganium chlorocarpum	3	1	0	0	15	14	1	0		4	Nocalc
Sparganium eurycarpum	3	1	0	0	21	0	0	0	5	7	Nonsig
Typha angustifolia	0	0	0	0	14	0	0	0		2	Nocalc
Typha latifolia	28	0	0	1	88	9	1	3	8	19	– – –
Utricularia geminiscapa	3	3	0	1	32	43	3	3		2	Nocalc
Utricularia gibba	3	0	0	0	41	37	9	3		1	Nocalc
Utricularia intermedia	3	0	1	0	35	30	2	1		2	Nocalc
Utricularia vulgaris	3	3	0	0	50	59	14	0		4	Nocalc
Vallisneria americana	215	318	86	33	94	266	114	36	316	44	+ + +
Zanichellia palustris	19	8	3	1	3	1	4	5		3	Nocalc
Zizania aquatica	6	4	1	0	59	26	3	0	15	9	Nonsig

*Nocalc = no calculation; nonsig = nonsignificant association using chi-square ($p < .05$). + + – –, + + + – – – = moderate or strong positive or negative association.

Table 4. Similarity of stands based on relative frequency

		Substrate 1				Substrate 2		
	Depth	1	2	3	4	1	2	3
	1	1.00						
Substrate 1	2	0.74	1.00					
	3	0.58	0.76	1.00				
	4	0.53	0.69	0.83	1.00			
	1	0.69	0.65	0.54	0.49	1.00		
Substrate 2	2	0.64	0.72	0.70	0.64	0.76	1.00	
	3	0.54	0.67	0.73	0.69	0.63	0.79	1.00
	4	0.53	0.66	0.72	0.71	0.57	0.71	0.84
Total similarity		5.24	5.89	5.85	5.75	5.33	5.95	5.86

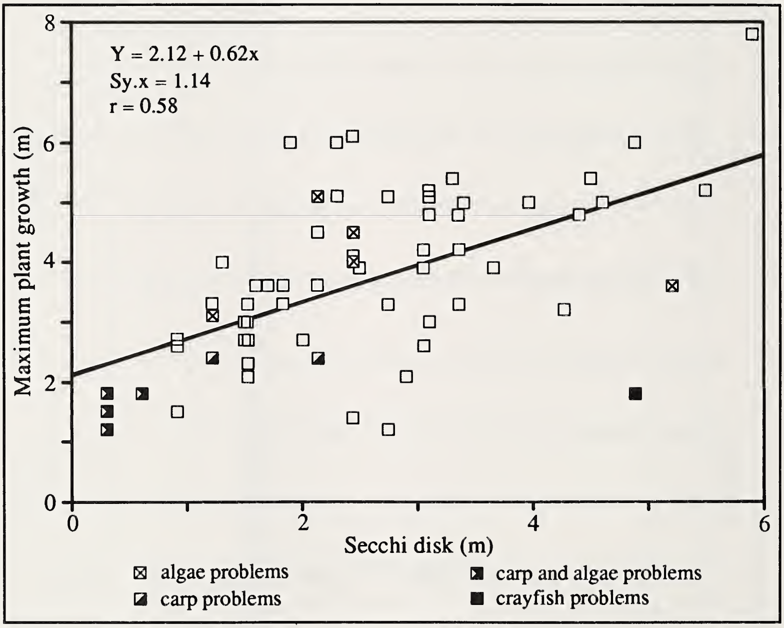

Figure 2. *Secchi disk reading versus maximum depth of plant growth*

expected)/(square root expected) was calculated for each cell of the chi-square table. If the score was less than ± 1 *Z*, the association is weak (designated + or − in Table 9). If it ranged from 1 to 2 *Z*, the association is moderate (designated + + or − − in Table 9). If *Z* was greater than 2, it is a strong association (designated + + + or − − − in Table 9).

A valid chi-square test requires a minimum number of occurrences in each cell. To fit the criteria of a valid test, species with dif-

Table 5. Positive correlation between maximum plant growth depth and secchi depth ($p < .05$)

Species	*Correlation coefficient*
Chara spp.	0.61
Ceratophyllum demersum	0.29
Elodea canadensis	0.38
Eriocaulon septangulare	0.93
Myriophyllum exalbescens	0.42
Najas flexilis	0.57
Potamogeton amplifolius	0.40
Potamogeton gramineus	0.48
Potamogeton pectinatus	0.51
Potamogeton pusillus	0.54
Potamogeton richardsonii	0.49
Vallisneria americana	0.39
Zizania aquatica	0.70

ferent numbers of occurrences had to be tested in different ways. All species with 50 or more occurrences were tested with the full eight-cell chi-square pattern of four depth classes and two substrate types. Species with 25 to 50 occurrences were analyzed separately in a four-cell depth preference test and a two-cell substrate preference test. Species with 15 to 25 occurrences were analyzed with a two-cell substrate preference pattern. Species with fewer than 15 occurrences were not analyzed.

The patterns of positive and negative associations were sorted until species with like patterns occurred close to each other in a list. The list was subjectively split, and species groups were labelled with habitat preference based on the pattern of positive and negative associations (Table 9).

Twenty-six species showed a preference for soft sediment; 14 species preferred hard bottoms. A depth preference with no substrate preference was evident for 27 species. The majority of these species showed a preference for shallow water. No species showed a unique preference for hard bottom and deep water. With minor exceptions, species showed a smooth transition between adjacent habitats. No species showed a strongly bimodal distribution.

Myriophyllum heterophyllum, M. verticillatum, Potamogeton epihydrus, P. pectinatus, P. illinoensis, Heteranthera dubia, and *Chara* spp. are classified as shallow species by this technique. They may have a deeper distribution than mid- to deep-water species when boxplots are compared. Depth in this test is relative to the maximum depth of plant growth in a lake, whereas boxplots compare absolute depth. Therefore, the two tests need not give the same results.

Species association with turbid water

Twenty-one percent of the quadrats occurred in turbid lakes (lakes with secchi disk readings of 1.5 m or less, Table 1). A chi-square test was done on the 43 species that occurred in five or more lakes to determine whether they were found more or less frequently than expected in turbid water (Table 3). A Z score was calculated as noted previously to describe the strength of the association.

No significant association was found for 14 of the species, 15 species showed a positive association for turbid water, and 14 species showed a negative association with turbid water (Table 3).

Species density and habitat type

Differences in species density ranking for the four depth classes and two substrate types were tested using a two-way analysis of variance. Because of differences in occurrence, the test had to be modified for some species. Originally all species with 50 or more occurrences were tested for depth, substrate, and depth-substrate interaction. Because of data limitations, two-way analysis of variance could not provide a valid interaction model for some species. In these cases the interaction test was dropped and the analysis was recalculated for only depth and substrate.

This test asks whether there is a significant difference in mean density rank for a single species between habitats where it is found. A probability of $F < .05$ and at least a .5 difference between the largest and smallest mean density were the criteria established to

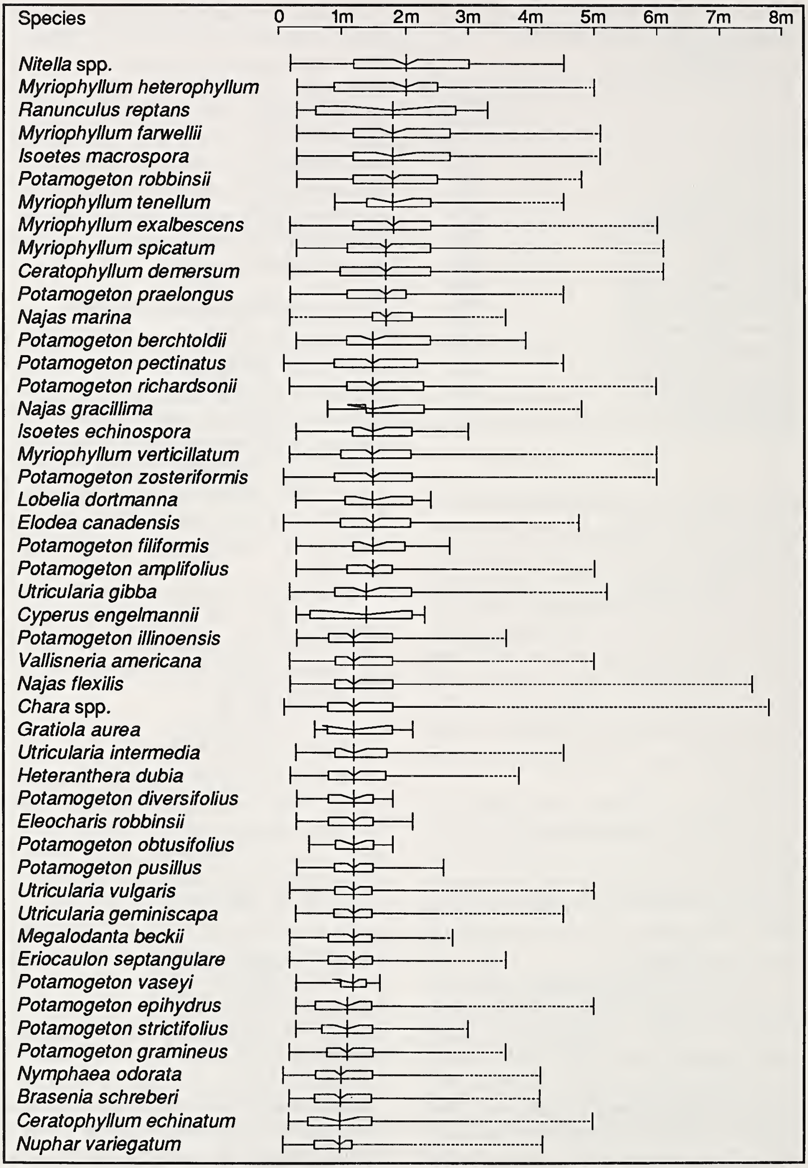

Figure 3. *Boxplots of species depth distributions. Definitions follow Ryan, Joiner, and Ryan (1981)*

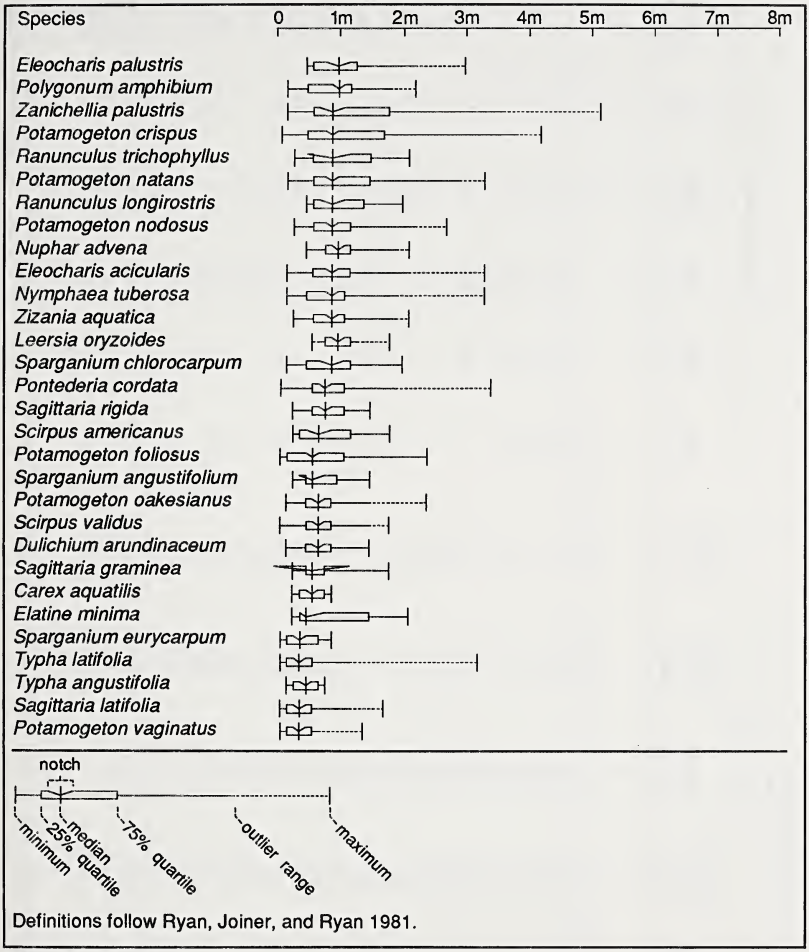

Figure 3—*Continued*

test for significant differences. For any depth-substrate cell in a single test to be significantly different from another cell, the $p <$ .05 criterion was used, but the mean density difference of .5 was not used.

Twenty-six species showed no significant difference across the range of depths and substrates. Five species showed significantly higher densities on soft substrates (Fig. 4). Seven species showed significantly different densities according to depth (Fig. 5). Density of *Elodea canadensis* and *Eriocaulon septangulare* differed depending on depth and substrate, but the depth-substrate interaction was not significant (Fig. 4 and 5).

The density of the remaining ten species

Table 6. Comparison of maximum plant growth depths

Species	Study lakes: Median depth	Study lakes: Trimmed maximum depth	Study lakes: Maximum depth	Study lakes: Median maximum depth	Study lakes: Median maximum/ secchi	Comparison lakes: 1* Lake Mendota	Comparison lakes: 2* Devil's Lake	Comparison lakes: 3* Trout Lake	Comparison lakes: 4* SE Minn. lakes	Comparison lakes: 5* Long Lake	Comparison lakes: 6* Lake George
	m	*m*	*m*	*m*		*m*	*m*	*m*	*m*	*m*	*m*
Brasenia schreberi	1.0	2.9	4.1	1.5	0.6				1.8		
Ceratophyllum demersum	1.7	4.5	6.1	3.0	1.6	6.0	8.7	6.5	4.7		
Chara spp.	1.2	3.3	7.8	2.6	1.1	2.9	1.8	5.0	1.6	8.8	
Elatine minima	0.3	2.1	2.1								2.0
Eleocharis acicularis	0.9	2.1	3.3	1.5	0.5		2.0	1.5			
Eleocharis palustris	1.0	2.1	3.0					0.5			
Elodea canadensis	1.5	3.9	4.8	2.6	1.1		6.7	4.5	3.4	7.5	12.0
Eriocaulon septangulare	1.2	2.6	3.6	1.4	0.4						3.0
Gratiola aurea	1.2	2.1	2.1					0.3			
Heteranthera dubia	1.2	3.1	3.8	1.9	1.1				1.7	5.5	5.0
Isoetes echinospora	1.5	3.0	3.0				1.7				7.0
Isoetes macrospora	1.8	5.0	5.1					2.5			9.0
Lobelia dortmanna	1.5	2.4	2.4					0.3			2.0
Megalodanta beckii	1.2	2.6	2.7	2.1	0.7			3.5			7.0
Myriophyllum exalbescens	1.8	4.2	6.0	2.5	1.3				3.7	6.8	
Myriophyllum spicatum	1.7	4.4	6.1	3.6	1.2		9.0				
Myriophyllum tenellum	1.8	3.8	4.5					4.0			3.0
Myriophyllum verticillatum	1.5	3.9	6.0	3.2	1.3	5.8		3.5			
Najas flexilis	1.2	3.2	7.5	2.3	1.1	5.3		5.5	1.6	4.5	9.0
Nitella spp.	2.0	4.5	4.5	2.6	1.4		9.0	5.0		11.5	
Nuphar advena	0.9	1.8	2.1	1.2	0.7	1.4					
Nuphar variegatum	1.0	2.1	4.2	1.5	0.7				2.8		
Nymphaea odorata	1.0	2.9	4.1	1.4	0.5	1.0		1.0			
Nymphaea tuberosa	0.9	1.9	3.3	1.4	0.9				1.6		
Potamogeton amplifolius	1.5	2.9	5.0	2.4	1.1	3.9	4.7	5.0	3.9	5.5	7.0
Potamogeton crispus	0.9	3.9	4.2	2.1	1.3		2.9		2.8		3.0
Potamogeton diversifolius	1.2	1.8	1.8				3.7				
Potamogeton epihydrus	1.1	2.9	5.0	1.5	0.5			0.3			

Continued on next page

Table 6—*Continued*

Species	Study lakes					Comparison lakes					
	Median depth	Trimmed maximum depth	Maximum depth	Median maximum depth	Median maximum/ secchi	1* Lake Mendota	2* Devil's Lake	3* Trout Lake	4* SE Minn. lakes	5* Long Lake	6* Lake George
	m	*m*	*m*	*m*		*m*	*m*	*m*	*m*	*m*	*m*
Potamogeton gramineus	1.1	2.6	3.6	2.0	0.7			4.5			7.0
Potamogeton illinoensis	1.2	3.3	3.6	2.1	0.7						7.0
Potamogeton natans	0.9	2.9	3.3	1.5	0.6			1.8	1.6		
Potamogeton nodosus	0.9	2.1	2.7	1.8	0.7				1.3		
Potamogeton pectinatus	1.5	4.4	4.5	2.3	1.0	4.5		2.5	2.2	4.5	3.0
Potamogeton praelongus	1.7	3.6	4.5	3.0	1.3			4.5	2.6	5.5	7.0
Potamogeton pusillus	1.2	2.6	5.0	2.4	1.2			6.0			9.0
Potamogeton richardsonii	1.5	4.1	6.0	2.8	1.1	3.7		5.0	1.6		
Potamogeton robbinsii	1.8	4.5	4.8	2.7	1.0		6.5	6.0	4.3		10.0
Potamogeton vaseyi	1.2	1.8	1.8						2.3		
Potamogeton zosteriformis	1.5	3.9	6.0	2.7	1.4	5.7			4.7	6.8	5.0
Ranunculus longirostris	0.9	2.0	2.0	1.2	0.9				2.4		5.0
Ranunculus reptans	1.8	3.3	3.3					0.3			
Sagittaria graminea	0.6	1.8	1.8					4.0			3.0
Sparganium angustifolium	0.6	1.5	1.5					0.3			
Utricularia vulgaris	1.2	2.4	2.6			0.9			1.7		
Vallisneria americana	1.2	3.2	5.0	2.2	1.1	5.3	3.5	4.5	2.4		7.0
Zanichellia palustris	0.9	3.6	5.1						1.6		

*1, Denniston 1921; 2, Lillie 1986; 3, Wilson 1941; 4, Lind 1976; 5, Schmid 1965; 6, Sheldon and Boylen 1977.

Table 7. Correlation coefficients of depth order predictors

	Mendota	*Devil's*	*Trout*	*Minn.*	*Long*	*George*	*Median correlation*
Median	0.71	0.73	0.35	0.63	0.40	0.43	0.53
Trimmed maximum	0.71	0.61	0.50	0.46	0.35	0.37	0.48
Maximum	0.56	0.22	0.64	0.20	0.10	0.52	0.37
Median maximum	0.75	0.72	0.73	0.47	0.36	0.50	0.61
Median maximum/secchi	0.88	0.53	0.79	0.58	0.42	0.08	0.55
Average correlation	0.72	0.56	0.60	0.47	0.33	0.38	

Table 8. Distribution of vegetated quadrats by depth-substrate type

	Depth				
	1	*2*	*3*	*4*	*Total*
Substrate					
1	917 10.9%	1111 13.2%	439 5.2%	224 2.7%	2691 32.0%
2	1362 16.2%	2034 24.2%	1400 16.6%	932 11.0%	5278 68.0%
Total	2279 27.1%	3145 37.4%	1839 21.8%	1156 13.7%	8419 100.0%

varied significantly in the interaction between depth and substrate (Fig. 6). Plants commonly displayed significant density differences across depth on one substrate but not the other. This is the pattern displayed by *Ceratophyllum demersum, Heteranthera dubia, Myriophyllum verticillatum, Nymphaea odorata,* and *Vallisneria americana.* The first two species showed no significant density difference with depth on hard bottom; the other three species showed no significant density difference with depth on soft bottom.

Another common pattern is increasing density with depth on soft substrates and decreasing density with depth on hard substrates. *Potamogeton berchtoldii, P. gramineus,* and *P. richardsonii* displayed some variation of this response. *P. robbinsii* was the only species that showed an increased density with depth on both substrates.

Discussion

The decreasing number of taxa found with increasing depth confirmed results found by Lind (1976) and Sheldon and Boylen (1977). Most deep-water species also occur in shallow water, and species distributions are skewed toward shallow water. Lind (1976) nicely summarizes this relationship by stating, "Many species are restricted to shallow water while others are broadly tolerant of water depth variation."

Since hard substrates appear less suitable for plant growth (Barko, Adams, and Clesceri 1986), it is surprising that taxa richness is not influenced more by substrate type. Where species density is influenced by substrate, higher densities are found on soft substrates. This is especially true in deep water. The shallow-water, hard-bottom communities are probably most dissimilar to other areas because they contain higher frequencies of emergent and rosette species. Emergent species are not found in deep water, and rosette species are found less frequently in deep water and in shallow, soft-sediment areas.

The 1.2-to-7.8-m range of maximum plant growth depths for lakes in this study is similar to that reported by Hutchinson (1975) and

Table 9. Substrate-depth relationships

Species								
*Substrate-depth preference**	*Hard bottom*				*Soft bottom*			
	1	*2*	*3*	*4*	*1*	*2*	*3*	*4*
	Soft-bottom, shallow-depth species							
Zizania aquatica	− −	− − −	− −	− −	+ + +	+	− − −	− − −
Potamogeton crispus	−	− −	+	−	+ + +	+	− −	− −
Potamogeton pusillus	− − −	− − −	− − −	− − −	+ + +	+ + +	− − −	− − −
Utricularia gibba	− − −	− − −	− − −	− −	+ + +	+ + +	− − −	− − −
Utricularia geminiscapa	− − −	− − −	− − −	− −	+ + +	+ + +	− − −	− − −
Utricularia vulgaris	− − −	− − −	− − −	− −	+ + +	+ + +	− −	− − −
Nymphaea tuberosa	−	− − −	− − −	− − −	+ + +	+ + +	− − −	− − −
Nuphar variegatum	−	− − −	− − −	− − −	+ + +	+ + +	− − −	− − −
Potamogeton diversifolius	− −	− − −	− −	− −	+ + +	+ + +	− −	− − −
Utricularia intermedia	− −	− − −	− −	− −	+ + +	+ + +	− − −	− − −
Megalodanta beckii	−	+	−	− − −	+ + +	+ + +	− − −	− − −
	Soft-bottom, shallow- to mid-depth species							
Myriophyllum farwellii	− − −	− − −	− −	− −	+ + +	+ + +	+	−
Najas marina	− − −	− − −	− −	− −	+ +	+ + +	+ +	− − −
Potamogeton zosteriformis	− − −	− −	−	− −	+ +	+ + +	+ + +	− − −
Elodea canadensis	− − −	− − −	−	−	+ +	+ + +	+ + +	−
Nuphar advena	− − −	− − −	−	− −	−	+ + +	− −	− − −
Potamogeton amplifolius	− − −	−	− −	− −	−	+ + +	− −	− − −
	Soft-bottom, mid- to deep-depth species							
Potamogeton praelongus	− − −	− − −	− − −	− − −	+	+ + +	+ + +	−
Potamogeton foliosus	−	− − −	− − −	− − −	+ + +	− −	+ + +	+
Myriophyllum exalbescens	− − −	− − −	− −	− − −	− − −	+ + +	+ + +	− −
Eleocharis robbinsii	−	− −	− −	− −	− − −	+ + +	+ +	−
Ceratophyllum demersum	− − −	− − −	− −	− − −	−	+ + +	+ + +	+ + +
	Mid- to deep-depth species							
Myriophyllum spicatum	− − −	− − −	+ + +	+ + +	− −	+ + +	−	− − −
Nitella spp.	− − −	− − −	+ +	+ +	− −	+	+ +	+ + +
Potamogeton robbinsii	− − −	− −	+ + +	+ + +	− −	+ + +	− −	+ + +
Potamogeton richardsonii	−	+ + +	+ +	+	− − −	+ +	− −	− −
	Shallow-depth species							
Myriophyllum heterophyllum	− − −	+ + +	−	− −	+	−	− − −	− − −
Myriophyllum verticillatum	+	− −	+ +	− −	+ + +	+ + +	− − −	− − −
Polygonum amphibium	+	− − −	− − −	− −	+ + +	− −	− − −	− − −
Nymphaea odorata	+ +	− −	− − −	− − −	+ + +	+ + +	− − −	− − −
Pontederia cordata	+ +	−	− − −	− −	+ + +	+ +	− − −	− − −
Potamogeton epihydrus	+ +	− − −	− −	−	+ +	+ + +	− −	− −
Potamogeton pectinatus	+ +	−	− − −	− − −	+ + +	+	+	− − −
Brasenia schreberi	+ + +	− − −	− − −	− − −	+ + +	+ + +	− − −	− − −
Potamogeton vaginatus	+ + +	− − −	− − −	− −	+ + +	− − −	− − −	− − −
Typha latifolia	+ + +	− − −	− − −	− −	+ + +	− − −	− − −	− − −
Dulichium arundinaceum	+ + +	− − −	− −	− −	+ + +	− − −	− − −	− − −
Potamogeton illinoensis	+ + +	−	− − −	− − −	+ + +	+ +	− − −	− − −
Potamogeton natans	+ + +	−	− − −	− − −	+ + +	+ +	− − −	− − −
Heteranthera dubia	+ + +	−	− − −	− − −	+ + +	+	− − −	− −
Chara spp.	+ + +	+	− − −	− − −	+ + +	− −	− − −	− − −
Potamogeton nodosus	+ + +	+	− −	− −	−	+ +	− − −	− −
Scirpus validus	+ + +	+ + +	− − −	− − −	+ + +	− − −	− − −	− − −

Continued on next page

Table 9—*Continued*

Species								
*Substrate-depth preference**	*Hard bottom*				*Soft bottom*			
	1	*2*	*3*	*4*	*1*	*2*	*3*	*4*
	Hard-bottom, shallow- to mid-depth species							
Potamogeton strictifolius	+ + +	+	− −	− −	− −	−	− − −	− − −
Eleocharis acicularis	+ + +	+	+	− −	−	− − −	−	−
Eriocaulon septangulare	+ + +	+ +	+	− −	−	−	− − −	− − −
Najas flexilis	+ + +	+ + +	− −	− − −	− −	+	− − −	− − −
	Hard-bottom species							
Vallisneria americana	+ + +	+ + +	+ + +	−	− − −	−	− − −	− − −
Potamogeton gramineus	+ + +	+ + +	+	+ +	− −	− −	− − −	− − −
Isoetes macrospora	+	+ + +	+ + +	+	− − −	− − −	− −	− −
Potamogeton berchtoldii	+	+ + +	+ + +	+ + +	− − −	−	− −	− −

Substrate and depth preference	*Bottom*		*Depth*			
	Hard	*Soft*	*1*	*2*	*3*	*4*
Sagittaria latifolia	Nonsig		+ + +	− − −	− −	− − −
Sparganium eurycarpum	Nonsig		+ + +	− − −	− − −	− −
Scirpus americanus	Nonsig		+ + +	+	− − −	− − −
Ranunculus longirostris	Nonsig		+ + +	+	− −	− −
Isoetes echinospora	Nonsig		+	+ +	− −	− − −
Potamogeton filiformes	Nonsig		− −	−	+ + +	−
Sparganium chlorocarpum	− − −	+ +	+ + +	+	− − −	− −
Ceratophyllum echinatum	− − −	+ + +	+ + +	+	− −	− −
Sagittaria rigida	− −	+ +	+ + +	−	− −	− −
Zanichellia palustris	+ + +	− − −	+ + +	− −	−	−
Myriophyllum tenellum	+ + +	− − −	+ +	+ +	− − −	− − −

Substrate preference	*Hard*	*Soft*
Ranunculus trichophyllus	Nonsig	
Sagittaria graminea	Nonsig	
Potamogeton obtusifolius	− −	+ +
Ranunculus reptans	+ + +	− − −
Lobelia dortmanna	+ + +	− − −
Potamogeton oakesianus	+ + +	− − −
Eleocharis palustris	+ + +	− − −

* + −, + + − −, + + + − − − represents weak, moderate, or strong association. Nonsig = nonsignificant association using chi-square test ($p < .05$).

broader than the 1.0-to-4.5-m range reported by Lind (1976) for eutrophic lakes in southeastern Minnesota. They are more shallow than the 12-m maximum depth for Lake George, New York (Sheldon and Boylen 1977), the 11-m depth for Long Lake, Minnesota (Schmid 1965), or the 9-m depth of Devil's Lake, Wisconsin (Lillie 1986). They are considerably more shallow than the 18-m maximum depth for *Utricularia geminiscapa* (Singer, Roberts, and Boylen 1983) in Silver Lake, New York, the 20-m maximum depth for bryophytes in Crystal Lake, Wisconsin (Fassett 1930), or the approximately 150-m maximum depth for charophytes and bryophytes in Lake Tahoe, California (Frantz and Cordone 1967).

This study supports the findings of Hutch-

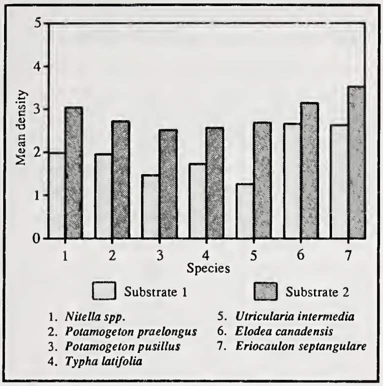

Figure 4. *Mean density of species by substrate*

inson (1975), Dunst (1982), Chambers and Kalf (1985), and Canfield et al. (1985) that there is a significant regression between secchi disk and maximum depth of plant growth. The regression line is not significantly different from one based on Hutchinson's data and one reported by Chambers and Kalf (1985). Not enough statistical information is provided by Canfield et al. (1985) to compare regressions. The regression calculated in this study is significantly different from Dunst's regression (1982). His equation predicts deeper plant growth. This is surprising because the Dunst regression is based on data from 51 lakes in southeastern Wisconsin (Modlin 1970; Belonger 1969).

A possible explanation for the difference is the strong presence of charophytes or *Najas flexilis* in the lakes used by Dunst. This study shows that *Chara* spp. and *Najas flexilis* had the deepest maximum growth depths and *Nitella* spp. had the greatest median and 75% quartile depths. However, a regression equation for lakes where charophytes occurred in the deepest quadrat was found to be significantly different from and would not

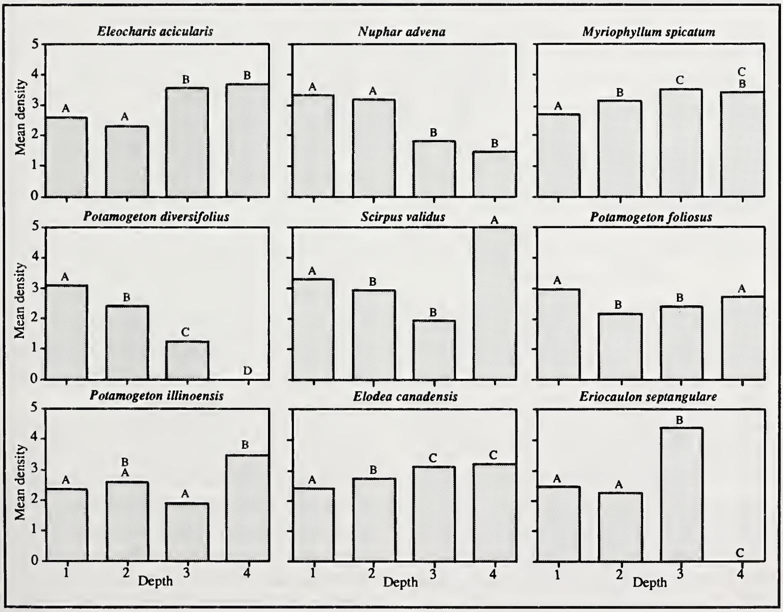

Figure 5. *Mean density of species by depth class*

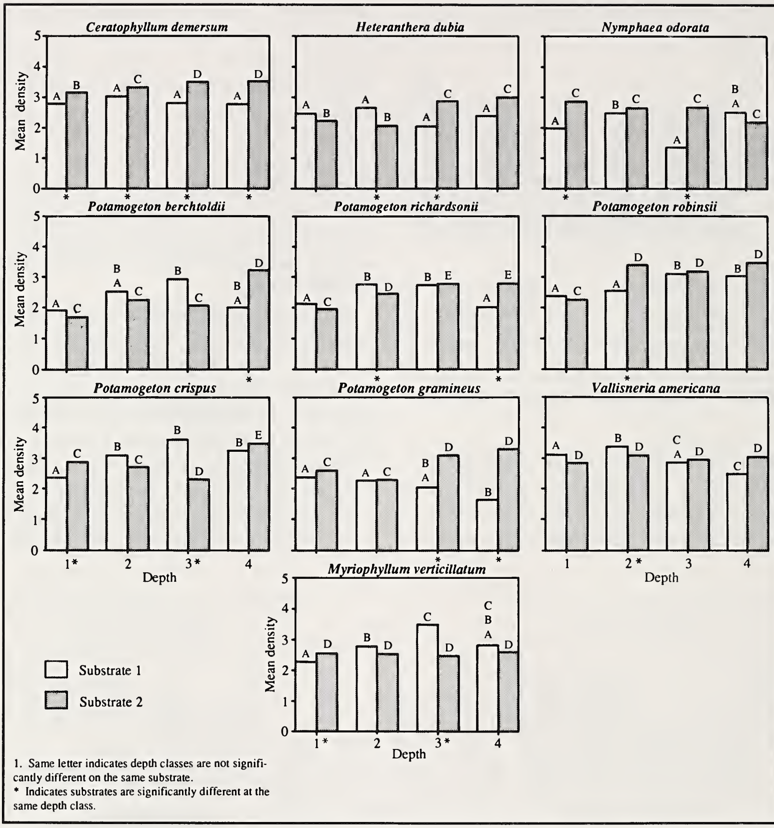

Figure 6. *Mean density of species by substrate type and depth class*

predict plant growth as deep as Dunst's regression.

Decreases in maximum depth of plant growth with increased turbidity have been previously reported (Vander Zouwen 1982; Hutchinson 1975; Spence 1982). The lakes in this study with the shallowest secchi reading and shallow plant growth were strongly influenced by carp and algae (Fig. 2). Their influence appears to be turbidity related. All lakes with carp problems had maximum plant growth depths below the regression line. All lakes but one with heavy algae blooms had maximum plant growth depths above the regression line. This may provide insights into the overall impact these two biotic factors have on plant growth.

Similar to the findings of Davis and Brinson (1980), a linear relationship was found between secchi disk reading and maximum plant growth for some submerged species. Theories that ascribe the maximum depth of plant growth to a single factor are deficient. Actual limitation may be brought about by a combination of factors (Singer, Roberts, and Boylen 1983). Therefore, it is not surprising that maximum depth growth for many submerged species was not correlated with secchi reading. *Zizania aquatica,* the only emergent species significantly correlated to secchi reading, is an annual species that grows from seed each year. Light penetration could influence its growth. It is also a species that is highly susceptible to water turbulence at a critical period in its life cycle. Clear water could be an indication of quiet water.

This study found no correlation between maximum depth/secchi ratio, which Davis and Brinson (1980) call a turbidity tolerance index, and the association with turbid water (Table 3). The results of the chi-square habitat preference test and the analysis of the variance density test need not be complementary. If they are complementary, habitat preference is reflected in species density. This could mean that depth and/or substrate has a strong influence on species density. Species that show a similarity between tests are *Nitella spp., Potamogeton praelongus, P. pusillus, Utricularia intermedia, Myriophyllum spicatum, P. diversifolius, P. foliosus, Elodea canadensis, Ceratophyllum demersum, Myriophyllum verticillatum, P. richardsonii, P. robbinsii,* and *Vallisneria americana.*

Lack of similarity is more difficult to explain. One possibility is that a species was found only in preferred habitats, so densities were similar wherever it was found. A second, and probably more likely, possibility is that something that was not measured in this study limits species distribution or density. One easily overlooked possibility is interspecific competition, which could limit a species in a lake even though the habitat is suitable for its growth.

Summary

This study reinforces information from other studies that taxa numbers decrease with increasing depth; that many species are restricted to shallow water, while others are broadly tolerant of water depth variation; that the depth distribution of many species is skewed towards shallow water; that the maximum growth depth for many species is highly variable; that there is a significant linear relationship between water clarity and maximum depth of plant growth; and that water clarity, water depth, turbidity tolerance, and substrate preference influence species association. It was an unexpected finding that taxa richness is not different between substrate type. This study differs from other studies because it provides descriptions of depth distribution and substrate and turbidity preferences for a variety of Wisconsin lake plants. The information should be very useful for managing Wisconsin's lake plant resources and for doing further ecophysiological studies on individual species.

Acknowledgments

Murray Clayton, Peter Crump, and Emmanuel Maurice of the University of Wisconsin–Madison, College of Agriculture and Life Sciences, provided statistical and computing assistance. Sandy Engel and Richard Lillie of the Wisconsin Department of Natural Resources and Michael Adams of the University of Wisconsin–Madison, Department of Botany, are gratefully acknowledged for critically reviewing the manuscript. The Wisconsin Department of Natural Resources provided lake vegetation and water chemistry data. The Institute for Environmental Studies, University of Wisconsin–Madison, provided partial funding for data entry and analysis.

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From Wisconsin Poets

Three years ago when Carl Haywood asked me to collect and edit a selection of poetry for each issue of *Transactions,* I leapt at the chance to share the joy and insight that I find in poetry with members of the Academy and other readers of the journal. I have been nothing but astounded and immensely pleased at the level of support I have had for this project from the Academy Board, the staff of *Transactions,* and the poets themselves, who have given unstintingly of their work and their time. This ground swell of interest and support found perhaps its epitome with the recent publication of the special issue of *Transactions* entitled *Wisconsin Poetry,* an anthology of three hundred poems by sixty-five Wisconsin poets, which represents the largest and most comprehensive collection of Wisconsin poetry published in nearly fifty years.

I am especially thankful for the interest and support expressed to me by members of the Academy I have met at readings throughout the state held in conjunction with publication of that special issue. It is a direct result of that interest, and the efforts of Carl Haywood, that there will be an ongoing session devoted to Wisconsin poetry at the yearly meeting of the Academy, as well as sponsorship of the publication of individual collections of poetry by Wisconsin poets.

The editorship of *Transactions* is changing, along with the site of its publication. I am sure that poetry will continue to be a part of *Transactions* as well as a part of the mission and service of the Wisconsin Academy of Sciences, Arts, and Letters.

Bruce Taylor

About the Poets

Art Lyons *manages tutoring programs at UW–Eau Claire. He has published a text-workbook titled* Writing for Workplace Success *(Paradigm 1991). His poems have appeared in* Wisconsin Poetry, Slant, Confluence, Upriver 4, Wisconsin Dialogue, *and* Black Buzzard Review.

Jeri McCormick, *of Madison, teaches creative writing at senior centers and elderhostels and works as an editor in the State Department of Administration. She has published* The Sun Rides in Your Ribcage, *a chapbook of poems, and co-authored* Writers Have No Age, *a text for older adults. Her poems have appeared in the* Wisconsin Academy Review, *the* Wisconsin Poets' Calendar, Poet Lore, Isthmus, *and* Wisconsin Poetry.

Kyoko Mori *received her doctorate from UW–Milwaukee and teaches English at St. Norbert College. She has published a book of short fiction,* The Ritual in Roses and Silk. *Her poems have appeared in the* South Florida Poetry Review, The Forbidden Stitch, *the* Denver Quarterly, *and the* Madison Review.

Thomas R. Smith *is a poet and essayist living in Minneapolis. He has one book of poems,* Keeping the Star, *from New Rivers Press and a second,* Horse of Earth, *nearly completed. He is an Associate Editor for Ally Press, where he is editing a* festschrift *for Robert Bly.*

Jean Tobin *lives in Black River, along the shore of Lake Michigan. She is Professor of English at the University of Wisconsin Center–Sheboygan.*

Marilyn Taylor *recently earned her doctorate at UW–Milwaukee, where she received the 1991 Academy of American Poets Prize. Her work has appeared in* Poetry, Wisconsin Review, *and* Poetry Northwest. *Her first collection,* The Accident of Light, *was published by Thorntree.*

Laurence Giles *is a Madison physician who says, "Medicine is my life, but poetry is one of my more positive obsessions." He has published a slender volume entitled* Goat Cottage Dream Poems, *and his poems have appeared in* Abraxas *and* The Literary Preview. *He is also a licensed private pilot and a scuba diver.*

Joan Rohr Myers, *Director of Human Relations and Affirmative Action at UW–Eau Claire, has received the Catholic Press Association award for poetry as well as the Wisconsin Regional Writers' Association Jade Ring and Bard's Chair awards for her poems. Her poetry has appeared in over a hundred journals and anthologies.*

Bruce Taylor, *the Poetry Editor of* Transactions, *is Professor of English at UW–Eau Claire. He has published two chapbooks,* Idle Trade: Early Poems *(Wolfsong Press) and* The Darling Poems *(Red Weather Press). His poems have appeared in* The Nation, New York Quarterly, *and the* New Orleans Review.

Ralph Schneider *is Professor of English at UW–Eau Claire. A country dweller, he finds much of his poetic material in the Wisconsin natural environment. He spent the spring semester of 1991 on a poetry-writing sabbatical, and "Breakfast" was one of the poems that developed during that regenerative period.*

Child to Father (later)

That all truths have their time, you never knew.
In your white ranch house, your Buick four-door,
you never knew the lies time chose for you.

You loved the timely truth of screw or be screwed;
in your time, a fuller garage bought a higher score.
That all truths have their time, you never knew,

so you hated every nigger, every spic and jew,
but loved white men whose cars out-buicked yours.
You never knew the lies time chose for you,

and wily time chose lies for me too—
truths against your lies—but let me ignore
that all truths have their time. You never knew,

I'm sure, that my spiteful words with every new
disgust meant I doubted you, doubted myself more;
you never knew the lies time chose for you.

Out of time now, your body tells the truth:
We live in time and time decides what for.
That all truths have their time, you never knew.
You never knew the lies time chose for you.

—Art Lyons

Looking at Skulls

The first skull I saw
   gleamed from a stereoscope
in Grandma's front room.

The scene was a Mideast catacomb,
   Jerusalem, perhaps, or Babylon;
Grandma favored the Bible lands.

In three scoped dimensions
   two shadowy orbs leered at me
from a knob of chalky bone.

I scrambled for the next card—
   benign camels crossing the desert
or the somber stillness of Golgotha,

anything to squelch that deep vacancy.

Now, all these years later,
   I've met Hamlet and others
who do not turn from skulls;

I've lost Grandma
   whose hidden remains still comfort,
whose skull is surely beautiful.

And I've made peace
   with my own scaffolding—
femur, tibia, clavicle—

gliding me through this life
   like a fine ghost ship,
at sea with lofty captain

intent on solid grace,
   yet content with the usual gear:
a nose, an ear or two, eyes,
   the accoutrements of face.

—Jeri McCormick

Vehicles of Change

i.

Our last week together, I borrow his
car to move my boxes. Daily, I cross
the bridge with books, dishes. The brake shoes are

slipping. By Wednesday, every stop grinds
to the roar of airplanes descending,
urgent upon the car roof. I am crash-landing

through lost time. I maneuver my craft
to lose it. I want to walk away from its
burning in some farmer's field as the camera

crew rushes to record the miracle
of my get-away. In the ditches, cow
parsnips rotate purple shafts; rank white

crowns rise above the odor of burning
metal. Black smoke trails my path and becomes
a pack of cats skulking in my shadow.

ii.

The First of June, my friend's
driving the panel van, the radio's
stuck on a country station, and
I'm in the passenger's seat

with furniture rattling in
back. The world shrinks up and
jumps into the side mirrors:
the lanes are parallel and skewed

both like corridors in
perspective drawings. You could
wrap them around the earth's
core without their crossing. Never

the twain shall meet. I tower
over traffic; below, sunlight
glints off car tops like
pebbles I could flick over

water. Across the bridge, the wind
takes the words from my mouth and
erases.

iii.

Unpacking, I re-enact the Apartment
Within I've carried from place to place like
an absurd parody of the Soul, the God

imprinted in my heart. Its universals
include cups eye-level on a kitchen
shelf, scissors in the left-hand utility

drawer, the vacuum cleaner plopped among
coats conspicuous as a widower
in a grocery line. In this enactment,

white walls scrape easily to reveal
a fuzzy grey almost of cardboard. I
welcome this lightness—no more solid

doors, dark cabinets. I perform my life
inside a pop-up book, every moving part
collapsible, seamed to the center.

iv.

The next day in his absence, I
clean the house, wipe away the traces—
the dust of shed skin, an ear-ring
long lost, thrums from scarves woven

for gifts, and the inevitable
hair—thrums of daily life
unwoven. The house unravels
into a place where I've paid

rent. Already, its hallways
darken and merge into
others, each room floats up
disjointed in my mind. My

steps no longer connect them.

v.

In my dream that night, a giraffe
wades leisurely in the wake
of a barge across shallow
waters. The big cats, one of each,

feed from my hands while I wait
in a windowed cubicle for
a ride in some vehicle I
cannot begin to imagine. Far

off, planes dive into the sea
to rise as dolphins, whales
breach and send up a horizon-
ful of sheep clouds, and the world

spins back into flickers of light
struggling to become the animals.

—*Kyoko Mori*

End of Summer

1.

September rain slants into the heavy alfalfa. Water pours from the square and brutish mouth of the spout and runs away into the boyish grass. Circles of rust at the bottom of the bucket are thoughts, growing inward, of a mind simplified by solitude, monotony of rain. . .

2.

Things done or not done for a long time lodge in odors, in old clothes furrowed with brooding, in soot of bygone cooking black on the widower's stove, in the small varnished cross nailed to a bedroom door, and in the dirty rose curtain on tarnished brass rings, all left as they were when the old man died.

3.

Did he paint near the end so as not to have to watch night shambling toward the barns? We find on the obverse of a cornfield scene with pheasants a far older landscape of lacquered trees and rocks. Implacably symmetrical, halved precisely by the glass knife of a falls, the left side is green, the right side ochre, this picture turned toward the wall. . .

—Thomas R. Smith

A Readiness to Weep

Five years later, we have returned
to the lake where we spent our
honeymoon, two people who knew
even less about marriage than we do.
I had refused for years, then
gave in because I feared some damage
to your happiness with me.
"I did it," I told you,
"but I don't know what it means,"

and wept. Today, a day clear
as that one we drove down the dirt
road to the cabin after the wedding,
I squat in these marshy woods
that have always been, in my mind, October
and give again my gift from
five years ago, a readiness to weep.

I sit quietly in the still sunlight
with you and feel the years, and
do not feel them. I let the peach-
flushed leaf I saved fall from my hand—
Yes, I want time to stop for us,
doesn't everyone?—No, I let it go.

The fallen branch we sat on breaks
suddenly but lets us down unharmed—
the ground isn't in the least sentimental.
We laugh together, then the tears again.
I soak my knees leaning to cup
in hands chill water from the lake
to splash over my burning eyes.

When I look up, every man
and woman ever married look with me
out across the autumn lake
toward the gold pavilions of uncertainty.

—*Thomas R. Smith*

Poems from Paintings

Dream of MOMA

(Rousseau's *Yadwiga's Dream,* 1910)

A confounded round-eyed lion looks straight out
the canvas. She, poised calmly, lying nude
upon a jungle divan hears intrude
a black man garbed in rainbow loincloth, doubt-
lessly hears melodies to ravish. His
seductive clarinet beguiles the moon,
now rising round and ghostly, begs full blooms
of heavy-headed lotus, blue and reddish
pink, entreats gold-winged, long birds to listen
to his song on silent canvas. Toward
her lifting high his trunk, an elephant
is hidden in the background—leaves that glisten
brightly, edged in yellow, sharp as swords,
precisely painted from Jardin des Plantes.

—*Jean Tobin*

Miss Martin at Four O'Clock

I am LaShanda's teacher
and to LaShanda that is all
I am. Every day she waits
for this, the breakaway hour
when the windows of my eyes
start to blacken behind
the neat rows of paper cutouts
facing the street
and the wide broom of darkness
comes, pushing blood-red
dust along my corridors.

LaShanda thinks I sleep
in a wooden drawer, folded
on a bed of thumbtacks—my
left hand gripping a bone
of chalk that screams
by day, while my right
brandishes a scarlet
Eversharp, scattering
the swarm of butterflies
that will drift forever
in LaShanda's head.

—Marilyn Taylor

Tercets from the Train

Human dramas implode without trace.
—Marge Piercy

Gorgeous, they are gorgeous, these two women getting
on the train, one in lime green silk, black hair
a mile wide, the other slim as a whip, coiled

in red linen. Their two small boys, grinning,
have squirmed into facing seats, bubbling with spare
energy, the cuffs of their designer jeanlets rolled

at the ankles, their studded shirts glinting.
I overhear the women talking over what to wear
to some convention (should it be the gold

Armani or the St. Laurent?) while the boys are gazing
through the rain-spattered window, practicing their
locomotive lingo in shrill, five-year-old

voices, demanding information: are we going
faster than a plane, where is the engineer,
does this train have electricity or coal?

But the women's eyes are fierce, they are grumbling
over Lord & Taylor, which was once a store
to be reckoned with, although the one with wild

hair points out that even Bloomingdale's is growing
unmistakably more K-Martish than it was before.
Don't you ever interrupt me, child,

she hisses to the boy who wonders why the train is grinding
so slowly through the towns, and where
the bathroom is and what the ticket-man is called

until she bends over him, glaring
from beneath her shadowed eyes, a crimson flare
on either cheek. *You're interrupting me,* she growls.

Now you'll be sorry. His mouth is gaping
  as the flat of her pale hand splits the air,
    annihilating two long rows of smiles.

I warned you, didn't I, darling?
  Now don't you dare cry. Don't you dare.
    Up and down the aisle, the silence howls.

—*Marilyn Taylor*

Are There Sounds You Shouldn't Hear?
(A Poem for William Stafford)

Are there sounds you shouldn't hear?

No, not trumpets of god
    the walls of cities falling
        the lamentations of Jeremiah
            the doors closing at Auschwitz

Nor whispers behind my back
    nor drill sergeants' words
        the slavers' whips
            newborn whimpers for food in a starved world

The end of history, the voice of Zeus in shrieking wind
    the convulsive roar of the Minoan volcano 35 centuries into time
        the Aegean tidal wave that pummels ships to death
            the screaming horses that trample my children

The conductor dropping his baton
    the crack of the firing squad
        the drums of Autumn
            birds and no singing, like Beethoven and the *Song of Joy*

The trap slam of King Henry's scaffold
    the avalanche in the High Himalayas
        the teeth of the shark that grind my bones
            the fall of the dagger in the Aztec Temple

The crash of trees into fire and prairie
    the engine that sputters out over oceans
        the ice freezing in great cracks round Arctic ships
            the man who cries with his tongue cut out

The gnawing of rats in dark dungeons
    the forever farewell from voices of love
        the sound boom of the comet that streaks to my feet
            the whistling train over the dynamited trestle

The singer breaking glass and ear drums with notes gone cracked
    the frenzied still of the oscilloscope beat in the Intensive Care Unit
        the suicide striking the pavement
            Russian Roulette and no click from the pistol

The rafters smashing in the mine shaft, the end of Welsh and Appalachian songs
    the snort of the Cape Buffalo in my frozen face
        the flutter of Robert Scott's tent in the South Polar wind
            the screams of the *castrati* under the knife

The prayers of every prisoner and captured woman
    the cries of "Bring out your dead," in plague-filled Warsaw, and Angkor-wat
        the birth of babies, and no breath
            the planes, the bombs ripping houses into falling night and screaming rain

No, none, not one
we shall not listen, heed, or obey
but

there is, yes, finally, one sound
I should not hear:
the last sound, the last

vaporized into a shadow on the wall
we shall see that sound as light before we hear it
the last sound,   last.

—*Laurence T. Giles*

December Lights

Beyond the mall's warrens of promise
we drive to snow-stilled streets
where trees dance in small lights.

Before every bright fresco, I wonder
how things create lives—
how houses hand out habits
like how much to drink
and when to wake up,
how kitchens coax hearts
to always want more.

If the owner's away
from the fading grey stucco
and we pass out of our bodies
and through the glass
to a past accrued
on porcelain plates,
would we learn
what a body softens to
when love is traced
on monogrammed sheets
and hands are shaped
by the garden gate?

Or are we bound
in the warm current
of this car
to watch tints of the known
expand
into the opening arms
of the galaxy?

—Joan Rohr Myers

Flight

(from the notebooks of Leonardo da Vinci)

See tomorrow to all these matters and the copies. Leave them in Florence so that if you lose those you take with you, the invention will not be lost.

[birds]

The science of birds
is the science of the wind
which is the science of water.
If you would know how things fly,
you must first study
what floats and what falls.

[of man]

The life of birds conforms
better to the needs of flight
than the will of man,
especially in the almost
imperceptible movements which
preserve an equilibrium.

[with drawings]

spring of horn
of steel fastened upon wood,
of willow encased in reed—

Let A be the first movement.
Undo one and remove.
Double canes—soaped—
of rag, of skin, of flying fish.

spring with lock,
wire that holds the spring,
spring of wing—

Tomorrow morning
the second of January
I'll make the thong and the attempt.

[in which the figure of the man is seen
exerting force with arms and legs]

If you stand up on the roof at the side of the tower
the men at work on the cupola will not see you.

The machine should be tried over a lake
and you should carry a large inflated wineskin so
if you fall you will not drown.

Let the machine be 12 braccia high
and let the span of the wings
be 40 braccia
and the body from stem to prow
20 braccia
and the outside all covered
with cane and with cloth—

Ladder for ascending and descending.

[the atmosphere]

The air moves like a river
and carries the clouds with it
just as moving water carries
all things that float upon it.

Surface is the name
of that division which the body
makes with the bodies it encloses.

It does not partake
of the body which surrounds it,
or of the body which it surrounds.

Surface has a name
but not a substance
for that which has
substance has place.

[words crossed out in manuscript]

Just as a stone thrown
into water becomes the center
and the cause of various circles,
so a motion made in the air
spreads itself out in circles.

So every body in the luminous air
spreads itself out in circles
and fills the sky with
infinite images of itself.

—*Bruce Taylor*

Breakfast

After feet find the dark floor
after the pulling-on of socks and shirt and pants
after building up the fire with oak and breath
and putting the kettle on

there's the sizzle of cold potatoes browning
as tomato's upstart bite jangles the mouth
and chunks of yesterday's ham color the potatoes' hiss
and a brighteyed egg tops it off
with a sprinkle of salt for savor.

Then coffee in a chair
while the red comes up behind the horizon
past the silhouettes of hill and branch
that turn to gray and then
to glowing brown detail:
bark and leaf and blade of grass.

The empty cup is the origin of philosophy
as is the end of this dawn
fallen to the dingy day incapable
of this gray illumination.

—Ralph Schneider

First Report of Natural Bridges in Eastern Wisconsin

Richard A. Paull

Abstract. *Although natural bridges are well-known features in the Driftless Area of Wisconsin and adjacent states, none of these delicate landforms is documented in the recently glaciated region of Wisconsin. This report describes natural bridges at two localities along the Silurian escarpment in eastern Wisconsin.*

A bridge 40 feet (12 m) high with a span of 14.5 feet (4.4 m) has developed in the Lower Silurian Mayville Dolomite at Fonferek Glen in Brown County, 4.3 miles (7 km) south of Green Bay. This feature was created in two stages. The first was differential undercutting of bedrock on the outside of a meander at a higher elevation than present-day Bower Creek during the waning stage of glaciation in late Wisconsinan time. Collapse of the inner part of the overhang along prominent joints in the Holocene completed the bridge.

Six bridges have developed at the contact between the Lower Silurian Mayville Dolomite and the overlying Middle Silurian Byron Dolomite at Oakfield Ledges in Fond du Lac County, 10.5 miles (17 km) east of Waupun. The bridges vary in dimensions from 15 feet (4.5 m) to 20 feet (6 m) high, 3.3 feet (1 m) to 15 feet (4.5 m) wide, and 4 feet (1.2 m) thick, with spans of 4 feet (1.2 m). These features formed by the opening of three solution-enlarged joints in the Mayville Dolomite by downslope movement at the escarpment after retreat of the Green Bay glacial lobe. The Byron Dolomite remained in place as the underlying Mayville moved outward. This created a roof of Byron Dolomite for these bridges. It is possible that the present-day bridges along each joint were once part of cave-like features.

Natural bridges are common in the Driftless Area of Wisconsin and parts of immediately adjacent states (Fig. 1). According to Martin (1932, 353), "All of these features . . . are of the sort that can exist only in the Driftless Area. They are relatively fragile and would certainly have been eroded away or buried in glacial deposits." The one exception known prior to this paper is a small natural bridge in Middle Ordovician dolomite at Krape Park, Freeport, Illinois (Paull and Paull, 1980, 85) (Fig. 1). The genesis of this bridge is similar to the developmental history for the one at Fonferek Glen described below.

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This report describes seven natural bridges developed in dolomite along the Silurian escarpment in the recently glaciated area of eastern Wisconsin. One of these bridges is in Fonferek Glen south of Green Bay, Brown County, Wisconsin (Fig. 1). I first observed this feature while studying Ordovician and Silurian rocks in this area in 1967. Donn P. Quigley of the Neville Public Museum, Green Bay (verbal communication 1988), had discovered this bridge earlier in the 1960s.

At least six natural bridges are present in, or adjacent to, the Wisconsin Department of Natural Resources Oakfield Ledges Scientific Area in southern Fond du Lac County (Fig. 1). A descriptive article about this scenic locality

Figure 1. Location map showing natural bridges in Wisconsin and adjacent parts of Iowa and Illinois. Most of these delicate landforms are within the Driftless Area (HN and LH, Hornets Nest and Luncheon Hall, Martin 1932; MC, Maquoketa Caves, Paull and Paull 1980; MVA, Mt. Vernon Arch, Martin 1932; NBSP, Natural Bridge State Park, Martin 1932; Paull and Paull 1977; RA and ER, Rockbridge Arch and Elephant Rock, Martin 1932; Paull and Paull, 1980; and RMA, Readstown Multiple Arch, Martin 1932), but several occur within the recently glaciated region (FG, Fonferek Glen Bridge; KP, Krape Park Bridge, Paull and Paull 1980; OL, Oakfield Ledges Bridges). The bridges in eastern Wisconsin (FG and OL) are described in this paper.

by Peter Toepfer (1979) suggested that natural bridges might be present here, and this proved to be correct.

When I started this project, I thought I knew what a natural bridge is. The deeper I have delved into the problem, the more uncertain I have become. The *Glossary of Geology* (Bates and Jackson 1980, 442) defines a natural bridge as an arch-like rock formation created by erosion that spans a drainage, or the remnant of the partial collapse of the roof of a cave. The water becomes muddier when the editors referenced above define an arch as a natural bridge resulting from erosion, or a landform similar to a natural bridge not formed by erosive agencies. Leading geomorphology textbooks fail to clarify the issue. One thing that all features called bridges and arches have in common is a relatively resistant uppermost lithologic unit that forms the span. It is also apparent that these delicate features are short-lived geologic landforms.

In this paper I define a natural bridge as a free-standing rock formation that allows human passage across a relatively narrow span. Such features could result from either erosion or selective gravity-induced movements or a combination of the two processes. Specifically excluded, however, are down-dropped blocks of rocks that result in "bridging" across openings (usually joints). Examples of this type of feature are Devil's Doorway at Devil's Lake State Park (Paull and Paull 1977, 127) and several rock fall "bridges" at Oakfield Ledges.

Fonferek Glen Natural Bridge

A single natural bridge occurs in the Lower Silurian Mayville Dolomite along Bower Creek in Fonferek Glen, about 800 feet (240 m) downstream from Fonferek Falls (Polish Falls in older literature) (Fig. 2 and 3). The glen is a narrow, deeply cut reentrant in the east-west trending Silurian escarpment. This locality is 1.15 miles (1.85 km) east of the crossroad community of Kolb along County Highway MM, and about 4.3 miles (7 km) south of Green Bay in Brown County (SW¼, SE¼, NE¼, NW¼, Sec. 34, T.23N.–R.21E., Bellevue 7.5′ quadrangle, 1954) (Fig. 2). The Fonferek natural bridge is 40 feet (12 m) high, 5 feet (1.5 m) wide, and 5 feet (1.5 m) thick. It spans 14.5 feet (4.4 m) at the top and opens to more than 40 feet (12 m) in the erosional alcove below (Fig. 4 and 5).

The genesis of the natural bridge at Fonferek Glen has a long geologic history. The

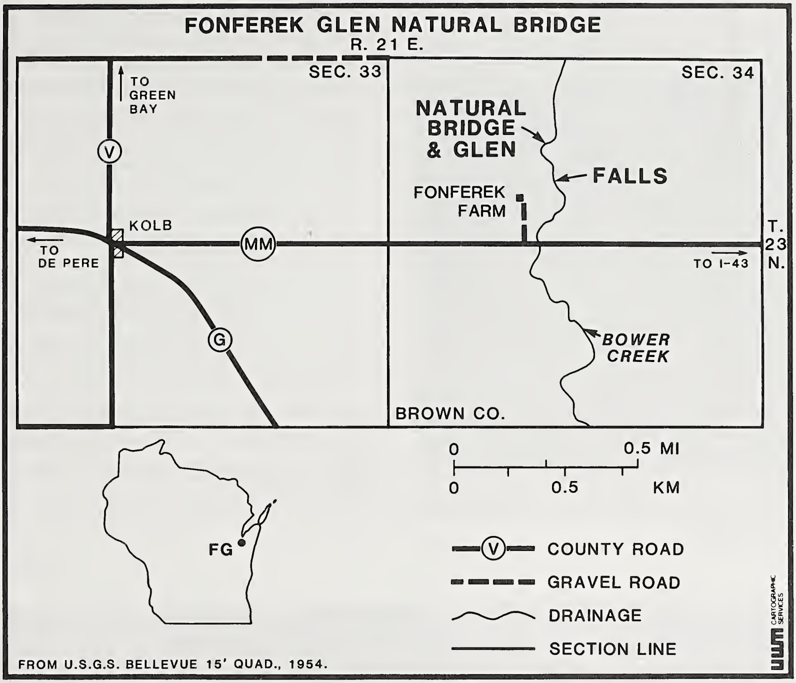

Figure 2. *Location map of Fonferek Glen Natural Bridge in Brown County, Wisconsin. Fonferek Falls, at the head of the glen, is a southerly reentrant cut by Bower Creek into the Silurian escarpment, which trends east-west across the northern part of the map area.*

Lower Silurian Mayville Dolomite at this locality consists of three distinctive lithologic units that are described in Figure 5. The upper and lower units are resistant dolomite, and the uppermost forms Fonferek Falls and the span of the natural bridge. The middle unit is a relatively nonresistant, chert-rich dolomite that weathers more readily than the overlying and underlying rock.

The Lower Silurian bedrock surface at Fonferek Glen was polished and striated by southerly moving glacial ice that deposited reddish till of the Glenmore Member of the Kewaunee Formation in late Wisconsinan (Greatlakean) time (Need 1985, 1). The gently rolling till plain in this area is locally overlain by deposits that accumulated in Glacial Lake Oshkosh, an impoundment that formed in the Green Bay lowland behind the northeasterly retreating ice dam.

Fonferek Glen developed when the late Wisconsinan ice retreated far enough to allow Glacial Lake Oshkosh to drain easterly into ancestral Lake Michigan. Rapidly falling lake levels allowed an earlier version of Bower Creek to downcut across the Silurian escarpment. At this time, precipitation rates were apparently high, and Bower Creek carried significant amounts of runoff. As erosion proceeded, the waterfall that initially was at the edge of the Silurian escarpment retreated upstream, leaving a narrow gorge behind.

When Bower Creek eroded downward into the chert-rich middle unit of the Lower

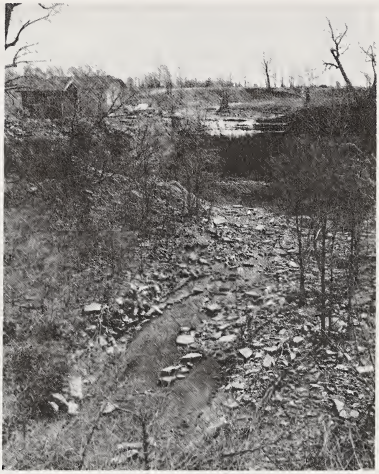

Figure 3. *Fonferek Falls plunges over Lower Silurian Mayville Dolomite at the head of Fonferek Glen.*

Silurian Mayville Dolomite, it carved two caves in this relatively erodible rock at the outside of meanders in the canyon below the waterfall (Fig. 6 and 7). At the upstream meander an eddy current developed, and a third cave formed (Fig. 6). As downcutting continued into the basal resistant unit of the Mayville, the bedrock valley narrowed.

Two sets of joints in the upper unit of the Mayville Dolomite facilitated frost wedging, and rock falls enlarged the eddy-formed cave to create a large alcove. In the middle 1950s two horses strayed onto the prominent overhang and broke through the roof to create the natural bridge (Norbert Fonferek, verbal communication 1988) (Fig. 8). Both horses were pulled free, and the opening was fenced off for safety reasons. Joint blocks continue to fall, and ultimately Fonferek Glen Natural Bridge will collapse.

Figure 4. *Fonferek Natural Bridge spans an alcove carved by fluvial erosion in the relatively nonresistant, chert-rich, middle unit of the Lower Silurian Mayville Dolomite. The span of this feature is formed from the resistant, upper unit of the Mayville Dolomite. The well-jointed nature of the roof rock is apparent in the photo.*

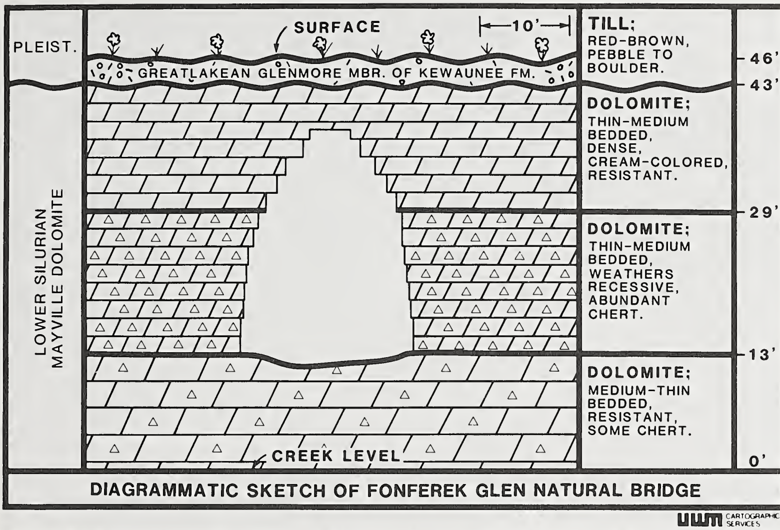

Figure 5. *A diagrammatic sketch of Fonferek Natural Bridge detailing the geology at this locality.*

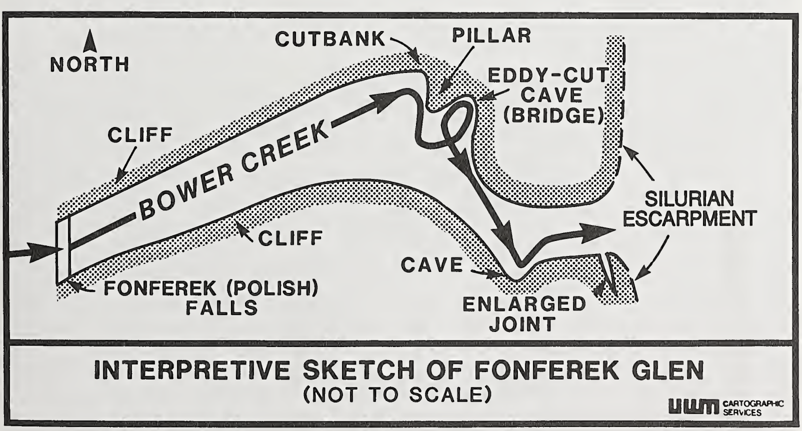

Figure 6. *A schematic sketch detailing the development of three caves in Fonferek Glen during high stream flow at an earlier erosional level of Bower Creek.*

Figure 7. *This cave was developed in the relatively nonresistant, chert-rich, middle unit of the Lower Silurian Mayville Dolomite at the outside of the second meander downstream from Fonferek Falls (Fig. 6). This feature is a precursor of the type of opening that developed into the Fonferek Glen Natural Bridge upstream from this locality. A well-developed, open joint is also visible to the left of the cave. Jointing facilitated the formation of the natural bridge in this area.*

Figure 8. *A downward view of the Fonferek Natural Bridge from the top of the Silurian escarpment.*

Oakfield Ledges Natural Bridges

Six natural bridges occur within three joints along the southwest-northeast trending Silurian escarpment in, and adjacent to, the Wisconsin Department of Natural Resources Oakfield Ledges Scientific Area. This locality is about 10.5 miles (17 km) east of Waupun in the W½, NW¼, SW¼, Sec. 27, T.14N.–R.16E., Fond du Lac County (Waupun 15′ quadrangle, 1955) (Fig. 9). The bridges range from 15 feet (4.5 m) to 20 feet (6 m) high, 3 feet (1 m) to 15 feet (4.5 m) wide, and 4 feet (1.2 m) thick, with spans of 4 feet (1.2 m). Other bridges may also be present along joints in the talus-mantled, westward-facing Silurian cliff face in this general area.

The Silurian escarpment at Oakfield Ledges consists of medium- to massive-bedded Lower Silurian Mayville Dolomite and the overlying thin- to medium-bedded, relatively resistant, Middle Silurian Byron Dolomite (Shrock 1939; Mikulic and Klussendorf 1983) (Fig. 10). These rocks dip gently eastward into the Michigan Basin.

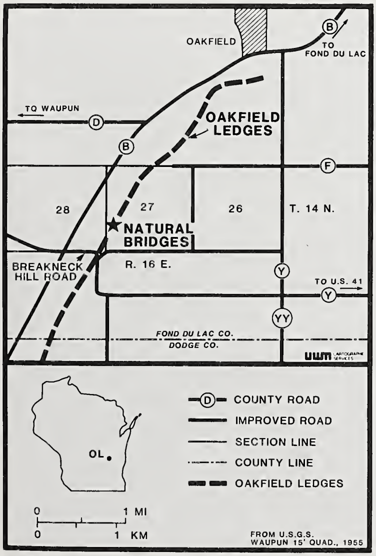

Figure 9. *Location map of Oakfield Ledges, part of the Silurian escarpment in Fond du Lac County, Wisconsin.*

Silurian bedrock in this region was polished and striated by the southerly moving Green Bay glacial lobe in late Wisconsinan time. The thin, reddish, bouldery till of the Horicon Formation was also deposited during this glaciation (Mickelson et al. 1984). This lobe, and previous ice advances, scoured the relatively nonresistant shale of the Upper Ordovician Brainard Formation of the Maquoketa Group to create the lowland region west of the Silurian escarpment now occupied by Green Bay, Lake Winnebago, and Horicon Marsh.

Upon retreat of glacial ice from the Green Bay lowland, the Silurian dolomite overlying the relatively soft shale of the Brainard Formation was unsupported. Rock falls from the cliff face and rotational downslope movement of Silurian rock along the Brainard surface were facilitated by solution-enlarged joints that generally parallel the cliff face (Fig. 11). This rotational type of slope failure along the Silurian escarpment in Brown County was previously detailed by Stieglitz (1980, 83).

The unique aspect of the downslope movement of jointed masses of Silurian rock at Oakfield Ledges is the differential separation along individual joints in the Mayville and Byron formations (Fig. 12). This allowed the Mayville to move along the unstable Brainard surface, while part of the Byron remained in place to bridge the gaps over the enlarging joints (Fig. 13). This created caves along three solution-enlarged joints. Selective collapse of the roof rock created a series of three bridges in one joint and two in another. A single bridge is present along the third joint.

The natural bridges at Oakfield Ledges are unusual features, but they meet the criteria previously defined for natural bridges. As downslope movement continues along these major joints within the Mayville Dolomite, the bridging roof rock of the Byron Dolomite will become unsupported. Collapse will follow, and the natural bridges at Oakfield Ledges, as well as at Fonferek Glen, will no longer enrich the Wisconsin landscape.

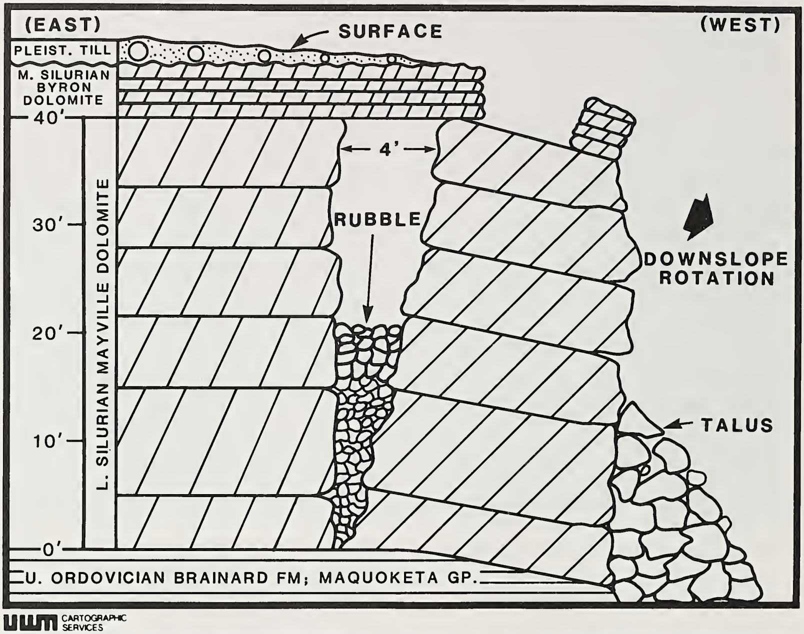

Figure 10. *A schematic sketch defining the geology of Oakfield Ledges and illustrating the formation of the natural bridges at this locality.*

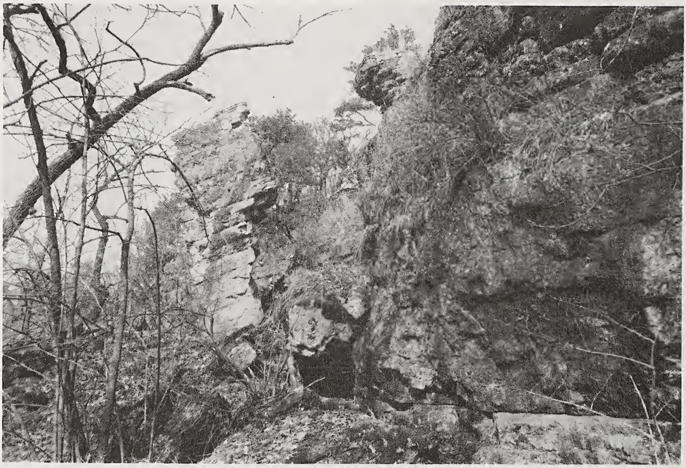

Figure 11. *View along a major joint essentially parallel to the Silurian escarpment at Oakfield Ledges shows the rotational downslope movement of a major mass of dolomite. The overhanging rock at the top of the rotated block is the Middle Silurian Byron Dolomite.*

Figure 12. *Overhang of the thin- to medium-bedded Middle Silurian Byron Dolomite across an enlarged joint in the Lower Silurian Mayville Dolomite at Oakfield Ledges.*

Figure 13. *View along a major joint at Oakfield Ledges illustrates bridging by the Middle Silurian Byron Dolomite.*

Acknowledgments

The following individuals generously provided information and advice during this study: Genevieve Bancroft, Norbert Fonferek, Joanne Klussendorf, Donald G. Mikulic, Meredith Ostrom, Donn P. Quigley, and Ronald D. Stieglitz. Field investigations and preparation of the manuscript were aided by Rachel K. Paull.

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Live Capture Methods of Sympatric Species of Flying Squirrel

Thomas C. Engel, Michael J. Lemke, and Neil F. Payne

Standard methods of capturing other tree squirrels are not as effective for flying squirrels, which spend proportionately less time foraging on the ground (Sollberger 1940; Sonenshine et al. 1979). They can be captured in natural or artificial dens (Sonenshine et al. 1973) or in Sherman live traps attached to trees (Sonenshine et al. 1979). Sumner (1927) captured flying squirrels with rat (kill) traps nailed in trees. Burt (1927, 1940), Jackson (1961), Sonenshine et al. (1979), and Mowrey and Zasada (1984) reported that traps set in trees are effective but did not present trapping details or trap sympatric species of flying squirrels. The objective of this study was to determine the trapping success for sympatric species of flying squirrel relative to tree species, trap type, and height of trap in tree.

The study area was the 83-ha Schmeeckle Reserve, University of Wisconsin–Stevens Point, an area within the vegetational tension zone (Curtis and McIntosh 1951; Curtis 1959) that includes plants and animals typical of both the prairie and boreal forest ecotone extending northwest-southeast in Wisconsin. Forest composition was 5.7 ha of mixed hardwoods including oak (*Quercus* spp.), maple (*Acer* spp.), elm (*Ulmus* spp.), white birch *(Betula papyrifera),* and quaking aspen *(Populus tremuloides);* 14.3 ha of pine *(Pinus strobus, P. banksiana, P. resinosa);* 15.6 ha of mixed woods containing mature hardwoods and scattered mature white pine; and 8.9 ha of oak savanna (Engel 1980).

Methods

To test trap type, we used wooden box traps (Mosby 1955 in Day, Schemnitz, and Taber 1980), Sherman sheet metal box traps 7.5 × 7.5 × 26 cm (Sonenshine et al. 1979) and 13 × 13 × 45 cm, and Havahart wire cage traps 13 × 13 × 45 cm; all were baited with peanut butter. In 1978 we added tree traps to three traplines consisting of wooden box traps set on the ground 30 m apart, which had produced 0.2 flying squirrels per 100 trapnights in 1977. Because the size and weight of the wooden box traps made them awkward to secure in trees, we set Sherman and Havahart traps 60 m apart in trees next to the ground traps. Trees for trap placement were selected for convenience to the trapline; height of trap placement was determined by the ease of climbing without spikes. Trap heights were grouped as 0 (ground), 1–3.1 m, and > 3.1 m. Tree species of trap placement were pooled as red maple *(Acer rubrum),* other hardwoods, jack pine *(Pinus banksiana),* red pine

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(P. resinosa), and white pine *(P. strobus).* Traps were secured in trees with a rubber band cut from an auto tire inner tube and looped around one end of the trap and passed beneath a branch, or around the tree trunk of smaller trees and looped over the opposite trap end. When large branch size precluded this method, the rubber band was cut and extended with a short length of light rope. Traplines were operated 24 September–3 October, 10–20 October, and 22 October–2 November 1978 in three locations within the study area and checked at dawn. Flying squirrels were sexed, tagged in each ear with a numbered aluminum fingerling tag No. 1 (National Band and Tag Co., Newport, KY), and released. After two flying squirrels died in traps early in the study, we added shredded wood packing materials and/or cotton to the tree traps to provide insulation and help absorb moisture from respiration. We used loglinear models (Fienberg 1980) to analyze capture data.

Results

In 1978 we captured 13 *G. volans* and 14 *G. sabrinus* in live traps 39 and 31 times, respectively. Tree sets were nearly sixteen times more effective than ground sets for capturing flying squirrels ($X^2 = 300.3$, $p < .001$, df = 2) (Table 1). No difference existed ($p > .05$) in capture rates of traps set 1–3.1 m from the ground and > 3.1 m. Small sample sizes precluded statistical comparisons of the ease of trapping the two species, although *G. sabrinus* seemed slightly more predisposed to ground traps (Table 1).

The number of flying squirrels trapped per 100 trapnights (Nelson and Clark 1973) in trees was 15.4 in wire traps, 10.8 in large Sherman traps, and 10.2 in small Sherman traps. These catch rates are not different, although wire traps might have been superior had sample sizes been larger. No squirrels died in the wire cage traps; squirrel mortality was 10% in the other traps. No difference existed in survival due to squirrel species or trap type ($G^2 = 6.89$, $p = .44$, df = 7), but sample size was small.

We caught flying squirrels in all species of trees (Table 2). The best loglinear model ($G^2 = 6.33$, $p = .90$, df = 12) indicates that the tree species in which traps were placed was more important than trap type or trap height in determining capture rates. Indications are that the most successful combination of trap and tree used was a wire trap set in a white pine (Table 2).

Discussion

The lack of differences among trap types and the importance of ground versus tree placement suggest that wooden traps set in trees would be effective and that other types of traps set on the ground would not, although study design precluded testing these combinations. The relatively high capture rates of both species in white pines in our study area (Table 2) might not reflect habitat preference or tree species as much as size of tree, especially for *G. volans,* because pines were available in all habitat types and were the biggest trees. Most white pines in the study area were taller than the forest canopy. Post-

Table 1. Trapping success for flying squirrels*

Trap height above ground	N *trapnights*†	N *captures* G. volans	G. sabrinus	*Total captures/100 trapnights*
m				
0.0	1484.5	2	8	0.7
1.0–3.1	387.0	18	20	9.8
3.1	155.5	19	3	14.12
Total	2027.0	39	31	3.5

*University of Wisconsin–Stevens Point, September–November 1978.
†Adjusted for sprung traps (Nelson and Clark 1973).

Table 2. Trapping efficiency for flying squirrels for traps set in various tree species*

Tree species	N trapnights†	N captures G. volans	N captures G. sabrinus	Total captures/100 trapnights
Hardwoods	178.5	4	3	3.9
Red maple	66.5	5	0	7.5
Jack pine and red pine	88.5	3	6	10.2
White pine	209.0	25	14	18.7
Total	542.5	37	23	11.1

*Three types of trap were used, but there was no difference in catch rates. University of Wisconsin–Stevens Point, September–November 1978.
†Adjusted for sprung traps (Nelson and Clark 1973).

release observations of *G. volans* and *G. sabrinus* indicated that squirrels choose the most direct route to a large (> 40-cm diameter at breast height [dbh]) mature tree. Squirrels climbed only 2–3 m up smaller (12–30 cm dbh) trees before gliding to the base of another small tree in a direct route to a large white pine or oak. Squirrels climbed to canopy height and glided longer distances only from large trees. Trees > 40 cm dbh typically were selected as targets for glides initiated at canopy heights. Sonenshine and Levy (1981) and Ando and Imaizami (1982) also found strong positive associations with extreme height and gliding. Bendel and Gates (1987) suggested that trees > 40 cm dbh and open upper-understory (> 10–15 m) aid locomotion and escape, and that clearcuts > 75 m wide are barriers. Mowrey and Zasada (1984) suggested clearcuts not be > 40 m wide, with ≤ 20 m preferable.

Acknowledgment

D. Heisey provided statistical analysis and help with interpretation of data.

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Range Extension of Northern Flying Squirrels

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While trapping small mammals in Stevens Point, Portage County, Wisconsin, we examined a northern flying squirrel *(Glaucomys sabrinus)* collected on the University of Wisconsin–Stevens Point campus in 1976. In 1977 in the same area we captured an adult female northern flying squirrel in a Museum Special snap trap set on the ground for small mammals. Dr. C. Long, museum curator at the university, identified and retained the specimen (no. 4927). This evidence extends the known range of the northern flying squirrel south of the previously known range, into Portage County, Wisconsin.

Our study area was the 83-ha Schmeeckle Reserve, University of Wisconsin–Stevens Point, an area within the vegetational tension zone (Curtis and McIntosh 1951; Curtis 1959) that includes plants and animals typical of both the prairie and boreal forest ecotone extending northwest-southeast in Wisconsin. Forest composition was 5.7 ha of mixed hardwoods including oak (*Quercus* spp.), maple (*Acer* spp.), elm (*Ulmus* spp.), white birch *(Betula papyrifera),* and quaking aspen *(Populus tremuloides);* 14.3 ha of pine *(Pinus strobus, P. banksiana, P. resinosa);* 15.6 ha of mixed woods containing mature hardwoods and scattered mature white pine; and 8.9 ha of savanna (Engel 1980).

Our population estimates from live trapping (Overton 1965; Davis and Winstead 1980) were 17 ± 2.5 southern flying squirrels (0.4 per ha) and 14 ± 2.8 northern flying squirrels (0.3 per ha). Density of southern flying squirrels in Virginia was 31–38 per ha (Sawyer and Rose 1985); for northern flying squirrels in Alaska density was 0.3 per ha (Mowrey and Zasada 1984). The lower population estimates of southern flying squirrels in our study area, where sympatry occurred, might be due to limited availability of large trees for dens, suitable understory (Sonenshine and Levy 1981; Bendel and Gates 1987), and food in this type of presumably marginal habitat normally associated with range limitation.

A broad zone of potential sympatry of northern flying squirrels and southern flying squirrels exists in North America, coinciding with northern hardwood or mixed vegetation (Hall and Kelson 1959). But little actual overlap in the ranges of the two species of flying squirrel exists, with little evidence of sympatry due to highly variable and often exclusive niches (Weigl 1978). In Wisconsin, records of sympatry exist in Jackson (Rausch and Tiner 1948), Clark (Jackson 1961), and now Portage counties, and in the Upper Peninsula of Michigan (Stormer and Sloan 1976). The potential zone of sympatry in Wisconsin comprises the tension zone (Curtis and McIntosh 1951; Curtis 1959) within which Jackson, Clark, and Portage counties occur. Sympatry of northern flying squirrels and southern flying squirrels is likely in other counties within the tension zone.

We found northern flying squirrels almost exclusively in pine habitat and southern flying squirrels mostly in mixed woods but also in deciduous habitat. Weigl (1978) also found northern flying squirrels associated with conifers and southern flying squirrels with deciduous or mixed woods in North Carolina, where altitude influences habitat. Much (67%) of our study area is pine or a mixture of oak and pine, which Sonenshine and Levy (1981) found southern flying squirrels to use less than lowland deciduous areas. Wells-Gosling

(1985) compiled a list of habitat types in North America occupied by both species of flying squirrel.

The northern range of mast trees limits distribution of southern flying squirrels (Weigl 1978). Both species are omnivores, but southern flying squirrels eat mainly mast in winter, while northern flying squirrels eat fungi and the abundant lichens which most animals do not eat, resulting in an exclusive energy source for northern flying squirrels and little competition for food (Weigl 1978). Also, northern flying squirrels feed on cached fungi in red squirrel *(Tamiasciurus hudsonicus)* middens (Mowrey and Zasada 1984); both species generally are found together in coniferous forests. Population densities were 0.4 per ha for red squirrels and 1.4 per ha for gray squirrels *(Sciurus carolinensis)* in the study area.

Southern flying squirrels use only tree cavities for dens (Weigl 1978). They are not hibernators, and den in aggregations for warmth in winter (Muul 1968). Northern flying squirrels are larger, more thickly furred, and thus more tolerant of cold temperatures. They use tree cavities and outside nests. More tree cavities are available in deciduous than coniferous forests. Although smaller, southern flying squirrels are more aggressive in defending a home range. When both species occupy a deciduous forest, southern flying squirrels can displace northern flying squirrels into less suitable habitat, thus possibly reducing their reproductive success (Weigl 1978).

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The Modern Spiritual Condition and the Ancient Wisdom of the *I Ching*

Claire E. Matthews

We are in a period of religious crisis, Mircea Eliade tells us. Many elements of modern life are attempts to recover the sacredness of life and nature and to recover the religious dimension of authentic and meaningful "human existence in the cosmos." As evidence, Eliade cites the contemporary rediscovery of nature, uninhibited sexual mores, and emphasis on "living in the present." He points to these as creative and therefore unrecognizable answers to the crisis and expressions of potentially new experiences of the sacred (Eliade 1969, preface).

Joseph Campbell states that "one of our problems today is that we are not well acquainted with the literature of the spirit" (Campbell and Moyers 1988, 3). Myths are stories that give us a perspective on what is happening to us. We have lost the function of myth in contemporary society, and there is nothing comparable to take its place. Themes that have supported human life and informed religions over the millennia are gone. Gone also are the pieces of information that gave us guidance concerning deep inner problems, mysteries, and rites of passage. Without them we are left to "work it out" ourselves (Moyers and Campbell 1989, 3f).

According to Eliade, when myth is living and functioning in a society, it supplies models of human behavior and gives meaning and value to life (Eliade 1969, 2). Myth also narrates a sacred history and explains, through the deeds of supernatural beings, how reality, the cosmos, or a portion of it, came into being (Eliade 1969, 5–6). Through his work in comparative mythology, Joseph Campbell found that there are certain timeless, universal themes from every culture but with varying cultural inflections. He also believes that mythology is what lies behind literature and the arts. Mythology likewise informs our personal lives, particularly in relation to certain life stages. Mythology imparts structure and meaning to the initiation ceremonies that move the individual from childhood to adult responsibilities, from the unmarried to the married state, for example, or into a responsible new role. Campbell maintains that the conservative call for "old-time religion" is a terrible mistake, that it would be trying to return to something vestigial that no longer serves us (Campbell and Moyers 1988, 10–12).

The *I Ching* or *Book of Changes* as it is often called in English, is an ancient Chinese manual of divination and wisdom that functions as a means of access to these transcultural, mythic patterns. It did this historically for the ancient Chinese and can do the same contemporarily for Western humanity. It also offers a paradigm of Eastern thought that has implications for the Western mind. The kind of assumptions that the *I Ching* makes—that physical and psychological realities have a connection at some deep level—have significance for our Western society.

Marie Louise von Franz points out that the unconscious aspect of the psyche is con-

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nected to matter; we know only that this is so, and our scientific knowledge has come to an end in this respect for the time being (1980a, 79). In a sense, this perspective or world view of the ancient Chinese points to a religious attitude that instructs us never to act only in accordance with conscious reasoning, but with constant attention to what could be termed irrational or unknown participating factors. This might mean consulting a valid oracle, such as the *I Ching,* or concentrating on an attempt to get a sign from within ourselves as to the right thing to do, the proper path to take. In Chinese philosophy this would mean paying constant attention to the Tao to see if the personal action is in Tao. Applying Chinese philosophy to Western thought would yield a new definition of living in a religious way: being constantly on the alert for those unknown powers that guide one's life. This may be a feeling as to whether something is the right thing to do or an instinctive feeling against it. As von Franz puts it, "A bell does not always ring warning us, but if it comes and one ignores it, then something goes wrong" (1980a, 96).

One of the most important books in the history of Chinese culture, the *I Ching* is one of the Five Classics that, along with four other works, made up the basic Confucian canon (Gentzler 1988, 339). John Blofeld, who made a modern translation of the *I Ching* (1965) and who is obviously taken with its value as an oracle, remarks that it was very common for a Chinese individual to be Taoist, Confucian, or Buddhist and something more as well. He states, "There are whole segments of traditional Chinese religion which don't fit into those categories and have existed for several thousand years without acquiring a name" (1965, 38). The *Book of Changes* reflects all of these Chinese attitudes toward religion, cosmology, and metaphysics because much of it took shape before distinctions between religions had arisen and Taoism and Confucianism became separate entities. According to Blofeld, the text contains the seeds or prototypes of both religions and is not contradictory.

The archaic mode of expression used in the *I Ching* adds to the difficulty in understanding the oracles. Blofeld states that frequently the meaning is so esoteric that the mind is baffled until intuition, careful thought, or some unforeseen experience provides sudden illumination. The obtuse language, as well as the 2500 to 3000 years, creates a vast period of time separating us from King Wen and his contemporaries, who edited the *I Ching,* and the disparity between Eastern and Western culture further hinders clear understanding (Blofeld, 32).

There are many varying explanations of the origins of the *I Ching,* although the most probable is that, like many other ancient works, it assumed its present form through a long process of evolution. According to R. L. Wing, the *Book of Changes* was probably a cooperative effort spanning many centuries. The oldest stratum of ideas may have been handed down from the elders of the nomadic Siberian tribes. The early authors of the *I Ching* observed all the cycles of life, natural and human—the tides and the stars; plant and animal life; the seasons; patterns of relationships in families and in societies, in business and in warfare; and the eternal human dramas of life, ambition, and conflict—and made a guide to the way things change. This system is not a fixed chart of the cosmos, but fluid and interconnected. These writers created a guide that offers a perspective on the eternal, universal human drama (Wing, 8).

There are also discrepancies as to the exact date of its conception. James Legge (1899) states in his translation that the basic text was prepared before 1000 B.C. in the last days of the Shang Dynasty and the early part of the Chou Dynasty. Confucius edited and wrote commentaries on it that still exist as part of some editions today. The Confucian commentaries often refer to the "superior man," the *"chün-tzu";* there is also frequent reference to the inferior man who is not *"chün-tzu."* The commentary usually relates what the "superior man" would do in a situation and frequently uses politics or government as an example of the arena (Blofeld 1965, 24).

The term "superior man" in the original text was used to indicate a person striving to live his life in the best possible way (Wing 1979, 30). It is reported that Confucius wished he had fifty more years of life so that he could study the *I Ching*. King Wen wrote commentaries on the social and political implications of the hexagrams, making a monumental addition to the ancient hexagrams. His son, the Duke of Chou, completed his father's work by writing commentaries on each of the six lines within each of the sixty-four hexagrams. Interestingly, both Taoist and Confucian schools have claimed the *I Ching* as their own classic. Later, even certain Buddhists consulted, studied, and commented on it.

The core of the *I Ching* is a divination manual overlaid with the explanations and commentaries already mentioned. To consult the oracle, we follow a simple divination ritual of tossing coins or sorting yarrow stalks. We would approach the oracle as we would a wise spiritual mentor, bringing the concerns that we would like to see in a larger perspective. In this way the more appropriate action can be chosen. This is thought to work because a mutual resonance echoes between the currently active pattern informing the situation under question, the objects used in the divination (the coins or the yarrow stalks), and the symbolic form described by the book. Each coin toss (or sorting of the yarrow stalks) is translated into a line which is either yin (represented as broken: --) or yang (represented as unbroken: —). The casting or meditation is done six times, giving six lines that are grouped in two sets of three lines each called trigrams.

The six lines constituting the hexagram represent the interrelationship of two fundamental forces, "yin" and "yang," two concepts that are an integral part of ancient Chinese philosophy and the Chinese spiritual perspective. The Chinese frequently looked to nature as a representation of the macrocosm and microcosm. Yin and yang refer to basic principles that are purely symbolic representations of energies of what we commonly call "maleness" and "femaleness" (Whitmont 1969, 171). Originally these words referred to the sunny and shady sides of a stream but were more generally symbolically representative of the female (passive) and male (active) principles in human beings, nature, and the macrocosm. No moral verdict was intended; neither principle is "better" or "stronger" than the other. The Chinese saw them as two equally potent, grounding principles on which all the world rests, and in their interaction they inform, constitute, and decompose all things. Their belief in this universal diad also informs the *I Ching* (Campbell 1972, 119).

As previously mentioned, casting the coins six times gives six lines that are either yin or yang and form two groups of three lines each, called trigrams. There is a traditional belief that the legendary sage-emperor Fu-hsi came by the idea for the trigrams from a map found on the back of a horse or dragon-horse (or, according to another source, a turtle) that emerged from the Yellow River. The map was supposedly preserved for some time but has long since perished. It was composed of a concentric configuration of lines made of dark and light dots. In Legge's opinion, the purpose of perpetuating the legend was "to impart a supernatural character to the trigrams and produce a religious veneration for them." Legge (1899, 15–17) believed that King Wen first used lines instead of circles and was supposedly the first to combine two trigrams to form a six-line figure called a hexagram, of which I have more to say later.

The trigrams had an interesting evolution from the supreme absolute as understood by the ancient Chinese. They regarded the supreme absolute as the yin and yang of the cosmos out of which all that exists is produced. They saw yang as always turning into yin and yin in the process of becoming yang, a process called enantiodromia, in which one energy or thing turns into its opposite when it has reached a zenith or nadir of development. This dynamic interplay in the cosmos creates life, and this creative energy of life manifests the cosmos. The ancient Chinese have this to say in reference to the creative force: "From the Creative (yang) and the Receptive (yin) emerge the ten thousand things" (Wing 1979, 13). The yin and yang lines combined in four different ways to represent the seasons. A third line was added to represent humanity as the synthesis of yin and yang, heaven and earth, thereby creating the eight elemental trigrams meant to represent all the cosmic and physical conditions on earth. The trigrams and their attributes are as follows:

☰	☱	☲	☳
Ch'ien	Tui	Li	Chên
heaven, sky	water (as in a marsh or lake)	fire, the sun; lightning	thunder
☴	☵	☶	☷
Sun	K'an	Kên	K'un
wind and wood	water (as in rain, the clouds, springs, streams); the moon	hill, mountain	the earth

The trigrams were used in early forms of divination since they could easily be recognized and memorized. They represented, for example, family members, parts of the body, seasons, and many sets of ideas, as well as more abstract attributes, so that they constituted a very useful almanac for the ancient Chinese to use in understanding the tendencies of change. The trigrams were also used for divination in an arrangement of polar opposites (e.g., heaven across from earth, water from fire). A later arrangement according to periodicity is attributed to King Wen. Various pairings of the trigrams by Chinese scholars later led to the sixty-four hexagrams. The union of the two trigrams represents the dynamism of heaven and earth, their interaction representing cosmic forces as they affect human affairs (Wing 1979, 14–15).

Carl G. Jung wrote an illuminating preface to the English edition of Richard Wilhelm's translation. Blofeld praised Jung's introduction as a joy to read and declared that Jung "courageously dared the scorn of his fellow scientists by publicly asserting his belief in the *I Ching*'s predictions. He even went so far as to attempt to show why they are correct" (1965, 25). Jung's concepts of acausality, synchronicity, and archetypes are essential to understanding the reliability of the *I Ching*.

Concerning the causal view of the world, Jung writes in *Mysterium Coniunctionis* (1970, 464):

> The causalism that underlies our scientific view of the world breaks every thing down into individual processes which it punctiliously tries to isolate from all other parallel processes. This tendency is absolutely necessary if we are to gain reliable knowledge of the world, but philosophically it has the disadvantage of breaking up, or obscuring, the universal interrelationships of events so that a recognition of the greater relationship, i.e., of the unity of the world, becomes more and more difficult.

Jung regarded this idea as a world view that could be seen as valid, although very different from our Western perspective.

According to Marie Louise von Franz, the Jungian author of *On Divination and Synchronicity,* synchronistic reasoning is the classical Chinese way of thinking. The Chinese think in terms of "fields" and know innately that certain things "like" to happen together in a meaningful way. In their thinking, no differentiation has been made between "psychological" and "physical" facts. In synchronistic thinking, both inner and outer facts can occur together. Causal thinking regards time as linear and each moment as qualitatively equal to any other; in acausal, synchronistic thinking, time is viewed as a qualitative "field" in which groupings of events typically occur. Thus in a certain moment in time a complex of events made of inner (i.e., thoughts, dreams) and outer (i.e., physical) events constellate (1980b, 8).

Jung (1931, 85) stated in his commentary on *The Secret of the Golden Flower* (which Richard Wilhelm had translated from the Chinese) that the Chinese developed intuition to a very high degree. Because of this keenly developed intuition, the Chinese were able to recognize the polarity and paradox in what is alive. Whether this gave them a greater predisposition to comprehend the spiritual—specifically the cosmos and the individual's right place in it as evidenced by the use of the *I Ching* as a tool—is an interesting speculation for the Western mind to ponder.

Blofeld also sheds some light on the essential difference between Eastern and Western thinking. "Asia's thinkers," he states, "were chiefly occupied with the search for life's meaning (or at any rate, man's true goal) and for ways of utilizing that knowledge for self cultivation and self-conquest" (Blofeld 1965, 23). He felt the *I Ching* invaluable as an aid to understanding life's rhythmic process with a view to bringing man back into harmony with it.

The ancient Chinese perspective—almost opposite to our Western view but possibly complementary in its introverted, intuitive way that takes into account the simultaneous reality of spirit and matter—may hold something valuable for us if we can be open to it.

In an essay on one of the hexagrams of the *I Ching*, Rudolph Ritsema (1976, 191) states that if the philosophical system and the cosmological as well as social and historical implications of the *I Ching* are left behind, what remains is a book that contains a whole web of interrelated archetypal images underlying our world. He views the *I Ching* as a door to the archetypal realm, its position between a dream and a mythology. Dreams, he states, reveal the individual relevance of an archetypal pattern or image, and mythology shows the archetypal patterns at work in their own world. The *I Ching* enables one to connect with the archetypal pattern underlying the specific situation in time. The ancient Chinese language lends a particular advantage to this in that it allows images and concepts to join in single words as well as in sentences of the *I Ching*.

Just what are archetypes, and why is it important to be in proper relationship to them? According to Frieda Fordham (1957) in *An Introduction to Jung's Psychology,* archetypes are unconscious and can therefore only be postulated, but we can become aware of them through certain typical primordial images. We may hazard a guess that these primordial images or archetypes formed in the unconscious during the thousands of years when the human brain and human consciousness were emerging from the animal state, and are modified or altered according to the era in which they appear. They can be experienced as emotions as well. When we encounter a level of deep human experience such as birth or death, triumph over obstacles, transitional stages of life, or extreme danger, the personal level of experience taps a deeper level. These "impressive" experiences break through into an old, previously unconscious riverbed, and the experience is extremely powerful.

According to Whitmont's interpretation of Jung, archetypes manifest in individuals as automatic or instinctive emotions and drives. The archetype appears as an experience of fundamental importance and presents itself as numinous. Its power can be either constructive or destructive, depending on the form of actualization and the attitude taken by consciousness (Whitmont 1969, 103f).

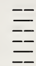
This does not mean that God is "nothing but an archetype." Rather, the transpersonal power of archetypes that expresses itself to us subjectively through psychological experience as if it were personal guidance and confronts us with meaning in our personal lives and destinies is the transpersonal power that has been called God, and this is one of the ways we can experience Him. This may shed some light on the nature of this ancient book and how it was able to function as the core of Chinese spirituality for so many years.

Blofeld (1965, 31) quotes a Chinese friend who had written a newspaper article in which he explained:

> The responses to be won from the *Book of Changes* are sometimes of such tremendous import that they may save us from a lifetime of folly, or even from premature death. It must be treated with the deference due to its immense antiquity and to the wealth of wisdom it contains. No living man can be worthy of equal deference, for it is not less than a divine mirror which reflects the processes of vast and never-ending cosmic change, those endless chains of actions and interaction which assemble and divide the myriad objects proceeding from and flowing into T'ai Chi—the still reality underlying the worlds of form, desire and formlessness. It has the omniscience of a Buddha. It speaks to the transient world as though from the Womb of Change itself—Change, the one constant factor amidst all the countless permutations and transformations of mental and material objects which, when the eye of wisdom is closed, appear to us as meaningless flux. That their infinite number can be mirrored in so small a compass is because they all proceed according to adamantine laws and all are facets of that spotless purity and stillness which some men call T'ai Chi or the Tao and others the Bhutatathata, the Womb of the Tathagatas (Buddhas), the Source of All.

Jung felt that man needs to find a new religious attitude, a new realization of our dependence upon superior dominants (archetypes), that he is frequently operated on and maneuvered by "archetypal forces" instead of his "free will." "He should learn that he is not master in his own house and that he should carefully study the other side of his psychic world which seems to be the true ruler of his fate." Jung stated that "if the archetype, which is universal, i.e., identical with itself always and anywhere, is properly dealt with in one place only, it is influenced as a whole, i.e., simultaneously and everywhere." Paraphrasing Confucius' commentary in the *I Ching*, Jung said, "The right man sitting in his house and thinking the right thought will be heard 100 miles away" (*Letters* 2:594).

Since the *I Ching* is an ancient oracle, and since the thesis of this paper is that the *I Ching* can address our contemporary condition with its wisdom, I asked *I Ching* how it would like to be presented in this paper. The divination procedure yielded hexagram number 58, "The Joyous," one of eight hexagrams formed by doubling a single trigram, "Tui," the image of the "smiling lake" whose attribute is joyousness (Wilhelm 1967, 223).



With each hexagram in the *I Ching*, the reader finds a "judgment" and a statement of the "image." This is the judgment attached to hexagram 58:

> The joyous. Success.
> Perseverance is favorable.

Wilhelm comments that "true joy, therefore, rests on firmness and strength within, manifesting itself outwardly as yielding and gentle" (1967, 224). In each trigram, a "strong" or yang line (i.e., unbroken) lies "within," that is, flanked ("without") by a "weak" or yin (broken) line. Here is the image accompanying hexagram 58:

> Lakes resting one on the other:
> The image of The Joyous.
> Thus the superior man joins with friends
> For discussion and practice.

Wilhelm (1967, 224f) interprets the image in these words:

> A lake evaporates upward and thus gradually dries up; but when two lakes are joined they do not dry up so readily, for one replenishes the other. It is the same in the field of knowledge. Knowledge should be a refreshing and vitalizing force. It becomes so only through stimulating intercourse with congenial friends with whom one holds discussion and practices the application of the truths of life. In this way learning becomes many-sided and takes on a cheerful lightness, whereas there is always something ponderous and one-sided about the learning of the self-taught.

The enduring wisdom of the *I Ching* is manifest in this answer to the question. The joy and success come through my inner enthusiasm coupled with a genuine feeling of wanting to share this information with others. Use of the present paper would do well to take the form of a discussion among friends with whom one would ponder the truths of life and their practical application.

The Western mind may agree or disagree that the *I Ching* is a vehicle to tap the unconscious for its guidance and perspective, and that it has as much relevance for modern Western man as for the ancient Chinese as an alternate but valid spiritual world view. But even without this perspective, the *I Ching* exists like a venerable old Chinese master, an example of the Chinese philosophical and religious world view, with many secrets to be explored and pondered.

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Distribution, Abundance, and Diversity of Mollusks (Bivalvia: Unionidae) from the Lower Chippewa River, Wisconsin

Terry Balding

Abstract. *The lower Chippewa River, from the dam in Eau Claire to its mouth at Mississippi River Mile 763.4, was divided into 37 sampling stations each about 2 km in length. During the summers of 1986–1989, mollusks from each station were collected, mainly by wading; 4,832 empty shells were identified to species and kept. In addition, 2,161 live shells were identified as to species, measured, and returned to the river substrata. Twenty-six different species were found, 24 having living representatives. The lower half of the river had significantly fewer species and individuals* ($p < 0.01$).

Freshwater mollusks or freshwater mussels of Wisconsin have been studied by Baker (1928) and by Mathiak (1979). These two studies were statewide in scope and therefore did not give intensive coverage to the mussels of the Chippewa River. Data of an intensive scope are needed for the Chippewa because mussels are good ecological indicators of water quality, and the expanding human population is placing an increasing burden on water quality. Freshwater mussel base-line data need to be obtained so that they may be used as a biological monitor of the environment or as a means of detecting changes by a comparison to future studies. Any plan to impound the lower Chippewa River should refer to these data in order to assess the detrimental effect on the mussels, which are a river species. A recent Wisconsin income tax checkoff for non-game species has made money available and created interest in determining the presence and status of species such as mussels.

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Study area. According to Simons et al. (1980), the Chippewa River begins in the Upper Peninsula of Michigan, drains about 17% of Wisconsin, and empties at Mississippi River Mile 763.4. The Chippewa averages 243 m in width at its mouth and deposits 553 million kg of sediment per year into the Mississippi (recurrence interval, two years). It is impounded many times, with the last dam in Eau Claire, Wisconsin, where it averages 158 m in width and discharges .028 cubic meters per second. The last 92 km of the Chippewa River is free flowing from the dam in Eau Claire downstream to its junction with the Mississippi River. The 64-km portion from Eau Claire to Durand has a sinuosity of 1.49 and slope of 1.5 feet per mile. The substrata are primarily sand, gravel, and glacial rocks. There is stratification of these substrata as the channel meanders. Occasionally there are areas of silt deposits, but in others the bottom is sandstone bedrock. The last 27 km of river from Durand to the Mississippi is less sinuous. Erosion from stream banks and islands results in a braided channel with shifting sand sediments. In a few places the channel cuts into large hills, and sandstone bedrock breaks off into angular pieces and falls into the channel.

Methods

The first segment of river within the city limits of Eau Claire was an 8-km stretch from the dam to Interstate 94. This segment was designated as an area for intensive study. All shorelines were searched diligently to find mussel concentrations. The remaining 84 km of the Chippewa was divided into 36 segments numbered from upstream to downstream. Convenient landmarks such as islands, small streams, bridges, and hills were used to divide segments. Segments in this portion of the river averaged about 2 km and were searched by boat or by walking rapidly along the shoreline. Once an area was found to have mussels, it was searched more intensively using a wading-pollywogging technique. This technique was used because the upper part of the study area has extensive amounts of rocks, making the brailing method impractical. A SCUBA technique, searching 1 m on each side of a 30-m transect (60 m^2), when compared to the wading-pollywogging technique showed no statistical difference. SCUBA is a more expensive method of sampling and is more important in deeper water. The shallow nature of this river seemed to lend itself to wading-pollywogging. The severe drought of 1988 and a lesser drought in 1987 reduced the water level and made the wading-pollywogging technique more effective. Lakes, side channels, and sloughs adjacent to the main channel were not searched. In some areas, which seemed likely to harbor mudpuppies (*Necturus maculosus*), rocks were turned over to search for the salamander mussel (*Simpsonaias ambigua*).

Except for specimens that were kept as vouchers, all live mussels were identified as to species, enumerated, measured for length, and returned to the river substrata. The length, in millimeters, was the longest straight-line distance from the anterior end of the shell to the posterior end. The identification of the voucher specimens was confirmed by Dr. David Stansbery, and they were deposited with him to be catalogued into the Ohio State University Museum of Zoology.

All empty shells were collected and deposited at the University of Wisconsin–Eau Claire, where they were later identified. However, two empty shell specimens, the only representatives of their respective species, were sent as vouchers to Dr. Stansbery, who confirmed their identifications.

Results and Discussion

Twenty-six species of mussels were identified from the Chippewa River between Eau Claire and its junction with the Mississippi River (Table 1). Twenty-four species were collected alive, whereas only empty shells were found for *Elliptio dilatata* and *Pleurobema sintoxia*. The most abundant live species were *Fusconaia flava* and *Obovaria olivaria*, with other abundant species including *Leptodea fragilis, Lampsilis ventricosa,* and *Lasmigona complanata*. However, *Lampsilis ventricosa* and *Obovaria olivaria* occurred more frequently than other species (Table 1). One species that was found frequently yet not abundantly was *Potamilus alatus*.

In Table 1 the mean length is given along with the range length and the standard deviation. The importance of these numbers can be seen by noting *Quadrula metanevra*. The mean length shell is large, but there is a small range and standard deviation. This indicates that only older shells exist and no recruitment of new individuals for this species has occurred in several years. The small number of shells and the observation that all live specimens had considerable erosion would support the theory that this shell may soon be extinct in the study area.

Simpsonaias ambigua can almost be considered colonial, in that under a single rock large numbers of specimens were found tightly packed together. Total numbers of this species might not be a true reflection of its abundance relative to other species; therefore, total numbers were not recorded. Of the three sites where live salamander mussels were found, one site was searched for a long time before they were discovered; on the other two sites they were found without much effort. In contrast, a fourth site about 100 m long was searched for four hours by two persons, and while several mudpuppies were observed, no salamander mussels were found. Since it was time-consuming to turn over rocks in search of the salamander mussel, only a few sites were searched for this species. Therefore, the 8.1% frequency found in this study may not be a true representation of the occurrence (Table 1).

Comparisons between the rank in abundance for species found alive versus dead (Table 1) reflect only general agreement. This could be because of collector bias or some other cause. Nevertheless, finding empty shells in pristine condition very likely indicates that a species presently lives in the vicinity and is a general indication of the relative proportions of each species.

Mussels do not occur uniformly dispersed in a river, but rather large numbers may be found clustered in one area and none in another. If a cluster is examined, several species will probably be found. The proportionate numbers of a species in a cluster may differ from cluster to cluster. This needs to

Table 1. Data for freshwater mussel species found on the lower Chippewa River

	No. live	No. dead	Frequency of occurrence of a live species	Live length range	$\bar{X}$ live lengths	Standard deviation
				mm	mm	
Actinonaias ligamentina (Lamarck 1819)	6	9	8.1	51–168	112.6	4.16
Alasmidonta marginata (Say 1818)	69	185	37.8	40–116	81.2	1.50
Amblema plicata (Say 1817)	37	8	48.6	18–153	105.4	3.25
Anodonta grandis (Say 1829)	50	24	54.0	50–155	116.8	2.17
Elliptio dilatata (Rafinesque 1820)	D*	1				
Fusconaia flava (Rafinesque 1820)	453	578	67.6	20–117	63.3	.33
Lampsilis radiata (Lamarck 1819)	38	184	37.8	54–132	89.3	2.10
Lampsilis ventricosa (Barnes 1823)	187	1072	81.1	38–154	107.9	2.28
Lasmigona complanata (Barnes 1823)	183	330	64.9	47–190	129.0	2.56
Lasmigona costata (Rafinesque 1820)	60	105	40.5	71–124	97.4	1.35
Leptodea fragilis (Rafinesque 1820)	212	785	78.4	24–170	113.0	2.87
Ligumia recta (Lamarck 1819)	52	120	51.4	56–161	123.7	2.33
Obliquaria reflexa (Rafinesque 1820)	4	37	10.8	45–63	53.2	.83

*D = no live specimens found.

Continued on next page

Table 1—*Continued*

	No. live	No. dead	Frequency of occurrence of a live species	Live length range	$\bar{X}$ live lengths	Standard deviation
				mm	mm	
Obovaria olivaria (Rafinesque 1820)	420	647	81.1	20–126	76.6	2.09
Plethobasus cyphyus (Rafinesque 1820)	12	31	13.5	43–133	107.2	2.51
Pleurobema sintoxia (Rafinesque 1820)	D*	1				
Potamilus alatus (Say 1817)	119	89	73.0	63–180	126.8	2.77
Potamilus ohiensis (Rafinesque 1820)	11	12	10.8	44–152	95.0	3.88
Quadrula metanevra (Rafinesque 1820)	10	34	5.4	108–124	112.7	.41
Quadrula pustulosa (Lea 1831)	16	15	27.0	47–100	72.4	1.61
Simpsonaias ambigua (Say 1825)	12	4	8.1	None measured		
Strophitus undulatus (Say 1817)	120	372	59.5	30–165	97.6	1.42
Toxolasma parvus (Barnes 1823)	15	6	8.1	15–36	28.7	.59
Tritogonia verrucosa (Rafinesque 1820)	45	31	32.4	91–184	144.7	2.08
Truncilla donaciformis (Lea 1827)	9	64	24.3	24–41	31.5	.71
Truncilla truncata (Rafinesque 1820)	33	88	40.5	28–69	49.0	1.17
	2161	4832				

*D = no live specimens found.

be kept in mind when examining Table 1, as the figures can be misleading. For example, it would appear that *Fusconaia flava* (453 live specimens) might be very common. However, the actual data show nearly 300 live shells taken in only two small areas of the entire river.

The Wisconsin Department of Natural Resources has listed *Plethobasus cyphyus* as endangered and *Quadrula metanevra, Simpsonaias ambigua,* and *Tritogonia verrucosa* as threatened. These species were found live in the study area. Our general observations and the abundance, frequency, and size data indicate that all but *Quadrula metanevra* are surviving and reproducing.

The number of species per station is shown in Figure 1. Data recorded for the number of specimens per station, shown in Figure 2, reflect a similar trend. A paired t-test ($p < .01$) demonstrated that the number of species found per station was significantly greater for the first 18 stations than for the last 18 stations. The difference is that at Station 19 the Red Cedar River enters the Chippewa River, and downstream there is a gradual loss of sinuosity combined with more erosion of stream banks and islands, which creates shifting sand sediment. Observations revealed that stations downstream of Station 19 with high species diversity were related to areas where the channel cut into sandstone hills and pieces of bedrock were found in the channel. In a few instances populations were found where islands or peninsulas created pockets of water that were protected from shifting sand sedi-

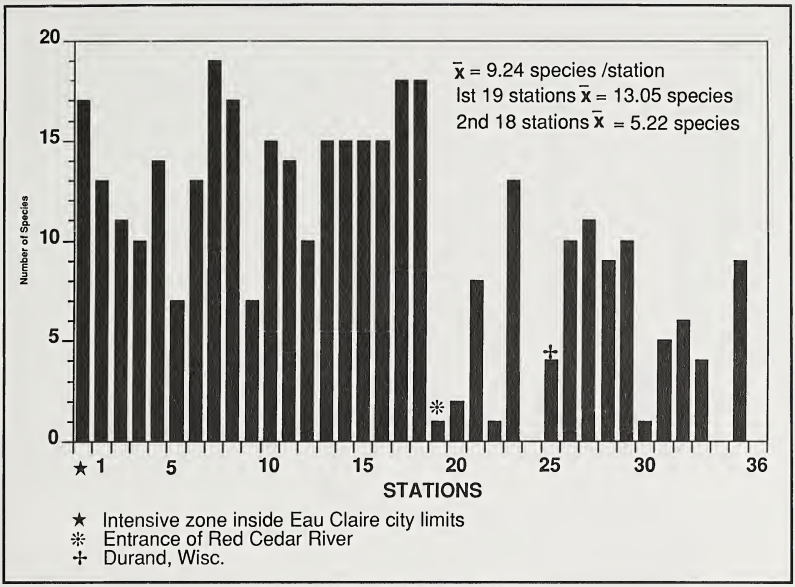

Figure 1. *Number of species found at each station on the lower Chippewa River. Station 1 is 8 km downstream from Eau Claire; station 36 joins the Mississippi River at Mile 763.4.*

ments. The only species found to inhabit the shifting sand were *Anodonta grandis, Lampsilis ventricosa, Leptodea fragilis, Obovaria olivaria, Potamilus ohiensis,* and *Potamilus alatus;* most were younger specimens.

Besides the entrance of the Red Cedar, another site where there were conspicuously fewer mussels was the first 5 km downstream of the Eau Claire dam. The author intends to continue this study to the source of the Chippewa River and then its tributaries. It will be interesting to see whether a trend exists regarding the virtual absence of mussels below a dam or entrance of a large tributary.

Mussels were found marooned in a small pool (maximum depth 15 cm) at Station 1. Since the pool would soon go dry, it was decided to transplant the mussels to a nearby suitable habitat with deeper water. Ninety-seven live specimens (all that were visible) were identified, measured, and transplanted on 13 September 1988. On a return visit four days later an additional 112 live specimens were found and transplanted. A chi-square test showed no significant difference in the species composition between the two visits. On 7 October 1988 a third visit proved not all the living mussels on the first two visits were found. Another 100 specimens were discovered but not moved. There was a significant difference (chi-square test, $p < .01$) between the species composition on the third visit compared to either of the first two visits. Clearly, mussels are not always detected because they must totally bury themselves for periods of time. Perhaps also some species may remain buried longer than others. In fact, on one occasion a live mussel was found buried under at least 5 cm of sand and gravel where there had been no water for several hours. The mussel had good adductor reflexes and seemed healthy.

Overall, the Chippewa River shells seem to be in rather poor condition, especially the

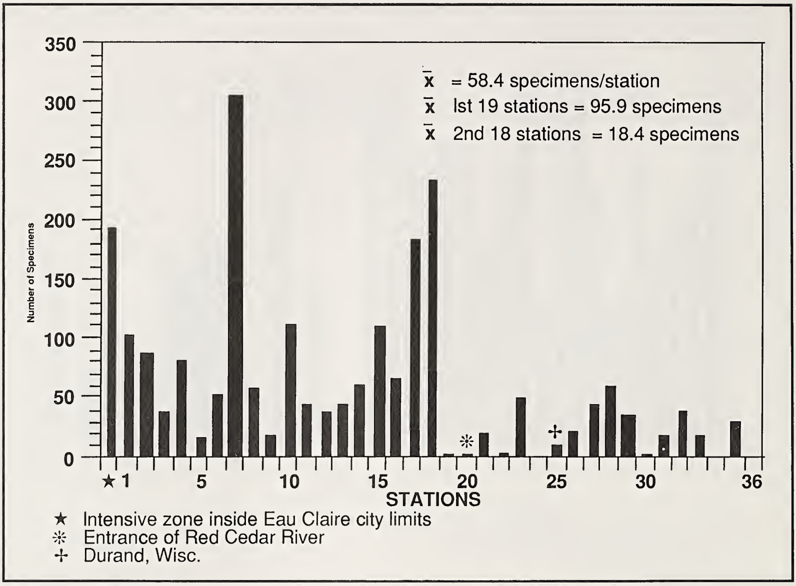

Figure 2. *Number of specimens found at each station on the lower Chippewa River.*

umbone area, probably because of the glacial rocks rolling into them; then when the periostracum is injured the acid water of the Chippewa River erodes the shell considerably. There is good mussel species diversity on the Chippewa, and some species seem to have healthy populations. Some are apparently in decline, and species represented by only a few specimens do not give much indication as to the health of their population. Densities do not seem to be as high as in other rivers I have visited such as the Mississippi, Namekagon, and St. Croix. The highest density on the Chippewa was about 30 mussels per m^2. This collecting location was markedly better than any other site on the Chippewa.

Acknowledgments

Thanks are due to Pope and Talbot of Eau Claire and the University of Wisconsin–Eau Claire for funding student help. I am indebted to Dr. David Stansbery for verification of the mussel identifications and other helpful assistance with this study. I appreciate the help in collecting and identifying mussels provided by Leslie Scalzo; Andrea Pokrzywinski; Marc and Sheri Harper; Rod, Jason, and Brian Beheler; Shawn Balding; Lori Lyons; Doug Stevens; and Linda Carls. A very special thanks is due to my wife Nancy for spending many hours by my side collecting and identifying mussels.

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TRANSACTIONS

of the Wisconsin Academy of Sciences, Arts and Letters

Volume 81 • 1993

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TRANSACTIONS of the Wisconsin Academy of Sciences, Arts and Letters

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ISSN 0084-0505

Contents

TRANSACTIONS

Volume 81 • 1993

From the editor vi

The impact of chemical rehabilitation on the parasitic fauna of fish in a Wisconsin lake 1

Omar M. Amin, Colleen A. Dickey, and Alan R. Spallato

The application of rotenone at 1.5 ppm for chemical rehabilitation of Little Elkhart Lake, Sheboygan County, Wisconsin, in 1981 caused the total elimination of *Proteocephalus ambloplitis*, a damaging tape worm of bass, by 1988. This finding, related events, and control measures are discussed.

Lemanea *(Rhodophyceae) in Wisconsin* 7

John L. Blum

Populations of the red alga *Lemanea* (subg. Lemanea) are reported from streams in Iron and Marinette counties, Wisconsin. Contrasts are drawn and explained between members of this subgenus and subgenus Paralemanea, which is not known from Wisconsin.

Plant ecology comes of age in the United States 12

Joshua C. Blumenfeld

This paper presents a history of the early twentieth-century work in plant ecology in the United States and, in particular, looks at the work of Henry Cowles, Frederick Clements, Henry Gleason, and William Cooper in the development of the basic theories of plant ecology and plant community development.

The effects of ant mounds and animal trails on vegetation pattern in calcareous fens 23

Quentin J. Carpenter and Calvin B. DeWitt

The effects of ant mounds and animal trails upon the distribution of plants on calcareous fens was investigated at three sites in southeastern Wisconsin. One grass, *Muhlenbergia mexicana*, was consistently associated with ant mounds, and several species were significantly more common near animal trails.

Exhumed early Paleozoic landforms on the Baraboo Hills, Wisconsin 31

Lee Clayton and John W. Attig

Some landforms in the Baraboo Hills were formed in Precambrian or early Paleozoic time, were then buried and preserved through Paleozoic time, were exhumed in Mesozoic or Cenozoic time, and are preserved today in nearly their original form.

Notes on the biology of the American brook lamprey
(Lampetra appendix) *in Wisconsin* 39

Philip A. Cochran, Martin E. Sneen, and Alan P. Gripentrog

Collections of adult American brook lampreys from two localities revealed that spawning occurred at temperatures cooler than previously reported and that males and females differed in several morphological features. Also, analysis of distributional records showed that American brook lampreys tend to occur upstream from northern brook lampreys in those streams from which both have been collected.

Recent changes in the aquatic macrophyte community of Lake Mendota 47

Elisabeth R. Deppe and Richard C. Lathrop

The authors summarize the results of aquatic macrophyte surveys conducted during 1989–1991 on Lake Mendota, a lake with a long-term record of macrophyte community changes. *Ceratophyllum demersum* and *Myriophyllum spicatum* were the two most abundant species, but changes in the entire macrophyte community occurred probably as a response to unusually poor water clarity in 1990.

Were wild turkeys found historically in northwest Wisconsin? 59

James O. Evrard

New evidence indicates the wild turkey was found in northwest Wisconsin outside previously accepted historical range limits.

Creating the California Alps 65

Marguerite Helmers

Two articles by John Muir illustrate his use of eighteenth- and nineteenth-century conventions of picturesque and sublime representation. While Muir employed these established modes of representation, he also used them to satirize an audience of tourists and leisure-class readers who expected that Nature conform to the rules of painting.

Blanchard's cricket frogs
(Acris crepitans blanchardi) *in southwest Wisconsin* 79

Robin E. Jung

State-endangered Blanchard's cricket frogs were found in 19 of 40 sites which historically had populations of this species. Of all habitat and water quality indices measured, only water temperature differed significantly between sites with and without Blanchard's cricket frogs.

A survey of the summer phytoplankton communities of 579 Wisconsin lakes 89

Richard Lillie, Robert Last, Paul Garrison, Paul Rasmussen, and John Mason

The results of a survey of phytoplankton communities from 579 Wisconsin lakes are presented in this paper by a group of scientists from the Department of Natural Resources. Blue-green algae (Cyanaopyceae) are shown to be, beyond any doubt, the most common group of phytoplankton associated with blooms in Wisconsin lakes.

Discriminant analysis of geographic variation in long-tailed deer mice from northern Wisconsin and Upper Michigan 107

Charles A. Long and John E. Long

The similar long-tailed deer mice of northern Wisconsin and Upper Michigan are analyzed statistically to facilitate identification and appraise geographic variation.

Status and biology of paddlefish (Polyodon spathula) *in the Lower Wisconsin River* 123

John Lyons

Paddlefish are currently rare in most of Wisconsin, but a large population persists below the Prairie du Sac dam on the Wisconsin River. A recent study provides some of the first biological data on the species in the state.

An "Education into Gladness": Ron Wallace's The Makings of Happiness *and "The Mid-life Progress" narrative* 137

Bruce Taylor

This paper presents a critical appreciation of the work of Wisconsin poet Ron Wallace, especially as represented in his latest book, *The Makings of Happiness.* Taylor discusses this book both as a collection of individual poems and as a remarkable narrative about mid-life progress.

From the editor

On this beautiful May morning, awash (after many rains!) in spring flowers and the first blossoms of fruit trees, several stray visitors have found their way into my office through an open window. I opened the window because the University's air conditioning has not been turned on for the season. The fresh air, of course, is the welcomed visitor. The most obvious unwelcomed guest is the sound of passing traffic on Algoma Boulevard, but my sneezes and itchy eyes remind me that pollen from the tulip beds beneath my windows has entered the office, too.

By far the most interesting visitor, however, is a magnificent queen bumblebee who has been trying for over two hours, without success, to find her way back to the window by which she entered! She has expended a good deal of energy attacking a closed window and the fluorescent lighting fixtures and now sits barely four feet away from me next to a heap of books, resigned, evidently, to a temporary life of scholarly contemplation. Since the books are piled right next to my telephone, it remains to be seen whether I will dare to answer if it rings!

By the time this 1993 issue of *Transactions* appears, circumstances in my office will have changed dramatically, I expect. Windows will be locked shut against the fall or early winter cold, the heating plant will be in action, pollen will have been replaced by late molds, pumpkins and squashes will represent the last hurrahs of the growing season, and according to my entomologist colleague down the hall, the queen bee may have settled into an abandoned mouse or bird's nest for overwintering—if she ever finds her way out of the office!

I have found my first year as editor of *Transactions* not unlike the experience just described. Saying "Yes" to the editorship has opened a window to visits by all sorts of new experiences, expected and unexpected, but almost all of them welcomed. Best among these has been the opportunity to make the acquaintance of and to collaborate with the outstanding array of authors, reviewers, and production staff represented by this issue.

I have been extremely impressed, for example, by the willingness of professional colleagues to spend much time, care, and energy on their review of manuscripts. I have enjoyed telephone conversations with many of them as well as the usual written correspondence. Some are my own colleagues at UW Oshkosh, whose expertise at reviewing I have only just discovered. As we all know, the work of reviewers often goes unheralded, although it is a scholarly service absolutely essential for ensuring that only articles worthy of publication and of further scholarly citation are actually published. Without fear of contradiction, I can speak for all the authors by acknowledging the debt they owe to the constructive criticisms and suggestions forwarded by their reviewers. All of us as readers are indebted as well to these reviewers, whose only compensation for their scholarly contribution is our "Thank You" and their own satisfaction at having furthered the cause of responsible research and of clear, accurate and reader-friendly written communication.

Of course, I also opened my window to the authors themselves, several of whom I have had the great pleasure of meeting on campuses and at workshops and conferences around Wisconsin during the past year. Altogether, the variety of research they report in this issue should be of interest to a wide spectrum of readers and should contribute to the related studies and research of many. And for all of us who simply take delight in learning more about the natural and human history of Wisconsin, there is much here to please: from a discussion of paleozoic landforms in the Baraboo Hills to an appreciation of John Muir's picturesque creation of the California Alps; from endangered cricket frogs in southwest Wisconsin, calcareous fens in the southeast, and parasitic fauna in eastern Elkhart Lake to deer mice and wild turkeys in the north and northwest; from paddlefish in the lower Wisconsin River to American brook lamprey in Taylor and Jambo creeks; from the red alga *Lemanea* in the streams of Marinette and Iron counties to the macrophyte community on Lake Mendota and to the summer phytoplankton on 579 Wisconsin lakes; from a history of early twentieth-century work in plant ecology in Wisconsin and the Midwest to a critical appreciation of a late twentieth-century midlife progress as portrayed by one of Wisconsin's premier poets.

Readers may notice an updated look in the design and layout of the 1993 *Transactions*, thanks to the artistic eye of our indefatigable Managing Editor, Patricia Duyfhuizen. Her contributions to the actual production of this journal are too many to begin to enumerate. Suffice it for me to express my gratitude to Tricia for transforming a heap of individual manuscripts into a finished publication of which members and supporters of the Wisconsin Academy justifiably may be proud. Thanks also to former editor Carl Haywood, *Wisconsin Academy Review* editor Faith Miracle, Executive Director LeRoy Lee, and my special on-site all-around advisor and collaborator at UW Oshkosh, Neil Harriman, for their generous assistance in helping me handle all the "visitors," expected and unexpected, who have come in through the window during this first year of my editorship.

Bill Urbrock

P.S. I trapped the queen bee in a cup and released her outside!

Omar M. Amin, Colleen A. Dickey, and
Alan R. Spallato

The impact of chemical rehabilitation on the parasitic fauna of fish in a Wisconsin lake

Abstract *A 23-ha, meso-eutrophic lake in eastern Wisconsin was treated with rotenone (1.5 ppm) in November, 1981, to kill its rough fish and restock with desirable fish populations. Pre- and post-treatment samples of fish were examined for parasites in September, 1981 and 1988, respectively. Moderately heavy infections with* Proteocephalus ambloplitis *(Cestoda) disappeared after the rotenone treatment, which killed its fish hosts, largemouth bass,* Micropterus salmoides, *and sunfish in 1981. Infections with* Neoechinorhynchus cylindratus *and* Leptorhynchoides thecatus *(Acanthocephala) decreased and increased dramatically, respectively, as a result of changes in their fish host populations following rotenone use. Metacercariae of* Posthodiplostomum minimum *(Trematoda) in sunfish and* Hysterothylacium brachyurum *(Nematoda) in largemouth bass were also present before and after the chemical treatment, respectively. The observed loss of* P. ambloplitis *after 1981 points to a possible method for its control.*

Efforts to establish desirable fish populations by rotenone treatment of lakes dominated by winter-kill resistant species, e.g., bullhead, and restocking have recently been attempted by the Wisconsin Department of Natural Resources, as well as by other agencies throughout the United States since the mid-1930s (Gilderhus et al. 1986). The impact of such chemical treatments on invertebrate and fish populations and consequently on their parasite fauna is, however, not known. The case of the recent chemical rehabilitation of Little Elkhart Lake in eastern Wisconsin provided an opportunity to examine the effect of chemically induced host population changes on the composition and prevalence of parasite species. Findings not only reflected answers to scientific curiosity, but also indicated a possible new approach to the control of some injurious fish parasites.

Materials and Background

Little Elkhart Lake is a 23-ha glacial lake that is 3 and 8 meters in average and maximum depth and 1.3 years in average water residence time, in Sheboygan County, eastern Wisconsin. The meso-eutrophic lake is an extension of hard ground water table with moderate nutrient level, e.g., total phosphorus, nitrogen, and alkalinity averaged 0.04, 1.0, and 124 mg/l, respectively, at various water depths. Dominant species of rooted aquatic vegetation included *Myriophyllum spicatum, Najas flexilis, Potamogeton illinoensis,* and *P. amplifolious.* Algae were present in low densities.

Before the chemical treatment in 1981, the fish population was dominated by black bullhead, *Ictalurus melas,* with a small number of northern pike, *Esox lucius;* walleye, *Stizostedion vitreum;* largemouth bass, *Micropterus salmoides*; bluegill, *Lepomis macrochirus;* pumpkinseed, *L. gibbosus*; black crappie, *Pomoxis nigromaculatus,* yellow perch, *Perca flavescens;* white sucker, *Catostomus commersoni*; golden shiner, *Notemigonus crysoleucas*; and yellow bullhead, *I. natalis.* A typical complex of lake invertebrates included abundant copepods and cladocerans and rare daphnias. Shore terrestrial vertebrates that may be involved in the life cycle of helminths infesting fish as larvae included many bird species (mallard, blue-wing, teal, wood duck, etc.) and mammals (mink, weasel, muskrat, raccoon, etc.); see Claggett (1981) for more details.

Little Elkhart Lake has a history of stunted sunfish and intermittent good largemouth bass populations. It is characterized by infrequent winter kill (1952, 1959), a chemical treatment and restocking with northern pike, largemouth bass, walleye, yellow perch, and golden shiner in 1961 (Schulz 1964, 1965), and subsequent accidental introduction of black bullhead, pumpkinseed, and largemouth bass by 1971. Black bullhead population increased as another winter kill in 1975 (Belonger 1976) caused weeds and undesirable fish species to become overabundant.

The lake was electroshocked to sample pre-treatment fish on September 22 and 23, 1981. On November 17, 1981, 220 gallons of rotenone were applied at a concentration of 1.5 ppm. Except for bullhead, total kill of all other fish species, including largemouth bass and sunfish, was noted. The crustacean and other invertebrate communities, however, remained practically intact (Nelson 1985a and pers. comm.). In May and June, 1982, the lake was stocked with 10,000 fingerling largemouth bass from Crystal and Gerber lakes, and 54,310 fingerling hybrid sunfish (bluegill x green sunfish) and bluegill from Beechwood Lake, as well as with 118 big largemouth bass up to 37 cm long. Subsequent electroshocking efforts in 1983 and 1984 demonstrated good survival of largemouth bass, sunfish hybrid, bluegill, and black bullhead (Nelson 1985b).

On September 1, 1988, a post-treatment sample of fish was similarly taken from the lake. Both pre- and post-treatment fish samples were promptly examined for parasites after transfer to the lab on ice. Parasites were systematically recovered and routinely processed for microscopical examination.

Results

Two fish species were collected and examined during each of the 1981 and 1988 surveys: largemouth bass (40 fish, 16–41 (mean 26) cm long in 1981 and 42, 17–28 (24) cm long in 1988) and bluegill (9, 13–18 (15) cm long in 1981 and 12, 10–20 (15) cm long in 1988). Largemouth bass and bluegill, along with all other species, except black bullhead, were totally eliminated from the lake as a result of the 1981 treatment. The 1988 samples were from new fish introductions mostly during 1982. Four pumpkinseed, 12 black crappie, and 13 yellow perch were also examined in 1981, and 7 black bullhead were examined in 1988.

In the 1981 pre-treatment study, the prevalence and intensity of *Proteocephalus ambloplitis* (Leidy) (Cestoda) infections in largemouth bass were moderate to heavy in intestinal and body cavity (gut surface, liver, spleen) locations (Table 1); only 27 mature gravid adults were localized in the intestine. The distribution of *P. ambloplitis* also extended into the body cavity of other fish species, e.g., 14 worms in 4 of 9 bluegill (Table 1), 1 in 1 of 12 black crappie, 6 in 5 of 13 yellow perch, and 4 in 2 of 4 pumpkinseed. In the 1988 post-treatment study, *P. ambloplitis* was absent from all sites in the 3 fish species examined then, including 42 largemouth bass, its major host.

The prevalence and intensity of *Neoechinorhynchus cylindratus* (Van Cleave) Van Cleave (Acanthocephala) was relatively high in largemouth bass before the chemical treatment but decreased by 1988. The opposite trend was observed in the other acanthocephalan *Leptorhynchoides thecatus* (Linton) Kostylev; its intensity of infection increased from 2.12 to 64.24 per examined fish in gut locations and from 0.37 to 0.93 in the body cavity of largemouth bass. Bluegill were not infected with either acanthocephalan species in 1981 but were considerably more frequently and heavily infected with *L. thecatus* than with *N. cylindratus* in 1988 (Table 1). In addition, 176 *L. thecatus* were also recovered from the gut of 5 of 7 black bullhead (48 worms) and the body cavity of 2 other bullheads (128) in 1988 .

In 1981, the sex ratio of *N. cylindratus* in largemouth bass was 1 male : 2.31 females (91% had eggs) and 1:1.44 in *L. thecatus* (all females had eggs). In 1988, the sex ratio was 1:0.61 and 1:0.63, in the same order. Gravid females of both acanthocephalan species were considerably less frequent than in 1981.

In addition, 33 *Posthodiplostomum minimum* (MacCallum) (Trematoda) were recovered from the body cavity of 3 of 4 pumpkinseed (32 metacercariae) and from the body cavity of 1 of 9 bluegill (1) in 1981, and 11 *Hysterothylacium brachyurum* (Ward and Magath) (Nematoda) were recovered from the body cavity (6) and intestine (5) of 7 of 42 largemouth bass in 1988.

Discussion

Parasite community succession stabilization was estimated to take at least 5 years from the initiation of major ecological shifts, e.g., impoundment (Becker et al. 1978). In this study, 8 years elapsed between the pre- and the post-treatment studies. Brown and Ball (1943), Sharma (1949), and Wright (1957) indicated that populations of microcrustaceans, e.g., *Daphnia* and *Cyclops*, were variably affected but not eliminated after treatment with rotenone. Major ecological shifts were shown not to deplete crustacean populations, e.g., copepods (Becker et al. 1978). The half life of rotenone in warm (24°C) and cold water (0°C) ponds in Wisconsin during September and March was 13.9 and 83.9 hr, respectively (Gilderhus et al. 1986). Rotenone at a concentration of 1 ppm remained toxic to bluegills in wire cages for 7–18 days in ponds during an Alabama winter but caused no residual deleterious effects upon subsequent bluegill production (Wright 1957). Mortality of caged fathead minnows, *Pimephalus promelas,* was 100% 48 hours after 0.15 mg/l rotenone treatment of a Wisconsin pond during September but

Table 1. Pre- and post-treatment surveys of parasites of *Micropterus salmoides* and *Lepomis macrochirus* in Little Elkhart Lake

			Pre-treatment (1981)		*Post-treatment (1988)*	
Fish species	*Parasite species*	*Site of infection*	*No. fish inf./exam. (%)*	*No. of parasites (mean/exam. fish)*	*No fish inf./exam. (%)*	*No. of parasites (mean/exam. fish)*
Micropterus salmoides	*Proteocephalus ambloplitis*	Intestine	34/40 (85)	138 (3.45)	0/42	0
		Body cavity	32/40 (80)	357 (8.93)	0/42	0
	Neoechinorhynchus cylindratus	Intestine	34/40 (85)	382 (9.55)	29/42 (69)	79 (1.88)
		Body cavity	2/40 (5)	2 (0.05)	0/42	0
	Leptorhynchoides thecatus	Intestine	10/40 (25)	85 (2.12)	41/42 (98)	2,698 (64.24)
		Body cavity	1/40 (2.5)	15 (0.37)	13/42 (31)	39 (0.93)
Lepomis macrochirus	*Proteocephalus ambloplitis*	Intestine	0/9	0	0/12	0
		Body cavity	4/9 (44)	14 (1.56)	0/12	0
	Neoechinorhynchus cylindratus	Intestine	0/9	0	1/12 (8)	1 (0.08)
		Body cavity	0/9	0	0/12	0
	Leptorhynchoides thecatus	Intestine	0/9	0	3/12 (25)	23 (1.92)
		Body cavity	0/9	0	6/12 (50)	28 (2.33)

declined to 0 after 72 hours (Gilderhus et al. 1986). These data support findings about the mortality of fishes and survival of Crustacea after the 1981 treatment of Little Elkhart Lake with rotenone.

The complete disappearance of *P. amblo-plitis* from bass and sunfish is perhaps the most dramatic outcome of the 1981 chemical treatment. This clearly corresponded with the mortality of the definitive host, largemouth bass (where adult worms reproduce), and the principal intermediate hosts, e.g., bluegill and other sunfish species, and probably resulted from it, following the application of rotenone.

The mortality of sunfish in 1981 was also considered responsible for the dramatic decline in *N. cylindratus* population. The major intermediate host of this acanthocephalan species is bluegill (see Becker et al. 1978); other sunfish species are important paratenic (transport) hosts, e.g., pumpkinseed among others (Hoffman 1967). The fact that one of the paratenic hosts of *N. cylindratus* is black bullhead, which survived the 1981 chemical treatment, might have helped that acanthocephalan's marginal survival (Table 1).

The assumption that the loss of *P. amblopliitis* was related to changes in the fish and not the crustacean (cladoceran, copepod, or amphipod) host populations is based on the following. The increase in *L. thecatus* infections after the treatment must have been related to the survival of its amphipod intermediate hosts including *Hyalella* sp., e.g., *H. knickerbockeri* which is also an intermediate host for *P. ambloplitis*. The mortality of the definitive and paratenic hosts of *L. thecatus*, particularly largemouth bass and sunfish in 1981, indicates that *L. thecatus* could have only survived the chemical treatment in the crustacean host. The survival of *N. cylindratus* was also possible because of the survival of its ostracod intermediate host, possibly *Cypria* sp.

The complete eradication of the bass tapeworm, *P. ambloplitis*, by eliminating its fish hosts in a closed system like Little Elkhart Lake under the above conditions points to a practical method for the control of this injurious worm. This goal can be accomplished at the same time the quality of the fish fauna is being upgraded.

The loss of the light *P. minimum* infections after the 1981 treatment might have been affected by the mortality of its centrarchid fish intermediate hosts. The new *H. brachyurum* infections in bass after 1981 were probably introduced from stocking sources. The significant changes in the sex ratio and reproductive state of the two acanthocephalan species are not fully understood.

Acknowledgments

This work could not have been done without the help and cooperation of James McNelly, Larry Claggett, and John Nelson, Wisconsin Department of Natural Resources.

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***Alan R. Spallato** contributed to the pre-treatment study while studying at the University of Wisconsin where he received his BS in Biology in 1983. He worked at the Madison Hazleton Laboratories before he became an Environmental Chemist at the State Laboratory of Hygiene, Madison, Wisconsin, in 1989.*

John L. Blum

Lemanea *(Rhodophyceae) in Wisconsin*

Lemanea Bory is a relatively large and firm, attached freshwater red alga. Seen underwater, it might easily be mistaken for a small vascular plant. It grows most conspicuously in and around waterfalls, thus in some of the more scenic and recreational sites. In the northern states, it is generally represented by a species of the subgenus *Lemanea* (formerly *Sacheria* Sirodot). The other subgenus (*Paralemanea*) consists of algae which are more complex in structure. Species of subgenus *Paralemanea* are well represented in the southern states, the Pacific states, and are especially abundant in the Ohio Valley, but have never been reported in Wisconsin. The closest collection appears to be from the Greencastle, Indiana, area. Because species of subgenus *Paralemanea* tend to occur where certain types of limestone are abundant (Palmer 1933, 1940, 1941), rapids of streams in southeastern Wisconsin where limestone strata are exposed probably represent the best possible places for finding members of *Paralemanea* within the state.

The earliest known Wisconsin collection of *Lemanea* subg. *Lemanea* was made by L. S. Cheney in 1894 in the vicinity of Stevens Point (precise location not identified) (MIN).* J. B. Moyle found it in the Black River (Douglas County) in 1940 (MIN), and J. W. Thomson also collected it there in 1942 (PH). The relative paucity of sites compared with other states led to a search for other possible locales. The author has more recently added other sites in the Pike (Dave's Falls), Pemebonwon (Long Slide Falls), and Peshtigo (Strong Falls) rivers (Marinette County), in the Potato (at Upson) and Montreal

*Herbarium specimens referenced are in the Field Museum (F), the University of Minnesota Herbarium (MIN), and the Academy of Natural Sciences of Philadelphia (PH).

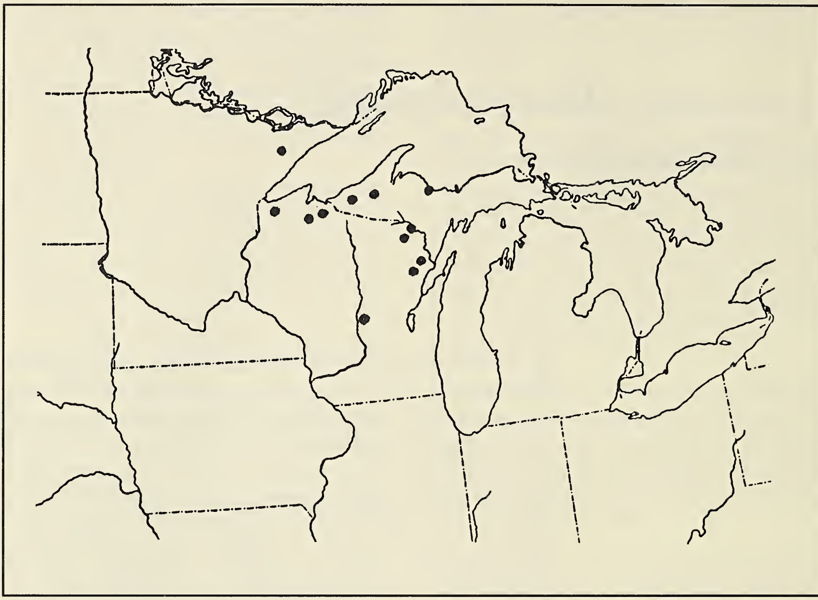


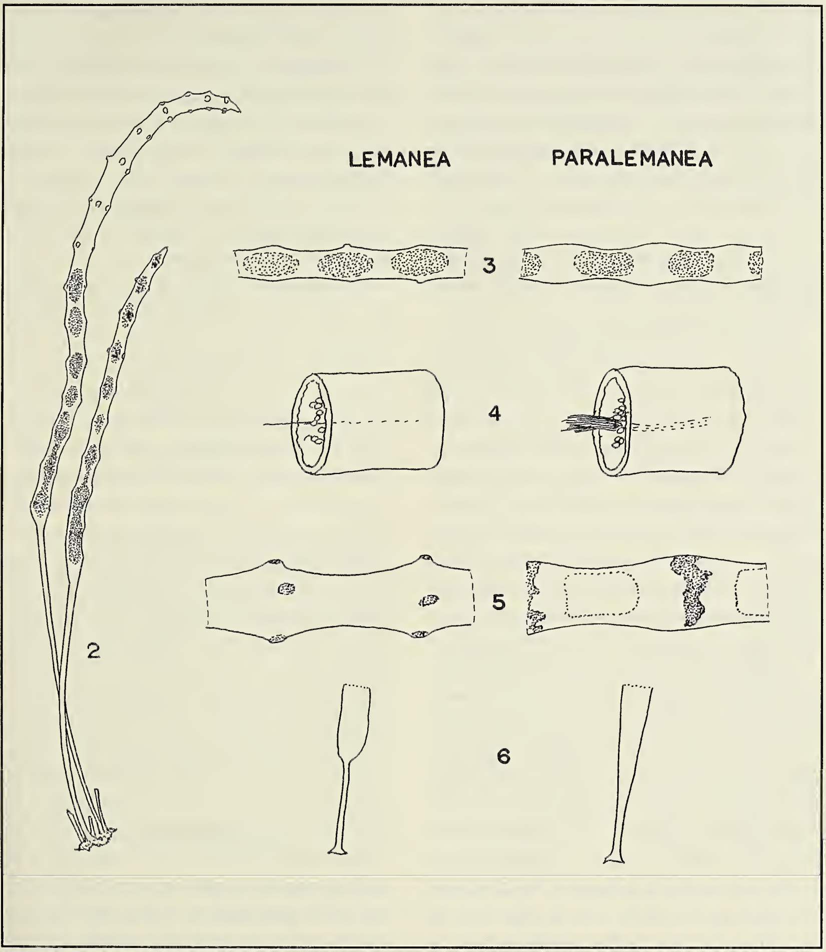
Fig. 1. Distribution of *Lemanea* (subgenus *Lemanea*) in the upper Great Lakes Region.

(near Hurley) rivers (Iron County), as well as sites in northern Michigan (Fig. 1), including Jackson Creek (Gogebic County) and the Ontonagon River (Ontonagon County). Vouchers will be deposited in F and elsewhere.

Lemanea appears to be abundant mostly over short reaches of streams. It reproduces sexually and produces large numbers of carpospores within the gametophyte thallus. Stewart (1983) and Sheath (1984) indicate that it can also grow as a perennial from attached basal filaments, and the author has found it growing at numerous sites in Indiana where C. M. Palmer found it forty or more years before.

Vis and Sheath (1992) have recently discussed and revised the taxa of *Lemanea* in North America. Their treatment permits identification of Wisconsin and Upper Peninsula material under the names of European entities, e.g., *Lemanea fluviatilis* (L.) C. Agardh and *L. fucina* Bory. In view of some uncertainties in the applications of these names, which I am unable to resolve, it seems preferable not to attempt the identification to species of my materials at this time.

The gametophytic plant of *Lemanea* bears, following fertilization, the carpospores. Various characters of the gametophyte thallus constitute the principal basis for differentiation of the two subgenera. This differentiation can usually be made with a hand lens. The thallus is nodose-cylindric in both subgenera with the carpospores visibly borne *en masse* internally at the "nodes" in subgenus *Lemanea* and at the internodes in subgenus *Paralemanea* (Figs.



Figs. 2–6. *Lemanea* (subgenus *Lemanea*) spore-producing plants from Long Slide Falls, Pemebonwon River, Marinette County, Wisconsin, collected 26 August 1985, *J. Blum #4764*. X 10. Figs. 3–6 show points of differentiation between spore-bearing plants of subgenus *Lemanea* and subgenus *Paralemanea*. Fig. 3. diagram shows relative position of the spore masses in relation to the "nodes." Carpospore masses are shown by stippling. Fig. 4. diagram contrasts the presence (subgenus *Paralemanea* with the absence (subgenus *Lemanea*) of rhizoids surrounding the axial filament. Fig. 5. diagram contrasts the position of the spermatangial areas (stipples). Fig. 6. diagram contrasts the bases of plants.

2, 3). This difference is less visible in certain species and certain specimens than in others. Sectioning the thallus reveals a single central axial filament in subgenus *Lemanea* whereas in subgenus *Paralemanea* numerous internal rhizoidal filaments surround the axial filament and constitute a strong central strand (Fig. 4) reminiscent of the stele in dicot roots. Observation of the central strand cannot easily be done with a hand lens, but free-hand sections reveal the essential point of distinction.

A third point of distinction is noted in the spermatangial (male) areas of the thallus, which are external and found at the nodes: subgenus *Lemanea* has protuberant spots of spermatogenous tissue whereas in subgenus *Paralemanea* the spermatangial areas form a nearly complete ring or band encircling the nodal areas (Fig. 5). Thus in subgenus *Lemanea* the gametangia of both sexes are found in the nodal areas; in subgenus *Paralemanea* they essentially alternate, with the nodes bearing the male gametangia and the internodes bearing the female gametangia. In early stages of growth, the minute trichogynes, the receptive external female structures, can be seen at 440X magnification. These trichogynes mark the areas where the (internal) future carpospore masses will develop; they appear on the flanks of the enlarged "nodes" in subgenus *Lemanea* and in the internodes in subgenus *Paralemanea*. The trichogynes can be seen in edge view on the silhouette of a thallus whole mount, as well as in surface view of a sufficiently cleared and stained specimen.

Lemanea carpospores are frequently ripe in populations of the eastern United States after approximately 1 July, and are dispersed when the thallus decays or breaks apart.

The fourth point of distinction is a simpler but less dependable one: the base of the gametophytic thallus in subgenus *Paralemanea* is regularly and gradually narrowed to its point of attachment, whereas in subgenus *Lemanea*, at least in Wisconsin material, there is frequently a distinct and non-nodose stipe (Figs. 2, 6) which is sharply marked off from an enlarged fertile upper part. Branching of the spore-bearing thallus in subgenus *Lemanea* is also more frequent than in subgenus *Paralemanea* or at least in the American species of *Paralemanea*.

All points of distinction can be misread: (1) The single axial filament in subgenus *Lemanea* is nearly approximated in some California *Paralemanea* species which may have only 2–4 internal rhizoids accompanying the axial filament. (2) The protuberant male areas in subgenus *Lemanea* are occasionally confluent within the nodal area and approximate the interrupted male "bands" in some material of subgenus *Paralemanea*. Additionally, this essential distinction is not easy to make without prepared slides and good microscope equipment. (3) The presence of carpospores in either nodal or internodal areas is a seasonal phenomenon and will not be observed in early spring or if fertilization has not occurred. The position of the female apparatus and carpospore masses is also considered a species character in subgenus *Paralemanea*, and in both subgenera, spores may escape from their usual position so that individuals are commonly seen with carpospores thoroughly scattered in the cavities of the gametophyte thallus. (4) The contrast between the gradually and the abruptly narrowed basal segment is frequently not pronounced.

The spore-producing haploid thallus alternates in its life history with a minute, filamentous stage, the *"Chantransia"* stage (Sirodot 1872; Atkinson 1890), which is a diploid plant. Meiosis occurs in apical cells of tiny branches that grow from the diploid, *Chantransia* stage (Magne 1967). The resulting haploid cells then develop into the macroscopic monoecious gametophytes; hence, the gametophytes develop from and are attached to the *Chantransia*. The *Chantransia* stage should not be disregarded by the collector. Bourrelly (1970) considers that the *Chantransia* stage is probably necessary for species determination in this genus. Summer collections of the spore-bearing thallus unfortunately are unlikely to have the *Chantransia* stage attached; after about 30 April, only fragments of it remain.

Summary

1. *Lemanea* (Rhodophyceae), erstwhile considered to be rare in Wisconsin, is shown to occur in streams of Iron and Marinette counties.

2. *Lemanea* may have permanent sites of residence in streams, since several places where it was collected over the past century have been successfully re-collected by the author in the 1980s.

3. Points of distinction between the two subgenera of *Lemanea* are summarized. Useful caveats in applying them are recommended and explained.

Acknowledgments

The author expresses his gratitude to Professors Michael Wynne and Neil Harriman for their detailed comments on the manuscript and to Ronald Meister and Robert Wakeman, who gave extensive help in field work.

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Joshua C. Blumenfeld

Plant ecology comes of age in the United States

Who were the first [ecologists] in America? Pound and Clements, Cowles, Gleason, Harshberger, and Harper, in about that order, followed very closely by Transeau and Shantz—

Henry A. Gleason, 1953

The final years of the nineteenth century and the first half of the twentieth century saw not only the establishment of plant ecology as a discrete field of study, but the American dominance in vegetation theory and research (Tobey 1981). The later Wisconsin work of Curtis, McIntosh, and Cottam was built on the groundwork laid by this early, and predominantly Midwestern, group of ecologists. By the time Ernst Haeckel's term "oekologie" was officially changed to "ecology" by the Madison Botanical Congress of 1893, university programs in plant ecology were already well established, with the first ecological doctorate awarded in 1879 (Arthur 1895; Gleason 1953).

Two distinct schools of thought developed in America, both centered in the Midwest: one, a holistic/organismic tradition influenced primarily by Oscar Drude and the works of Alexander von Humboldt and August Grisebach, the other, a reductionist/individualistic tradition influenced by Johannes Warming and Augustin Pyramus de Candolle (Cowles 1898; Crawley 1986; Gleason 1953). The center of the holistic/organismic school developed at the University of Nebraska (chartered in 1869), while believers in the reductionist/individualistic school gravitated to the University of Chicago (founded in 1891) (Kormondy 1965; McIntosh 1976, 1985).

Tobey (1981) points out that one possible reason for Chicago's orientation was the university's policy of strictly pure research, as opposed to the land-grant college orientation of practical science:

> Chicago's ecology was concerned less with controlling than with preserving the natural world. [Nebraskan] ecology grew out of and returned for nourishment to the practical soil of agriculture.

John Merle Coulter, a former student of Asa Gray and, most recently, president of both Indiana University and Lake Forest College, arrived at the University of Chicago in 1891 (Rodgers 1944; Sears 1969). Coulter was but one member of an impressive faculty assembled to teach at the new university and was given the task of establishing the school's Department of Botany (McIntosh 1976).

Coulter was profoundly influenced by Warming's works and based a series of initial graduate lectures on them, hampered by the fact that, at the time, Warming's works were available only in the original Danish. However, as Charles Chamberlain, a graduate student in the class, recalled, "None of us could read Danish except a Danish student, who would translate a couple of chapters, and the next day Coulter would give a wonderful lecture on Ecology" (Chamberlain 1940).

One student in the lecture series grew impatient with this slow translating process and over time taught himself Danish, eventually reading Warming's works long before an English translation was available (Chamberlain 1940). This student was Henry Chandler Cowles (1869–1939), who would eventually become chairman of the department founded by Coulter.

Cowles received a fellowship to study geology at the University of Chicago in 1895, where he initially concentrated on landforms and plant fossils and was introduced to the glacial features and beach ridges of the Chicago area (Humphrey 1961). In addition, through Coulter's lectures, Cowles quickly grasped the new ideas put forth by Warming (Chamberlain 1940).

Coulter encouraged Cowles's interest in plant ecology, suggesting that Cowles combine his extensive knowledge of geomorphology with plant ecology to see if Warming's studies of Danish sand dunes was applicable to the dunes along Lake Michigan (Cook 1980). Cowles eventually turned the results of his findings into his Ph.D. dissertation, *An Ecological Study of the Sand Dune Flora of Northern Indiana* (1898).

By this time, Cowles was the recognized expert on plant ecology at the university, and Coulter called on him to teach most of the ecology courses. Aside from his teaching duties, Cowles took an active role in writing for the *Botanical Gazette*, founded by Coulter in 1875 and published by Coulter at the university. The *Gazette* was an ideal forum for the dissemination of Cowles's research, which was published in the journal between February and May, 1899 (Cowles 1899).

Through these papers, as well as two others published between 1899 and 1901, Cowles not only established himself as one of the pre-eminent plant ecologists of the time, but also formulated two concepts which, according to Cook (1980), form the center of his theories of vegetation:

> The paramount influence of the shape of the land—the topography—on the composition of plant communities, and the patterns of change over time by which one plant community succeeds another, leading gradually to a climax formation.

In his studies of the dunes of Lake Michigan, Cowles noted several distinct communities which replaced each other before terminating in a "mesophytic beech-maple deciduous forest," which Cowles interpreted as being the final community type (Cowles 1899). Cowles noted that each successive community altered the conditions of the dune, transforming what was originally a dry environment into a much more mesic environment (Cowles 1899).

In 1901, Cowles applied Warming's methods to the much broader area of "The physiographic ecology of Chicago and vicinity; a study of the origin, development, and classification of plant societies." Published in the *Botanical Gazette* and called "a landmark in the developmental study of vegetation" (Clements 1916), the article set forth Cowles's "physiographic theory" of vegetation. This held that, along with moisture content of the soil, topographic differences were necessary to permit a variety of plants to grow at similar moisture levels (Cowles 1901).

Cowles classified the landforms of Chicago and vicinity into different series and proceeded to describe the general succession pattern in each (Cook 1980; Cowles 1901). Cowles considered different plant species occurring on different landforms with an identical degree of soil moisture to be remnants of previous successive stages in the community development (Cowles 1901). Stressing that the past history of a landform had to be considered in any study of vegetation, Cowles stated that "the laws that govern changes in plant societies are mainly physiographic; whether we have broad flood plains, xerophytic hills, or undrained swamps depends on the past and present of the ever-changing topography. The idea of constant change must be strongly emphasized" (Cowles 1901).

After 1901, Cowles dedicated most of his time to teaching, earning a full professorship in 1915 and becoming chairman of the Department of Botany in 1925 (Humphrey 1961). As Gleason (1953) states, "[Cowles's students] were Cowles's chief contribution to ecology. Go through his printed works and you will soon see that his only important scientific contributions were in his few papers on succession."

While Coulter and Cowles were shaping plant ecology in Chicago at the turn of the century, Charles Edwin Bessey (1845–1915) was applying his ideas and experience in developing the botany program at the University of Nebraska.

Bessey began his studies in civil engineering, but soon concentrated his efforts on botany (Humphrey 1961). Like his contemporary, Coulter, Bessey worked his way West, serving on the faculty of Iowa's College of Agriculture for fifteen years before being invited to the University of Nebraska to establish their Department of Botany (McIntosh 1976). Bessey, too, was a student of Asa Gray and received much of his advanced botanical training from Gray at Harvard (Rodgers 1944).

One of Bessey's key undertakings was the formation of the Botanical Seminar (Worster 1977). Originally a rather loose association of undergraduate students, the seminar became formalized by the early 1890s and was given the task of cataloguing all the native vegetation of the state before it fell to the plow (McIntosh 1985). This became the start of the Nebraska Survey, lauded by George Vasey in 1893 as "setting an example, which if followed by other States, will soon give us a complete botanical Survey of the Country" (Rodgers 1944).

The students in the seminar were an incredibly strong group, most of whom came to botany from other fields and who would, eventually, form the basis for one branch of ecological thought. This school of thought was characterized by a holistic/organismic view of vegetation, much in the tradition of Drude, and was influenced greatly by Nebraska's topography (or lack thereof) and the nature of the land-grant college (McIntosh 1985). As Worster (1977) points out, while Cowles and Gleason observed succession on the individual sand dunes of Lake Michigan, Pound and Clements concentrated on the whole of Nebraska.

Roscoe Pound (1870–1964) was one of Bessey's students in the seminar. He began his studies in law, took degrees in botany, and ended up as dean of the Harvard School of Law where he established a reputation as a legal scholar (Pound 1954; Sears 1969). Pound, along with J. G. Smith, started the Botanical Survey of Nebraska and the Flora of Nebraska, and Pound credits himself with the idea of a Phytogeography of Nebraska (Pound 1954). However, after 1901 and the publication of *The Phytogeography of Nebraska*, Pound was forced to devote all his time to law.

Another Bessey student was Frederick Edward Clements (1874–1945), called "the greatest individual creator of the modern science of vegetation" (Worster 1977) and "the outstanding ecologist of his time and generation" (Phillips 1954). Among his many accomplishments, Clements is credited with developing the classical theory of succession, a view which dominated plant ecology well into the twentieth century and which is still used in vegetation classification today (Barbour, et al. 1987; Braun 1958; Whittaker 1962).

Frederick Clements was born in Lincoln, Nebraska, just down the road from the new University of Nebraska. Clements entered the University of Nebraska, receiving his B.S. in 1894, his A.M. in 1896, and his Ph.D. in 1898 (his alma mater would later confer the honorary degree of LL.D. in 1940) (Clements 1960; Humphrey 1961).

Clements eventually rose to full Professor of Botany at Nebraska, but resigned to accept the position of Professor of Botany and Head of the Department of Botany at the University of Minnesota (1905), where he remained until 1917. From 1917 until his death in 1945, he was associated with the Carnegie Institution of Washington, D.C., where he concentrated his work on soil conservation and the ecology of the West (Barbour et al. 1987; Pool 1954).

Clements's first work in vegetation was as a student in Bessey's Botanical Seminar, to which he was the first undergraduate admitted in 1892 (Tobey 1981). At that time, Pound was one of the graduate leaders of the seminar and was attracted to Clements "by his zeal, ability and diligence," recommending him for admission and putting Clements to work on the flora of Nebraska (Pound 1954).

By 1896, Pound and Clements were working together on the fungi of Nebraska. At this time, Pound got the idea of a phytogeography of the state. The resulting work, *The Phytogeography of Nebraska*, was published in 1898, partly as Clements's Ph.D. dissertation, and gained recognition as an important new work in the field (Cowles 1898; McIntosh 1976). It is interesting to note that one of the main reviews of the book is by Cowles in *Botanical Gazette* (1898, vol. 25), who considers the work "the pioneer work of its kind in America." Cowles also brings up a subject that would be a sticking point between plant ecologists and Clements throughout his publications—his creation of new terms and words "in place of the simpler and more expressive English equivalents" (Cowles 1898).

The Phytogeography of Nebraska deals

with a study of plant formations (as opposed to the Warming concept of plant societies), which Pound and Clements describe as either primitive or recent (Pound and Clements 1898). The recent classification is further divided into origin by nascence (occurring only on bare areas) and origin by modification (occurring through changes in existing communities). However, formation by nascence *always* occurs after a plant formation is destroyed "through the agency of fires, floods, man, etc." (Clements 1916).

Of particular importance is the introduction of the quadrat method of vegetation analysis, which Pound and Clements use to determine the structure and development of vegetation (Clements 1916; Pound and Clements 1898). Basically, the quadrat method is a means for determining the composition of vegetation in a large area by looking at the vegetation of limited, and representative, smaller areas (Curtis 1959; Gleason 1920; Pound and Clements 1898).

While Pound left the seminar to pursue law, Clements continued his ecological research. *Plant Succession* (1916), Clements's eighth book, not only introduced the concept of classical succession, but became one of the most important works on plant ecology, establishing a variety of concepts and a plethora of new terms and phrases. The work is mainly a summation of Clements's earlier research into the ultimate end of plant development (called the "climax"), first treated in *The Development and Structure of Vegetation* (1904) and again in *Research Methods in Ecology* (1905).

Clements was very forthright as to the purpose of the book, stating in the introduction that "the earlier concept of the formation as a complex organism with a characteristic development and structure in harmony with a particular habitat is not only fully justified, but that it also represents the *only* complete and adequate view of vegetation" (Clements 1916) [emphasis added].

Succession in general is concerned with the process of vegetation change—the way in which populations of a particular species are gradually replaced by populations of other species over time, usually making the original site more fertile and mesic (Braun 1950; Curtis 1959). In the Clementsian view of succession, a series of different plant communities (called "seres") will occupy a given site in a set pattern based on the history of the site (Pyne 1982). Knowing the location of a particular site, it is possible, according to Clements, to predict the pattern of change from pioneer species to the ultimate "climax" community, which is controlled by climate and is self-replicating (Clements 1936; Kormondy 1965). This optimum community is regarded as being a mesic forest, although Clements makes provision for deserts and aquatic communities (Clements 1916).

The most important aspect of this process is Clements's view of the climax community as an organism (Clements 1905). This "super-organism" view is not new, and is seen in the writings of Plato (viz. *Timaeus*) as well as in the concept of the Balance of Nature. As Clements describes it:

> The unit of vegetation, the climax formation, is an organic entity. As an organism, the formation arises, grows, matures, and dies. . .The climax formation is the adult organism, the fully developed community, of which all initial and medial stages are but stages of development (Clements 1936).

Like all of Clements's earlier works, *Plant Succession* introduced a multitude of new terms and definitions. As Gleason (1953) states, "To Clements, an association was soon regarded as an organism, and he really meant organism. You know Clements's passion for terminology: if he had not meant an *organism*, he would have coined a different word." As mentioned earlier, this emphasis on new terminology would be a continuing theme in the criticism of Clements's work, noted by, among others, Cowles (1898), Tansley (1935), Egler (1951), Gleason (1953), Phillips (1954), and Whittaker (1962).

Clements continued to develop and refine his ideas of succession and the climax community, culminating with "Nature and structure of the climax," published in the *Journal of Ecology* (1936). In this encompassing article, Clements presents the crux of what is considered classical or Clementsian succession. This work was followed in 1939 by *Bio-Ecology*, co-authored with Victor Shelford, in which the concept of the "biotic community" comprising both plants and animals (the "biota") was advanced. As Worster (1977) points out, even at this late date, Clements was insistent that it was the vegetation which determined the animals in a community, not the animals which determined the vegetation. By its recognition of animals as well as plants in the community, *Bio-Ecology* was able to unite the two fields of animal ecology and plant ecology and foreshadowed the development of systems ecology in the latter half of the century.

Whittaker (1962) points out three aspects of the Clementsian system which drew criticism: the erection of a formal system of classification based on hypothetical dynamic relations, the unlikely character of some of the successional relations required of the climax theory, and the inappropriateness of the system to the interpretation of natural communities. Curtis, in his landmark work *The Vegetation of Wisconsin* (1959), criticizes in particular the delineation by Weaver and Clements (1938) of the "Lake Forest" climax community to cover the vegetation of the upper Great Lakes and St. Lawrence valley, commenting that this "is an indication of the pitfalls that may be met when attempts are made to place vegetation into a preconceived framework without supporting quantitative evidence."

The Clementsian view of succession was not the only theory being developed at this time, and alternative theories of vegetation development were brought forth (i.e. Braun-Blanquet 1913; Cooper 1926; Ramensky 1926). Of these, the most influential in the U.S. was the individualistic concept of vegetation development, which was used extensively in the work of Curtis and his students at the University of Wisconsin and most closely identified with the work of Henry A. Gleason (1882–1975) (Curtis 1959; Whittaker 1962).

Gleason was yet another Midwesterner, growing up in Illinois and attending the University of Illinois (B.S. 1901, M.A. 1904) and Columbia University (Ph.D. 1906). Gleason returned to the University of Illinois; however, in 1910 he left for the University of Michigan and in 1919 joined the New York Botanical Garden (McIntosh 1975).

Gleason grew up at the prairie-forest edge and as early as 1909 was aware that factors other than climate were influencing the transition of prairie into forest (McIntosh 1975, 1985). Further, he recognized that different types of communities could, and did, invade similar areas (Gleason 1909).

After the publication of *Plant Succession*, Gleason replied with an article entitled "The structure and development of the plant association" (1917). Gleason presents four main problems with Clements's arguments: (1) the view of the unit of vegetation as an organism, (2) the inclusion not only of the climax but of all stages leading to the climax as part of the vegetation unit, (3) a view of vegetation so complex that it requires the burdensome addition of many new terms, and (4) the exclusion of exceptions to Clements's views of plant community development "by definition" (Gleason 1917).

Gleason then proceeds to list twenty-eight points in sketching out what he calls the "individualistic concept of ecology." This thesis holds that "the phenomena of vegetation depend completely upon the phenomena of the individual [plant]" and that "individuals of the same species may occupy apparently different habitats and have different associates in different localities." Gleason points out that while many seeds of a particular species may enter an area through dispersal, the germination of a particular seed is dependent on the surrounding vegetation and the environment: those species which are best adapted to a particular combination of vegetation and environment will be selected. As Gleason states, "the association represents merely the coincidence of certain plant individuals and is not an organic entity of itself."

One important concept raised by Gleason in his article is the idea of transition zones between vegetation associations. These zones are areas of species mixing where one association ends and another begins, much like the tension zone presented by Curtis for the state of Wisconsin (Curtis 1959). This is in contrast to the Clementsian view, which holds that one would find no such mixing, but, rather, a more abrupt shift between communities as one climax turns into another (Curtis 1959; Gleason 1917; Whittaker 1962).

Finally, Gleason challenges Clements on the unidirectional trend of the climax, stating that while forest may succeed prairie, the opposite is also seen, termed retrogressive succession by Gleason. Clements denies the existence of these reversals and, according to Gleason, excludes them from his system through definition. Gleason formalized his individualistic concept in his landmark article "The individualistic concept of the plant association" (1926).

Gleason states that the two factors which most influence the structure of a plant association are the environment and the surrounding vegetation. While the vegetation of a particular area may show a great deal of homogeneity (such as the Wisconsin portion of the Mississippi Valley), this uniformity is lost when one takes a larger geographic view (such as the entire Mississippi Valley).

It is this diversity in space which forms the basis for the individualistic concept of the plant association: "The plant individual shows no physiological response to geographical location or to surrounding vegetation *per se*, but is limited to a particular complex of environmental conditions, which may be [affected] by the vegetation" (Gleason 1926). That is, a viable seed which migrates to an area of favorable environmental and vegetation conditions will germinate, while those falling into unfavorable conditions will not. To Gleason, chance, rather than a predetermined series, plays the crucial role in the appearance of the community.

To account for succession, Gleason presents a model where, because of changes in the environment, older species find it increasingly difficult to propagate. At the same time, seeds of outside species are constantly entering. Eventually the environment will pass the physiological limits of the old species and become favorable to the migrants, which proceed to propagate rapidly and thus change the form of the community. As Gleason states, "the next vegetation will depend entirely on the nature of the immigration which takes place in the particular period when environmental change reaches the critical stage" (Gleason 1926).

To say that Gleason's concepts generated criticism would be an understatement. As Gleason recounts, his concept was debated in 1926 at the International Botanical Congress and met with sharp disagreement and ridicule (Gleason 1953). By the end of the conference, the taxonomists still supported Gleason, but the ecologists would have no part of him, in effect ostracizing Gleason for about ten years (Gleason 1953).

As McIntosh (1975) points out, until the late 1940s, Gleason's concepts were essentially ignored in the popular texts of the period, appearing in only one textbook, *Plant Ecology* (McDougall 1927), and then barely mentioned. However, in 1947, F. E. Egler, S. A. Cain, and H. L. Mason all published articles in *Ecological Monographs* strongly supporting Gleason's individualistic concept of the plant association. It is interesting to note that this revival of the individualistic concept occurred only after the death of Clements in 1945.

By the time the articles came out, Gleason had stopped publishing articles on ecology (his last strictly ecological article appeared in 1939) and devoted his efforts to taxonomy, a field in which he excelled and found more support (Steere 1958). McIntosh (1975) notes that Gleason is probably the only person who is cited in bibliographies as both the author of a major ecological concept and the source of the plant nomenclature used.

The works of the European ecologists exerted great influence on the development on the Clementsian and Gleasonian theories and concepts. In fact, it appears that an individualistic concept of the plant association was put forth in a number of countries at about the same time: Ramensky in Russia, Negri in Italy, and Lenoble in France (Kormondy 1965; McIntosh 1975). Ramensky's ideas are remarkably similar to those of Gleason; he presents a concept of vegetation continuity and species individuality in his "Die grundgesetzmassigkeiten im aufbau der vegetationskecke," published in 1926, the same year as Gleason's article. Ramensky also states that observation of communities cannot be done by a reduction of the community to small units. Rather, he suggests the use of statistical surveys of greater areas and the averaging of these surveys, which would include such factors as frequency and abundance, a method which bears striking resemblance to that used by Curtis in *The Vegetation of Wisconsin* (1959) (Kormondy 1965).

The Clementsian school also had its European supporters, including Sukachev (or Sukatchew) in Russia, who likewise viewed the community as a distinct entity. It appears that the Ramensky/Sukachev difference was essentially a Russian version of the Gleason/Clements arguments, with Sukachev taking a dominant role and the works of Ramensky being suppressed for quite some time after publication (Kormondy 1965; McIntosh 1975).

Clements and Gleason were not the only ecologists in America making headway in plant ecology during the first half of the century. As Gleason points out, a number of ecologists contributed to the establishment of plant ecology (Gleason 1953). Two who made large contributions to plant ecology at the time are John W. Harshberger and William S. Cooper.

John W. Harshberger (1869–1929) spent his academic career in Philadelphia and concentrated his studies primarily on plant geography (Humphrey 1961). By far his greatest contribution to plant geography is the authorship of volume 13 of *Vegetation der Erde: Phytogeographic Survey of North Amer-*

ica (1911). While many considered this work unreliable and inaccurate, Egler (1951) points out that this work "presents an overall picture of what vegetation *is*, rather than what the successions and climax theoretically are."

Among Harshberger's more regional studies are "An ecological study of the New Jersey strand flora" (1900) and "An ecological study of the flora of mountainous North Carolina" (1903). Of particular interest in the "North Carolina" article is the recognition of shade tolerant and shade intolerant trees, which Harshberger proceeds to classify. Like Curtis (1959), Harshberger recognizes sugar maple as being the most shade tolerant while white oak is placed near the bottom of the tolerance list. Overall, Harshberger recognizes that the vegetation of an area becomes stratified due to changing conditions of moisture and light. Whittaker (1962) credits this article as being one of the first to distinguish the formation and the association in their modern senses.

William S. Cooper, a student of Cowles, directed his research at the University of Minnesota toward studying succession and the mechanisms behind the climax community (McIntosh 1985). While Cooper studied succession throughout the United States, his very detailed studies on Isle Royale are of particular note to the Midwest.

After studying trees and vegetation, Cooper reached the conclusion that a linear succession did not necessarily exist. Rather, vegetation was in the form of a "flickering mosaic" in a state of continuous change brought on by small disturbances, especially windfalls (Cooper 1913, McIntosh 1985).

Cooper's ideas of vegetation change are most succinctly stated in "The fundamentals of vegetative change" (Cooper 1926). Cooper emphatically rejects the Clementsian concept of the super-organism to represent the development of the plant community, stating that while the concept of an organism is convenient in the descriptive sense, its application to vegetation in a biotic sense is totally unwarranted.

To describe the development of the plant community, Cooper proposes a model of a braided stream. Cooper begins with two premises: (1) the universality of change, that is, a study of vegetation must include not only the present but also the past, and (2) the field of study must include *all* types of vegetation change. Cooper then likens the vegetation of the earth to a flowing stream, which is composed of braids and which has its headwaters in the distant past. While many small streams strive to take an individualistic path, the merging and simplification is balanced by a growing diversification in species. These changes may be fast or slow, with the so-called climax community representing a stream which is changing at an imperceptibly slow rate. As Cooper summarizes, "Vegetational change is due to the interaction of changing organisms and changing environment, just as the contour of a stream is continually modified by the interaction of its changing current and changing banks."

This, then, was the state of plant ecology at the end of the first quarter of the twentieth century. Establishment of the Ecological Society of America in 1915 did much to advance the spread of research in the field by bringing together both plant and animal ecologists, while the journals of the Society, *Ecology* and *Ecological Monographs*, served as the American outlets for ecological research (Sears 1969).

From its first formal beginnings at Chicago and Nebraska, plant ecology literally burst upon the scientific consciousness in the twentieth century, not only establishing itself as a formal and respected field of professional study, but supplying the initial paradigms of thought—the Clementsian and Gleasonian views of community development. Supplemented by the theories of Harshberger and Cooper, among others, plant ecology entered the next phase of its development in the United States. The University of Wisconsin played a key role in this next phase, with the works of Curtis, McIntosh, and Cottam helping to synthesize the Clementsian and Gleasonian views in the creation of a more modern view of community development aided by mathematical and statistical analysis.

Acknowledgments

The author wishes to express his appreciation for the advice and input given by Dr. Calvin DeWitt, Dr. Elliott Sober, and Dr. Edward Beals (retired) of the University of Wisconsin-Madison. Sincere thanks to Barbara Borns and the staff of the Institute for Environmental Studies for their help in the production of this project.

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Quentin J. Carpenter and Calvin B. DeWitt

The effects of ant mounds and animal trails on vegetation pattern in calcareous fens

Plant communities are not distributed randomly over the landscape, but are correlated with various climatic, topographic, geologic and biotic factors, including many anthropogenic features (Jenny 1980). Similarly, most plant communities are not homogenous, and the distribution of species within a community is correlated with special niches (Whittaker 1970). In calcareous fens, some previous authors (e.g., Frederick 1974; Reed 1985; Boyer and Wheeler 1989) have noted a two-part pattern in many (but not all) sites. This pattern consists of a zone of taller herbaceous vegetation, termed "Fen Meadow" (Frederick 1974), contrasted with a short zone, described as "Marl Meadow" (Fredrick 1974) or "Discharge Window" (Reed 1985). The "Marl Meadows" often include many of the "Fen Meadow" species in depauperate form, but they also include other uncommon or rare species, not found generally distributed on the fen. Recent studies suggest that this tall-short contrast may be due to geochemical processes which affect the availability of phosphate and potassium to the plants (Boyer and Wheeler 1989; Wassen et al. 1990).

In observing a number of fen communities in southern Wisconsin, we have noticed two other possible sources of vegetation heterogeneity, both of them biotic: ant mounds and mammal trails. Ant mounds, while not usually common on fens, are very noticeable, often rising 10 to 30 cm above the general surface and bristling with vegetation. A few ant mounds are a meter in diameter, but most tend to be less than 0.5 m across. Bruskewitz (1981) found that the locations of ant mounds were positively correlated with the occurence of shrubs on the Waubesa Peat Mound Fen in southern Wisconsin, but did not examine the relationships of other species to ant mounds. The species of ant which builds mounds on calcareous fens in this area is *Formica montana* [= *Formica cinerea montana*], the same species which is responsible for most mound building on Wisconsin prairies (Greg Henderson, pers. comm., 1988). Studies of this species at a wet prairie site in southwestern Wisconsin found that hydraulic conductivity and nutrient availability were higher in the ant mounds than in the surrounding gleyed soil; vegetation-ant relationships were not studied (Dening et al. 1977).

The mammal trails through the zone of tall vegetation ("Fen Meadow") appear to be made by deer, muskrats, raccoons, and humans. Our observations suggest that these trails often contain species which we more commonly find in the "Marl Meadows" zone; in fact, animal trails are often the only place where we noted these species in fens where no clear "Marl Meadow" zone was identifiable. The present study was designed to test our perceptions by obtaining quantitative vegetation data to answer the following two questions:

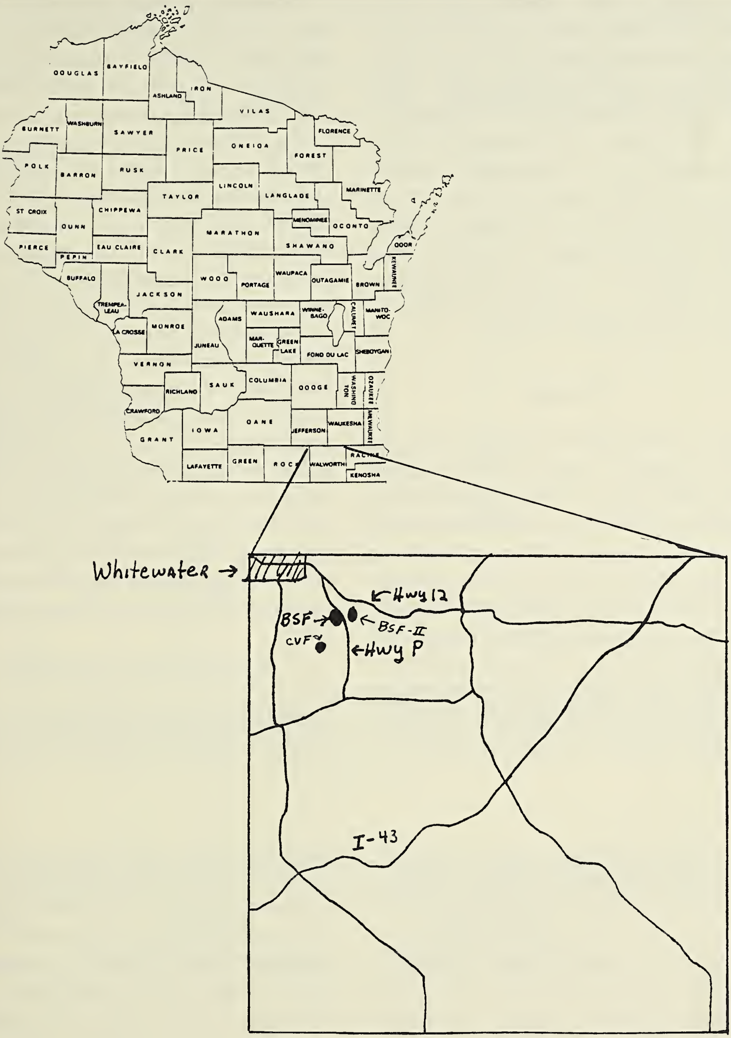
1. Is the vegetation found on or near fen ant mounds significantly different from that of the fen in general?

2. Is the vegetation found on or near trails made by animals across fens significantly different from that of the surrounding fen?

Methods

All ant mounds on three calcareous fens in Walworth County, Wisconsin, were marked while collecting general vegetation data from these sites for a related study (Carpenter 1990 and unpublished). Nine ant mounds were located on Bluff Springs Fen I (BSF-I), 18 on Bluff Springs Fen II (BSF-II), and 15 on Clover Valley Fen (CVF) (Fig. 1). During late summer or early fall, the vegetation on and immediately surrounding each of these ant mounds was surveyed using a square 1 m^2 quadrat frame centered on the ant mound, while the general vegetation of the fens was surveyed using the same apparatus randomly placed within cells of a grid system which covered most of each fen (Carpenter 1990). Species abundance data were recorded as per cent cover. After arc-sin square root transformation, means for each species found in quadrats centered on ant mounds on a particular fen were compared to means of the same species obtained from the general survey of the same fen using an unpaired t-test (Snedecor and Cochran 1980). Because the ant mound surveys and the general vegetation surveys were not conducted at the same time (time differences varied from two to four weeks depending on the site), a conservative standard of difference ($p < .01$) was adopted recognizing that the relative abundances of many species change gradually throughout the season.

To determine if the vegetation on or very near animal trails differed from the adjacent fen vegetation, 15 quadrat pairs were read on BSF-I on 16 September 1988 and 13 quadrat pairs on BSF-II on 30 September 1988; a distinct animal trail of sufficient length to provide at least 10 paired sampling locations could not be located on CVF. The 1 m^2 quadrat pairs shared an edge and were spaced at 5 m intervals along a fisherpersons' trail (BSF-I) and a deer trail (BSF-II) which crossed the respective fens east-west. At each sampling point, the quadrat frame was first read centered on the trail. It was then flipped over, to the south at the first sampling point, to the north at the second, etc., such that 15 (or 13) vegetation samples were obtained centered on the trail, and 15 (or 13) samples were obtained centered 1 m off the trail in



County.

Fig. 1. Location of study site in Wisconsin and Walworth County. Source: State Cartographers Office, Madison.

nearly equal numbers on either side of the trail. As in the ant mound survey, abundance data were collected as per cent cover, then arc-sin square root transformed for statistical analysis. Because of the small sample size, only those species which attained at least 0.5% mean cover were subjected to statistical analysis. Means were compared using a paired t-test (Snedecor and Cochran 1980). Since the paired design of this part of the study allowed better control of time and distance disparities, a less rigorous standard of difference ($p < 0.05$) was used.

Results

Table 1 summarizes the results of the general fen vegetation versus ant mound vegetation study. Only one species, *Muhlenbergia mexicana*, was found to be significantly more common (at $p < 0.01$) on or near ant mounds when all three fens were lumped. Three other grasses, *Andropogon gerardii, Bromus ciliatus* and *Sorgastrum nutans,* met a lower standard ($p < .05$) on at least two of the three fens, suggesting a possibly weaker association with the ant mounds. No broadleaf herb or shrub met either standard.

Tables 2 and 3 present summaries of the data from the mammal trail surveys for BSF-I and BSF-II. Thirty six taxa met the 0.5% mean cover criterion on at least one fen; fifteen of these taxa were shared by both fens. The data from Tables 2 and 3 suggest that 38% of the taxa considered from BSF-I and 44% of those considered from BSF-II were affected significantly ($p < 0.05$) by the proximity of trails. Nevertheless, while each fen contained many species affected by trails, only three taxa (*Lobelia kalmii, Parnassia glauca,* and bare ground) were significantly more common on trails in both fens; *Parnassia glauca* was strongly favored ($p < 0.01$) on both sites. Only detritus was negatively associated ($p < 0.05$) with trails on both fens. Disregarding significance, eleven of the fifteen taxa in common varied monotonically (i.e., the taxon increased or decreased on both fens), while four species did not. No taxon was significantly favored on one fen, but significantly disfavored on the other.

Discussion and Conclusions

Muhlenbergia mexicana and perhaps some of the prairie grasses are more common on and

Table 1. Summary of distribution of *Muhlenbergia mexicana* on three fens in Wisconsin. Mean cover on ant mounds was compared to that over the general fen using an unpaired t-test.

	Ant mounds		*General Fen*		*p-value*
Site	*mean % cover*	*presence*	*mean % cover*	*presence*	*(cover)*
BSF–I	23	8/9	0.15	2/20	p<0.001
BSF-II	12	10/18	1	7/30	p<0.01
CVF	10	8/15	1.5	13/29	p<0.03
Combined data	13.6	26/42	1.0	22/79	p<0.01

Table 2. Summary of trail study on Bluff Springs Fen I, 26 August 1988.

Species tested	*Raw mean on trail (% cover)*	*Raw mean off trail (% cover)*	*Raw difference (on-off)*	*t-value after arc-sin sqrt transform)*	*Significantly different @ 5% level*	*Significantly different @ 1% level*
Aster lateriflorus	0.9	0.9	0.0	0.00		
Aster puniceus	1.8	1.3	0.5	1.76		
Carex leptalea	2.1	3.9	-1.9	-1.77		
Circium muticum	0.9	0.9	0.0	0.00		
Cornus stolonifera	1.1	11.1	-10.0	-3.16	D	D
Eupatorium maculatum	0.5	1.7	-1.2	-1.89		
Eupatorium perfoliatum	1.0	1.7	-0.7	-0.63		
Gerardia purpurea	0.6	0.2	0.4	2.52	F	
Lobelia kalmii	0.9	0.6	0.3	2.19	F	
Lysimachia quadriflora	2.0	1.1	0.9	2.10		
Muhlenbergia glomerata	1.7	2.6	-0.9	-1.12		
Panicum flexile	1.6	0.7	0.9	2.46	F	
Parnassia glauca	2.6	1.0	1.6	3.87	F	F
Rhynchospora capillacea	9.5	2.5	7.0	2.12	?	
Rudbeckia hirta	0.9	0.7	0.1	0.78		
Scirpus acutus X validus	3.3	3.9	-0.6	-0.32		
Scleria verticillata	14.0	4.5	9.5	3.56	F	F
Solidago ohioensis	6.7	6.9	-0.3	0.32		
Sorgastrum nutans	6.4	4.8	1.6	1.24		
Bare ground	10.0	1.9	8.1	5.41	F	F
Dead material	9.0	11.0	-2.0	-2.32	D	

Data are from 15 paired 1-m-square quadrats centered either on or 1 m from the center of a human trail. After arc-sin square root transformation, differences in means were compared using a paired t-test. An "F" indicates a taxon significantly more common on or near a trail (= Favored). A "D" indicates a taxon significantly less common on or near the trail (= Disfavored).

around ant mounds than in the general fen. From observations of the behavior of the mound-building ant *Formica montana* on the Whitewater area fens over several seasons, we suggest the following explanation for this association: during April the ants clear away all dead material on or near their mound; during May and the early part of June, they prune any green shoots which erupt through the mound. During the summer, however, shoots are allowed to grow and often drape over the mound. We suspect the ants' vegetation management is related to thermo-regulation of the ant mound, removing shading vegetation in the cool spring, but allowing it to grow in the hot summer. Whatever the reason for the ant behavior, the repeated cutting of shoots seems to favor late-season grasses, which often do not emerge until June and which flower in the late summer. Further, we have observed that, of all the grasses found on fens, *Muhlenbergia mexicana* is the last to flower, sometimes as late as early October; we suspect that the strong association between this grass and the ant mounds is

Table 3. Summary of trail study on Bluff Springs Fen II, 16 September 1988.

Species tested	*Raw mean on trail (% cover)*	*Raw mean off trail (% cover)*	*Raw difference (on-off)*	*t-value (after arc-sin sqrt transform)*	*Significantly different @ 5% level*	*Significantly different @ 1% level*
Aster junciformes	0.2	0.6	-0.5	-2.82	D	
Aster lateriflorus	1.9	1.5	0.4	1.95		
Aster puniceus	1.0	1.1	-0.1	-0.13		
Betula pumila	14.2	21.9	-7.7	-1.72		
Carex lasiocarpa	2.3	2.3	0.0	-0.00		
Carex leptalea	9.4	4.4	5.0	3.69	F	F
Carex sterilis	7.7	6.1	1.6	1.38		
Carex stricta	8.2	9.8	-1.5	-0.53		
Cladium mariscoides	1.3	0.9	0.4	0.47		
Comandra richardsiana	1.4	0.2	1.2	2.33	F	
Cornus stolonifera	1.9	5.8	-3.8	-1.08		
Eleocharis rostellata	3.8	1.9	1.9	1.26		
Eupatorium maculatum	0.9	1.8	-0.9	-0.34		
Galium boreale	1.9	3.1	-1.2	-2.17		
Lobelia kalmii	1.1	0.2	0.9	5.55	F	F
Lysimachia quadriflora	1.3	0.7	0.6	3.09	F	F
Muhlenbergia glomerata	5.9	2.1	3.8	5.78	F	F
Muhlenbergia mexicana	1.2	0.7	0.5	0.21		
Parnassia glauca	1.2	0.3	0.9	3.73	F	F
Potentilla fruticosa	18.5	28.8	-10.4	-2.43	D	
Pycnanthemum virginianum	1.3	0.8	0.5	1.19		
Rudbeckia hirta	0.7	0.1	0.6	2.21	F	
Scirpus acutus	4.6	4.8	-0.2	-0.27		
Solidago gigantea	0.5	0.7	-0.2	-0.49		
Solidago ohioensis	5.3	1.8	3.5	4.96	F	F
Solidago uliginosa	1.6	0.2	1.4	4.69	F	F
Sorgastrum nutans	5.0	2.5	2.5	1.57		
Typha latifolia	1.3	1.2	0.2	-0.05		
Valeriana cilliata (edulis)	2.5	0.8	1.7	3.28	F	F
Viola cuculata	1.1	0.6	0.5	1.50		
Bare ground	5.3	2.6	2.7	2.78	F	
Detritus	8.5	17.5	-9.0	-2.90	D	

Data are from 13 paired 1-m-square quadrats centered either on or 1 m from the center of a deer trail. After arc-sin square root transformation, differences in means were compared using a paired t-test. An "F" indicates a taxon significantly more common on or near the trail (= Favored). A "D" indicates a taxon significantly less common on or near the trail (= Disfavored).

somehow related to this trait. The increased hydraulic conductivity and nutrient availability found by Denning et al. (1977) may also play a role in favoring grasses on or near ant mounds.

The trail at the base of BSF-I is used primarily by persons trout fishing in Bluff Creek and to a lesser extent by deer, raccoons, and mink, while the trail on BSF-II appears to be used mostly by deer. Most of the species favored by the trails, such as *Carex leptalea* and *Lobelia kalmii*, are also small, and were classified as "competition-intolerant species" by Zimmerman (1983). If this classification is correct, they would be expected to benefit from the trampling in the center of a trail which might more adversely affect some of the larger competitors. Others, however, such as *Solidago ohioensis* and *Muhlenbergia glomerata*, are among the tallest and most common herbs on these fens (Carpenter 1990); thus, the single explanation of competition intolerance may not apply to all species affected. We suggest that the increased vigor of the apparently more competitive species may be analogous to the pattern one sees along a sheep or cattle trail in a pasture where the grass grows tallest and greenest just at the edge of a trail (personal observation). The simplist explanation for this observation is that the taller and greener plants are far enough away from the center of the trail to avoid trampling, yet close enough to the trail to benefit from the extra nutrients found in manure and urine.

The disfavored shrubs (*Cornus stolonifera* on BSF-I and *Potentilla fruticosa* on BSF-II) may be victims of browsing or are perhaps simply killed by trampling when small. One might speculate that the trails were simply rerouted around shrubs; however, inspection of several aerial photos of the sites (1947 to 1980) suggests that the trails are long established and relatively straight.

The idea of trails, especially human trails, across natural areas is a complicated and often emotional issue. On the one hand, the evidence presented here suggests that trails provide special habitat for some uncommon competition-intolerant species; on the other hand, trails provide access for humans to damage the integrity of the natural area by excessive trampling, flower picking and inadvertant introduction of exotics such as purple loosestrife (*Lythrum salicaria*) and fen buckthorn (*Rhamnus frangula*). Many disturbance or pioneer wetland species are commonly associated with fens (Zimmerman 1983). Observations from fens in Wisconsin, Iowa, and Ohio (Zimmerman 1983; Loeschke 1991; Denny 1991) which have had their surfaces severely disturbed but have maintained their former groundwater supplies suggest that many of the rare competition-intolerant species such as *Scleria verticillata, Parnassia glauca,* and *Rhynchospora capillacea* appear in great abundance after disturbance. Thus, we suggest that all disturbance is not detrimental to fens and that managers must judge specific types of disturbances on their individual ecological merits or dangers.

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Lee Clayton and John W. Attig

Exhumed early Paleozoic landforms on the Baraboo Hills, Wisconsin

Abstract *The Baraboo Hills of southern Wisconsin consist of extremely durable Precambrian quartzite. Some of the well-preserved landforms seen there today were formed during the early part of the Paleozoic, were then buried, and were subsequently exhumed in Mesozoic or Cenozoic time. Valleys in the western part of the South Range were cut in Middle Cambrian time or earlier and buried in Late Cambrian time. Subsummit benches and scarps were cut by marine shore erosion in early Ordovician time and buried soon after. Summit plateaus were cut by subaerial or marine-shore processes, probably in Middle Ordovician time, and buried in Late Ordovician time.*

The Baraboo Hills of south-central Wisconsin (Fig. 1) contain some remarkably well-preserved Paleozoic landforms. Late Cenozoic landforms are present, but in this paper we conclude that many of the landforms were cut into the Baraboo quartzite early in the Paleozoic, buried soon thereafter, and exhumed in late Mesozoic or early Cenozoic times. These Paleozoic landforms include valleys, subsummit benches and scarps, and summit plateaus.

Although some of these landforms were recognized more than a century ago (Irving 1877, 504–05), they were poorly known until studied by Thwaites (1931, 1935, 1958, 1960). However, some elevations on the topographic maps available to Thwaites are in error by more than 100 m, and some features are misplaced horizontally by as much as 1 km. As a result, Thwaites was unable to adequately document the location and elevation of the landforms or to convincingly demonstrate the relationship between these landforms and the Paleozoic formations of the area.

Accurate topographic maps now exist, and the geology of the region has been mapped in greater detail (Dalziel and Dott 1970; Clayton and Attig 1990; Attig and Clayton 1990; Attig et al. 1990). As a result, we now are able to document the el-

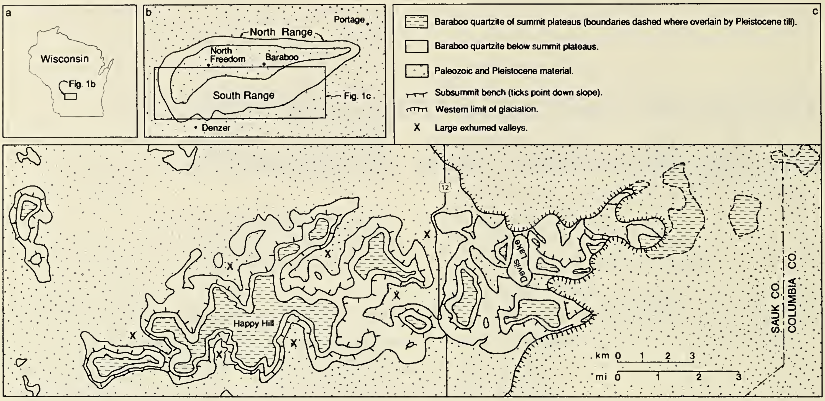

Fig. 1. Location of landforms of the South Range of the Baraboo Hills.

evation and the location of these landforms and relate them more confidently to the Paleozoic stratigraphy of the region. In this paper we reevaluate Thwaites' speculations about the age and origin of these landforms.

Description

The Baraboo Hills

The geology of the Baraboo Hills has been outlined by Dalziel and Dott (1970) and Clayton and Attig (1990). In the area surrounding the Baraboo Hills, Paleozoic rock lies on a generally flat unconformity on Precambrian rock. Before the Paleozoic sediment was deposited, the Baraboo Hills rose more than 350 m above the surrounding plain (Fig. 2). Then, as now, the hills were made up of quartzite of the Baraboo Formation, which was more than 1.5 km thick. The quartzite consists of quartz sand that underwent low-grade metamorphism to produce a rock that is highly resistant to erosion. The Baraboo Formation was folded into a doubly plunging syncline, resulting in the oval pattern of hills shown in Figure 1b. The north and south halves of the oval are called the North Range and the South Range, respectively.

The Baraboo Hills then were buried with quartz and lime sand during Late Cambrian and Early Ordovician time. At least the top of the South Range was reexposed by erosion during Middle Ordovician time, and the hills again were buried during Late Ordovician time, beginning with the quartz sand of the St. Peter Formation. By Late Paleozoic time, an additional few hundred meters of marine sediment had probably been deposited on top of the hills. Marine deposition had ceased by late Pennsylvanian time (Shaver et al. 1985). During the ensuing 200 million years, the land surface was lowered to near the level of the top of the Baraboo Hills.

The summit of South Range probably was exposed again just before the fluvial gravel of the "Windrow Formation" was deposited on one of the highest parts of the South Range, above the East Bluff of Devils Lake (Fig. 1c; Thwaites and Twenhofel

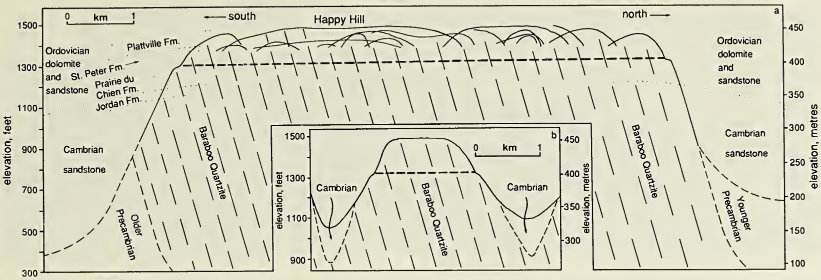

Fig. 2. **a**: Composite profile of summit plateaus of the South Range (the thin, solid lines at the top of the diagram), viewed from east to west. Vertical exaggeration x 10. The position of the subsummit benches is shown with a heavy dashed line. The thin dashed lines in the Baraboo quartzite indicate dip of the quartzite. The Precambrian, Cambrian, and lowest Ordovician stratigraphy shown at the north and south flanks of the range is based on local information, but the Platteville Formation has been projected from an area 40 km farther south. **b**: Cross section through a representation plateau, with flanking valleys and valley fills (middle of the South Range; sec. 17, 20, and 28, T11N, R6E).

1921, 296–97). It is unknown when that event occured, but guesses have generally ranged from Early Cretaceous to Pliocene (Thwaites and Twenhofel 1921, 307–10; Andrews 1958; Anderson 1988, 255–56). The landscape surrounding the Baraboo Hills since then has been lowered about 60 m at the west end, 250 m at Devils Lake (Fig. 1c; WGNHS Geologic Logs Sk-17 and Sk-39), and 300 m at Portage near the east end of the hills (Fig. 1b; WGNHS Geologic Log Co-634). The stratigraphic relationships summarized here and shown in Figure 2a indicate that the Baraboo Hills are much the same shape today as they were in Middle Cambrian time.

Valleys

The North and South Ranges of the Baraboo Hills are irregular quartzite ridges cut by gorges and valleys. The gorges have been cut completely through the ranges. They had a complex history, including considerable Pleistocene erosion when they functioned as spillways of glacial Lake Wisconsin (Clayton and Attig 1989); they will not be further discussed.

In contrast, the valleys head within the ranges. The largest valleys in the unglaciated part of the South Range are marked by *X*s in Figure 1c. These are a few kilometers long, about 1 km wide, and about 100 m deep. They tend to be of uniform width and abruptly terminate at broad, rounded valley heads. The valleys are walled with Baraboo quartzite, but their bottoms are generally underlain by 20 to 60 m of Cambrian sandstone and conglomerate (Fig. 2b).

Subsummit Benches and Scarps

Nearly flat benches have been cut into the Baraboo quartzite on the sides of each of these valleys (Fig. 1c, 2a, and 2b). The benches are typically a few tens of meters wide. Above the bench is a scarp with a slope of about 20°. Below the bench, the valley side typically slopes about 10° to 15°. The benches are about 30 m below the edge of the summit plateaus (Fig. 2a), and are at nearly the same elevation throughout the South Range, descending slightly to the south at about 1 m/km; they are at an elevation of about 402 m (1320 ft) on the north side of the South Range and at about 393 m (1290 ft) on the south side.

The benches are generally covered by forest, but, even so, in many places they are obvious from a distance (Fig. 3a). In addition, they are generally conspicuous in the few places where crossed by roads, especially when leaves are off the trees and patches of snow remain on the bench after a thaw. The benches can be seen where Freedom Road descends from the summit plateau on the south side of Happy Hill (4 km northeast of the community of Denzer) and at the junction of Tower and Denzer Roads (6 km north of Denzer; Fig. 3b).

Summit Plateaus

The highest hill tops in the unglaciated part of the South Range are remarkably flat (Fig. 2a, 2b, and 3c). These summit plateaus are typically about 0.5 km wide, with a maximum width of 1.5 km and a maximum length of 7.5 km (Fig. 1 and 2). The middles of the plateaus, at elevations between about 430 m (1410 ft) and 454 m (1490 ft), are horizontal, with slopes increasing to several degrees near the edge, at elevations between about 421 m (1380 ft) and 433 m (1420 ft). The plateaus are quartzite overlain by a few meters of yellowish-brown silt and clay containing quartzite fragments. Thwaites (1935, 401; 1958, 147; 1960, 37–38) reported scattered loose fragments of Paleozoic chert on the plateau surface, as well as a few small exposures of in-place lower-Paleozoic conglomerate along the edge of the plateaus.

Age and Origin

Valleys

Most large valleys in the South Range are known to have formed before Late Cambrian time, because there is Late Cambrian sandstone and conglomerate in the valley bottoms (Fig. 2b; Dalziel and Dott 1970). The valleys are known to have been at least 20 to 60 m deeper at the beginning of Late Cambrian time than they are today, because the Late Cambrian fill is that thick, and the interfluves may have been considerably higher, if the summit plateaus were eroded in Ordovician time, as will be discussed. Otherwise, the general shape of the valleys probably has changed little, because thin patches of Cambrian rock occur in a few places high on the valley walls (Thwaites 1935, 401; Thwaites 1958, 147; Thwaites 1960, 38).

Most large valleys in the unglaciated part of the South Range are shaped like typical stream valleys. They require no explanation other than hillslope and stream erosion through Early and Middle Cambrian time and perhaps also during latest Precambrian time.

Subsummit Benches and Scarps

The subsummit benches on the South Range are not structural terraces, because they slope only about 1 m/km (less than 0.1°) but are cut in quartzite that dips 10° to 40° (Fig. 2). These are not fluvial terraces because they slope to the south, whereas the valleys slope north and south on either side of the range. Thwaites (1935, 401; 1958, 147–48; 1960, 38–39) concluded that these benches and the scarps above were cut into the quartzite by marine shore erosion. We agree, because no other explanation seems

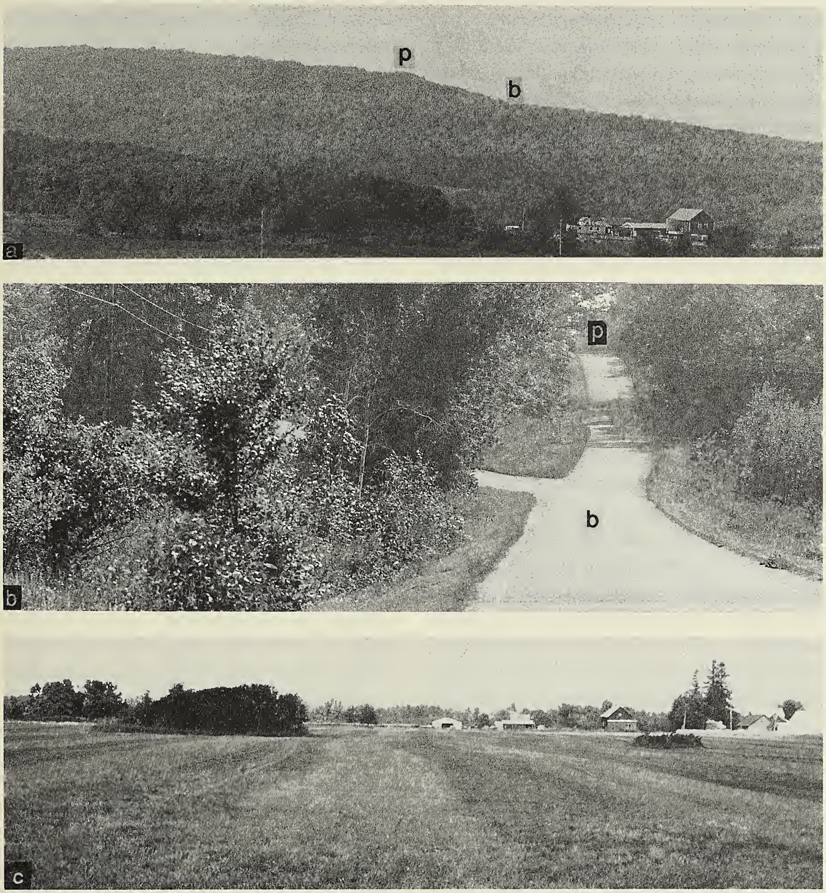

Fig. 3. **a**: North edge (p) of the summit plateau northeast of Happy Hill (Fig. 1c), with subsummit scarp (p-b) and bench (b); taken west-northwestward from middle of NE ¼ sec. 22, T11N, R6E. **b**: West edge (p) of the summit plateau of Happy Hill, with subsummit scarp (p-b) and bench (b); taken southward at southwest corner of SE ¼ SW ¼ sec. 27, T11N, R5E. **c**: Summit plateau of Happy Hill; taken northward from the south edge of the SE ¼ SE ¼ SE ¼ sec. 26, T11N, R5E.

plausible. However, the scarps clearly have been rejuvenated in places by mass movement when permafrost was present during the Pleistocene (Clayton and Attig 1990).

Although there is no direct stratigraphic evidence, these shore benches were most likely cut during the Ordovician. Patches of early Paleozoic conglomerate occur locally on the slope just below the benches (Thwaites 1958, 147; Thwaites 1960, 38). The formations present on either flank of the South Range can be projected into the range (dotted lines in Fig. 2a), using the stratigraphic and structural information of Clayton and Attig (1990, Plates 1 and 2, Fig. 13 and 14); the contact between the Jordan Formation (Late Cambrian) and Prairie du Chien Formation (Early Ordovician) is about 30 m below the benches. The original thickness of the Prairie du Chien here is unknown, but it is 60 m thick 40 km to the south (WGNHS Geologic Log Dn-993) and may have been that thick across the South Range. If the Prairie du Chien dolomite was deposited near sea level on the Baraboo Hills, the benches would have been cut before the upper Prairie du Chien was deposited, during Early Ordovician time, as suggested by Thwaites (1935, 401; 1958, 147; 1960, 38). This conclusion is corroborated, in a general way, by the dip of the benches; as shown in Figure 2a, the benches slope southward about 1 m/km, about the same as the regional dip of the Prairie du Chien Formation in the Baraboo area (Clayton and Attig 1990, Fig. 14).

If the benches were eroded at that time, much eroded quartzite would be predicted to occur in the upper part of the Prairie du Chien Formation. However, we know of no sedimentological evidence for increased erosion and deposition of quartzite around the Baraboo Hills at that time, because appropriate exposures are unavailable—no more than about the lower 25 m of the Prairie du Chien Formation is exposed in the Baraboo region.

Other less conspicuous benches and scarps occur at lower elevations on both the North and South Ranges. Wanenmacher (1932, 75–76) and Raasch (1958) interpreted these as marine shore terraces formed in Late Cambrian time, and we agree with this interpretation.

Summit Plateaus

If the top of the South Range had been rounded or marked by a series of hogbacks over harder layers in the northward-dipping quartzite, the shape of the range would require little explanation other than normal subaerial erosional processes operating over a long period of time. However, the summit plateaus, crosscutting the dipping quartzite, require some special explanation. Before Thwaites studied them, the summit plateaus were considered the remnants of a peneplain, or at least of a subaerial erosion plain.

Martin (1916, 68) and Smith (1931, 128), and others, thought this was a peneplain cut in Precambrian time. Thwaites (1935, 398; 1958, 141; 1960, 37), however, thought the plateaus were cut after Precambrian time, doubting that the Precambrian surface surrounding the Baraboo Hills could have been lowered 350 m without destroying the erosion-surface remnants on the hills. Furthermore, the summit plateaus seem to slope southward at about the same inclination as the subsummit benches and the Prairie du Chien Formation (1 m/km; Fig. 2a); if the summit plateaus were cut before the Precambrian plain surrounding the Baraboo Hills, they should slope south at least as steeply as that plain (2 to 4 m/km; Thwaites 1957).

Others, such as Trowbridge (1917, 352–53), suggested that the summit plateaus are remnants of a plain (the "Dodgeville peneplain") cut by subaerial processes when the South Range was being exhumed in Mesozoic or Cenozoic time. Thwaites (1935, 403; 1958, 149; 1960, 37) argued that if subaerial erosion was capable of planing the extremely resistant quartzite, erosion should also have been capable of planing the much weaker Paleozoic dolomite and shale of Blue Mounds (40 km south of the Baraboo Hills), one of which is 70 m higher than the South Range. Thwaites argued further that scattered loose blocks of Paleozoic chert on the plateaus are an indication of much less erosive activity than would have been required to plane the quartzite from the top of the South Range. The patches of lower-Paleozoic conglomerate on the plateaus also indicate they could not have been formed in Mesozoic or Cenozoic time.

As indicated in the discussion of the subsummit benches, if the formations on either side of the South Range are projected into the range (Fig. 2a), the position of the middle Ordovician unconformity (at the base of the St. Peter Formation) is unclear, but it may be near the level of the edges of the summit plateaus. This suggests the possibility that the summit plateaus were cut by subaerial erosion during this hiatus, which lasted about 25 million years (Shaver et al. 1985). This possibility suffers from none of the objections listed for Precambrian and post-Paleozoic subaerial erosion plains, but much less time was available. In addition, the summit plateaus seem too flat to correspond to the middle Ordovician unconformity, which is known to have considerable local relief near the Baraboo Hills; in some places the unconformity is as low as or even below the base of the Prairie du Chien Formation (suggested in left-hand side of Fig. 2a; Clayton and Attig 1990).

Thwaites (1931, 745; 1935, 401–02; 1958, 145–47; 1960, 36–38) suggested that the summit plateaus on the South Range are the result of marine shore erosion rather than subaerial erosion. Thwaites favored this interpretation for the following reasons. If subaerial erosion is ruled out, marine erosion is the only reasonable alternative, and marine shore erosion seems more capable of eroding the quartzite than any other process. Once the subsummit bench had been interpreted to result from shore erosion, it was reasonable to extend this interpretation to the summit plateaus. However, a shore plain might be expected to be even flatter than the plateaus on the South Range, although Thwaites suggested that sea level gradually rose as the plain was cut.

The age of the summit plateaus, if in fact they are marine shore terraces, is less clear than that of the subsummit benches. Thwaites (1935, 401; 1958, 147; 1960, 37) suggested that if the Paleozoic formations farther south are projected into the South Range, the summit plateaus would coincide with the base of the Platteville Formation (Late Ordovician). Our projection (Fig. 2a) shows this also, but because the original thickness of the Ordovician units is uncertain here, this projection could be in error. No sedimentological evidence is available for increased Platteville erosion and deposition around the Baraboo Hills, because there are no Platteville outcrops in the area.

Conclusion

The Baraboo Hills retain early Paleozoic landforms that have undergone little change since they were exhumed in Mesozoic or Cenozoic time. The large valleys in the South Range (except Devils Lake gorge) are normal stream valleys that formed before the Late Cambrian. The subsummit benches and scarps are almost certainly a marine shore terrace, which probably formed during the Early Ordovician. The summit plateaus are remnants of a plain formed by marine shoreline erosion or by subaerial erosion, possibly during either the Middle or Late Ordovician.

Acknowledgments

We wish to thank David M. Mickelson, W. N. Melhorn, and Thomas W. Gardner for reviewing an earlier version of this paper.

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Notes on the biology of the American brook lamprey (Lampetra appendix) *in Wisconsin*

Abstract *American brook lampreys* (Lampetra appendix) *were collected from Taylor Creek in Rock County and were documented for the first time from Jambo Creek in Manitowoc County. Spawning at both sites occurred in early May at lower water temperatures (12–14°C) than previously recorded in Wisconsin. Although most spawning groups occurred in the open on gravel substrate, as is typically reported of spawning by lampreys, some spawning groups were found beneath cover. The sample of adult lampreys from Taylor Creek included a statistically significant excess of males. Adult male lampreys had relatively larger oral discs than females, whereas females displayed swelling along the leading edge of the second dorsal fin. A review of previous studies indicated that mean total lengths of adult males tend to be greater than those for females, although differences between means are rarely statistically significant at individual sites. Where the two species of nonparasitic lampreys have been collected from the same stream systems in Wisconsin, American brook lampreys occur upstream from northern brook lampreys* (Ichthyomyzon fossor) *significantly more often than vice versa.*

The American brook lamprey (*Lampetra appendix*) is widely distributed in eastern North America (Rohde 1980). Although it has been studied in other parts of its range (e.g., Hoff 1988; Lanteigne et al. 1981; Rohde et al. 1976; Seagle and Nagel 1982), little information on this species has been collected in Wisconsin (Becker 1983). Since the time that Becker's (1983) account was prepared, additional references to American brook lampreys in Wisconsin have been confined primarily to locality records (Cochran 1984; Fago 1982, 1983, 1984a, 1984b, 1985a, 1985b, 1986, 1992). The purpose of this note is to report new data on the biology of the American brook lamprey in Wisconsin, including several topics absent from or incompletely considered in Becker's (1983) account.

Methods

We collected adult lampreys in breeding condition at two sites. Taylor Creek is located in the Rock River basin (Mississippi River drainage) in Rock County (T2N, R10E, Sec. 30/31). At the site of capture, the West Church Road crossing, stream width was 4–5 m, the water was clear and up to 1 m deep, and the bottom was primarily sand, except for a concentration of rock slabs, cobble, and gravel beneath the bridge. Jambo Creek is a tributary to the East Twin River (Lake Michigan drainage) in Manitowoc County (T21N, R23E, Sec. 26). Stream width was 4–5 m, depth was 15–100 cm, and the water was clear with a slight reddish stain. Several gravel-bottomed riffles were present. American brook lampreys have been reported previously from Taylor Creek (Fago 1982) and from the East Twin River (Fago 1985b) but not from Jambo Creek (Fago 1985b).

Samples of lampreys were taken to the laboratory, where they were anesthetized with tricaine methanesulfonate (MS-222), measured for total length to the nearest mm, and weighed to the nearest 0.01 g. Oral disc lengths of lampreys from Jambo Creek were measured by pressing them flat against a transparent rule. Voucher specimens were placed in the University of Wisconsin-Madison Zoology Museum (Taylor Creek: UWZM 8432, Accession No. 84–77; Jambo Creek: UWZM 9951, Accession No. 91–176). Statistical analyses of morphological data were conducted with MINITAB (Schaefer and Anderson 1989).

It has been stated that American brook lampreys tend to be found upstream from northern brook lampreys *(Ichthyomyzon fossor)* when the two species occur in the same stream system (Morman 1979). We tested the applicability of this conclusion to Wisconsin waters with distribution maps provided by Fago (1983, 1984a, 1984b, 1985a). By overlaying transparencies of the maps for the two species, it was possible to tally cases in which one species occurred upstream of the other or vice versa. Deviations from random were tested through use of the binomial expansion (Sokal and Rohlf 1981).

Results

At Taylor Creek, 11 American brook lampreys were collected on May 4, 1984, at a water temperature of 14°C. All were captured beneath the bridge; 8 of the 11 were captured after a single individual was observed next to a rock slab and that slab was overturned. Ten of 11 lampreys were male, a result significantly different from expected under the null hypothesis that both sexes are equally abundant and equally vulnerable to capture (binomial test, $p = 0.012$). The males were readily made to express a rather transparent fluid from their urogenital papillae; the milt of spawning male American brook lampreys was described by Dean and Sumner (1897) as nearly colorless. Many individuals displayed the sorts of abrasions and other minor wounds that result from spawning activity.

At Jambo Creek, we observed spawning lampreys in 1988, 1989, and 1992. Several spawning groups were detected on May 2, 1988, but only one lamprey was found on May 4 at the same site. Water temperature was not measured on May 2, but was 16°C on May 4. In 1989, spawning groups were not observed on April 22, April 26, or April 30, but were present on May 3 at a water temperature of 13°C. All spawning groups were located just above riffles. Five groups were on open gravel substrate; individual group sizes were 6, 6, 7–10, 10–15, and 20–30. In addition, a group of ten lampreys was building a spawning depression beneath an overhanging stump, and a group of unknown size was building a pit beneath a large rock slab. Ten lampreys, five of each sex, were collected from among the spawning groups. On May 4, the lampreys had for the most part dispersed from the area occupied on the previous day; a single lamprey was observed beneath the stump that had sheltered a spawning group. Two spawning groups were located much further downstream. Water temperature remained at 13°C. In 1992, approximately 15 lampreys were observed over approximately 150 m of stream. All were in the open, and most were isolated individuals, but two pairs and one group of three were found in flat water just above riffles. Six females and three males were collected. Water temperature was 12°C.

The mean total length of the 30 American brook lampreys collected during this study was 160 mm (range: 139–187 mm). Mean body mass was 6.61 g (range: 3.83–11.27 g). Use of student's t-tests revealed significant differences between lampreys collected at Jambo Creek in 1989 and 1992 in mean total length ($t = 4.43$, $p < 0.001$) and mean body mass ($t = 4.52$, $p < 0.001$) (Table 1). Differences in mean total length and body mass between lampreys from Taylor Creek and Jambo Creek (1989 and 1992 data pooled) were not significant. For each of the three samples from Taylor and Jambo creeks, mean total length and body mass of male lampreys were greater than corresponding values for females (Table 1). When data for the three samples were pooled, the sexes were significantly different in both mean total length ($t = 2.81$, $p < 0.01$) and mean body mass ($t = 2.77$, $p = 0.01$).

The simple linear regression of the natural logarithm of body mass in grams (lnW) on the natural logarithm of total length in mm (lnL) was:

$$\ln W = -16.9 + 3.70 \ln L \quad (1)$$

($r^2 = 0.921$, $n = 30$). Analysis of covariance failed to reveal significant differences between regression lines calculated separately for the two sexes or for the two collection sites.

We measured the oral disc length of each lamprey from Jambo Creek and calculated relative disc length as the ratio of disc length to total length (expressed as a percentage). Total length was positively correlated with disc length ($r = 0.617$, d.f. = 17, $p < 0.01$). Analysis of covariance, with total length as the covariate, revealed a significant difference in disc length between the two sexes ($F_{1,16} = 12.53$, $p < 0.005$). This reflected a difference in mean relative disc length of males (5.83%, S.E. = 0.21%) and females (5.12%, S.E. = 0.13%). In addition to having relatively smaller oral discs, the Jambo Creek females displayed swelling along the leading edge of the second dorsal fin.

At Taylor Creek, American brook lampreys were collected with spotfin shiners (*Cyprinella spiloptera*), bluntnose minnows (*Pimephales notatus*), white suckers (*Catostomus commersoni*), banded darters (*Etheostoma zonale*), johnny darters (*Etheostoma nigrum*), and fantail darters (*Etheostoma flabellare*). At Jambo Creek, a designated trout stream, electrofishing on October 21, 1991, yielded the following species: brown trout (*Salmo trutta*), creek chub (*Semotilus atromaculatus*), common shiner (*Luxilus cornutus*), white sucker, black bullhead (*Ictalurus melas*), smallmouth bass (*Micropterus dolomieui*), green sunfish (*Lepomis cyanellus*), and mottled sculpin (*Cottus bairdi*). Only sculpins and young-of-the-year suckers were observed in large numbers.

We found 12 cases in which American brook lampreys and northern brook lampreys occurred together in the same stream

Table 1. Mean total length in millimeters and mean body mass in grams of American brook lampreys (*Lampetra appendix*) collected at Taylor and Jambo creeks, Wisconsin. Standard errors are in parentheses. All measurements were of living, anesthetized animals.

Locality	*Sex*	*Sample size*	*Total length (mm)*		*Body mass (g)*	
Taylor Creek	Male	10	161.5	(3.0)	6.80	(0.46)
	Female	1	158.0	—	5.48	—
	Both sexes pooled	11	161.2	(2.7)	6.68	(0.44)
Jambo Creek	Male	5	174.8	(4.9)	9.20	(0.84)
	Female	5	160.0	(2.1)	6.71	(0.47)
1989	Both sexes pooled	10	167.4	(3.5)	7.95	(0.61)
	Male	3	153.3	(1.3)	5.48	(0.17)
	Female	6	148.3	(2.3)	4.80	(0.25)
1992	Both sexes pooled	9	149.9	(1.7)	5.02	(0.21)
Both sites pooled	Male	18	163.8	(2.7)	7.25	(0.46)
	Female	12	154.0	(2.2)	5.65	(0.35)
	Both sexes pooled	30	159.9	(2.1)	6.60	(0.34)

(Fago 1983, 1984a, 1984b, 1985a). The American brook lamprey was reported further upstream in 10 of 12 streams. This result is significantly different from expected under the null hypothesis that the two species are equally likely to be found further upstream (binomial test, $p = 0.039$).

Discussion

Some generalizations about the temperature at which American brook lampreys spawn in the spring appear to be inaccurate. Becker (1983) stated that spawning in Wisconsin may begin at water temperatures of "about 17.2°C (63°F)." Robison and Buchanan (1988) cited Becker (1983) but inexplicably raised the temperature to "about 65°F (18°C) . . . ." In contrast, we observed spawning groups at temperatures of 12–14°C, and spawning at one site was apparently completed by the time water temperature had reached 16°C. Moreover, Cochran (1984) reported the occurrence of several spawning groups in Waukesha County at a water temperature of 15.4°C. While it is true that spawning by American brook lampreys in other parts of North America has been reported at temperatures as high as 20.6°C, most published accounts place the onset of spawning well below 15°C (Table 2).

Lampreys typically are reported to spawn in open, shallow, gravel-bottomed habitats. Cochran and Gripentrog (1992), however, reported that several species in the genus *Ichthyomyzon* aggregate beneath cover objects and sometimes spawn beneath cover. Our observations at both Taylor and Jambo

Table 2. Water temperatures at which American brook lampreys (*Lampetra appendix*) have been observed spawning.

Locality	*Temperature*	*Authority*
Wisconsin	12°C, 13°C, 14°C	This study
Wisconsin	15.4°C	Cochran (1984)
Michigan	17°C	Young & Cole (1900)
Michigan	First appear at 13–14.5°C	Okkelberg (1921)
Michigan	Mean of 14.1°C with a range of 6.7–20.6°C and a peak in one stream from 9.5–13.5°C	Morman (1979)
Quebec	8.3°–20.5°C with a peak at 17°C	Vladykov (1949)
Massachusetts	10–11°C	Hoff (1988)
New Hampshire	10–15.5°C	Sawyer (1960)
New York	10–18°C, but usually 15–18°C	Gage (1893, 1928)
New York	18.9°C	Dean & Sumner (1897)
Delaware	6.8–12.0°C	Rohde et al. (1976)
Tennessee	<15.5°C	Seagle & Nagel (1982)

creeks show that American brook lampreys also occasionally aggregate and spawn beneath cover objects. Young and Cole (1900) reported that nests may be situated beneath overhanging banks or logs.

In one of our samples of spawning-phase adults, males outnumbered females by a significant margin. Care must be taken when interpreting the literature on this topic. For example, Schuldt et al. (1987) cited Seagle and Nagel (1982) among authors who reported an excess of males, but Seagle and Nagel (1982) stated that the sex ratio was not statistically different from 1:1. Hoff (1988) and Scott and Crossman (1973) cited Young and Cole (1900) as reporting that males outnumbered females by a ratio of 5:1, but it was Dean and Sumner (1897) who reported that figure. Hoff (1988) reported that females outnumbered males 5:2, but with a sample size of 7, that result is not significantly different from 1:1 (binomial test, $p = 0.453$). Generally, however, adult male American brook lampreys outnumber females in collections made during or just prior to the spawning season (Dean and Sumner 1897; Young and Cole 1900; Kott 1971; Schuldt et al. 1987). Presumably, the sex ratio varies over time, since males are reported to precede females to the spawning site (Young and Cole 1900; Okkelberg 1921; but see Kott 1971).

Becker (1983) listed several traits for which American brook lampreys in Wisconsin are sexually dimorphic. Breeding males each have a long, threadlike urogenital papilla and relatively high dorsal fins separated by a sharp notch. Breeding females each have a prominent anal fin fold and relatively low dorsal fins separated by a broad notch. In addition, we report here that males have relatively larger oral discs than females and that the leading edge of the second dorsal fin in females may be swollen. A difference in disc size has been previously noted for American brook lampreys in Quebec (Kott

1974) and Delaware (Rohde et al. 1976); the larger discs of male lampreys may reflect their relatively greater role in nest construction (Beamish 1982). Swelling along the anterior margin of the female's second dorsal fin was mentioned by Gage (1928) and previously reported in several other species of *Lampetra* (Pletcher 1963; Larsen 1980; Hardisty 1986a, 1986b). Perhaps the swelling provides support for the body of the male, which during the spawning act fits into the notch between the first and second dorsal fins of the female (Breder and Rosen 1966).

Adult male American brook lampreys tended to be larger than females in our samples (Table 1). In each of five previous studies (Okkelberg 1921; Hubbs 1925; Sawyer 1960; Kott 1974; Rohde et al. 1976), mean total lengths of males were slightly but not significantly greater than those for females. However, if all paired samples for the two sexes were drawn randomly from populations with identical means, the probability of obtaining such a sequence of results is very low ($p = 0.0156$, binomial test). The apparently real trend for male American brook lampreys to be on average slightly larger than females is reinforced by the results of Schuldt et al. (1987), who obtained a mean total length for males slightly but significantly greater than that for females. Such a tendency may reflect a balance of opposing selective factors. Malmqvist (1983) and Beamish and Neville (1992), respectively, found that fertilization and spawning success declined as size differences between male and female lampreys increased; fertilization was most successful when the female/male length ratio was 1.05–1.14 (Malmqvist 1983). In contrast, Malmqvist (1983) and Becker (1983) reported behavior interpreted as fighting between male brook lampreys. The former results would select against substantial sexual divergence in size; the latter phenomenon would presumably favor larger males.

The tendency for American brook lampreys to be found upstream from northern brook lampreys reflects their preference for cooler temperatures (Scott and Crossman 1973), which are often associated with spring-fed headwaters. This pattern is not inviolate, however. Classical patterns of longitudinal zonation of stream fishes may be disrupted in drainages where springs empty cold water into the mid-reaches of streams (Swaidner and Berra 1979). Morman (1979) provided examples of inverted distributions of American and northern brook lampreys that apparently were related to reversed stream temperature gradients. An example of this phenomenon in Wisconsin may occur in the Mukwonago River (Cochran 1984). Northern brook lampreys were collected not far downstream from Eagle Springs Lake, the surface of which presumably warms quickly in the spring, whereas American brook lampreys were collected further downstream, below where a trout stream and numerous springs enter the river.

Wisconsin's native lampreys are not well understood by the general public (Cochran 1984) and may suffer through association with the sea lamprey (*Petromyzon marinus*), an exotic parasitic species that has caused great destruction of valuable fish in Lake Michigan and the other Great Lakes (Smith 1971). The American brook lamprey is nonparasitic and does not harm other fishes. Nevertheless, landowners along Jambo Creek informed us that they had encouraged a Cub Scout pack to catch and kill what they mistakenly thought were sea lampreys spawning on their property. (Spawning-phase sea lampreys from Lake Michigan do ascend the East Twin River to within 4 km of its confluence with Jambo Creek, but they are blocked by the Mishicot spillway from ascending closer.) We hope that further research on Wisconsin's native lampreys will help to dispel this sort of misunderstanding.

Acknowledgments

We thank John Lyons, Tim Pettinelli, Joe Marks, Doug Basten, and Jennifer Cochran for assistance in the field. John Lyons and two anonymous reviewers provided valuable comments on earlier drafts of this manuscript, and Marge Dollar and Kristen Lucier contributed to its production.

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Elisabeth R. Deppe and Richard C. Lathrop

Recent changes in the aquatic macrophyte community of Lake Mendota

Abstract *The aquatic macrophyte community of Lake Mendota was surveyed in the summers of 1989, 1990, and 1991 using a technique based on plant recovery on a rake. For comparison, more limited surveys were conducted during 1990 and 1991 on the other three lakes in the Yahara River Chain—Monona, Waubesa, and Kegonsa. For Lake Mendota, presence, relative frequency, and density of twelve species were determined. In 1989 and 1990, the Lake Mendota macrophyte community was dominated by* Ceratophyllum demersum L. *followed by* Myriophyllum spicatum L., *plants with biomasses especially heavy near the water surface. While the relative frequencies of these and other species remained nearly constant, almost all species decreased in density from 1989 to 1990. In 1991,* Ceratophyllum *declined again, and* Myriophyllum *became the most dominant. This same pattern was observed in Lakes Monona and Waubesa between 1990 and 1991. These density decreases were probably caused by especially poor spring and/or summer water clarity in 1990 in all three lakes. In Lake Mendota, this poor clarity resulted from an unusually long and dense blue-green algal bloom during May and June. Areas of high plant density along the west and southwest shorelines, including University Bay, showed the largest density decreases. This was probably due to an accumulation of algae in these regions, blown in by northeast winds during the crucial spring growth period. While Lake Mendota has been dominated by either* Myriophyllum spicatum *or* Ceratophyllum demersum *since the 1960s, our survey results indicate that plant densities can vary greatly in the short-term due to stochastic events.*

The submersed aquatic macrophytes of Lake Mendota, a calcareous 3,985-ha lake near Madison, Wisconsin, have been of interest to ecologists and lake managers for decades. Lake Mendota has undergone steady eutrophication since the mid-1800s, when its watershed was first developed (Lathrop 1992). Prior to the 1960s, the lake was dominated by wild celery (*Vallisneria americana* Michx.) and native pondweeds (*Potamogeton* spp.) (Lathrop 1989; Nichols et al. 1992). Since then, the plant community became less diverse, being dominated by Eurasian water milfoil (*Myriophyllum spicatum*). *Myriophyllum* was especially dense from the mid-1960s to the mid-1970s, when densities declined in Mendota and other Yahara River lakes (Monona, Waubesa, and Kegonsa) and Lake Wingra (Carpenter 1980; Lathrop 1989; Nichols et al. 1992).

Local lake managers continuously devote energy and resources to managing overabundant littoral biomasses of mainly *Myriophyllum*, particularly in Lakes Mendota, Monona, and Waubesa (Lathrop 1989). While providing important habitat for many fish species, this plant can become a nuisance to lakeside residents, boaters, and even anglers when growth is unchecked. In Lake Mendota, improved water clarity during 1986–88 caused ecologists and lake managers additional concern that *Myriophyllum* would increase in density and spread into deeper water.

To address these concerns, and because a systematic, detailed macrophyte survey had not been conducted on Lake Mendota since 1920 (Rickett 1922), the Wisconsin Department of Natural Resources (WDNR) undertook full shoreline surveys in the summers of 1989–91 to document the presence, relative density, and maximum rooting depth. The other three lakes in the Yahara River chain were also surveyed in the summers of 1990 and 1991 for comparison. The survey information should aid managers responsible for controlling overabundant macrophytes while indicating areas of native species deserving protection.

Methods

Field Survey

Lake Mendota's macrophytes were surveyed during the last two weeks of July and the first week of August in 1989–91. Plants were sampled along 47 transects positioned perpendicular to the shoreline at approximately 750-m intervals around the lake (Fig. 1). Transects were 300 m apart in University Bay, where we wanted additional data for historical comparison. Lakes Monona and Waubesa were surveyed in late June of 1990 and 1991 and Lake Kegonsa in early July of 1990 and 1991. Macrophytes were sampled along 13 evenly spaced transects in Monona (plus one in Monona Bay), 10 in Waubesa, and 8 in Kegonsa.

The surveys were conducted from a boat, which was moved between sampling stations designated at 0.5-m water depth intervals (0.5 m, 1.0 m, 1.5 m, etc.) on each transect until no vegetation occurred. Depths were determined using a measured pole in waters <3.0 m and a Lowrance FISH-LO-K-TOR depth-finder in waters 3.5–5.5 m. Each sampling station was subdivided into four quadrants, located off the front left, front right, rear left, and rear right of the boat. Each quadrant was then sampled by a single cast with a double-headed, weighted garden rake with a head width of 35 cm and 14 teeth, each 5 cm long. The rake was thrown into the water and dragged approximately 2 m across the bottom by means of an attached line. After the rake was pulled off the bottom it was flipped 180 degrees to ensure that plants snagged from the bottom would remain on the rake. This sampling technique for dividing stations into quadrants and collecting plants by rake casts followed Jessen and Lound (1962).

Plants collected on rake teeth were iden-

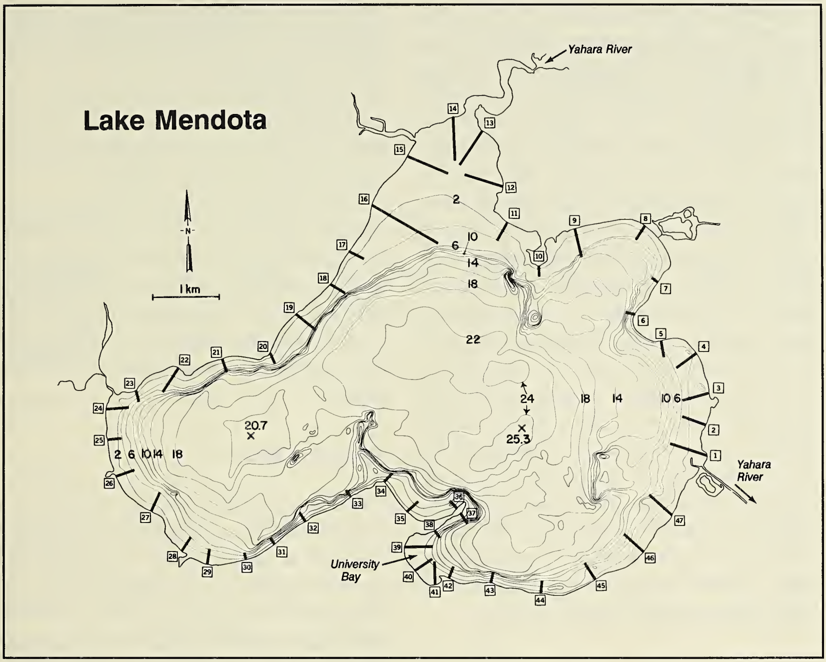

Fig. 1. Hydrographic map of Lake Mendota (with contours in meters) showing locations of the 47 study area transects.

tified following Fassett (1957) and Voss (1972). Whereas Jessen and Lound rated species on rake teeth only as present or absent, we developed a measure of estimating density as well. For each rake throw, a species was assigned a density rating from 0–5 based on the coverage of the upper rake head (both number of teeth and length of teeth covered). For example, species covering 1–20% of the rake head were given a rating of 1, species covering 21–40% were rated 2, etc. Ratings resulting from the four individual throws at each station were averaged to determine a density rating (DR) for each species. Further information on the rake survey method was provided in Deppe and Lathrop (1992). The simpler Jessen and Lound method of presence/absence on each rake was used for the 1990 surveys on Monona, Waubesa, and Kegonsa.

Statistical Analysis

Relative frequencies, which describe each species as constituting a certain percent of the whole macrophyte community, were computed for each lake. In addition, separate relative frequencies were computed for University Bay (transects 38–42) of Lake Mendota for the purpose of comparison with previous surveys only conducted in that area. Relative frequency for each species was calculated as the total number of rake casts on which a species appeared, divided by the total number of such encounters for all species. These calculations were based on data for all stations. While frequency of occurrence more accurately reflects a species distribution in a lake, we present only relative frequency information in this paper. Because different plant sampling methodologies were used in past surveys, only relative frequency data are directly comparable. However, it should be noted that relative frequency data were found to parallel frequency of occurrence data for Lake Mendota's macrophytes.

For Lake Mendota, density of plants is presented in two ways. Mean density ratings (MDRs) were calculated for the abundant and common species at each depth across all transects. In order to characterize the macrophyte community with respect to shoreline areas, density ratings of each species were summed for each transect and called their additive density ratings (ADRs).

Results

Macrophyte Community Composition

A total of ten submersed and two floating-leaved species were found in Lake Mendota during 1989–91 (Table 1). *Ceratophyllum demersum* (coontail) and *Myriophyllum spicatum* were the two most dominant species, each comprising 26–43% of the macrophyte community in 1989–91 (Table 1). Four other species—*Potamogeton pectinatus* L. (sago pondweed), *Vallisneria americana* (wild celery), *Heteranthera dubia* (Jacq.) MacM. (water stargrass), and *Elodea canadensis* Michx. (American elodea)—were common, each comprising 3–9% of Mendota macrophytes in 1989–91. The other six species were infrequently encountered (relative frequencies of each generally <1% in 1989–91). Composition of the macrophyte community in University Bay of Lake Mendota was almost the same as for the whole lake, dominated by *Myriophyllum* and *Ceratophyllum*, and containing seven of the other ten less abundant species found in Lake Mendota (Tables 1 and 2).

The macrophyte community of Lake Monona was very similar to Lake Mendota's, only lacking the two floating-leaved species and one uncommon *Potamogeton* (Table 1). Lakes Waubesa and Kegonsa were much less diverse, harboring only three species besides *Ceratophyllum* and *Myriophyllum.*

Abundant Species

Our Lake Mendota surveys document a transition from a *Ceratophyllum*-dominated macrophyte community to one dominated by *Myriophyllum. Ceratophyllum* was the most abundant species in 1989 and 1990, with higher relative frequencies and mean density ratings (MDRs) than *Myriophyllum* (Table 1 and Fig. 2). Both species experienced substantial decreases in density from 1989 to 1990 (Fig. 2). Densities of *Ceratophyllum* declined again in 1991, while densities of *Myriophyllum* remained nearly constant from 1990 to 1991, making *Myriophyllum* the most abundant species in 1991.

For both *Ceratophyllum* and *Myriophyllum*, areas of greatest abundance in 1989 exhibited the most dramatic decreases in density. In 1989, *Ceratophyllum* grew most densely along Lake Mendota's northwest and west shorelines and in University Bay (Fig. 3). Between 1989 and 1991, *Ceratophyllum* densities declined along the northwest shoreline and in University Bay by 68% and 95%, respectively. Relative frequencies in University Bay also portrayed a dramatic decrease in *Ceratophyllum* density from 1989

Table 1. Relative frequencies of macrophytes in Lake Mendota in 1989–91, and in Lakes Monona, Waubesa, and Kegonsa in 1990–91.

	Mendota			*Monona*		*Waubesa*		*Kegonsa*	
Species	*1989*	*1990*	*1991*	*1990*	*1991*	*1990*	*1991*	*1990*	*1991*
Submersed species									
Ceratophyllum demersum	42.5	42.4	26.4	43.2	10.1	43.0	10.2	5.4	9.5
Myriophyllum spicatum	34.1	32.0	40.9	41.4	61.2	41.8	60.2	83.9	82.5
Potamogeton pectinatus	6.8	8.5	8.3	2.5	14.5	3.5	2.3	8.9	3.6
Heteranthera dubia	5.8	5.5	7.1	0.9	3.5	4.1	5.5	–	0.8
Vallisneria americana	5.4	5.8	6.3	0.2	3.5	–	–	–	–
Elodea canadensis	3.6	3.3	7.0	1.3	1.8	–	–	–	–
Potamogeton crispus	0.7	0.5	0.9	10.1	2.6	7.6	18.0	1.8	3.6
Potamogeton richardsonii	0.5	0.4	0.6	0.4	1.8	–	–	–	–
Potamogeton zosteriformis	0.1	–	–	–	–	–	–	–	–
Potamogeton foliosis	–	0.1	1.5	–	1.0	–	–	–	–
Floating species									
Nymphaea tuberosa	0.3	0.3	0.8	–	–	–	–	–	–
Nelumbo lutea	0.3	1.1	0.2	–	–	–	–	–	–

to 1991 (Table 2). Along the south and southeast shorelines, areas of moderate *Ceratophyllum* density in 1989, densities dropped by 80% from 1989 to 1991. *Myriophyllum*, while fairly evenly distributed around the lake in 1989, was slightly more abundant in University Bay and along the west shoreline (Fig. 3). After decreases in nearly all regions from 1989 to 1990, sharpest in University Bay and along the west

Table 2. Percent relative frequency of macrophyte species in University Bay in selected years since 1966.*

Species	*1966*	*1978*	*1979*	*1980*	*1984*	*1989*	*1990*	*1991*
Ceratophyllum demersum	13.6	10.3	25.4	3.7	26.4	47.9	62.1	14.7
Myriophyllum spicatum	55.6	39.4	29.6	45.4	38.4	24.1	9.1	42.0
Vallisneria americana	15.7	14.3	14.8	14.2	1.2	8.9	8.3	8.7
Heteranthera dubia	1.2	–	–	1.0	–	11.3	7.6	7.3
Elodea canadensis	0.3	5.1	9.2	2.5	18.0	3.1	0.8	3.3
Nymphaea tuberosa	7.1	4.6	4.9	5.3	3.6	3.1	9.8	4.0
Nelumbo lutea	0.4	–	–	1.2	1.2	1.2	2.3	1.3
Potamogeton pectinatus	1.1	6.3	1.4	19.6	2.4	0.4	–	17.4
P. crispus	–	2.3	–	1.5	–	–	–	1.3
P. filiformis Pers.	–	0.6	10.6	–	–	–	–	–
P. foliosis	<0.1	15.4	4.2	2.0	–	–	–	–
P. nodosus Poiret	–	–	1.4	–	–	–	–	–
P. richardsonii	1.7	–	–	0.9	–	–	–	–
P. zosteriformis	0.1	–	–	–	–	–	–	–
Najas flexilis (Willd.) Rostk. & Schmidt	0.1	0.6	–	1.0	–	–	–	–
Ranunculus trichophyllus Chaix	1.5	–	–	–	–	–	–	–
Zannichellia palustris L.	<0.1	–	--	1.2	–	–	–	–
Unidentified spp.	–	–	–	–	7.2	–	–	–

*Data sources: 1966 (Lind and Cottam 1969); 1978–79 (raw data used by Andrews 1980); 1980 (Vander Zouwen 1982); 1984 (R. Lathrop, Wis. DNR, unpubl. data); 1989–91 (this study). All surveys were conducted during July–August.

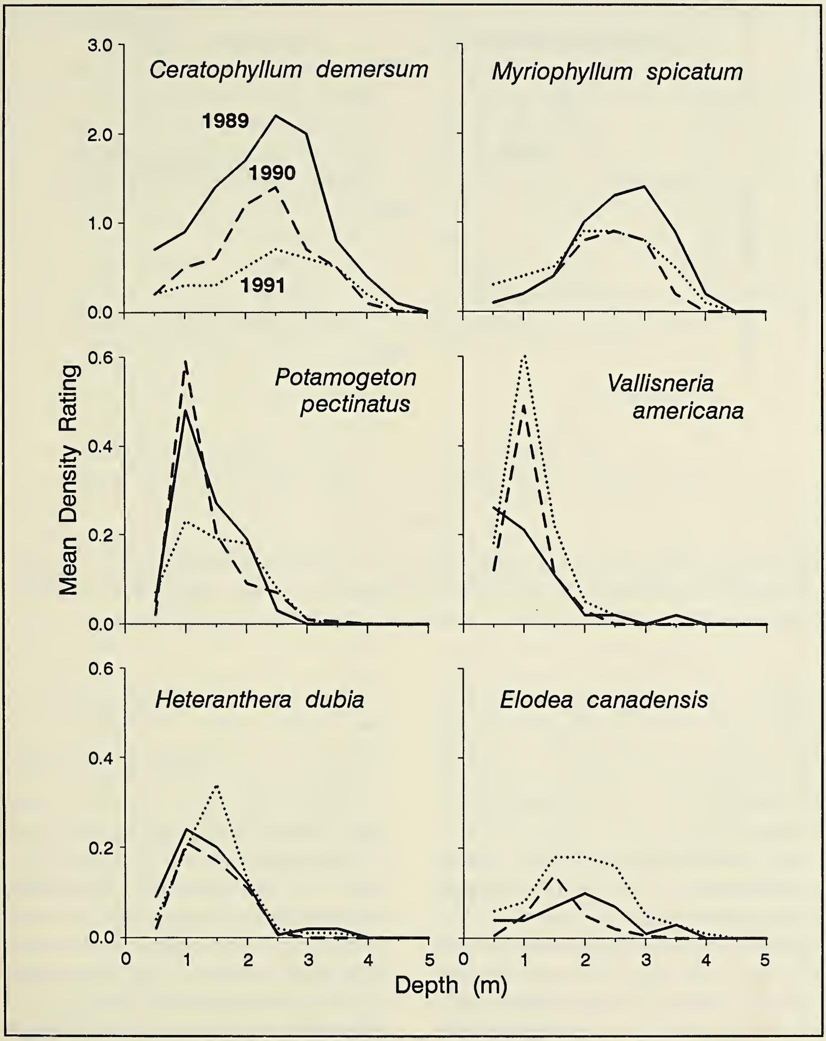

Fig. 2. Mean density ratings with respect to depth for abundant and common species in Lake Mendota, 1989–91. (Abundant species in top panels have scale 0–3.0; common species in middle and bottom panels have scale 0–0.6; 1989 – solid line, 1990 – dashed line, 1991 – dotted line.)

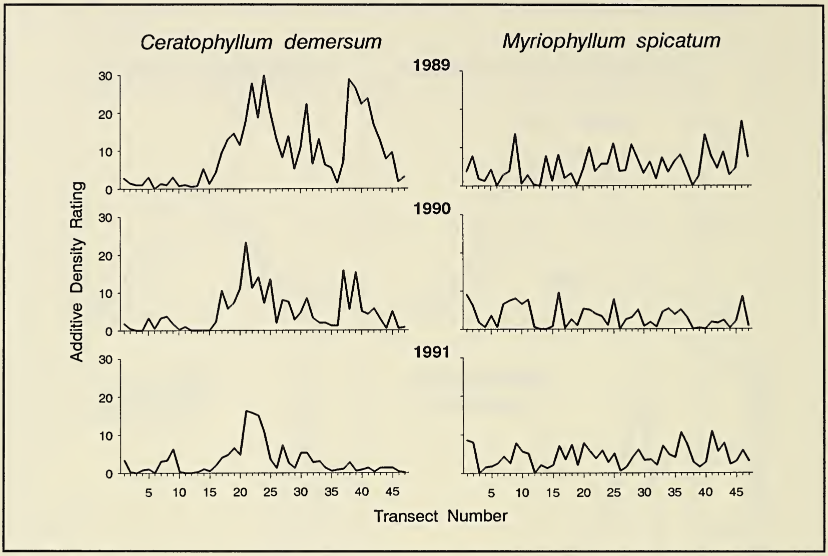

Fig. 3. Additive density ratings of *Ceratophyllum demersum* and *Myriophyllum spicatum* in regions of Lake Mendota and the percent change in these ratings from 1989–91. (University Bay = transects 38–41. See Figure 1 for other transect locations.)

shoreline, *Myriophyllum* densities almost regained their 1989 levels in 1991, unlike *Ceratophyllum*. During 1989–91, *Ceratophyllum* grew most densely between 2.0 m and 3.0 m of water depth, and *Myrophyllum* between 2.5 m and 3.0 m (Fig. 2).

In Lakes Monona and Waubesa, *Ceratophyllum* dominated in 1990 but dropped dramatically in relative frequency in 1991, while *Myriophyllum* frequencies increased (Table 1). Relative frequency for Lake Kegonsa, a lake with much sparser macrophytes, was almost totally dominated by *Myriophyllum* in both 1990 and 1991.

Common Species

The four common submersed species—*P. pectinatus*, *Vallisneria*, *Heteranthera*, and *Elodea*—were found less frequently and in lower densities than *Ceratophyllum* and *Myriophyllum* at all water depths, but grew most abundantly in shallower depths (< 2.0 m) (Table 1 and Fig. 2). In 1989, *Vallisneria*, *Heteranthera*, and *Elodea* had peak MDRs at depths of 0.5–1.0 m, 1.0–1.5 m, and 1.5–2.0 m, respectively. Small differences in MDRs occurred during the three years for these four species, but no consistent trend was evident. They were generally found at transects scattered all over the lake, with some prevalence on certain shorelines. Distribution of *P. pectinatus*, although fairly uniform in 1989, seemed less random than the others. It was entirely absent from University Bay in 1990; however, its greatest densities occurred there in 1991, reflected by its relative frequency of 17.4% (Table 2).

Uncommon Species

In the three survey years, six species were found very infrequently and at very low densities in Lake Mendota: *Potamogeton crispus* L., *P. richardsonii* (A. Benn.) Rydb., *P. zosteriformis* Fern., *P. foliosis* Raf., *Nelumbo lutea* (Willd.) Pers., and *Nymphaea tuberosa* Paine (Table 1). In 1989 and 1990, *P. crispus* was found at low densities on transects off the eastern and northern shorelines, while in 1991 it was found almost exclusively along the west and south shorelines. In all three years, *P. richardsonii* was found in moderate abundance at transect 45 and more sparsely at a few other transects during 1989–91. For all three years, the two floating-leaved lily species *Nelumbo lutea* and *Nymphaea tuberosa* grew densely at 1.0 m in University Bay at transect 39, and elsewhere in the bay at varying densities from 1989–91. These species were also found along the east shoreline at transect 47 in 1989. *P. foliosis* was found at scattered sites in 1990–91, and *P. zosteriformis* was found at only one station in 1989.

Depth Limit of Growth

The depth limit of plant growth in Lake Mendota was somewhat variable between transects but generally occurred between 3.0 and 4.0 m for 1989–91 (Table 3). Depth limits shifted to slightly shallower ranges in 1990, but returned to near-1989 levels in 1991. Depth limit decreased by 0.5 m from 1989 to 1990 at all transects in University Bay and along the northwest shoreline where plant growth was densest.

Depth limit of plant growth in Lake Monona generally occurred at 3.5 m in 1990, but at 2.5 m in 1991. Similarly, in Lake Waubesa these figures went from 3.0 m in 1990 to 2.0–3.0 m in 1991. In Lake Kegonsa, depth limits increased from 2.0–2.5 m in 1990 to 3.0 m in 1991.

Because most plant growth occurred at 3–4 m in Lake Mendota, it is noteworthy that 10% of stations 3 m in 1989 were devoid of plants, while 20% had no vegetation in 1990 and 1991. In 1990, 7% and 1% of stations 3 m were without vegetation in Monona and Waubesa, respectively, but this increased to 30% and 48% for the two lakes in 1991. In Lake Kegonsa, 58% of stations 3 m were without macrophytes in 1990, but only 21% in 1991.

Discussion

Depth Distribution

In our 1989–91 surveys in Lake Mendota, macrophytes were found almost entirely at water depths between 0.5 and 3.5 m, while certain depths favored growth of particular species. *Ceratophyllum* and *Myriophyllum spicatum*, tall-growing plants with biomasses heaviest near the water surface, grew most densely between 2.0 and 3.0 m. The common species, tending not to grow as tall, were found largely between 0.5 and 2.0 m, where they can receive adequate light. Their infrequent occurrence in water depths >2.0 m suggests that they may be shaded by algal blooms and dense growths of *Ceratophyllum* and *Myriophyllum.* Lack of macrophyte growth at the 0.5 m contour is probably due to one or more of the following reasons: rocky substrate, more pronounced wave action, ice shifting in winter, and the controlled lowering of the lake level over the winter months.

Macrophyte Community of University Bay Since the 1960s

Myriophyllum spicatum dominated the plant community from its introduction in the

Table 3. Depth limits of macrophyte growth in Lake Mendota in 1989–91.

Sampling Station (m)	*No. transects where plants ceased*					
	1989		*1990*		*1991*	
0.5	0		0		0	
1.0	0		0		1	(2%)
1.5	0		0		0	
2.0	0		1	(2%)	2	(5%)
2.5	3	(7%)	2	(5%)	5	(12%)
3.0	12	(29%)	12	(28%)	8	(18%)
3.5	13	(31%)	20	(47%)	15	(35%)
4.0	9	(21%)	7	(16%)	11	(26%)
4.5	4	(10%)	1	(2%)	1	(2%)
5.0	1	(2%)	0		0	
Total	42*		43*		43*	

*Transects 12–15 at the Yahara River inlet were excluded in all years because of shallow maximum depths; transect 6 was also excluded in 1989 because no plants were found there due to rocky substrate

early 1960s until the mid-1970s, while *Potamogeton* spp. and *Vallisneria* declined (Table 2). *M. sibiricum* Komarov (native water milfoil, formerly called *M. exalbescens* Fern.), apparently disappeared (Nichols 1975) and has not been recorded in surveys through 1991. After the mid-1970s, relative abundances of *M. spicatum* declined while *Ceratophyllum* began to increase, with the exception of 1980. This decline in *M. spicatum* abundance following approximately a 10-year period of domination has been observed in other lakes including Lake Wingra (Carpenter 1980), although the reasons for this are unclear. Transient increases in narrow-leaved pondweeds such as *P. foliosis*, *P. filiformis* and *P. pectinatus* occurred between 1978 and 1980 in University Bay. However, by the 1980s, several pondweeds had either dropped dramatically in relative frequency or totally disappeared from the bay, indicating steadily declining diversity.

Our surveys indicate the general continuation of *Myriophyllum*/*Ceratophyllum* dominance, but the trend of increasing *Ceratophyllum* relative frequency observed through the 1980s was reversed in 1991. While both species experienced reductions in area of coverage, mean density, and maximum depth distribution from 1989 to 1990, *Cerato-phyllum* densities dropped again in 1991 (Figs. 2 and 3). *Myriophyllum* densities, however, remained nearly constant from 1990 to 1991. This reversal caused *Myriophyllum* to once again dominate, but at lower densities than were noted in the late 1960s or early 1970s.

Effect of Water Clarity

Water clarity can critically influence the densities, species composition, and maximum rooting depth of submersed aquatic macrophyte communities (Canfield et al. 1985; Chambers and Kalff 1985). In our surveys, it is most likely that the sudden shift to a *Myriophyllum*-dominated community may have been caused, at least in part, by a difference in the responses of *Ceratophyllum* and *Myriophyllum* to severely reduced light conditions in the spring of 1990. This situation was particularly pronounced in University Bay. During the spring of that year, an atypical heavy bloom of blue-green algae occurred in Lake Mendota that resulted in unusually poor water clarity when compared to other spring periods (Lathrop 1992, WDNR unpubl. data). Because prevailing winds were predominantly from the northeast during May, rather than the more typical southwestern winds for this season, the buoyant blue-green algae accumulated in the bay. Extremely poor water clarity resulted, at a time of year when young plants require adequate light to initiate growth from the sediments. Water clarity was poorer than normal for much of the remaining spring and summer months of 1990. By August of that year, the shore side of the sand bar in University Bay was almost completely devoid of submersed vegetation, and the plant densities of the entire bay were severely reduced. In 1991, the bay still harbored only sparse macrophyte growth, although *P. pectinatus* was much more abundant than usual (Table 2).

Poor spring water clarity in 1979 (Lathrop 1992) also affected the macrophyte community in University Bay. Andrews (1980) noted a decline in macrophyte abundance (particularly *Myriophyllum*) from 1978 to 1979. In 1980, Vander Zouwen (1982) found *Ceratophyllum* to be quite sparse when compared to earlier and later surveys. Interestingly, *P. pectinatus* also exhibited increased abundances one year after poor water clarity in both 1980 and 1991 (Table 2).

Poor spring and summer water clarity in 1990 also had an impact on the macrophyte communities of Lakes Monona and Waubesa. Both lakes exhibited huge drops in the relative frequency of *Ceratophyllum* from 1990 to 1991 as had occurred in Lake Mendota. Water clarity was typically poor for both 1990 and 1991 in Lake Kegonsa, where plants were sparse. Relative frequencies were similar in both years with *Myriophyllum* being the dominant plant.

While densities of the macrophyte community in Lake Mendota as a whole dropped as a result of poor water clarity in both 1979 and 1990, it is unclear why only *Ceratophyllum* declined a second year in a row (1980 and 1991). Future summer surveys will help document the ongoing changes that have occurred in Lake Mendota's macrophytes, particularly since the invasion of *M. spicatum*. It will be interesting whether the next few years will show a resurgence of *Ceratophyllum* and/or *Myriophyllum* or an increase in diversity.

Acknowledgments

We are indebted to the many people who assisted on this project. In particular, D. E. Bergstrom, Jr., L. M. Hartman, and W. T. Seybold assisted in field sampling, and P. W. Rasmussen guided statistical analysis of the data. In addition, C. R. Molter gave us advice on field sampling techniques, and Dr. J. D. Andrews graciously provided unpublished raw data used in his 1980 report. S. B. Nehls made helpful suggestions on outlines and drafts of this report, and J. S. Winkelman provided helpful comments on the final draft. Finally, special thanks are given to Dr. S. R. Carpenter and Dr. S. A. Nichols for their critical review of an earlier draft.

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James O. Evrard

Were wild turkeys found historically in northwest Wisconsin?

The restoration of the wild turkey *(Meleagris gallopavo)* in North America is one of wildlife management's great success stories. Once near extinction, the wild turkey now numbers approximately four million birds. The wild turkey's restoration in much of its historic range and successful introduction in other areas were accomplished by transplanting wild birds into suitable habitat.

With increasing interest in new environmental issues such as biodiversity and restoration biology, the technique of releasing wildlife species outside their historical range is being increasingly questioned. It is, therefore, important to accurately delineate the original distribution of wildlife species. This distribution in North America is generally accepted as that existing at the time of European exploration and settlement.

In Wisconsin, Schorger (1942) delineated the northern limit of the historical range of the eastern wild turkey *(M. g. silvestris)* as a line from Prairie du Chien to Green Bay (Fig. 1). Recent turkey range distributions (Hewitt 1967; Kallman 1987) continue to be based upon his work. In reaching his conclusions, Schorger disregarded or discredited two observations of wild turkeys near Lake Pepin, a natural widening of the Mississippi River about 100 miles north of Prairie du Chien and at the same latitude as Green Bay.

Schorger disregarded Father Hennepin's report that his party killed seven or eight large turkeys *(Cog d'Inde)* near Lake Pepin in 1680. Hennepin also mentioned that Indians reported bustards or wild turkeys *(Outardes ou* [or] *Cogs d'Inde)* in that area. In this instance, *Outarde* or bustard was synonymous with the turkey.

Fig. 1. Original range of the wild turkey delineated by Schorger (1942) and the Tension Zone of Curtis (1959).

Schorger discredited Jonathan Carver's 1776 observations of turkeys at Lake Pepin because he concluded they were pilfered from Hennepin's writings. However, Parker (1976) questioned the validity of the plagiarism charges. Carver's turkey observations may, indeed, be more valid than Schorger believed.

Schorger also attempted to make the case that *Outarde* was the French word for Canada geese *(Branta canadensis)* by using two observations east of Wisconsin, one from Lake Champlain in 1683 and the other from the mouth of the Cumberland River in 1795. However, he appeared to contradict himself by stating:

> Early explorers naturally would call the new American animals by the names of creatures in Europe that they resembled most closely. The *Outarde* or Bustard is a large stocky bird.

> The spreading of the tail and other phases of courtship demeanor give it a decided resemblance to the Turkey. Only speculation can be offered for the synonymy of *Outarde* and Canada Geese.

Two records not available to Schorger in 1942 indicate the wild turkey may have existed nearly 100 miles north of Lake Pepin (Fig. 1).

An *Outarde* was provided to the fur trader, John Sayer, by his Ojibway hunters at the North West Company post on the Snake River, near Pine City, Minnesota, on September 18, 1804 (Gates 1965). The fur trading post was located about 12 miles west of the St. Croix River in Pine County. The *Outarde* could not have been confused with geese because Sayer's journal also mentions that he received geese from his hunters six days later and on five subsequent occasions.

The second record consisted of a wild turkey bone found in a refuse pit during an archeological excavation of a combined North West Company and XY Company fur trading post on the Yellow River in Burnett County, Wisconsin (Ewen 1983). The post was occupied during the winters of 1802–03 and 1804–05 and was located about 3 miles from the St. Croix River and about 28 miles east of the contemporary Snake River post. Journal entries from both forts (Gates 1965; Thwaites 1911) indicated that hunters took their game within 20–30 miles of the posts, suggesting turkeys were present in Pine and Burnett counties at that time.

How could the wild turkey have existed nearly 200 miles north of the original range outlined by Schorger?

A review of presettlement vegetation and the location of the "tension zone" in Wisconsin, a transitional boundary between northern and southern plant and animal communities described by Curtis (1959), supports the northern turkey records. Oak forests and prairies—both turkey habitat—were found south and west of the tension zone (Fig. 1). Oak forests and remnant prairies still cloak the Mississippi River bluffs from the Illinois border to the Minnesota border and along the St. Croix River north into Burnett and Pine counties.

If suitable turkey habitat existed in the Mississippi and tributary river valleys north of Prairie du Chien, why were there so few historical turkey records for the area?

A potential answer to this question was given by Schorger himself. He stated that the northern range limit of the wild turkey, like the bobwhite quail *(Colinus virginianus)* and prairie chicken *(Tympanuchos pinnatus)*, occurred in Wisconsin. He speculated that prior to European settlement, these species existed as members of Wisconsin's fauna only by periodic replenishment from Illinois. The northern limit of their range varied in response to the severity of winter weather, moving northward during a succession of mild winters and retreating southward following severe winters.

Schorger reasoned that the scarcity of wild turkey records in Wisconsin for the last half of the nineteenth century was primarily due to the severe winter of 1842–43 when the species was nearly extirpated in the state. Southern and western Wisconsin were not settled by Europeans until the 1850s so there were very few turkeys remaining for the settlers to see. Massive habitat destruction and unregulated hunting that accompanied settlement sealed the fate of the few remaining turkeys.

Kumlien and Hollister in 1903 stated:

> The Wild Turkey is to-day so rare in Wisconsin that it is safe to say that it is extinct. Authentic references are meager and fragmentary. Dr. Hoy and others say it was abundant in southern Wisconsin prior to 1840. Several references, of which Hoy's is one of the most

reliable, state that the winter of 1842 was practically fatal to them.

Shorger quoted Dr. Hoy concerning the near extinction of the turkey in Wisconsin:

> I am told by Dr. E. B. Wolcott that turkeys were abundant in Wisconsin prior to the hard winter of 1842–43, when snow was yet two feet deep in March, with a firm crust, so that the turkeys could not get to the ground; they hence became so poor and weak that they could not fly and so were an easy prey for the wolves, wildcats, foxes and minks. The Doctor further stated that he saw but one single turkey the next winter, and none since.

Shorger stated that the winter of 1842 was known as the "hard winter" for decades afterward.

There were other hard winters that affected wild turkeys, both historically and more recently. Schorger quoted from the diary of Marquette that the winter of 1674 was one of intense cold and deep snow at the present site of Chicago, Illinois. On December 12, Marquette wrote:

> We contented ourselves with killing three or four turkeys out of many that came around our cabin because they were almost dying of hunger.

Schorger concluded that since these conditions existed at Chicago, it was probable that most wild turkeys in Wisconsin perished that winter.

A more recent example is given by Robbins (1991). Wild turkeys released in the Meadow Valley area of central Wisconsin in the mid-1950s increased to 2,500 birds a decade later. However, the winter of 1968–69 was one of deep snow which took a heavy toll of turkeys. By 1973, the estimated population was only 70 birds.

With this in mind, delineating the historical range of the wild turkey in Wisconsin would depend upon the time period examined. Few turkey records for the northern edge of its range would be found for years following an exceptionally severe winter. Conversely, one could expect to find more wild turkey records during an extended period of mild winters.

European settlement prevented the natural ebb and flow of the northern limit of the occupied wild turkey range and eliminated the species in Wisconsin. But the conversion of much of the state's turkey habitat to agricultural uses set the stage for the eventual reestablishment of the wild turkey. The availability of waste corn in harvested fields and spread manure on today's farms provide winter food that was unavailable to turkeys before European settlement. Wild turkeys can now survive severe winters that would have been impossible in the past.

The wild turkey has returned to the area in east-central Minnesota and northwest Wisconsin where it was found in 1804. Birds released about ten miles south of Pine City, Minnesota, in the 1980s reproduced and spread northward and eastward, crossing the St. Croix River into Burnett and adjoining Polk counties, Wisconsin. The turkey population in this area of Wisconsin in the spring of 1992 was estimated to be 100–200 birds (Michael Johnson, Wisconsin Department of Natural Resources (WDNR), pers. comm. 1992). These birds survived the winter of 1991–92 despite snow depths of nearly 20 inches covering the ground more than five months.

It appears that the wild turkey is now a resident of northwest Wisconsin after an absence of nearly 200 years. The present population was bolstered by a release of wild-trapped turkeys from southern Wisconsin in early 1992. The WDNR plans an additional release of turkeys in the winter of 1992–93. Although severe winters may cause large population fluctuations, food supplied by current agricultural practices should ensure that scattered flocks will persist in this northern landscape.

Acknowledgments

I thank M. Johnson of the WDNR for the discussion that generated the idea for this paper. I also thank E. Oerichbauer of the Burnett County Historical Society for guidance to historical records and J. Hoefler, M. Johnson, J. Kubisiak, and W. Vander Zouwen of the WNDNR and an anonymous reviewer for critical review of the manuscript. Partial funding for this study was provided by the Federal Aid to Wildlife Restoration under Pittman-Robertson Wis. Proj. W-141-R.

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Marguerite H. Helmers

Creating the California Alps

John Muir, the nineteenth-century naturalist, was a prolific and elegant writer whose articles and books numbered in the hundreds through several revisions and editions. His nature writing combines the finest elements of scenic description with exciting adventure stories, but several of his short essays demonstrate much more: that certain styles of writing, like styles of clothing, painting, and music, are historically determined. Muir's writing obeys the conventions of the typical response to nature in the eighteenth and nineteenth century—appreciation of the sublime and the picturesque. This essay will trace Muir's uses of literary formulas of picturesque and sublime representation through two articles. These articles, "Snow-Storm on Mount Shasta" (1877) and "In the Heart of the California Alps" (1880), appeared during what Muir's literary biographer Herbert F. Smith refers to as Muir's "most fertile period," a time of discovery, experimentation, environmental activism, and written expression. They were published initially in *Harper's* and *Scribner's* magazines, although Muir later revised both for inclusion in his book *The Mountains of California* (1894).

These two short essays reveal also that Muir's writing is profoundly subversive. His efforts to incorporate description that would meet the demands of his leisure-class readers carries with it a touch of contempt at the passive mode of observation and conformity to convention that fostered those readers' demands. While he paints beautiful verbal pictures for his audience, inviting them to see the colors, shapes, and wonders of the mountains with him, he always leaves them behind as he moves, solitarily, into the frightful but enlightening adventures of the "California Alps." Literary biographers, including Herbert Smith and Michael Cohen, have noted the antagonism between

John Muir and the public. In many ways, this antagonism centered on a question of access. A solitary wanderer, Muir was fortunate to have access to the mountains, which enabled him to learn to study the peaks, in his words, "long and lovingly." It is such access that he wished to deny the tourists, fearing, like later preservationists, that sheer numbers of unappreciative humans would destroy the ecological balance and massive, expansive grandeur of the wild. Access requires railroads, coach roads, tour guides, walking paths, picnic grounds, in short, an entire institutional structure to accommodate viewing. These two essays reveal the conflict in his efforts to fashion the wilderness verbally, to encourage his readers that the wild was worth preserving, and yet to bar access to the pristine mountains of California. Muir's writings are a tourist's guide through the California mountains, through language and word-painting, but he is also in opposition to the aims of tourists and readers. He alone can find sublimity—a heightened experience—where others find views. While he followed established "rules" of scenic depiction in his writing, he used those rules to ridicule an audience of tourists and leisure-class readers who sought "fine scenes" in nature. My intent is to demonstrate the extent to which Muir employed verbal and artistic conventions in his writing and to show the degree to which these conventions carried an intentional, dual intent.

Herbert Smith contends also that Muir was a formula writer. Smith points to the fact that *Harper's Magazine* seemed to favor highly informational articles about exotic American subjects that could be illustrated nicely (H. Smith 80), such as stories about the wonders of nature. However, a more recent article by Michael Smith notes that Muir, like his fellow naturalist and writer Clarence King, was attempting to define a new style of writing, linking the scientific with the aesthetic (M. Smith 37). These two assessments are not mutually exclusive: while Muir sought to combine scientific writing, adventure, and scenic description, he still relied on specific aesthetic conventions in recreating the grandeur of the California Alps for his audience. Michael Smith's judgment points to an interesting point, however. Muir's writing in "Snow-Storm on Mount Shasta" and "In the Heart of the California Alps" is rather rough and experimental, at times awkward, and it is perhaps this roughness that has often caused biographers, critics, and admirers to turn to the revised versions in *The Mountains of California*. I believe, however, that these two early pieces give us a fresher look at the artist trying to mold his writing to the expectations of his audience while attempting to retain his own strong perspective.

The terms "picturesque" and "sublime" derive from painterly conventions dating from the eighteenth century. Literally, "picturesque" means bringing to nature the qualities of a picture. One of the foremost works of art criticism that deals with the picturesque is Christopher Hussey's *The Picturesque: Studies in a Point of View*. In that work, Hussey identifies the qualities selected by painters as elements of the picturesque:

> . . . roughness, lusciousness of texture, glinting, sparkling surfaces, the crumbling and decayed. These they found in the objects now known as picturesque: sandy lanes, dock leaves, gnarled trees, hovels, donkeys, and ruins. Their brushes were attracted to the rendering of these qualities, because they were well suited to paint. No moral feeling entered into the business, though sentiment was attached to many of these objects, particularly to rural scenes and ruins. (Hussey 246)

For painters (and, later, writers) who adopted its techniques, the picturesque became a way to moderate, to order, and to understand the wilderness of "the sublime." The sublime was, then, a rough and untamed version of wilderness, often frightening in its aspects. The picturesque aesthetically cultivated the raw landscape. Actual landscapes described as picturesque were ones in which life imitated the regularity of art, for the real was sought out for its most painterly qualities.

Hussey points out that the picturesque was "a practical aesthetic" prescribing rules to painters for observation and re-creation. The rules, which Muir applied to his writing, include: a scene composed of foreground, containing stock features such as rocks, cascades, broken ground, and ruins; a middleground, containing meadows and forests; off-skips, or side-screens, containing valleys, woods, rivers; and a background, consisting of perfectly pyramidal mountains and placid lakes (Hussey 116). Particular colors were in vogue. Greens were not allowed, while variations of brown were expected. Brown was associated with romance and sublimity, and because it is the season of browns, autumn became the season favored most by painters employing the picturesque (Hussey 43).

As Romantic poets turned to the picturesque and sublime for inspiration, certain words were intended to infuse language with the onomatopoetic sense of motion—of disorder breaking in on order. These were known as "words of high coloring" (Hussey 35). The presence of words like "shoot," "roll," "dash," "wrap," "bend," "rear," "stretch," "nod," "rage," "gush," "sweep," and "swell" became, like the color brown, another test for the presence of the picturesque (Hussey 35). Norman Foerster points out that Muir employed such onomatopoetic words frequently as a means of adding verisimilitude to what he described, and Foerster labels this Muir's "normal method" of writing (260).

Muir, in fact, combines words that evoke the sense of the picturesque and the sublime with painterly conventions of scenic arrangement. He composes the descriptions in these essays around orderly "scenes," often pausing in his narrative to point out to his audience the places where they may take in a picturesque view. It is not always easy to discern the differences between artistic conventions and literary conventions in his work, as there is a direct correspondence between the two. Conventional words of high coloring express the traditional tenets of picturesque and sublime painterly description. In her study of the intersection between Romantic poetry and conventions of representing nature, Marjorie Hope Nicolson has drawn attention to the ways in which Romantic poets depended on and perpetuated particular literary traditions of representing mountains, just as Muir chose specific words to evoke painter's qualities of color and form in California's Yosemite. Nicolson's work helps to illuminate the repetitions of standard scenic descriptions in Muir's two essays.

The progress of Muir's movements through the two narratives reveals an ascent from the easily comprehensible world of the picturesque to the awe-inspiring world of the sublime. Aesthetically, the picturesque was meant to have popular appeal. Virtually anyone could possess a "picturesque eye" (Hussey 83–84). The sublime, however, was a more exclusive experience, appealing to those with a "Romantic mind." While the picturesque eye could be easily enthralled by an arrangement of rocks and trees, the Romantic mind sought the moral implications of a scene. As Hussey writes, "The Romantic mind, stirred by a view, begins to examine *itself,* and to analyze the effects of the scenery upon its emotions. The picturesque eye, on the contrary, turns to the scene. . . ." (83–84).

In "Snow-Storm on Mount Shasta" and "In the Heart of the California Alps" Muir portrays himself as the possessor of a Romantic mind. In both of the essays, Muir is thrown by circumstances into dangerous situations which offer him the opportunity to reflect on the infinite. It is quite clearly implied in the essays that he alone is able to experience the sublime. While he often invites his readers to look upon a picturesque scene with him, he alone is forced into extraordinary feats of exertion that leave him pondering the workings of God in the world. Surrounded by boiling mud and noxious gases, the peak of the adventure story in "Snow-Storm," Muir seems almost cheerful to have the opportunity to contemplate "God's Design." He also records in "In the Heart of the California Alps" that when facing death atop Mount Ritter, hanging from a shard of rock, he is saved by a "Guardian Angel."

Muir constructs himself as the Romantic type, an exemplary mountaineer, insightful, sensitive, fearless, and self-sufficient. As Muir reveals in "Snow-Storm on Mount Shasta," he climbed mountains in shirt sleeves, packed no blankets, and, for sustenance, carried only a crust of bread and a tin cup with which to scoop water from mountain streams. Although he never mentions tourists in either of these articles, a knowledge of Muir's antagonism toward popular travel as documented in his letters and biographies sheds new light on his *ethos,* the way in which he constructs himself and reveals his attitude toward his audience. Travelers from the East, overburdened with clothing and provisions and blind to the true significance and potential danger of the wilderness around them, are conventional enough in themselves today, but Muir was working to fashion distinctions between those with a shallow perception of nature and those with a deeper understanding of nature, between those who were interested in the picturesque and those who were fascinated by the sublime. Fearful that the industries of farming and tourism would result in a desecration of wild spaces, Muir sought to portray to his audience the need to retain untouched spaces where the infinite might be experienced. In other words, as many people as possible had to remain behind on the path.

Muir's extraordinary sensitivity to the wilderness and his ability to experience the sublime workings of nature are shown to good advantage in "Snow-Storm on Mount Shasta," which is an unusual essay in that it combines an introductory section of scientific explication with picturesque descriptions and an adventure story. In the essay, Muir attends to the colors and contrasts of the landscape, introduces natural ruins, reflects with awe upon the powers of God, and directly appeals to the reader to behold scenes as picturesque. It is in "Snow-Storm on Mount Shasta" that Muir's efforts to combine scientific observation with literary writing seem most forced and awkward. Early in the essay, he divides the mountain into three botanic zones and enhances his verbal description with an illustration of three evenly concentric circles. He notes the elevation of each region and its indigenous flora and provides a list of all the coniferous trees he has discovered (Muir 523). The outermost zone, at the base of the mountain, is the chaparral zone, covered in evergreens and lilies; the inner zone, the fir zone, is covered in silver-firs; and the uppermost Alpine zone is covered in snow, dwarf pines, and some flowering plants. Following this catalogue, however, Muir shifts perspective, moving from a focus on the natural sciences to a focus on the aesthetic.

Muir opens the article by establishing the differences in texture, temperature, and tone between glacial ice and volcanic lava, contrasts which will figure prominently in the climax of the adventure story and which demonstrate nicely the desire to emphasize picturesque contrasts:

> Mount Shasta, situated near the northern extremity of the Sierra Nevada, rises in solitary grandeur from a lightly sculpted lava plain, and maintains a far more impressive and commanding individuality than any other mountain within the limits of California.
>
> Go where you will within a radius of from fifty to a hundred miles, there stands the colossal cone of Shasta, clad in perpetual snow, the one grand landmark that never sets. . . . During the glacial period Mount Shasta was a center of dispersal for the glaciers of the circumjacent region. The entire mountain was then loaded with ice, which, ever descending, grooved its sides and broke up its summit into a mass of ruins. (521)

Mount Shasta exhibits two qualities essential to sublime and picturesque description. Primarily, the mountain is introduced as a pyramid, part of the "backdrop" of the picture. The mountain is also irregular, broken into a mass of ruins. As Nicolson contends, irregularity began to replace the aesthetic of regularity in the late eighteenth century, when Addison praised the "rudeness" of the gardens in France and Italy in preference to the "regular," landscaped gardens of England (317). Acceptance of irregularity as a valid aesthetic quality gave new importance to the place of ruins in scenes. Nicolson notes that ruins were attractive because of their "asymmetry" (336). Muir describes the irregular summit of Mount Shasta as a mass of crumbled rock. It is, he writes, a natural "ruin."

The ruins and irregularity have further conventional associations, for Muir is careful to describe that they were formed by volcanic eruptions. Volcanoes were important to formulas of the sublime because the great geologic upheavals that they caused epitomized the ruining of nature: "The mountain bursts into flame, and man with all his works lies buried in the Ruins of Nature" (Nicolson 341). Ruins of nature reflected in turn on the frailness of human existence, which Nicolson refers to as the "Ruins of Time." Descriptive poets of the nineteenth century, most notably Byron and Shelley, shared the relish of earlier poets for thunderstorm and tempest, earthquake and volcanic eruption (Nicolson 380). Following the conventional literary usage of words of high coloring and the fascination with irregularity, ruins, volcanos, and natural violence, Muir paints Shasta's main summit. Viewing it from the north, he describes Shasta as:

> . . . an irregular blunt peaklet about ten feet high, fast disappearing before the stormy atmospheric erosion to which it is subjected. Hot sulphurous gases and vapors escape with a loud hissing noise from fissures in the lava near the base of the eastern ridge, opposite the highest peaklet. Several of the vents cast up a spray of clear bead-like drops of hot water, that ride repeatedly into the air and fall back until worn into vapor. (Muir 522–23)

As he begins the narrative portion of the essay—the story of his ascent of the mountain—he pauses to direct attention to the view from Strawberry Valley. It is the first direct appeal to the audience in the essay and suggests Muir's awareness of the leisured reader's demands for taking scenes. It is an awkward and theatrical intrusion into the narrative and an abrupt turning away from the concern with botanical taxonomies. With the potential for leisured readers to become inquisitive tourists, Cohen posits that "all of Muir's writings were for the tourists, since they involved the question of how to see. Most tourists did not want to hear philosophy, but wanted to know exactly where to stop and look" (Cohen 207). Muir, perhaps experimenting with what he saw as a necessity of the audience, caters to demands by writing that:

> . . . at Strawberry Valley there is a grand outopening of the forests, and Shasta stands revealed at just the distance to be seen most comprehensively and impressively.
>
> Looking at outlines, there, in the immediate foreground, is a smooth green meadow with its crooked stream; then a zone of dark forest, its countless spires of fir and pine rising above one another higher and higher in luxuriant ranks; and above all the great white cone sweeping far into the cloudless blue. . . . (524)

The obligatory picturesque elements of this tri-level view are the meadow and (irregular) "crooked stream" in the foreground, the forest zone "rising above" the foreground as all well-painted middlegrounds and sidescreens should, and the perfect pyramidal cone of the mountain, the focal point of the picture. Earlier in the essay, Muir had already written that Shasta was perfectly drawn, an exquisite pyramid: "[T]he regularity and symmetry of its outlines remain unrivaled. The mountain begins to leave the plain in slopes scarcely perceptible, measuring from two to three degrees. These are continued by exquisitely drawn gradations" to the surmounting crater (522).

Having painted the picture, he steps in through the frame with his climbing partner Jerome Fay. "For him," Cohen says about Muir, "it was not as important to view the scene as to be *in* it . . ." (241). Working with Fay to record "barometrical observations," his close inspection of the jagged cliffs and fumaroles of Mount Shasta is registered with the knowledge that the tourists to whom he writes will stay in the valley.

With his step inside the frame, the adventure story begins.

Fay and Muir make their climb three months before the regular climbing season begins and carry instruments designed to study fluctuations in weather. After two beautifully clear days, Muir and Fay are enveloped by a violent snowstorm. To give the reader an idea of the magnitude of the storm, Muir employs another conventional element of scenic description, the prospect view, which establishes "the larger spatial context in which . . . action takes place" (Nevius 30). As the heavy clouds begin to stir and brew, Muir looks about to see that:

> [t]he black lava beds made famous by the Modoc war; many a snow-laden peak far north in Oregon; the Scott and Trinity mountains; the blue Coast Range; Shasta Valley, dotted with volcanoes; the dark coniferous forests filling the valleys of the Upper Sacramento—were all in turn obscured, leaving our own lofty cone solitary in the sunshine, and contained between two skies—a sky of spotless blue above, a sky of clouds beneath. (Muir 526)

Here again are the contrasts essential to a picturesque scene: the clouds are absent from above, but obscure all below. And, as the snow falls, Muir records that it touched them "not a whit more harshly than warm rain on the grass" (528). Muir's experience on the mountain would be a sharp contrast to the experience of an ordinary tourist, safely within reach of shelter below, for he finds himself in a world where the trees are "crushed by winter snow, and shorn off by the icy winds," a world of "frost wind" and "scalding gas jets." Muir appears to address the absent readers as they sit comfortably fireside with their copy of *Harper's*:

> The ordinary sensations of cold give but faint conceptions of that which comes on after hard exercise, with want of food and sleep, combined with wetness in a high frost wind. (529)

To warm themselves, Muir and Fay find their way to a small patch of volcanic earth and are warmed by the thermal activity. The two explorers spend seventeen hours on this quarter acre of ground where contrasting temperatures pose dangers to their lives. From above they are threatened by the icy snowstorm; from below noxious fumes could poison them:

> The acrid incrustations sublimed from the escaping gases frequently gave way, opening new vents, over which we were scalded; and fearing that if at any time the wind should fall, carbonic acid, which usually forms so considerable a portion of the gaseous exhalations of volcanoes, might collect in sufficient quantities to cause sleep and death, I warned Jerome against forgetting himself for a single moment. . . . (528–29)

They suffer "the pains of a Scandinavian hell, at once frozen and burned" (Muir 529). It is a truly sublime experience, filled with terror, yet offering opportunities to reflect on life, death, and the infinite, which Muir and Fay (dutifully observing the conventions of sublimity) do. Fay wonders if prayers would help them, but Muir seems to dissuade him from praying with a rather deterministic speech about "the unflinching fair play of Nature." Violent tempests that threaten the lives of humans are all part of the Design: "Life is . . . a mere fire, that now smoulders, now brightens, showing how easily it may be quenched" (Muir 529).

Muir and Fay survive the night. "Snow-Storm on Mount Shasta" ends abruptly as they slide and shuffle into their camp, impeded by frozen trousers and hunger. Their descent is a descent from the sublime to the picturesque, both scenically and intellectually. For the sublime is the world of the Romantic and the Romantic's inward-turning eye; it inspires awe because it is too large to comprehend. But the picturesque can be appreciated by anyone who is familiar with painting; the picturesque is simple, flat, contained. When Muir returns to the chaparral zone he steps back through the picture frame. From the safety and comfort of his distant hotel room he may admire, for the audience, the view in the frame: the next morning "from the window I saw the great white Shasta cone wearing its clouds and forests, and holding them loftily in the sky" (Muir 530). In his assessment of Muir's life and work, Frederick Turner has noted that the cheerful ending gives no clue that Muir was suffering from severe frostbite (229).

"In the Heart of the California Alps," like "Snow-Storm on Mount Shasta," also places an adventure story within an artistic frame. Muir uses the elements of the picturesque and the sublime more self-consciously than in the earlier piece, often drawing attention to the qualities of nature that are similar to the elements of a painted landscape. For example, he sets his narrative in Indian summer and opens by "painting" the scene of the Tuolumne Valley with lavish detail:

> The intense azure of the sky, the purplish grays of the granite, the red and browns of dry meadows, and the translucent purple and crimson of huckleberry bogs; the flaming yellow of aspen groves, the silvery flashing of the streams, and the bright green and blue of the glacier lakes. (Muir 346)

The writing in this essay is less rough than "Snow-Storm on Mount Shasta," for Muir dispenses with diagrams and scientific pretenses and draws attention to the artistic qualities of the wilderness instead. He takes as his companions two artists in search of "a landscape suitable for a large painting" (Muir 346). Despite the fact that one of the artists (who remains nameless in the essay) was a close friend of Muir's named William Keith (Turner 209), it is clear from the text that the painters are constructed as possessors of picturesque eyes, interested only in what they can paint and not in the finer, less accessible, but more rewarding aspects of sublime experience.

Symbolically, Muir's ascent of Ritter represents a passage out of the banal appreciation of the picturesque to the greater understanding of the sublime. At times, however, Muir seems somewhat more sympathetic to the picturesque qualities of the valley, at one point remarking that the valley was waiting for "the elected artist"— "I could not help wishing that I were that artist," he laments (346). Nevertheless, although he is wont to throw up his arms "to inclose [the Tuolumne Valley] as in a frame" (346) and to wax eloquent on its majesty, it is significant that he eventually leaves the painters behind to sketch views while he alone accepts the challenge of climbing to the summit of Mount Ritter. Frederick Turner remarks, "as far as anyone knew it had never been climbed. Moreover, at this season (the last days of August), though the weather was still clear, there was the ever-present danger of snow. For Muir, all the conditions were right for climbing . . ." (209). Ritter posed a challenge for the individualist Muir.

At the start of the ascent to Mount Ritter, Muir notices that the best view of the California Alps comes from the headwaters of the Tuolumne River. Muir directs the reader's gaze to a scene he describes as "in a high degree picturesque, and in all its main features so regular and evenly balanced as almost to appear conventional" (345). He divides it into the traditional artistic foreground, middleground, and background. The foreground is the "magnificent valley" resplendent in autumn colors of brown, purple, and gold. It is "smooth, meadowy" and "level," dotted with "dipping willows and sedges" and "groves of arrowy pine." Through the foreground the waters of the Tuolumne flow from their source in the middleground, where it pours from "crystal fountains" and leaps in "white cascades." The middleground also contains the restricting "off-skips," narrowing and focusing the viewer's eyes toward the background. The off-skips in this painting are the "granite bosses" and the walls of the valley, "beveled away on both sides so as to embrace it all without admitting anything not strictly belonging to it." The background is colored in contrast to the foreground. The sky is cobalt blue, the glaciers are black, gray, and "pure, spiritual white." The focal point of this picture is "one somber cluster of snow-laden peaks . . . surging free into the sky" from the valley (345).

Curiously, while cataloguing the picturesque features of the scene from the valley, Muir asserts that "[f]ew portions of the California Alps are, strictly speaking, picturesque" (345). He argues that making a picture of these Alps would require separating the magnificence of the range to allow the discrete picturesque elements to be appreciated in isolation. However, he asserts, separating each mountain from the others so it might serve as the focal point of a painting would damage the incredible impression made by the whole range:

> The whole massive uplift of the range, four hundred and fifty miles long, by about seventy wide, is one grand picture, not clearly divisible into smaller ones; in this respect it differs greatly from the older and riper mountains of the Coast range. . . . But all were not brought forth simultaneously; and, in general, the younger the mountain landscapes, the less separable are they into artistic bits capable of being made into warm, sympathetic, lovable pictures. (345)

The artist companions, functioning as tourist-surrogates, are searching for such "artistic bits." Early in their journey into the mountains, they comment, "All this is sublime, but we see nothing as yet at all available for effective pictures" (Muir 346). Yet, although they are able to recognize the elements of the sublime, they are without feeling for it. The sublime does not create in them the appropriate response of fear and wonder. They are innocents, unable to wrestle with the implications of God in the wilderness. Their Puritan notion of the wilderness as something alien to humans, something to be conquered, gives root to their desire to tame the wild through pictorial representation—reducing it to a canvas three feet by four feet, imposing composition on the chaotic elements. The artists seek something recognizable, something known, something familiar, like the tourists on their approved path, following a conventional guidebook.

In the earlier article, Muir positioned himself in opposition to an assumed audience of tourists. He was able to find sublimity in a landscape where others found only views. It is evident in "In the California Alps" that Muir values the primacy of his *own* experience, and he hints that only he has the strength and the understanding to come to love the mountains, asserting that it is only after the mountains have been studied "one by one, long and lovingly," that one can begin to understand their full grandeur. Ironically, "loving" the mountains embodies the very aesthetic that he opposes—familiarizing the mountains into something to be framed and placed over a mantlepiece, destroying their ability to inspire fear and awe. In admitting his own attachment to the mountains, Muir deviates significantly from the conventional sublime response to the peaks—terror (Nicolson 356).

Loving, or "familiarizing," according to Walker Percy, is an inevitable part of being a tourist. Percy notes that visual, touristic, experience is bound by a "symbolic complex," a formulation of expectations prefigured by textual treatments (55). Satisfaction is measured by the way the tourist's experiences conform to the symbolic complex. So pervasive were the conventions of the picturesque in the nineteenth century (as John Sears in his work on nineteenth-century tourism and Nicolson have emphasized) that Muir's artist friends could not see beyond their expectations. They instead seek the familiar: a landscape suitable for painting. With the popular European Alps etching the scheme of mountains in their minds, Muir's artists eventually find a "landscape suitable for a large painting," and Muir records that one of the artists "dashed ahead, shouting and gesticulating and tossing his arms in the air like a madman. Here, at last, was a typical Alpine landscape" (346). With this incident, Muir not only points out to his readers that typical Alpine scenes are available for viewing in California, he shows the extent to which searching for the typical is ridiculous. So excited is this artist at finding a landscape which matches his conception of the European Alps, that he is blind to the authentic and particularly Californian charms of the Sierras. In this, as in other passages in these two essays, Muir invites readers to partake of the scenery while simultaneously drawing attention to the shortcomings of prefigured vision.

While the artists decide to remain at their mountain camp and sketch, Muir plans to continue climbing to the summit of Mount Ritter heretofore only visible as the focal point of the background, the "grand masterpiece." Again, as in "Snow-Storm on Mount Shasta," he steps through the foreground and middleground of the picture he paints. As he crosses the foreground, he traces "happy streams" to the "foot of a white cascade," which announces the beginning of the middleground, where he finds "painted meadows" and silvery lakes. When Muir begins to climb through the middleground toward his destination of the backdrop, he is able to look back on the land he has just traversed. It emerges as a prospect view, the far reaches of which exist in Muir's imagination:

> Over the summit, I saw the so-called Mono desert lying dreamily silent in thick, purple light—a desert of heavy sun-glare beheld from a desert of ice-burnished granite. Here the mountain waters divide, flowing east to vanish in the volcanic sands and dry sky of the Great Basin; west, to flow through the Golden Gate to the sea. (347)

As Muir pushes further toward the summit of Mount Ritter, he moves deeper into the realm of the sublime. The landscape now is full of "savage peaks," "spurs," and plunging "gorges"; it is sparse and bare. Such surroundings are the surroundings of the Romantic and Muir writes:

> In so wild and so beautiful a region my first day was spent, every sight and sound novel and inspiring, leading one far out of oneself, yet feeling and building a strict individuality. (347)

Although the picturesque is still evident here, in "little gardens" that decorate natural streams and pools, for instance, Muir is in the realm of the sublime. Sights and sounds are "novel." Like ruins atop hills, the flat-topped spurs are "marked and adorned with characteristic sculptures of the ancient glaciers that swept over this entire region like one vast ice-wind . . ." (347). When Muir sets his camp, he is encircled by "somber peaks, hacked and shattered . . . wearing a most savage aspect." A waterfall runs nearby, and "scraggy pines" in "rock-fissures" were "dwarfed and shorn" by wind (348).

Crossing mountains, Muir arrives at the final summit before that of Mount Ritter:

> There, immediately in front, loomed the majestic mass of Mount Ritter, with a glacier swooping down its face nearly to my feet, then curving westward and pouring its frozen flood into a dark blue lake, whose shores were bound with precipices of crystalline snow; while a deep chasm drawn between the divide and the glacier separated the massive picture from everything else. (349)

Although he is now amidst the sublime, the composition of the scene upon Muir's arrival atop the final summit before that of Mount Ritter is again a basic three-part structure recalling the picturesque. The foreground consists of the summit upon which he stands, the middleground is a grouping of a deep chasm, a glacier, and a lake toward the left side of the side-screen, and the background is the peak of Ritter itself. The atmosphere is far from placid and ordered, however. He faces steep gullies and vertical cliffs, which only emphasize the size of the mountain that lies ahead. Muir is atop an adjoining summit, so his view is not from the base of Mount Ritter, but from an elevation equal to about a third to half of Ritter. His vantage point does not come close to equalizing the relationship between his summit and the one that lies in front. Instead "massive battlements" stand forth, roughly hewn and shadowed. Even more telling, "huge, crumbling buttresses" extend to Muir's right and to his left, as far as he can see (Muir 349).

Suddenly, Muir's descriptions take on eery and unearthly overtones that seem to correspond to his reach into the sublime atmosphere that surrounds the summit of the mountain. Muir begins to employ bodily metaphors to emphasize the seemingly incomprehensible size of Mount Ritter, lying ahead; he defamiliarizes what had earlier been familiar, "loved," even understood. Turner recalls that Muir, traveling in his early years, had experienced a "dangerous weakness" from lack of bread (189), and perhaps the visions that he experiences here were induced by such deprivations. While the "head of the glacier sends up a few finger-like branches," Muir picks his way through numerous "narrow-throated gullies" and "across the yawning chasm," he hears the "gurgling of small rills down in the veins and crevasses," and he discovers "the mouth of a narrow avalanche gully." These human-like metaphors serve to reduce the extraordinary size and distance which he confronts, a technique employed, for example, by painter Thomas Cole in his *Snow Squall, Winter Landscape in the Catskills*. In a book that offers a psychoanalytical reading of American art history, Bryan Jay Wolf comments that the viewer will relate to the foreground plane of Cole's painting, a rocky promontory which juts vertically into a vacant chasm. A wolf and a few barren trees are the visible inhabitants of that promontory. However,

> [t]he wolf and trees that accommodate him, however uncomfortably, to the promontory world, individuating it and rendering it on human scale, either disappear in the middle-ground space or reappear in the case of the background forests in such proportions that their scale seems threatening and annihilating. . . . By traversing the valley and encountering the change of scale it implies, the viewer undergoes a process of "defamiliarization." The veil of familiarity is lifted from the face of nature and an alien strangeness left in its stead. (186)

Once looked upon "long and lovingly," the mountains are now something grotesque and fearsome, underscoring the deathly situation in which Muir soon finds himself: "at the foot of a sheer drop in the bed of the avalanche channel" (350). Although he clings to rocky footholds and handholds he fears that his doom is fixed. "I *must* fall. There would be a moment of bewilderment, and then a lifeless rumble down the one general precipice to the glacier below" (Muir 350). If, as Hussey sets forth, the mountains are "a *memento mori* on a gigantic scale" (Hussey 55), it is fitting that Muir should encounter imminent death clinging to the face of the most sublime of all peaks. It is significant, too, that his faith in the infinite once again allows him to survive:

> I seemed suddenly to become possessed of a new sense. The other self—the ghost of by-gone experiences, Instinct, or Guardian Angel—call it what you will—came forward and

> assumed control. Then my trembling muscles became firm again, every rift and flaw in the rock was seen as through a microscope, and my limbs moved with a positiveness and precision with which I seemed to have nothing at all to do. Had I been borne aloft upon wings, my deliverance could not have been more complete. (Muir 350)

Above the place where Muir faces his destiny, he describes the mountain as a place "savagely hacked and torn," chasms "yawn," "detached bowlders [sic]" fill the "crags." Nevertheless, befitting the mystical aesthetic of the sublime, despite its potentially horrendous consequences, the peak and his experience there is "glorious," and Muir stands suffused in "blessed light" (350).

Following his harrowing experience, Muir descends toward the valley, returning to the realms where the familiar scenic conventions of the picturesque dominate. The landscape becomes more composed. Mountains arch into the background, their peaks "swelling higher, higher as they sweep on southward" (350). Natural ruins abound: Cathedral Peak is "a temple of marvelous architecture," a mountain seems a "gigantic castle with turret and battlement, the clusters of Alps are "eloquent monuments of the ancient ice-rivers that brought them into relief" (351).

Back at the camp, Muir finds the artists worrying over his safety. They feared that he had been overtaken by the elements, not knowing that it was he who triumphed over the elements. Muir comments that their troubles seemed "curious." After all, his journey had been "only a matter of endurance and ordinary mountain-craft," and he had been absent only three days when he had warned that he might be absent for over a week (Muir 352).

The artists pack "their precious sketches," concluding the "fine double excursion" of artists and scientist into the picturesque and the sublime.

Muir's uses of the conventions of picturesque and sublime description were an inevitable result of the literary climate in which he worked. Yet, as I mentioned earlier, there is also a strong subversive element in his writing. Literary critic Marvin Fisher asserts that Muir's contemporary Herman Melville was a subversive writer, forced to "go underground" in order to satirize the very audience for whom he wrote. These two essays, when examined in light of Muir's own comments elsewhere and revelations of his predispositions by his biographers, seem to indicate that Muir too sought to satirize and patronize an audience upon whom he depended for financial support. Muir found himself linked to an audience for whom he held little respect. Fearful of the encroachments of technology, he was fighting to preserve the wilderness of the American West. He realized that his stories of the mountains would raise public awareness of western beauty and would be instrumental in enjoining Americans to protect the wild regions of Yosemite from farming and industry. Cohen points out that "Americans would need some encouragement, would need to know not only what they possessed, but why it was worth protecting and how this could be done" (205). Because the literary conventions of the sublime and the picturesque were well worn and would be well recognized by his readers, their effect was to make an unfamiliar landscape familiar to readers living thousands of miles away, something politically necessary.

Muir's texts are problematic, revealing a narrator in conflict about his role as preservationist and writer, for he knew his stories would extend beyond the page to encourage tourism, and he worried that the pristine land would be overrun by tourists in search of the picturesque. In his biography of Muir, Cohen notes that it was difficult for Muir to hide his contempt of complacent tourists, eager only for a view and not for knowledge about their surroundings (129, 207). To illustrate his point, Cohen draws from this letter written by Muir to his friend Jeanne Carr. Muir wrote, "They climb sprawlingly to their saddles like overgrown frogs pulling themselves up a stream bank through the bent sedges, ride up the Valley with about as much emotion as the horses they ride upon—are comfortable when they have 'done it all' and long for the safety and flatness of their proper homes" (Bade 220). His attitude toward the leisured class takes on importance in a study of his style, for it seems ironic that one so vehemently opposed to the domestication of the wild would seek not only to entice visitors forward, but would, though his very language, reduce Nature into a series of "fine scenes" for the pleasure of the audience.

Yet Muir was prepared to pander to the "frogs," and he did so at least in part through his application of the conventions of picturesque description. In his verbal landscapes, mountains become frosty cones settling into backdrops; sparkling lakes and twisted trees dapple his foregrounds. And it is quite surprising that Muir often pauses in his narration to point out "views." Coupled with his own stories of adventure and extreme exposure to inhospitable elements, the views seem inconsequential, almost afterthoughts. At times, especially after the more harrowing of Muir's adventures, his references to fine scenes seem a harshly reductive view of nature. Like the artists who accompany him on his journey into the heart of the California Alps, Muir loved mountains. His prose made them accessible, beautiful, and orderly, rather than terrifying and forbidding. In many ways, through his writing, Muir destroyed the aspects of the mountains that he prized most: their seclusion, their remoteness from human intervention, their inhospitability. Described according to traditional artistic and literary conventions, the Sierras lost their uniqueness, becoming just another typical example of an aesthetic norm determined by the European Alps.

When the artists with whom he travels into the California Alps pack their sketches, they close the book on nature. Muir, however, distinguishes himself as a privileged observer by finding the book continuously open. He would return to read "the records she has carved on the rocks, reconstruct . . . the landscapes of the past" (Alps 351). While Muir textually domesticated nature, reducing it into a series of fine scenes for an appreciative audience, he preferred to leave the reality wild, a setting for his many returns to the summits and peaks.

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Blanchard's cricket frogs (Acris crepitans blanchardi) *in southwest Wisconsin*

Abstract *State-endangered Blanchard's cricket frogs* (Acris crepitans blanchardi) *were censused in southwest Wisconsin and found at 19 of 40 sites which historically were known or were thought to have had populations of this species. Blanchard's cricket frogs were found most often at sites with mud and vegetation banks and shallow slopes leading to the water, although these trends were not statistically significant ($P > 0.15$). Neither habitat variables (e.g., water depth, bank type) nor indices of water quality (pH, conductivity, oxidation-reduction potential, turbidity) differed significantly between sites with and without Blanchard's cricket frogs. However, water temperature was significantly greater at sites with cricket frogs than without ($P = 0.011$). The total number of frog and toad species at a site (range = 0–7) was positively correlated with water temperature ($P = 0.017$) and negatively correlated with turbidity ($P = 0.021$). In addition, significantly more anuran species were found at sites without agricultural fields nearby ($P = 0.0026$).*

Recent reports of declining amphibian populations around the world (Blaustein and Wake 1990; Lohmeier 1990; but see Pechmann et al. 1991) have instigated research efforts toward understanding potential causes (e.g., habitat loss, pesticides, acid rain, drought). In Wisconsin, the Blanchard's cricket frog (*Acris crepitans blanchardi*) has declined precipitously during the last two decades (Vogt 1981; Mossman and Hine 1985) and has been on the State Endangered list since 1982 (Bureau of Endangered Resources 1989). Habitat loss, drought, and polluted water are a few of the factors hypothesized to have caused Blanchard's cricket frog population declines (Minton 1972; Oldham 1992; L. A. Wilsmann, pers. comm.). Wisconsin represents the northern limit of the geographic range of Blanchard's cricket frogs (Conant and Collins 1991), and it is possible that routine physiological stresses (e.g., during overwintering; cf. Bradford 1983) may be relatively high. Thus, Wisconsin populations of this species might be particularly sensitive to additional stressors, such as those related to deteriorating water quality.

M. J. Mossman and R. L. Hine (Mossman and Hine 1984, 1985) of the Wisconsin Department of Natural Resources (WDNR) initiated the Wisconsin Frog and Toad Survey in 1981. Relatively few (2 of 63) of the early WDNR survey routes, however, were located in southwest Wisconsin (Grant, Iowa, and Lafayette counties), where Blanchard's cricket frogs still occur (Mossman and Hine 1985).

The purpose of this study was to survey Blanchard's cricket frogs in southwest Wisconsin, and to determine whether selected habitat and water quality variables were related to the presence or absence of Blanchard's cricket frogs or other frog and toad species.

Methods

During the summer of 1991, I conducted a census of the Blanchard's cricket frog in southwest Wisconsin (Dane, Grant, Iowa, and Lafayette counties). I chose to study 40 sites which, according to records provided by the WDNR (Wisconsin Natural Heritage Inventory Program; Wisconsin Frog and Toad Survey, M. J. Mossman, pers. comm.) and the Milwaukee Public Museum (Wisconsin Herpetological Atlas Project, G. S. Casper, in prep.), were historically reported to support Blanchard's cricket frog populations. The sites were visited an average of 2.6 ± 0.99 times (range = 1–4) between 11 May and 17 July, during the peak chorusing season for cricket frogs (Vogt 1981). Most sites were visited at least once during the day and once at night. If no chorusing was heard, a tape recording ("Wisconsin frogs," produced by R. Anderson and D. Jansen, University of Wisconsin–Stevens Point) of Blanchard's cricket frog vocalizations, which is thought to elicit chorusing, was played for two minutes (Mossman and Hine 1985). Frogs and toads were identified by call, sight, and/or catching animals by hand. Numbers of calling males were estimated by walking the water's edge, noting differences in directions of calls, and listening for distinct vocalizations. Spring peepers (*Hyla crucifer crucifer*), western chorus frogs (*Pseudacris triseriata triseriata*), northern leopard frogs (*Rana pipiens pipiens*) and pickerel frogs (*Rana palustris*) were not adequately censused as they chorus primarily from March to May (Vogt 1981). Seven of the sites I censused were also covered in 1991 by the Wisconsin Frog and Toad Survey, so I incorporated additional species-presence data from this source as well.

Water samples were taken approximately 0.5 m from the water's edge. Four indices of water quality (temperature, pH, conductivity, oxidation-reduction potential [ORP]) were measured using a Cole-Parmer Water Test, Model 05556-00. Conductivity represents the total concentration of electrolytes in solution (higher conductivities corresponding to higher ion content, particularly Ca^{++}, Mg^{++}, Na^{+}, and K^{+}) and is expressed in micro-Siemens (Wetzel 1983). ORP, measured in millivolts (mV), is proportional to the equivalent free energy change per mole of electrons associated with a given reduction. Large, positive ORP values signify strongly oxidizing waters. In addition, turbidity of a water sample in a beaker was estimated by eye and scored on a scale of 0–5, ranging from clear to muddy.

Habitat variables assessed included: (a) whether the site was a lake/pond or stream/river, (b) water depth 10 cm from the edge, (c) percent cover of water area by rooted aquatic plants, (d) percent cover of water area by algae, (e) composition of water bottom (mud, mud and rock), (f) bank type (mud, mud and vegetation, vegetation), (g) bank slope (flat, flat and steep, steep), and (h) whether the site was adjacent to pasture land (primarily with cows) and/or agricultural land.

All statistical analyses were performed using SPSS (Norusis 1988). Significance was judged at $P < 0.05$. Yates' correction was used for chi-square tests of independence when any expected frequencies were < 5. For water quality analyses, I used mean values for pH, water temperature, conductivity, and ORP; I also computed a mean visitation date for each site to use as a covariate in statistical analyses.

Results

Habitat data for 39 sites (excluding Iowa County site 16) are presented in Table 1. No habitat data were collected for Iowa County site 16 because the lake had been completely drained in the spring of 1991, and Blanchard's cricket frogs no longer occurred there. Site locations are not presented here (see Wisconsin State Statute 23.27, section 3, paragraph B; Casper 1989), but are available from the WDNR Natural Heritage Inventory Program upon request. Blanchard's cricket frogs were found at 19 of the 40 (48%) sites which historically were reported to have supported cricket frogs. I estimated 125 cricket frog calling males at 18 sites (Table 1). Assuming equal sex ratios (see Pyburn 1958), the population estimate (males and females) for these sites is 250 frogs, yielding a mean ± standard deviation (SD) of 14 ± 9.6 frogs per site.

Blanchard's cricket frogs were heard chorusing during the day (between 11 a.m. and 6 p.m.) on seven occasions, but were most often heard chorusing after 6 p.m. (18 occasions). Breeding choruses of the Blanchard's cricket frogs tended to be dense (males within one meter of each other) and localized in mudflat areas or in vegetated shallow water habitat (see Perrill and Shepherd 1989). Exact densities of frogs or inter-male spacing were not recorded in order to avoid disturbing frogs and habitat and also because of the difficulty in delineating how much area comprised suitable habitat.

Chi-square and Mann-Whitney U tests indicated that the presence of Blanchard's cricket frogs was not related to the habitat variables I recorded. Of the 19 sites where Blanchard's cricket frogs were present, 12 were categorized as stream/river habitats and seven as pond/lake sites; cricket frogs were no longer present at 15 stream/river sites and 6 pond/lake sites ($X^2 = 0.311$, d.f. = 1, $P = 0.577$).

Most Blanchard's cricket frog populations were found at sites with flat slopes leading to the water's edge (17 of 19) and mud and vegetation banks (17 of 19; all with mudflats). However, because most sites surveyed had flat slopes (34 of 39) as well as mud and vegetation banks (30 of 39), the distribution of Blanchard's cricket frogs did not differ from random with respect to these habitat variables (X^2: $P = 0.614$ and 0.150, respectively). Only 6 of the 19 sites with Blanchard's cricket frogs were adjacent to agricultural (primarily corn) fields, yet a chi-square test comparing presence and absence of cricket frogs at sites adjacent versus not adjacent to agricultural fields was not significant ($X^2 = 1.766$, d.f. = 1, $P = 0.184$). No relationships were found between the presence versus absence of Blanchard's cricket frogs and pasture land, bottom type, water depth, or percent cover of algae or rooted aquatic plants. In summary, with respect to the variables measured, Blanchard's cricket

Table 1. Data for 39 sites in southwest Wisconsin.
Key: BC = Blanchard's cricket frog (0 = absent, 1 = present); #BC = estimated # of BC frogs; S = # of anuran species; H = Habitat (0 = stream/river; 1 = lake/pond); WD = Water Depth (cm); T = water temperature (C); C = conductivity (uS); ORP = oxidation-reduction potential (mV); Tu = Turbidity (0–5, clear-muddy); Aq = % rooted aquatic plants; Al = % algae; Bc (bottom composition): 1 = mud, 2 = mud/rock; Bt (bank type): 1 = mud, 2 = mud/vegetation, 3 = vegetation; Sl (slope): 1 = flat, 2 = flat/steep, 3 = steep; Cow: 0 = absent, 1 = present; Cr: 0 = no agricultural fields nearby, 1 = fields nearby. -9 indicates missing data.

Site	*BC*	*#BC*	*S*	*H*	*WD*	*pH*	*T*	*C*	*ORP*	*Tu*	*Aq*	*Al*	*Bc*	*Bt*	*Sl*	*Cow*	*Cr*
Dane																	
1	0	0	3	1	23	6.8	23.5	319	180	4	3	3	1	3	1	0	0
Lafayette																	
1	0	0	0	0	2	7.6	21.3	738	113	2	1	0	1	2	1	1	1
2	0	0	1	1	2	7.4	29.5	202	164	5	1	0	1	1	1	0	1
3	1	7	2	0	10	7.7	24.1	863	164	3	1	0	2	2	1	1	0
4	0	0	1	0	13	7.3	23.4	799	191	0	1	1	2	1	1	1	1
Iowa																	
1	1	10	5	0	10	8.1	24.6	571	152	2	1	1	1	2	2	1	1
2	1	7	3	0	10	8.6	28.7	306	126	0	2	1	1	2	1	1	0
3	1	20	4	1	10	8.6	27.1	191	113	0	1	2	1	2	1	1	0
4	1	-9	6	1	6	8.5	30.8	394	122	-9	1	1	1	3	1	0	0
5	1	1	3	1	-9	8.8	30.6	426	145	-9	1	1	1	2	2	0	0
6	1	3	7	1	22	8.0	29.2	511	111	-9	1	3	1	3	1	0	0
7	0	0	6	1	10	8.2	33.4	443	95	0	-9	3	1	2	1	0	0
8	0	0	1	1	-9	8.4	28.1	408	52	-9	1	2	1	2	1	0	0
9	1	3	3	0	5	7.6	25.1	663	152	0	1	1	2	2	1	0	0
10	1	10	4	1	10	8.4	32.1	472	163	-9	1	1	1	2	1	0	0
11	1	10	6	1	4	7.9	25.8	483	151	0	1	1	1	2	1	0	0
12	0	0	0	1	20	7.9	19.3	468	144	1	1	1	2	3	2	1	1
13	0	0	2	0	20	8.1	20.8	463	139	0	1	1	1	2	1	0	0
14	0	0	0	0	3	7.7	19.0	467	169	2	1	1	2	3	3	0	1
15	0	0	0	0	6	7.8	23.5	577	144	2	1	1	1	2	1	0	0
Grant																	
1	1	2	3	0	6	7.6	23.1	738	132	0	1	1	2	2	1	0	0
2	1	2	3	0	5	8.0	24.9	728	152	1	1	1	1	2	1	1	0
3	1	4	2	0	6	8.2	27.7	834	124	1	1	1	2	2	1	1	1
4	1	10	1	0	6	8.1	25.3	769	131	2	1	1	2	2	1	1	1
5	1	9	3	0	4	8.3	25.0	519	133	2	1	1	2	2	1	0	1
6	0	0	1	0	6	8.0	23.7	751	117	1	1	1	2	2	1	1	0
7	0	0	2	0	15	7.5	15.3	719	41	3	1	1	2	2	1	1	0
8	0	0	2	0	6	7.8	18.5	754	151	0	1	1	2	2	1	0	0
9	1	6	2	0	9	7.3	30.7	705	118	0	1	3	1	2	1	1	1
10	0	0	1	0	15	8.0	24.9	672	151	3	1	1	1	2	1	1	1
11	1	1	1	0	3	7.3	32.4	805	75	3	1	3	1	2	1	0	0
12	0	0	2	1	2	8.7	29.5	518	121	0	1	1	1	2	1	0	0
13	0	0	2	0	5	8.1	25.1	573	158	2	1	1	1	3	2	1	1
14	0	0	0	0	3	8.3	26.4	615	154	0	1	1	1	2	1	0	1
15	0	0	2	0	10	7.9	24.3	577	171	1	1	1	1	3	1	1	1
16	0	0	1	0	8	8.1	26.3	582	165	1	1	1	1	2	1	1	1
17	0	0	2	0	20	8.1	24.7	608	163	1	1	1	1	2	1	0	1
18	1	10	2	0	3	8.3	25.7	565	153	0	1	1	2	2	1	1	1
19	1	10	5	0	4	7.9	24.2	727	119	0	1	1	2	2	1	1	0

frogs had disappeared from sites whose habitat characteristics were similar to sites where they still occurred.

Using t-tests (Mann-Whitney U tests for turbidity), only one water quality variable, temperature, differed significantly between sites with and without Blanchard's cricket frogs ($t = 2.68$, d.f. = 37, $P = 0.011$). The mean (± SD) water temperature for sites with Blanchard's cricket frog was 27.22 C (± 2.971), as compared to 24.03 C (± 4.297) for sites without cricket frogs. Because water quality variables may vary with date, I also performed analyses of covariance predicting water quality variables with date and presence/absence of cricket frogs (scored as a 0–1 dummy variable). Both date ($F = 4.991$, $P = 0.032$) and presence/absence of cricket frogs ($F = 6.571$, $P = 0.015$) were significant predictors of temperature. However, presence/absence of cricket frogs was not a significant predictor of pH (mean range = 6.8–8.8), conductivity (mean range = 191–863), ORP (mean range = 41–191), or turbidity.

Blanchard's cricket frogs were found most often with green frogs (*Rana clamitans melanota*; 15 of 19 sites = 79%) and to a lesser extent with eastern gray tree frogs (*Hyla versicolor*) and American toads (*Bufo americanus*) (63% and 53%, respectively). Green frogs occurred most frequently, recorded in 29 of the 39 sites.

Thirty-four of the 39 sites (87%) supported anuran populations (Table 2). The greatest number of species recorded at any one site was seven (including data from the Wisconsin Frog and Toad Survey). To determine whether the number of species present at a site was related to the categorical habitat variables, I categorized sites as having either few (0–2) or many (3–7) species. Eight of 12 pond/lake sites had many species, whereas 21 of 27 stream/river sites had few species ($X^2 = 5.33$, d.f. = 1, $P = 0.021$). Also, 13 of 22 sites situated away from agricultural fields had many species, whereas 15 of 17 sites adjacent to agricultural fields had few species ($X^2 = 9.07$, d.f. = 1, $P = 0.0026$).

Species richness showed a significant positive correlation with water temperature (Pearson's $r = 0.381$, $n = 39$, $P = 0.017$) and a negative correlation with turbidity (Spearman's $r = -0.395$, $n = 34$, $P = 0.021$) (Table 3). In a multiple regression analysis, only temperature was a significant predictor of species richness. pH was significantly positively correlated with temperature, and negatively correlated with both conductivity and turbidity (Table 3).

Discussion

My estimates of Blanchard's cricket frog populations at each site are extremely conservative, because I did not attempt to capture all frogs, and frogs may not have been chorusing during visits. Even if frogs were chorusing, I may have underestimated the number of males since some males assume noncalling, or satellite, positions (see Perrill and Magier 1988). The sampling method I used represents only the greatest number of calling males heard at a site during short visits, and therefore is tenuous. Indeed, at two sites in Iowa County (sites 2 and 3) where I could distinguish only 27 male Blanchard's cricket frogs, D. Nicolai (Mossman and Hine 1985) counted over 220 frogs in the early 1980s. This situation may very well be the case at the other sites, a fact that points to the need for intensive censusing (e.g., mark-recapture) efforts and long-term monitoring if reliable population estimates are to be obtained.

Previous studies indicate that Blanchard's cricket frogs prefer to breed in permanent

Table 2. Anuran species at 39 sites in Dane, Grant, Iowa, and Lafayette Counties. SP = spring peeper, CGTF = Cope's gray tree frog, CF = chorus frog, GF = green frog, BCF = Blanchard's cricket frog, EGTF = eastern gray tree frog, AT = American toad, LF = leopard frog, PF = pickerel frog. (X) = data from Wisconsin Frog and Toad Survey (WFTS, 1991, B. Dhuel, pers. comm.).

County Site	*SP*	*CGTF*	*CF*	*GF*	*BCF*	*EGTF*	*AT*	*LF*	*PF*
Dane									
1			(X)	(X)					
Lafayette									
1									
2						X			
3					X		X		
4				X					
Iowa									
1	(X)			X	X	(X)	X		(X)
2				X	X		X		
3				X	X	X	X		
4	(X)			X	(X)	X	(X)		(X)
5					X	X	X		
6	(X)	(X)		X	X	X	X		(X)
7	(X)			X		X			(X)
8				X					
9				X	X	X			
10	(X)		(X)	X	X	(X)	X	X	
11	(X)		(X)	X	X	X	X		X
12									
13				X		X			
14									
15									
Grant									
1				X	X	X			
2				X	X	X			
3				X	X				
4					X				
5				X	X	X			
6				X					
7				X		X			
8				X		X			
9				X	X				
10				X					
11					X				
12				X				X	
13				X		X			
14									
15				X			X		
16				X					
17				X		X			
18				X	X				
19				X	X	X	X		X

Table 3. Pearson product-moment correlation coefficients (Spearman rank order correlation coefficients for turbidity) for water quality variables in relation to number of anuran species (top line, with P values below, n = 39 except n = 34 for turbidity correlations).

	pH	*Temperature*	*Conductivity*	*ORP*	*Turbidity*
# of Anuran species	0.289	0.381*	-0.241	-0.048	-0.395*
	0.075	0.017	0.139	0.773	0.021
pH		0.360*	-0.329*	-0.138	-0.360*
		0.024	0.041	0.403	0.036
Temperature			-0.289	-0.127	-0.170
			0.075	0.442	0.338
Conductivity				-0.050	0.078
				0.762	0.662
ORP					0.163
					0.358

* Pairwise 2-tailed $P < 0.05$.

or semipermanent bodies of water (Pyburn 1958) with mudflats, shallow slopes toward the water, and mud and vegetation banks (Burkett 1984; Minton 1972). Most of the 40 sites studied, all of which were reported to have had cricket frogs at one time, fit this description.

Only one of the sites used by cricket frogs in the past had been destroyed (drained). However, this does not preclude the possibility that subtle site modifications (such as aquatic vegetational changes) in the past may have impacted cricket frog populations.

Blanchard's cricket frogs were present at sites with higher water temperatures compared to sites without cricket frogs, and number of amphibian species was positively correlated with water temperature. Sites with higher water temperatures may be preferred by anurans for breeding. On the other hand, anurans may simply be more likely to be observed on warm days. However, I do not think this could account entirely for the relationships with temperature, in part because most sites were visited more than once.

No sites contained pH levels considered toxic to aquatic organisms (pH < 4.5 or > 9.5; Wetzel 1983), and I found no correlation between species richness and pH. Conductivity was within the range considered normal for bicarbonate-dominated lakes and streams (Wetzel 1983), but did show considerable variability among sites (coefficient of variation, CV = 30%). Oxidation-reduction potential (ORP) also varied (CV = 23%), but the mean value for all sites was 136 ± 31.9 mV, which is substantially lower than 500 mV, a value expected for neutral, fully oxygenated water equilibrated with air (Wetzel 1983). Turbidity was lower at sites with more species, which may indicate preference for clearer waters.

Significantly fewer anuran species were found at sites near corn and other crop fields. This result suggests that fertilizer or pesticide run-off from agricultural fields may affect anuran populations. Herbicides and insecticides still used on corn in Wisconsin (Doersch et al. 1991) can be toxic to amphibians and may have a significantly negative impact on amphibian populations or their prey base (atrazine, Hazelwood 1970; Birge et al. 1980; malathion, paraquat, and toxaphene, Sanders 1970; Hall and Kolbe 1980; Linder et al. 1990). Hylids in general, such as cricket frogs, may be more susceptible to pesticides than other anuran species, such as toads (Sanders 1970; Birge et al. 1979).

Other factors which may adversely affect anurans in southwest Wisconsin are low dissolved oxygen and high nitrogen concentrations. On the Little Platte River in southwest Wisconsin, Holmstrom et al. (1988) reported dissolved oxygen concentrations as low as 3.1 mg/l in early July, which is below the recommended 5 mg/l dissolved O_2 concentration for housing amphibians (National Academy of Sciences 1974). As well, nitrate/nitrite and ammonia levels were as high as 5.1 mg/l and 1.6 mg/l, respectively, during the amphibian breeding season, which exceed the 0.3 mg/l nitrate/nitrite and 0.2 mg/l ammonia concentrations considered safe for amphibians in the laboratory (National Academy of Sciences 1974). On the other hand, three of the sites included in the present study were on the Little Platte River, and all still had Blanchard's cricket frogs.

Acknowledgments

I thank R. Hay, M. J. Mossman, B. Dhuey, and C. Neumann from the Wisconsin Department of Natural Resources and G. S. Casper from the Milwaukee Public Museum for Blanchard's cricket frog site records and helpful discussion. Thanks also to S. M. Conlin, T. Garland, Jr., C. T. Hannan, and C. R. Vispo for field assistance, and to T. Garland, Jr., R. Hay, and two anonymous reviewers for improving the manuscript. This research was sponsored by the Lois Almon Fund and by the U.S. Department of Energy, Office of Energy Research, Environmental Sciences Division, Office of Health and Environmental Research, under appointment to the Graduate Fellowships for Global Change, administered by Oak Ridge Institutes for Science and Education.

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Richard A. Lillie, Robert Last, Paul Garrison, Paul Rasmussen, and John W. Mason

A survey of the summer phytoplankton communities of 579 Wisconsin lakes

Abstract *Phytoplankton and associated limnological data were collected from surface waters of a randomly stratified set of 579 Wisconsin lakes during the summer of 1979. Frequency of occurrence and relative dominance of phytoplankton genera were determined from preserved samples.*

Blue-greens were the most common and most frequently dominant taxa under all bloom conditions independent of sampling date (early to late summer). The frequency of occurrence of blue-green dominance increased with bloom severity (chlorophyll a *concentration). Blooms (defined as chlorophyll* a *concentrations above 10 µg/L) occurred above a threshold of 20 µg/L total phosphorus. Less than 7% of lakes that appeared blue or clear had any form of a bloom, while all lakes with severe or moderately severe blooms appeared either green, brown, or turbid. Quantitative definitions are presented for classifying the severity of phytoplankton blooms in Wisconsin lakes based on relationships between chlorophyll a and perceived water color.*

Phytoplankton blooms cause taste and odor problems in public water supplies and occasionally produce toxins that may be harmful to humans or livestock (MacKenthun et al. 1945; Rohlich and Sarles 1949; Gorham 1965; Gilbert 1990). Blooms are often comprised of algal species that are inedible, unpalatable, or toxic to zooplankton, thus affecting zooplankton standing crop, productivity, or community size-structure. Zooplankton, which utilize phytoplankton as a major food source, are, in turn, important food resources for fish. Therefore, phytoplankton blooms may seriously interfere with the efficient flow of nutrients and energy through the food chain. Nighttime respiration or the sudden death and collapse of blooms may cause total depletion of oxygen in the water column, resulting in fish kills (Mackenthun et al. 1945, Barcia 1975). In addition to these biological responses, the changes in water color that accompany the onset of a bloom (Lillie and

Mason 1983) may directly influence lake recreational use and affect lakeshore property values.

Direct control of phytoplankton blooms in Wisconsin has been primarily limited to the application of algicides containing copper. Many thousands of tons of copper sulfate have been applied to Wisconsin lakes since the early 1900s (Lueschow 1972). Over 20 tons of copper sulfate were applied to Lake Monona at Madison during 1935 alone (Domogolla 1935). The relative inefficiency of copper sulfate in controlling pelagic algae combined with environmental concerns of copper toxicity has led the Wisconsin Department of Natural Resources to ban whole-lake algae treatments (WDNR 1989) and has encouraged research and development of alternative management strategies to control blooms, including predator-prey manipulations and nutrient reduction.

Blue-green algae have long been recognized as being a dominant component of summer phytoplankton blooms in eutrophic lakes (Reynolds and Walsby 1975; Wetzel 1975; Spodniewska 1986; Stewart and Wetzel 1986; Canfield et al. 1989 among many others). Numerous phytoplankton studies (Sloey and Blum 1972; Bartell et al. 1978; Fallon and Brock 1980; Barko et al. 1984; Engel 1985; Narf 1985; Lathrop 1988; Barko et al. 1990; Klemer and Barko 1991) and general taxonomic surveys (Smith 1920; Smith 1924; Lackey 1945; Prescott 1970; USEPA 1978) of Wisconsin lakes and reservoirs indicate the important contribution of blue-greens to blooms in Wisconsin. However, because much of the previous work done in Wisconsin was restricted to eutrophic bodies of water, there was some concern that our perception of the problem may be wrong. Indeed, not all blooms consist of blue-greens; diatoms, dinoflagellates, and green algae were occasionally listed as dominant in some of the aforementioned studies. Consequently, in order to obtain a more accurate assessment of the composition of blooms on a statewide basis, we examined phytoplankton from a set of samples that had been collected in the summer of 1979 by the WDNR during an extensive limnological survey of 661 randomly selected Wisconsin lakes (Lillie and Mason 1983). Study objectives were (1) to determine the structural composition (occurrence and dominance) of summer phytoplankton communities in Wisconsin lakes, (2) to establish the relationship between bloom severity and composition of phytoplankton communities, and (3) to document the limnological characteristics of lakes experiencing blooms. Furthermore, because the lakes involved in this study were sampled only once during the summer, there was a legitimate concern that normal seasonal phytoplankton succession (per Stewart and Wetzel 1986; Bartell et al. 1978; Dokulil and Skolaut 1991) could invalidate our conclusions regarding dominance during blooms (i.e. the composition of blooms in lakes sampled early in the summer may have differed from blooms in lakes sampled later in the summer). Therefore, we evaluated the relationships between phytoplankton dominance and bloom severity between lakes sampled early in the summer versus lakes sampled late in the summer. This paper summarizes the conditions found during the summer 1979 survey and discusses the significance of these findings to lake management.

Study Sites

A stratified random sub-sample was selected from the approximately 2800 Wisconsin lakes over 10 ha (25 acres) in size and greater than 1.5 m (5 feet) deep. Lakes were stratified according to geographic distribution;

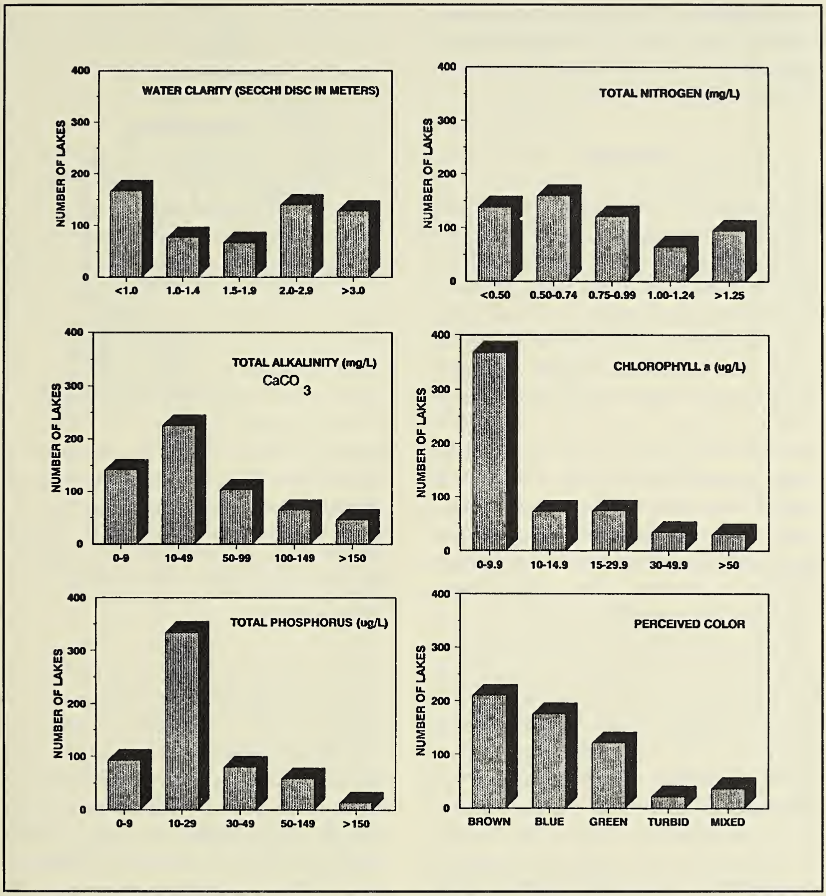

Fig. 1. Distribution of sampled lakes (N = 579) by water clarity (Secchi disc), total alkalinity, and total phosphorus, total nitrogen, and chlorophyll *a* concentrations, and perceived water color classification.

25% of all lakes present in each county were randomly chosen. Phytoplankton samples were available from only 579 of the 661 lakes in the survey. The sampled lakes represented a broad range of morphometric conditions and chemical compositions; sampled lakes were nearly equally divided between seepage (291) and drainage (287) and between thermally stratified (262) and mixed (256). Only 98 lakes were impoundments. Most lakes generally had low nutrient (nitrogen and phosphorus) and chlorophyll *a* concentrations and good water clarity (Fig. 1). Less than one third of the lakes were described as blue or clear. A more complete description of the limnological characteristics of the lakes in this study is provided in Lillie and Mason (1983).

Methods

One sample was collected from each of the 579 lakes during the period 7 July – 7 September, 1979. Samples were collected from the lake surface above the point of maximum depth (where known) or from a central basin location. All samples were preserved immediately in Lugol's solution. Aliquots were settled using the Utermohl settling technique (Lund et al. 1958) for a minimum of 4 hrs per cm settling tube height and analyzed at 1400 X and 560 X magnification using a Wild inverted microscope. Taxa identifications (to genus and species) were based on keys and descriptions provided in Smith (1920, 1924, 1950), Prescott (1970), and Weber (1971).

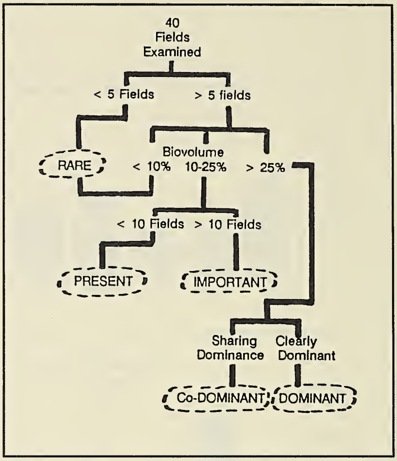

Fig. 2. Flow chart describing criteria for assessing phytoplankton dominance in visual scans of 40 randomly selected fields of view. Percentages (%)s refer to typical percent of total biovolume in most fields of view.

Dominance in algal communities may be computed on the basis of numerical abundance, biomass, or biovolume. Because cell sizes and chlorophyll content differ greatly among the various phytoplankton species, numerical dominance has less ecological significance than dominance based on either biomass or biovolume. Because biomass was not measured in this study, dominance of phytoplankton communities was based on estimates of relative biovolume. We developed and applied a semi-quantitative approach to evaluate cell biovolume dominance because quantitative determinations of cell biovolume of all 579 phytoplankton samples were economically impractical. Assessment of phytoplankton dominance was based on visual comparisons of cell biovolumes in scans of 40 randomly selected fields of view. Ratings of relative dominance and their respective numerical weights were defined as follows (see Fig. 2): absent (0) = not found; rare (1) = occurring in less than 5 fields, or if occurring in more than 5 fields then never accounting for more than 10 percent of the total biovolume in a field; present (3) = occurring in more than 5 fields but less than 10 fields and generally comprising 10–25 percent of the total biovolume in a field; important (5) = occurring in more than 10 fields and generally comprising 10–25 percent of the total biovolume in a field (but always secondary in rank to other taxa); codominant (7) = occurring in more than 5 fields and generally representing more than 25 percent of the total biovolume in a field but sharing dominance with one or more other taxa; and dominant (9) = occurring in more than 5 fields and representing more than 25 percent of the total biovolume and clearly dominant over other taxa. Samples in which dominance could not be clearly determined were identified as mixed assemblages. Numerical weights (numbers given in parentheses above) were averaged for all lakes (statewide) and separately for only those lakes in which the taxon occurred in determining the relative importance of each genus.

The accuracy of this method of assessing phytoplankton dominance was evaluated on a subset of lakes prior to applying the method to the entire set of samples. Independent assessments of cell biovolume dominance (by genus and class) were made by four limnologists (with a combined 30 years of experience) on a subset of 20 lakes selected to represent a broad range of phytoplankton communities. The 20 sets of assessments of phytoplankton dominance (four replicates for each lake) were compared with single assessments based on corresponding quantitative biovolume data. Cellular biovolumes were computed from measurements of cell dimensions taken from 10–25 randomly selected cells of each taxon in each sample. Concurrence in ratings of the dominant taxa was excellent among limnologists in samples from lakes with blooms (100%) and only decreased slightly (94%) in samples from lakes with more diverse communities. Relative assessments of dominance agreed with quantitative assessments of biovolume in 86 percent of the 80 determinations. The high degree of agreement justified the application of the rapid semi-quantitative assessment to the measurement of relative phytoplankton dominance in all 579 samples. All analyses were conducted by the same investigator (R. Last) to minimize subjectivity.

Severity of phytoplankton blooms was classed as mild, moderate, moderately severe, or severe based on chlorophyll *a* concentrations above a threshold of 10 µg/L (Table 1). Breakpoints chosen to separate the four categories were determined from linear regressions representing the interrelationships among chlorophyll *a* concentrations, total phosphorus concentrations, and water clarity measurements as reported by Lillie and Mason (1983).

Limnological data collection procedures and laboratory methods are detailed in Lillie and Mason (1983). Chlorophyll data represent trichromatic chlorophyll *a* (UNESCO equation), uncorrected for pheophytin (0.45 um membrane filters, homogenized 90% acetone extract, modification of Strickland and Parsons 1968). Total phosphorus concentrations were measured using acid digestion-molybdate colorimetry (Eisenreich et al. 1975).

Data analysis was conducted using SAS (SAS Institute, Inc. 1988). Values reported represent means ± 1 standard error unless otherwise stated. In order to evaluate whether phytoplankton succession had a significant impact on our results (i.e., whether phytoplankton dominance within specific bloom categories was independent of sampling date), we compared dominance frequency plots of each phytoplankton group for lakes sampled before and after August 8th (331 and 248 lakes, respectively). Logistic regression was used to test for differences in the relationship of phytoplankton

Table 1. Classification of phytoplankton blooms based on chlorophyll *a* concentrations.

Bloom Class	*Chlorophyll* a (*µg/L*)
Non-bloom	< 10
Mild	10 – 15
Moderate	15 – 30
Moderately-severe	30 – 50
Severe	> 50

Table 2. Taxonomic summary of algae by order, family, and genera for 579 Wisconsin lakes.

Taxonomic Group	Orders	Families	Genera
Chlorophyceae	5	14	36
Bacillariophyceae	2	9	21
Cyanophyceae	3	4	17
Desmidiaceae	–	1	14
Chrysophyceae	4	6	12
Euglenophyceae	1	1	4
Dinophyceae	1	4	4
Xanthophyceae	2	2	2
Cryptophyceae	1	2	2
Totals	19	43	112

dominance to chlorophyll concentration between early and late sampling periods. Importance values (Appendix A) represent the average of assigned weights given to relative dominance ratings (i.e., 1–9).

Results

One hundred twelve phytoplankton genera, representing 43 families and 19 orders, were identified from the 579 lake samples (Table 2). A copy of the laboratory identification sheet containing a complete list of genera and species and their relative abundance for each lake in the data set is available from the authors (in microfiche) upon request. Green algae (Chlorophyceae, including family Desmidiaceae = desmids) and diatoms (Bacillariophyceae) were represented by the most genera. Only 17 blue-green (Cyanophyceae) algal genera were recorded. Taxa richness within individual lakes ranged from 2 to 24 genera. Most genera were uncommon: 16 genera were found in only one lake, and 60 genera occurred in less than 5% of the lakes (Appendix A). Only 20 genera occurred in more than 25% of the lakes. *Cryptomonas*, a cryptomonad (Cryptophyceae), was the most common alga, occurring in 80% of the lakes. *Anabaena*, a filamentous blue-green alga, was the second most common genus. Also found to be relatively common were two green alga genera, *Scenedesmus* and *Oocystis*, a chrysophyte, *Dinobryon*, another cryptomonad genus, *Chroomonas*, two dinoflagellate genera, *Ceratium* and *Peridinium*, a desmid genus, *Staurastrum*, and another colonial blue-green genus, *Coelosphaerium*. *Fragilaria* and *Melosira* were the most common diatom genera.

Collectively, blue-green algae were the most frequently dominant taxonomic group, with mixed assemblages, dinoflagellates, and diatoms next in order of rank (Table 3). The rank order based on the percentage of lakes in which each of the various taxonomic groups of algae were rated as at least important (includes important, co-dominant, and dominant) did not differ substantially from that of the dominant group. Seven of the 20

Table 3. Phytoplankton dominance by major taxa classification in all 579 Wisconsin lakes. Numbers represent percent of lakes in which each taxonomic group was dominant or at least important.

Taxonomic Group	Dominant	at least Important*
Cyanophyceae	32	57
Mixed assemblages	24	—
Dinophyceae	18	43
Bacillariophyceae	11	40
Cryptophyceae	5	22
Chrysophyceae	5	20
Chlorophyceae	3	21
Desmidiaceae	3	11
Euglenophyceae	< 1	3

* includes lakes in which taxa were rated as important, co-dominant, and dominant.

Table 4. Twenty most commonly dominant and important genera in survey of 579 Wisconsin lakes.

Genus	*Dominant* (N)	(% lakes)	(Rank)	*at least Important** (N)	(% lakes)	(Rank)
Anabaena	108	19	1	230	40	1
Peridinium	69	12	2	131	23	2
Aphanizomenon	48	8	3	109	19	6[t]
Microcystis	36	6	4	110	19	5
Ceratium	33	6	5	115	20	4
Cryptomonas	28	5	6	120	21	3
Melosira	28	5	7	90	16	8
Coelosphaerium	24	4	8	109	19	6[t]
Dinobryon	17	3	9	79	14	9
Staurastrum	14	2	10	39	7	14
Glenodinium	13	2	11	43	7	13
Tabellaria	13	2	12	47	8	11
Oscillatoria	13	2	13	37	7	15
Fragilaria	12	2	14	76	13	10
Synura	12	2	15	29	5	18
Chroococcus	9	2	16	31	5	17
Cyclotella	8	1	17	34	6	16
Aphanocapsa	7	1	18	19	3	20
Synedra	3	< 1	19	44	8	12
Asterionella	3	< 1	20	28	5	19

* includes lakes in which genus was rated as important, co-dominant, and dominant.
t designates a tie.

most frequently dominant and important genera were blue-greens (Table 4). *Anabaena*, *Aphanizomenon*, and *Microcystis* were the most frequently dominant blue-greens; *Peridinium*, *Ceratium*, and *Glenodinium* were dominant dinoflagellates; and *Melosira*, *Tabellaria*, and *Fragilaria* were the most frequently dominant diatoms.

Composition of Blooms. Thirty-six percent of the lakes in the survey had some form of bloom present at the time of sample collection (Table 5), and only 11% of the lakes had severe or moderately severe blooms. Sampling date (early versus late summer) did not have a significant influence on phytoplankton dominace. Logistic regression indicated blue-green dominance increased ($p = 0.0001$) with chlorophyll concentration during both time periods. There was also an interaction ($p = 0.02$) between chlorophyll concentration and time period, because at low chlorophyll levels, blue-green dominance was less frequent during the early than the late sampling period, while at high chlorophyll levels blue-green dominance was similar in both sampling periods. Nevertheless, the overall trend for blue-green dominance to increase with chlorophyll concentration was present in both time periods. Therefore, although the frequency of occurrence of blooms was higher in lakes sampled during late summer, the dominance structure of blooms was not different from that found in lakes sampled earlier in the summer. Blue-greens were the most commonly dominant group within all bloom categories (Table 4), regardless of sampling date. The

Table 5. Phytoplankton dominance of major taxa relative to bloom condition (number of lakes in each class shown in parentheses). Data represent % of lakes within each bloom category in which taxa were dominant or co-dominant.

Taxa Group		*Bloom Condition*			
	Non-bloom (368)	*Mild (73)*	*Moderate (74)*	*Mod.-Sev. (34)*	*Severe (30)*
Cyanophyceae	23	37	45	68	70
Bacillariophyceae	12	8	7	18	20
Mixed assemblages	26	27	19	15	20
Cryptophyceae	5	3	7	0	13
Chlorophyceae	5	0	0	3	8
Dinophyceae	19	18	23	18	3
Chrysophyceae	5	10	7	3	0
Desmidiaceae	4	1	3	0	0
Euglenophyceae	< 1	1	0	0	0

frequency of blue-green dominance increased from 37% during mild blooms to 70% during severe blooms (Fig. 3b). Dinoflagellates were frequently dominant, and chrysophytes were occasionally dominant during mild and moderate blooms (Table 5), but both declined in importance during severe blooms (Fig. 3g and 3c). Cryptophytes tended to be more frequently dominant during severe blooms. Diatoms and greens tended to be important or dominant during moderately severe and severe blooms.

A core of 34 genera were commonly associated with blooms. (Commonness here is defined as those genera that were categorized as present in at least 25% of the lakes or as dominant in at least one lake experiencing a bloom; see Table 6). *Anabaena*, *Aphanizomenon*, *Aphanocapsa*, *Cryptomonas*, *Melosira*, *Oscillatoria*, and *Microcystis* were common dominants of severe and moderately severe blooms. *Aphanizomenon*, *Anabaena*, and *Peridinium* were common dominants of mild and moderate blooms. While the frequency of occurrence or dominance of most bloom genera did not appear to be directly related to degree of bloom severity, some genera, such as *Anabaena*, *Aphanizomenon*, *Aphanocapsa*, *Aphanotheca*, *Melosira*, *Oscillatoria*, *Pediastrum*, and *Scenedesmus* were most often dominant during severe or moderately severe blooms. A few genera, including *Peridinium*, *Synura*, *Tabellaria*, and *Dinobryon*, were more commonly dominant during milder blooms.

Characteristics of lakes experiencing blooms. Lakes experiencing phytoplankton blooms tended to be larger and shallower than lakes without blooms (Table 7). Lakes with blooms also had shorter residence times and had substantially higher nutrient concentrations and turbidities than lakes without blooms. Of 71 lakes with total phosphorus concentrations above 50 µg/L, 85% had some form of bloom at the time of sampling (54% severe or moderately severe). Only 9% of the lakes with total phosphorus concentrations less than 10 µg/L had a bloom (none were severe or moderately severe). Lakes with severe blooms had lower total nitrogen/total phosphorus ratios (TN:TP) (low TN:TP is an indication of possible nitrogen limitation) than lakes without blooms.

Table 6. Frequency of occurrence of genera listed as dominant during blooms or occurring in greater than 25% of lakes within a bloom class. Data represent percentages of lakes within each bloom class in which genus was dominant (% frequency of occurrence based on presence/absence shown in parentheses).

Genus	*Bloom Condition*				
	Non-bloom	*Mild*	*Moderate*	*Moder.-Severe*	*Severe Bloom*
Anabaena	14 (58)	32 (67)	28 (72)	50 (85)	55 (83)
Aphanizomenon	5 (14)	12 (36)	18 (41)	22 (59)	24 (47)
Aphanocapsa	< 1 (6)	0 (3)	2 (15)	3 (18)	14 (23)
Aphanotheca	0 (2)	0 (3)	0 (8)	0 (18)	3 (17)
Ceratium	8 (45)	7 (52)	1 (41)	12 (50)	3 (53)
Chroococcus	2 (37)	0 (22)	0 (24)	3 (29)	3 (30)
Chroomonas	< 1 (49)	0 (41)	1 (38)	0 (62)	0 (33)
Coelosphaerium	5 (33)	5 (47)	5 (43)	3 (35)	7 (57)
Coelastrum	0 (11)	0 (27)	0 (28)	0 (21)	0 (30)
Crucigenia	0 (30)	0 (27)	0 (22)	0 (9)	0 (20)
Cryptomonas	6 (80)	3 (84)	8 (77)	0 (76)	14 (80)
Cyclotella	2 (39)	0 (14)	0 (19)	3 (18)	3 (10)
Cosmarium	< 1 (28)	0 (20)	0 (20)	0 (23)	0 (33)
Dictyosphaerium	0 (9)	0 (12)	0 (31)	0 (15)	0 (17)
Dinobryon	3 (57)	5 (56)	5 (38)	3 (12)	0 (3)
Euglena	0 (8)	2 (19)	0 (16)	0 (21)	0 (27)
Fragilaria	3 (38)	2 (44)	1 (39)	3 (35)	0 (13)
Glenodinium	4 (30)	0 (19)	1 (24)	3 (26)	0 (33)
Gloeotrichia	< 1 (2)	2 (6)	0 (0)	0 (0)	0 (0)
Mallomonas	0 (25)	0 (37)	2 (31)	0 (26)	0 (13)
Microcystis	8 (32)	2 (33)	9 (41)	9 (59)	14 (43)
Melosira	4 (28)	5 (41)	6 (46)	12 (53)	17 (73)
Oocystis	1 (62)	0 (49)	0 (38)	0 (29)	0 (50)
Oscillatoria	3 (14)	2 (19)	0 (16)	0 (21)	14 (53)
Pediastrum	< 1 (17)	0 (20)	0 (35)	0 (29)	0 (57)
Peridinium	15 (46)	16 (44)	23 (42)	3 (9)	0 (0)
Scenedesmus	0 (56)	0 (53)	0 (70)	3 (56)	7 (77)
Staurastrum	4 (37)	0 (40)	3 (58)	0 (38)	0 (50)
Stephanodiscus	1 (11)	0 (8)	0 (16)	0 (26)	0 (43)
Synedra	< 1 (30)	2 (27)	3 (24)	0 (24)	3 (13)
Synura	2 (12)	7 (18)	3 (10)	0 (3)	0 (3)
Tabellaria	4 (25)	3 (30)	0 (19)	0 (6)	0 (0)
Tetraedron	0 (22)	0 (30)	0 (26)	0 (15)	0 (27)
Trachelomonas	0 (12)	0 (19)	0 (23)	0 (24)	0 (27)

Perceived water color was dramatically impacted by blooms (Table 8). None of the 64 lakes with severe or moderately severe blooms appeared blue or clear. Among lakes with mild or moderate blooms, 30% appeared green, 48% appeared brown, 7% appeared as a mixture of colors, 7% were turbid, and only 8% were clear or blue in appearance. While lakes without blooms also were frequently classed as colored (13% green, 35% brown, 3% mixed, and 2% turbid), 93% of the 176 lakes identified as blue or clear did not have blooms.

Discussion

Blue-green algae were dominant or co-dominant in one-third to two-thirds of all lakes

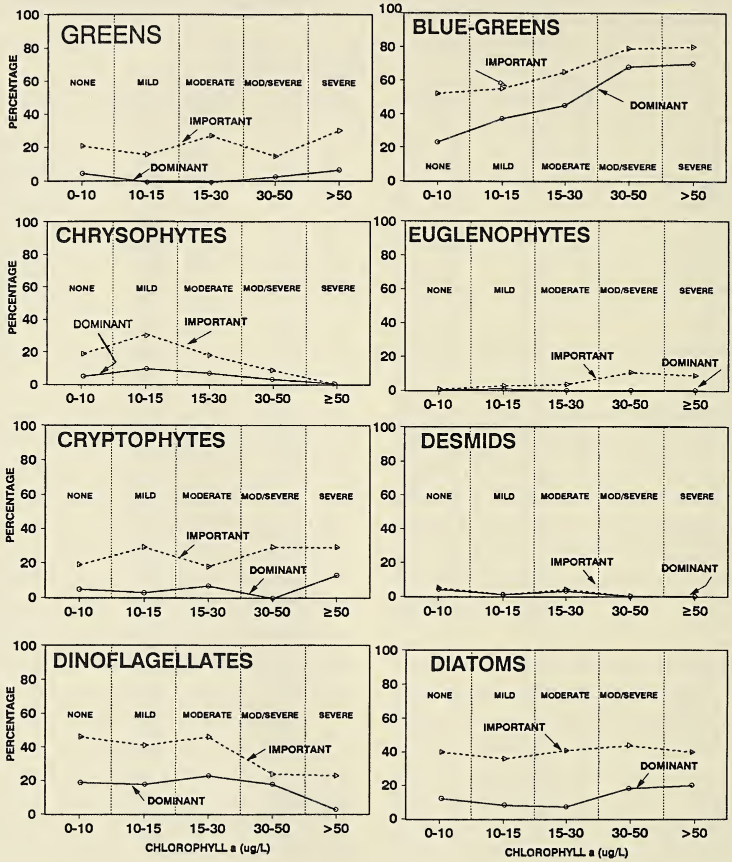

Figure 3. Relative dominance and importance of major taxa expressed as percentages of lakes within each bloom category that taxa were dominant (o) or important (^). Percent important also includes lakes in which taxa were dominant or co–dominant.

Table 7. Limnological conditions associated with phytoplankton blooms in Wisconsin lakes. Data represent means ± 1 SE.

		Bloom Condition					
Parameter	*Non-bloom*	*Mild*	*Moderate*	*Mod.-severe*	*Severe*	*All 579*	*661 Random***
(Chlorophyll *a* concentrations in µg/L)	5.6 ± 0.1	12.2 ± 0.2	20.6 ± 0.5	36.4 ± 0.8	82.3* ± 6.3	15.0 ± 1.3	14.3 ± 1.1
Physical:							
Size (ha)	116 ± 15	178 ± 78	943 ± 752	408 ± 175	338 ± 144	258 ± 98	242 ± 86
Mn Depth^p (m)	4.2 ± 0.2	3.8 ± 0.3	2.7 ± 0.2	3.2 ± 0.6	2.3 ± 0.3	3.8 ± 0.2	3.8 ± 0.2
Mx Depth (m)	8.9 ± 0.4	6.6 ± 0.5	5.4 ± 0.4	5.8 ± 0.7	4.3 ± 0.4	7.7 ± 0.2	7.7 ± 0.2
Residence^p (yr)	1.8 ± 0.2	1.0 ± 0.2	0.6 ± 0.1	0.6 ± 0.3	0.3 ± 0.1	1.4 ± 0.1	1.4 ± 0.1
Clarity (m)	2.7 ± 0.1	1.8 ± 0.1	1.3 ± 0.1	1.0 ± 0.1	0.6 ± 0.1	2.2 ± 0.1	2.2 ± 0.1
Chemical:							
Alkalinity (mg/L)	50.9 ± 2.8	54.5 ± 8.0	44.7 ± 6.3	71.8 ± 10.6	80.1 ± 13.2	53.2 ± 2.4	49.8 ± 2.2
Calcium (mg/L)	11.0 ± 0.6	12.7 ± 1.7	10.9 ± 1.4	16.7 ± 2.3	19.3 ± 2.8	12.0 ± 0.5	11.8 ± 0.5
Magnesium (mg/L)	7.1 ± 0.5	7.3 ± 1.3	6.1 ± 1.0	9.6 ± 1.8	10.9 ± 2.2	7.3 ± 0.4	7.2 ± 0.4
Chloride (mg/L)	3.2 ± 0.3	3.8 ± 0.7	4.3 ± 0.8	5.6 ± 1.0	8.0 ± 1.9	3.8 ± 0.2	3.8 ± 0.2
pH (units)	7.2 ± 0.1	7.2 ± 0.1	7.2 ± 0.1	7.5 ± 0.1	7.7 ± 0.2	7.2 ± 0.1	7.2 ± 0.1
Turbidity (JTUs)	2.4 ± 0.1	3.3 ± 0.3	4.2 ± 0.4	8.8 ± 2.4	10.8 ± 1.6	3.5 ± 0.2	3.4 ± 0.2
Color (units)	31.3 ± 1.7	40.9 ± 4.7	46.1 ± 4.5	52.2 ± 8.0	38.2 ± 3.9	35.9 ± 1.5	36.9 ± 1.5
Organic-N (mg/L)	0.49 ± 0.01	0.58 ± 0.04	0.72 ± 0.05	0.86 ± 0.08	1.21 ± 0.10	0.59 ± 0.02	0.59 ± 0.01
Total-N (mg/L)	0.69 ± 0.02	0.82 ± 0.04	1.06 ± 0.05	1.26 ± 0.07	2.09 ± 0.19	0.87 ± 0.02	0.85 ± 0.02
PO_4-P (µg/L)	7 ± 1	8 ± 1	20 ± 4	21 ± 4	82 ± 20	14 ± 1	13 ± 1
Total-P (µg/L)	19 ± 1	24 ± 2	38 ± 5	50 ± 7	149 ± 31	31 ± 2	30 ± 2

* excludes 1 lake with very high chlorophyll concentration.
** from Lillie and Mason 1983.
p = partial data, information not available for all lakes.

with blooms and in almost one-quarter of lakes without blooms. Collectively, blue-green genera were dominant among all categories of surface blooms. Blue-green dominance increased with the degree of bloom severity as measured by chlorophyll *a* concentration.

Although the frequency of blooms was higher in late summer, the dominance structure of phytoplankton communities did not differ substantially within bloom categories from early to late summer. Therefore, interpretation of relative phytoplankton dominance within specific bloom categories was not biased by the 63-day time period during which all 579 lakes were sampled. While the severity of blooms in many of the lakes sampled during the first half of the summer may have been higher had they been sampled during the later half of the summer sampling period, the composition of the blooms probably did not change significantly (at the group level). Such a conclusion is not altogether unexpected, as Bartell et al. (1978) reported relative constancy in species assemblages during the summer in extensive studies in Lake Wingra (Dane Co.). The frequency of occurrence of blooms and severity of blooms shown in Table 5 undoubtedly would have been higher if all lakes had been sampled during the later half of the sampling pe-

Table 8. Association between perceived color (visual appearance) and algal blooms in 579 Wisconsin lakes. Data represent numbers of lakes in each category.

		Bloom Severity				
*Perceived Color**	*Non-bloom*	*Mild*	*Moderate*	*Mod.-Sev.*	*Severe*	*Total*
Undescribed	9	1	0	0	1	11
Green	47	20	24	13	18	122
Brown	128	36	34	9	4	211
Turbid	9	4	6	3	0	22
Blue or Clear	164	11	1	0	0	176
Mixed	11	1	12	26	23	37
Subtotals	368	73	74	34	30	579

* some field observers did not differentiate between clear-green, green and turbid, or green and brown mixed.

riod. This, however, does not negate our conclusions regarding compositions of blooms.

These findings support conclusions regarding phytoplankton dominance derived from earlier cited studies of primarily eutrophic Wisconsin lakes. Blue-green algae are the single most important and dominant taxonomic group of algae in most Wisconsin lakes during summer months regardless of trophic state and, as such, should be targeted for management control.

The biomass of blue-greens in lakes has been shown to be directly correlated with TN:TP ratios under fixed light conditions (Smith 1986). No significant relationship was detected between TN:TP and the occurrence of blooms in our study; however, the ratio between mean TN and mean TP was lower in lakes with severe blooms than in lakes without blooms (Table 7). The progressive increase in frequency of occurrence of blue-green dominance with each level of bloom severity corresponds with the progressive decrease in TN:TP and agrees with Smith's (1983) findings. Furthermore, our data directly contradicts that of Canfield et al. (1989), who reported a decrease in frequency of blue-greens at TN:TP < 29. Light, temperature, inorganic nutrients, and zooplankton grazing can influence the relationship between blue-green dominance and TN:TP within individual lakes (McQueen and Lean 1987; Smith 1986; Spencer and King 1987).

Blooms were more common in large, shallow reservoirs or drainage lakes, in accordance with findings of other studies (Fee 1979). The greater internal recycling of nutrients, availability of sunlight, and thermal homogeneity of these systems provide a more optimum growth medium for blue-greens than that offered by deeper, thermally stratified lakes.

Limnological characteristics of the 579 lakes for which phytoplankton samples were available did not differ significantly from the characteristics of the entire 661 lakes in the random survey (Table 7). Therefore, findings regarding phytoplankton dominance reported in this survey and recommendations based on these data should be applicable to all Wisconsin lakes of similar size and depth. Based on the relationships between bloom severity and nutrient concentrations, as shown in Table 7, we propose the following in-lake phosphorus concentrations be established as thresholds for controlling blooms in Wisconsin lakes. An in-lake summer phosphorus concentration of

20 µg/L is an appropriate level to assure nonbloom conditions, while 30 µg/L TP is a more appropriate value to define the threshold between mild and moderate blooms. The former value corresponds with established spring phosphorus standards for southeastern Wisconsin lakes (SWRPC 1979) and with the results of the National Eutrophication Survey, which indicated that blooms did not occur in eastern United States lakes with less than 19 µg/L mean total phosphorus (Williams et al. 1977). Reduction of in-lake phosphorus concentrations below a given threshold value does not guarantee that a bloom will not occur (Welch 1989), as some lakes with phosphorus concentrations below the threshold will have blooms and some lakes with phosphorus concentrations above the threshold will not have blooms. Other factors, including differences in zooplankton grazing pressures, temperature, toxins, and other growth-limiting elements may interfere with the relationship. Threshold values may need to be adjusted according to a lake's geographic location to account for differences in phytoplankton dominance and response to nutrients that may occur among ecoregions (see Heiskary et al. 1987). Irrespective of the circumstances, reducing in-lake phosphorus concentrations will certainly decrease the likelihood that a bloom will occur or will reduce its intensity and duration.

Welch (1989) proposed that the fraction of total algae comprised of blue-greens is a sensitive indicator of nutrient concentrations and, thus, would make a good alternative eutrophication index were it not for the lack of agreed-upon trophic state threshold values. Based on the data collected in this study, a value of 25% blue-greens (by biovolume) may be an appropriate threshold criterion. Blue-greens were dominant (represented more than 25% of the total biovolume) in more than 50% of the lakes where chlorophyll *a* concentrations exceeded 30 µg/L. The 30 µg/L chlorophyll *a* concentration corresponds with our bloom classes of moderately severe and severe and matches the criterion for blooms established by Walker (1985).

Perceived water color (or visual appearance) has particular significance to lake managers in indicating blooms. In most cases, lakes that appear blue or clear do not have a bloom. Conversely, a green appearance to a lake does not necessarily signify a bloom as some lakes have a natural clear-green appearance. Likewise, while a brown appearance often corresponds with a diatom bloom, many lakes have a brown or yellow-brown stained appearance due to high concentrations of organic acids. However, if a lake's appearance changes from blue/clear to green, brown, or turbid, there is a very good probability that a phytoplankton bloom is occurring and that chlorophyll *a* concentrations exceed 10 µg/L. These color observations may not apply to other regions, but similar relationships may be established through direct observations. As such, general observations of water color can have a very important role in monitoring the trophic condition of a lake. Historical observations of blue or clear water color may be safely regarded as being indicative of good water quality (chlorophyll less than10 µg/L).

Lastly, the results of this survey demonstrate the utility of rapid subjective analysis of summer phytoplankton community compositions (in conjunction with other water quality data) as an informative monitoring tool in assessing water quality. Therefore, monitoring phytoplankton community compositions may be useful in measuring the effectiveness of agency-mandated nutrient control programs and lake restoration efforts.

Appendix A. Frequency of occurrence (as %), number of occurrences by relative dominance classification, and relative importance values for all phytoplankton genera found in 579 Wisconsin lakes during the summer of 1979.

Genera	Class*	Freq. of Occur.	Rare (1)	Present (3)	Important (5)	Co-dominant (7)	Dominant (9)	Importance Values State-wide	Importance Values Lakes where present
Actinastrum	CHLO	2.8	-	10	4	-	-	0.09	3.57
*Amphora**	BACI	0.9	1	2	2	-	-	0.03	3.40
Anabaena	CYAN	64.0	24	116	122	62	46	3.15	4.92
Aphanizomenon	CYAN	24.6	4	29	61	26	22	1.34	5.44
Ankistrodesmus	CHLO	4.0	2	18	1	-	-	0.11	2.90
Aphanocapsa	CYAN	8.5	-	28	12	4	3	0.34	4.21
Aphanotheca	CYAN	4.8	-	20	5	1	-	0.16	3.50
Arthrodesmus	DESM	16.3	-	74	15	2	1	0.55	3.49
Arthrospira	CYAN	0.2	-	1	-	-	-	0.01	3.00
Asterionella	BACI	14.0	6	47	25	1	2	0.51	3.67
*Bambusina**	DESM	0.3	-	-	1	-	1	0.02	7.00
Botryococcus	CHLO	0.3	-	2	-	-	-	0.01	3.00
*Caloneis**	BACI	0.2	-	1	-	-	-	0.01	3.00
Carteria	CHLO	0.2	-	-	1	-	-	0.01	5.00
Ceratium	DINO	45.8	13	137	82	20	13	1.88	4.11
Chlamydomonas	CHLO	9.1	20	28	7	1	1	0.27	2.72
Chlorogonium	CHLO	0.9	-	5	-	-	-	0.03	3.00
Chroococcus	CYAN	33.0	1	157	22	5	4	1.13	3.46
Chroomonas	CRYP	46.7	2	252	12	2	-	1.44	3.10
Chrysidiastrum	CHRY	0.2	-	1	-	-	-	0.01	3.00
Chrysococcus	CHRY	0.2	-	-	1	-	-	0.01	5.00
Chrysosphaerella	CHRY	1.7	-	5	4	-	1	0.08	4.40
Closteriopsis	CHLO	0.5	-	1	2	-	-	0.02	4.33
Closterium	DESM	6.1	-	29	4	-	-	0.19	3.24
Coelosphaerium	CYAN	37.5	-	106	85	17	7	1.60	4.29
Coelastrum	CHLO	17.3	1	92	5	-	-	0.52	3.07
*Cocconeis**	BACI	4.8	-	23	3	-	-	0.15	3.23
Cosmarium	DESM	26.1	44	99	7	-	1	0.67	2.55
Crucigenia	CHLO	27.2	-	144	11	-	-	0.84	3.14
Cryptomonas	CRYP	79.9	2	338	92	15	13	2.94	3.68
Cyclotella	BACI	30.4	14	128	26	2	6	1.03	3.39
Cymatopleura	BACI	0.2	-	1	-	-	-	0.01	3.00
*Cymbella**	BACI	4.3	-	20	5	-	-	0.15	3.40
Dactyloccopsis	CYAN	1.7	1	7	1	-	1	0.06	3.60
Desmidium	DESM	0.5	-	2	1	-	-	0.02	3.67
*Diatoma**	BACI	0.2	-	1	-	-	-	0.01	3.00
Dictyosphaerium	CHLO	12.8	-	61	13	-	-	0.43	3.35
Dimorphococcus	CHLO	0.5	-	2	1	-	-	0.02	3.67
Dinobryon	CHRY	49.0	19	185	62	5	12	1.78	3.63
Elakotothrix	CHLO	1.7	-	10	-	-	-	0.05	3.00
*Epithemia**	BACI	0.9	-	4	1	-	-	0.03	3.40
Erkenia	CHRY	3.5	2	18	-	-	-	0.10	2.80
Euastrum	DESM	3.8	2	19	1	-	-	0.11	2.90
Eudorina	CHLO	12.6	5	59	12	-	-	0.42	3.18
Euglena	EUGL	12.1	17	44	8	-	1	0.34	2.83
Fragilaria	BACI	37.2	15	125	64	8	4	1.39	3.71
Franceia	CHLO	0.2	-	1	-	-	-	0.01	3.00
Glenodinium	DINO	28.0	6	111	30	5	8	1.03	3.68
Gloeocystis	CHLO	1.0	-	4	1	-	1	0.04	4.33
Gloeothece	CYAN	0.5	-	2	1	-	-	0.02	3.67
Gloeotrichia	CYAN	2.1	-	6	4	1	1	0.09	4.50
Golenkinia	CHLO	0.7	-	4	-	-	-	0.02	3.00
*Gomphonema**	BACI	2.8	-	15	1	-	-	0.09	3.12
Gonatozygon	DESM	0.3	-	2	-	-	-	0.01	3.00
Gymnodium	DINO	5.2	-	26	4	-	-	0.17	3.27
*Gyrosigma**	BACI	0.2	1	-	-	-	-	0.01	1.00

Genera	Class	Freq. of Occur.	Rare (1)	Present (3)	Import-ant (5)	Co-dominant (7)	Dominant (9)	Importance Values State-wide	Importance Values Lakes where present
Hyalobryon	CHRY	0.2	-	1	-	-	-	0.01	3.00
Hyalotheca	DESM	0.2	-	-	1	-	-	0.01	5.00
Kirchneriella	CHLO	4.2	-	24	-	-	-	0.12	3.00
Lagerheimia	CHLO	2.2	-	13	-	-	-	0.07	3.00
Lepocinclis	EUGL	0.5	-	2	-	-	1	0.03	5.00
Lyngbya	CYAN	5.4	1	17	12	1	-	0.21	3.84
Mallomonas	CHRY	26.6	16	129	8	1	-	0.78	2.92
Merismopedia	CYAN	6.6	-	32	4	1	1	0.23	3.28
Micractinium	CHLO	0.9	-	5	-	-	-	0.03	3.00
Micrasterias	DESM	0.9	-	5	-	-	-	0.03	3.00
Microcystis	CYAN	35.3	8	86	74	20	16	1.59	4.50
Melosira	BACI	35.8	23	94	62	20	8	1.43	3.98
Monomastix	CHRY	8.8	-	47	4	-	-	0.28	3.16
*Navicula**	BACI	10.0	2	52	3	-	1	0.31	3.03
Nephrocytium	CHLO	1.9	-	11	-	-	-	0.06	3.00
Nodularia	CYAN	0.2	-	1	-	-	-	0.01	3.00
Ochromonas	CHRY	1.2	-	7	4	-	-	0.07	3.73
Onychonema	CHLO	0.7	-	3	1	-	-	0.02	3.50
Oocystis	CHLO	55.0	187	120	8	1	2	1.06	1.65
Ophiocytium	XANT	0.7	-	4	-	-	-	0.02	3.00
Oscillatoria	CYAN	17.6	19	46	24	7	6	0.66	3.72
Pandorina	CHLO	7.1	-	34	6	-	1	0.24	3.28
Pediastrum	CHLO	22.8	16	99	16	1	-	0.69	3.03
Peridinium	DINO	40.8	1	102	62	16	53	2.08	5.11
Phacus	EUGL	6.9	2	36	2	-	-	0.21	3.00
Phormidium	CYAN	0.7	-	3	1	-	-	0.02	3.50
*Pinnularia**	BACI	0.5	-	3	-	-	-	0.02	3.00
Pleodorina	CHLO	0.3	-	1	1	-	-	0.01	4.00
Pleurotanium	DESM	0.9	-	3	1	-	1	0.04	4.60
Psephonema	XANT	0.9	-	5	-	-	-	0.03	3.00
Quadrigula	CHLO	13.3	-	75	-	-	2	0.42	3.16
Rhabdoderma	CYAN	1.9	-	10	-	-	1	0.07	3.55
Rhoicospheria	BACI	0.3	-	2	-	-	-	0.01	3.00
*Rhopalodia**	BACI	1.0	-	6	-	-	-	0.03	3.00
Scenedesmus	CHLO	58.8	110	211	16	2	1	1.46	2.49
Selenastrum	CHLO	3.6	-	20	1	-	-	0.11	3.10
Schroderia	CHLO	7.3	-	42	-	-	-	0.22	3.00
Sorastrum	CHLO	0.5	-	3	-	-	-	0.02	3.00
Sphaerocystis	CHLO	16.6	11	70	12	2	1	0.53	3.17
Spirogyra	CHLO	13.8	1	1	3	2	1	0.07	5.25
Spirotaenia	DESM	0.2	-	1	-	-	-	0.01	3.00
Spondylosium	DESM	7.8	9	26	9	-	1	0.24	3.13
Staurastrum	DESM	40.5	60	135	25	6	8	1.21	3.00
*Stauroneis**	BACI	0.2	-	1	-	-	-	0.01	3.00
Stephanodiscus	BACI	13.8	13	53	11	-	3	0.44	3.18
Synedra	BACI	28.2	2	115	41	2	1	0.99	3.53
Synura	CHRY	11.8	-	39	17	6	6	0.52	4.26
Tabellaria	BACI	22.7	7	77	34	3	10	0.90	3.96
Tetraedron	CHLO	23.2	26	104	4	-	-	0.62	2.67
Trachelomonas	EUGL	15.6	14	70	6	-	-	0.44	2.82
Treubaria	CHLO	0.2	-	1	-	-	-	0.01	3.00
Ulothrix	CHLO	7.4	7	24	17	1	-	0.30	3.49
Uroglena	CHRY	0.9	-	-	3	-	2	0.06	6.60
Uroglenopsis	CHRY	0.2	-	1	-	-	-	0.01	3.00
Volvox	CHLO	1.4	-	3	4	1	-	0.06	4.50
Xanthidium	DESM	2.8	-	13	1	1	1	0.10	3.75

*taxa believed to be primarily epiphytic and only incidently found in the plankton (i.e. tychoplankton).
Taxon codes: BACI=Bacillariophyceae, CHLO=Chlorophyceae, CHRY=Chrysophyceae, CRYP=Cryptophyceae, CYAN=Cyanophyceae, DESM=Desmidiaceae, DINO=Dinophyceae, EUGL=Euglenophyceae, XANT=Xanthophyceae.

Acknowledgments

This study was conducted by staff of the Bureau of Research, Water Resources Research Section, with the assistance of numerous individuals who were acknowledged in Lillie and Mason 1983. We wish again to express our thanks to those individuals who conducted the field collections and completed the laboratory analyses. Co-author Robert Last diligently performed taxa identifications and determined relative dominance on all 579 samples over a period of several years and deserves most of the credit for seeing this project through to the end. We also thank I. Marx-Olson for assistance in computer data entry and D. Knauer for critical review of the manuscript. Thanks are also extended to W. Sloey, an anonymous reviewer, and the Editor for their many useful suggestions.

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Charles A. Long and John E. Long

Discriminant analysis of geographic variation in long-tailed deer mice from northern Wisconsin and Upper Michigan

Abstract *Identification of morphologically similar long-tailed mice* (Peromyscus spp.) *from the forests of northern Wisconsin and Upper Michigan was clarified by application of statistical analysis. Use of student t-tests, bivariate plots, Dice squares, analysis of variance, and a stepwise discriminant analysis revealed three distinctive populations. Previously, mice from this region were identified as* P. leucopus *or* P. maniculatus gracilis, *and neither was very clearly distinctive from the other. The best characters used to identify these mice were ear length, length of rostrum, and length of tail. Other characters varied significantly from group to group, but incisive foramina length, cranial depth and cranial breadth (previously given heavy weight by taxonomists) were the least reliable. Discriminant coefficients were developed that may be used in future studies classifying approximately 2,000 unidentified museum specimens, based upon the canonical functions that segregate the three groups best. Predictability based on probability of best fit, and next best fit, ranged from 82 to 90 percent. The deer mice from three isles in Lake Michigan closely resembled typical* P. maniculatus maniculatus *from Labrador even more than they resembled the northern Lake Superior mice formerly assigned to* P. m. gracilis. *Northern specimens approach* maniculatus *but the southernmost long-tailed deer mice are smaller. Six recently collected specimens from Washington Island, in Lake Michigan, resemble* P. leucopus *from central Wisconsin and are the first record of* P. leucopus *on any island in Lake Michigan.*

Aside from the confusing and well-known resemblance of the forest deer mouse (*Peromyscus maniculatus gracilis*) to the common white-footed mouse (*Peromyscus leucopus*), Long (1978) noted slight clinal variation in *P. m. gracilis* from north to south and documented differences (particularly in longer rostrum) in *P. m. gracilis* on St. Martin Island, Michigan. Cursory examination of *P. m. gracilis* specimens from the Apostle Islands revealed cranial differences from many Wisconsin *gracilis*, especially the narrower and shorter rostrum of the Apostle Islands *gracilis*. This form resembled *Peromyscus maniculatus maniculatus* from Ontario, as figured by Osgood (1909) in his classic taxonomic revision of *Peromyscus*. The difficulty in segregating two or perhaps three similar deer mice has hindered a proper classification (at the University of Wisconsin-Stevens Point [UWSP] Museum of Natural History) of nearly 2,000 specimens from Wisconsin and some from the Upper Peninsula of Michigan. Over the last decade, students who have regularly collected *gracilis* on Washington Island began to catch some specimens that appeared to be *P. leucopus*, hitherto unknown on any island in Lake Michigan.

In southern Wisconsin, Stromberg (1979) used discriminant analysis to distinguish *P. leucopus* from *P. m. bairdii*, a small, short-tailed prairie form inhabiting sandy soils of southern and western Wisconsin. However, these two species are easily identified even as young animals (Long 1968). Greater difficulty is encountered in separating *P. m. gracilis* from the Canadian race *P. m. maniculatus*, and both of them from *P. leucopus*.

Why is it that in the past two subspecies of long-tailed deer mice (*P. maniculatus*) have been recognized in Michigan but only one has been noted in Wisconsin? Baker (1983) followed Burt's (1948) earlier classification of Michigan mammals, and Burt, without comment, had followed Osgood's (1909) monographic revision of *Peromyscus*. Osgood reported *P. m. maniculatus* from Isle Royale and *P. m. gracilis* from both Upper and Lower Michigan. However, for nearby Wisconsin mice, Osgood (1909) and Jackson (1961) used only *gracilis*, and Minnesota workers, without comment, used *gracilis* there (Gunderson and Beer 1953; Hazard 1982). We, on the other hand, expected that *P. m. maniculatus* ranged southward into Wisconsin.

The only samples available to Osgood from northern Michigan and Wisconsin were a large series (N=55) from Isle Royale (this island lies very near the Ontario shore of southern Canada, and these mice seem referable to Canadian *maniculatus*) and a few specimens from all of Michigan (13) and Wisconsin (7). As classic and extensive as Osgood's (1909) revision was, his samples were inadequate to classify and map the detailed geographic distributions of these closely similar mice in this region. In our study we analyzed variation by rigorous statistical tests of the long-tailed kinds present in northern Wisconsin, the Upper Peninsula of Michigan, and islands in Lake Superior and Lake Michigan.

Taxonomic Characters

Typical *P. leucopus* may be distinguished from *P. m. gracilis* by several visible characters if one compares a series of specimens of one mouse or the other, or if any given individual possesses several trenchant characters. But if the collection is mixed—or if a specimen is unusual or, as is more often the case, subadult—then correct identification may be impossible. Mismeasured specimens, skins lacking skulls, or skulls lacking skins complicate taxonomic identification.

The white-footed mouse (*P. leucopus*) is most recognizable by a short tail (both actual and relative to body length) that is sparsely haired. Vestigia of ancient reptilian scales are commonly visible on it, and the sparse hairs seem dingy. In those specimens having such tails, the tail is not sharply bicolor nor does the tip ever bear a pencillate tuft. In those *P. leucopus* having bright-colored and well-haired tails, the short length helps in identification.

Peromyscus maniculatus gracilis, originally described by its elongate tail and only tentatively ascribed to "Michigan," has enormous ears, prominent and elongated whiskers (vibrissae), and a long snout. *P. m. maniculatus*, the nominate race of deer mouse ranging across much of eastern Canada, and reported by Osgood from Isle Royale in Lake Superior, resembles *gracilis* in long, pencillate tail and long ears. Reportedly it is darker in color. Owing to hybridization in southern Ontario, any distinctive features there in *P. m. maniculatus* reportedly are merged somewhat with *P. m. gracilis* (Osgood 1909).

Peromyscus maniculatus maniculatus has never been documented in Wisconsin, nor has anyone since Osgood bothered to investigate that possibility. However, skulls from the Apostle Islands and from nearby Drummond, Wisconsin, appreciably differ from those of *P. m. gracilis* from the Lake Michigan Isles (Washington Island, St. Martin Island, and Rock Island, Long 1978). We considered that the former sample might be referable instead to nearby Canadian *P. m. maniculatus*. The shape of their rostra, indeed, resembles the figured rostrum chosen for nominate *P. m. maniculatus* by Osgood (1909).

Osgood (1909) selected representative skulls to illustrate qualitative characters of form. In *P. leucopus* the rostrum is short and rather pinched anteriorly, and as a consequence the incisive foramina (Fig. 1) on the hard palate are likewise constricted anteriorly. In either *P. m. maniculatus* or *P. m. gracilis*, or in their intergrades, the rostrum is longer and the incisive foramina more nearly parallel, i.e., straight sided. In *P. m. gracilis*, the rostrum is supposed to be quite elongate and not so narrow as in *P. leucopus* or *P. m. maniculatus*.

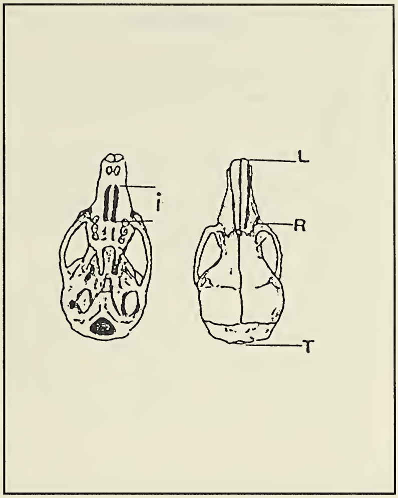

Fig. 1. Cranial measurements of *Peromyscus*. RL, length of rostrum; TL, total length or greatest length of skull; i, length of incisive foramina. The cranial width is measured across and including the convex bulges of the cranium immediately posterior to the zygomatic arches. The cranial depth is measured from the top of the braincase to its base, between (not including) the auditory bullae.

Rostral shape and incisive foramen length have been used by Hazard (1982) to distinguish *P. m. gracilis* from *P. leucopus*. Overlap of these characters between samples was considerable in Wisconsin. Burt (1948) reported the infraorbital canal as distinctive in form in Michigan *P. m. gracilis*, but in Wisconsin no difference in this character is apparent in *gracilis* and *leucopus* (Jackson 1961; Long 1974). Choate (1973) found rostral breadth useful in distinguishing these species, but in our series there was no significant difference in rostral breadth between *gracilis* and Portage County specimens of *leucopus*.

Methods

In this article, the following terms refer to the geographical areas where the large samples of specimens were taken:

Lake Michigan Isles—Washington Island, Rock Island, and St. Martin Island, all found in Lake Michigan near the northeastern Wisconsin shore.

Central Wisconsin—Portage County

Lake Superior—Outer Island and Stockton Island (both members of the Apostle Islands in Lake Superior near the northern Wisconsin shore); and Drummond on the mainland in northern Wisconsin.

Measurements used in this study included the standard measurements of skin labels, of which only the length of ear and tail proved useful. Cranial measurements (Fig. 1) included total length of skull; length of rostrum measured from the tips of the nasals to the slight constriction anterior to the zygoma; length of the incisive foramina; and in some samples cranial width, measured immediately posterior to the zygomata, and cranial depth (not including the auditory bullae). C. A. Long made all the cranial measurements. No size differences were noted between males and females. Young animals were excluded. These were recognized by juvenal pelage, small weak skulls, unworn upper molars, and an open basioccipital-basisphenoid suture.

Most of the specimens were from Wisconsin and Upper Michigan and are preserved in the UWSP Museum of Natural History. Eight specimens of typical *P. m. maniculatus* from Labrador were borrowed from the United States National Museum of Natural History (USNM). Also borrowed were Jackson's (1961) two specimens of *P. m. gracilis* caught in the Sheboygan Marsh in southern Wisconsin, a population disjunct from the geographic range of northern *gracilis.*

Skulls appreciably larger from the Lake Michigan Isles were compared (student t-tests of cranial width) with skulls of specimens from Outer Island, Lake Superior, and from Stockton Island in Lake Superior and nearby Drummond on mainland Wisconsin. Means of cranial width were calculated to compare the samples from Outer Island with those from Stockton-Drummond, as well as to compare Stockton mice with Drummond mice. These comparisons were made to consolidate the Lake Superior populations as a homogeneous group, even though the group includes insular and mainland populations. Means and standard deviations were calculated and compared from the Lake Superior population, the Michigan Isles population, numerous *P. leucopus* from Portage County in central Wisconsin, and other appropriate populations to study geographic variation along a generally northwest to southeast dimension or transect.

These three groups—the Lake Superior group, the Lake Michigan Isles group, and central Wisconsin *leucopus*—were analyzed by stepwise discriminant function analysis, using the aforementioned five linear variables (length of ear, tail, skull, rostrum, and incisive foramina) and ordering the characters by their apparent usefulness (F values) in identification. All specimens that did not fit well within their groups were flagged. Allocation to a group was determined by the probability of best fit, as well as by examining the specimens that showed the second highest probability for fit. Scatter plots were mapped using two discriminant functions to segregate the three groups. The data were evaluated to determine the percentage that fit in their appropriate groups, and discriminant coefficients were calculated for use in future testing. The three groups were used as standards against which some small samples were compared. One such sample reported herein was a collection of six mice that were tentatively identified in our study as *P. leucopus*, previously unknown in the fauna of Washington Island, or on any island in Lake Michigan or Lake Superior. The USNM series of typical *P. m. maniculatus* from Labrador was assigned to one of the three groups by use of the Fisher coefficients.

Results and Discussion

Measurements are given in Table 1 for the three large populations or groups analyzed (Lake Superior, Michigan Isles, and central Wisconsin). Although there is overlap in most of the measurements, *P. leucopus* can be identified usually by smaller dimensions, except for length of skull and rostral width. When length of the ear is plotted against length of tail (Fig. 2), there is clear separation of the Lake Michigan Isles mice from *P. leucopus.* Some collections of *Peromyscus* from Washington Island made in recent years scatter across the graph, and some specimens suspected to be *P. leucopus* indeed fit among the *leucopus* (central Wisconsin group).

The same results were found by plotting incisive foramina length against length of rostrum (Fig. 3). In this comparison numerous recently taken specimens fit among the *leucopus* specimens; none of them fit in the *gracilis* camp.

Transects of mice northwest to southeast (Figs. 4–7) reveal overlap of all characters chosen, except that the Lake Michigan Isles *gracilis* tended toward high values and differed most from *P. leucopus.* (Cranial width was not measured in *leucopus*, Fig. 7.)

In a t-test the mice from the Lake Michigan Isles were broader across the cranium than those in the Lake Superior group (12.32 ± .43 versus 11.95 ± .24, $p < 0.001$). Five specimens (of 22) in the Lake Michigan Isles group had open sutures (indicating subadult age), but their skulls were broader all the same. We expected the Lake Superior group to have the wider skulls. The two populations did not differ in total length of skull (26.5 versus 25.78 mm, $p < 0.001$) or tail length (83.1 versus 83.6, $p < 0.001$). Lake Michigan Isles mice also had wider skulls than those mice combined from Stockton Island and Drummond, but the latter two samples were significantly wider than the mice from nearby Outer Island. (The Stockton Island and Drummond mice did not differ significantly from one another.) Therefore, in cranial width the Lake Superior group was not strictly homogeneous.

Concerning cranial breadth or width, our study only proves that mice on Outer Island are narrow (though resembling our museum specimens from southern Ontario; see Fig. 7). Osgood's own figures and measurements do not confirm his claim that *P. m. maniculatus* has the wider skull, even though his representative specimens were collected in the eastern part of the range far from the zone of intergradation of that race with *P. m. gracilis.* The Labrador series we examined averaged 12.3 in the seven adults, which is but slightly wider than in Lake Superior group specimens (Table 1). We found no significant difference in tail length between the groups from Lake Superior and Lake Michigan (Table 1), or between Wisconsin deer mice and the Michigan *maniculatus* reported by Baker (1983).

In the analysis of variance, all five measured variables showed geographic variation, so that in the total analysis all three Wisconsin populations seemed distinct (Table 2).

Of the variables, ear length gave the highest F-value among the three groups (Table 2), but this field measurement is often slightly made in error. Hazard (1982) considered smaller ears as characteristic of *P. m. maniculatus.* However, the Labrador series of *maniculatus* averaged 19.7 mm. Short ear length statistically separates *P. leucopus* from the other two groups. Length of rostrum separates all three populations evenly. Small incisive foramina, short skull, and shorter tail separate *P. leucopus* out fairly well, except for the considerable overlap in all these variable traits (Table 1).

In the stepwise discriminant analysis, the variables were removed in the order listed in Table 2. Wilk's lambda varied from 0.54 to 0.31, all highly significant in length of ear and the other variables through incisive foramina.

The success in prediction of specimens for all the three groups (Fig. 8) exceeded 80 percent. Of 60 specimens from the Lake Michigan Isles, only 12 fit outside the group 1 sector, and eight fit better in the Lake Superior sector. Of 30 *leucopus* from central Wisconsin, 27 clumped together, and the remainder fit with the Lake Superior group. Of 20 specimens from the Lake Superior group, 15 clumped together. Three fit with the Lake Michigan specimens and two with central Wisconsin *leucopus*.

The Lake Michigan Isles mice had a predicted membership of 82 percent. *Peromyscus leucopus*, which is so difficult to identify by conventional characters, predicted very well with 90 percent strictly within its group. Most of the specimens that did not fit their appropriate group with highest priority did so as the *second* highest probability. Of the 12 in the Lake Michigan Isles group, six fit as a second probability. Of the three central Wisconsin mice, two fit as a second probability.

The six specimens tentatively identified in recent years as *P. leucopus* from Washington Island (hitherto unknown on any islands in Lake Michigan) identified closely with the central Wisconsin group (*P. leucopus*) (Fig. 9). A small group consisting of Washington Island mice not tentatively identified as *P. leucopus* but from the same recently obtained field collections (and including a few subadults) segregated poorly. The bivariate analysis (Figs. 2–3) also showed much overlap of characters in these recently collected specimens.

Fisher's Linear Discriminant Functions, useful as classification coefficients, are given in Table 3. The individual's measures are multiplied by the coefficients to weight them for taxonomic discrimination. Use of Fisher's coefficients surprisingly classified the two disjunct Sheboygan Marsh specimens with the Lake Superior deer mice, although the two skulls were so small and the ears so short they closely resemble *P. leucopus* (which now seems to be the only *Peromyscus* present in the Sheboygan Marsh). One of the two is not quite adult (USNM 227357). These two small skulls differ markedly from deer mice skulls of Lake Michigan Isles, geographically much nearer but isolated by water on islands of Lake Michigan. They are practically indistinguishable from a large sample recently examined from Lower Michigan (Long, unpublished).

The big surprise was the close resemblance of the Lake Michigan Isles group to the typical *P. m. maniculatus* from far away Labrador, rather than to mice nearer at Lake Superior. The resemblance was also close in color of the pelage. The Lake Superior group differed from the Labrador *P. m. maniculatus*, which was unexpected because mice from Ontario and nearby Isle Royale are referred to as *P. m. maniculatus*. All seven adults in the Labrador series fit with the Lake Michigan Isles group. They resembled *P. leucopus* least, which, of course, was to be expected.

Discriminant analysis weights the characters in the optimal way to allow the groups to segregate. Differences may or may not reflect speciation, and they must be perceived with caution. However, in Wisconsin, obvious but overlapping differences in the three groups justified the analysis. If the variation is spurious or drift-like, it is of interest all the same, because the resemblance to Labrador mice, which is very close, suggests that gracilis is a synonum of *P. m. maniculatus*. Such microgeographic variation may indeed be part of the problem (Ledehrle et al. 1985). On the other hand, the resemblance of Lake Michigan and Labrador mice may arise from effects of Pleistocene and early Holocene climate on the zoogeography of *Peromyscus maniculatus*.

The Canadian race *P. m. maniculatus* formerly may have been widespread, with some populations colonizing islands. Peripheral mainland populations may have evolved new characters, such as small size, leading perhaps to the geographic variation named *gracilis* by Osgood (1909) or described by us by using Osgood's name. Additional studies on electrophoretic variation in proteins, such as the work by Calhoun and Greenbaum (1991), may clarify the observed differentiation.

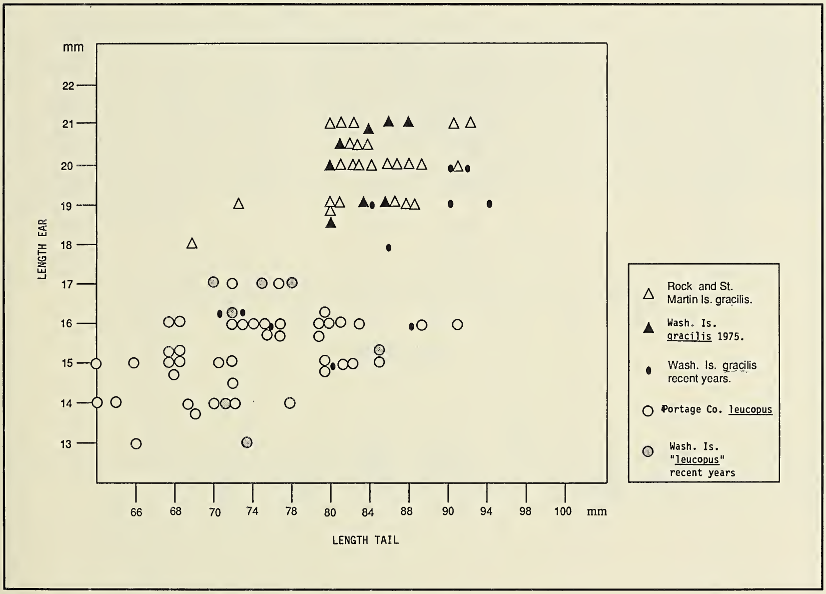

Fig. 2. Bivariate plot of length of ear and length of tail.

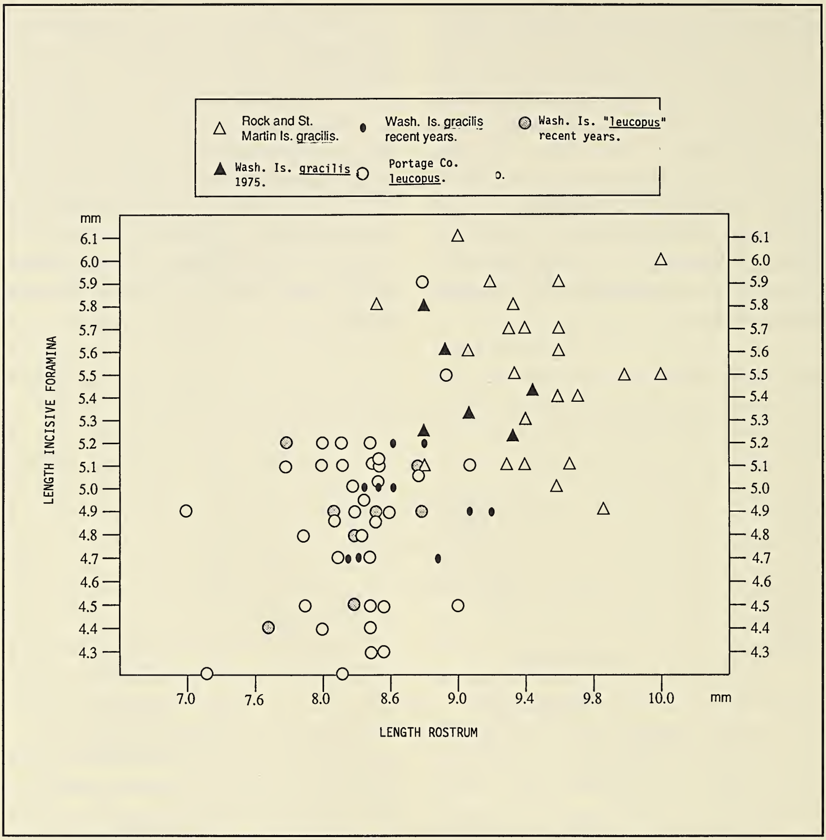

Fig. 3. Bivariate plot of incisive foramina length and length of rostrum.

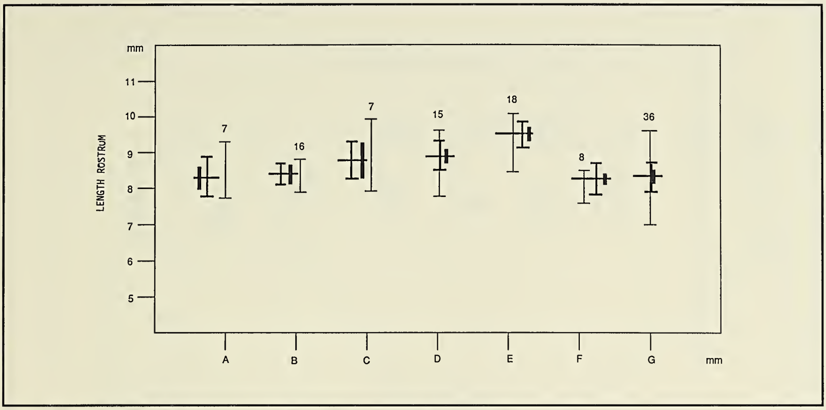

Fig. 4. Transect of deer mice localities based on rostral length, northwest to southeast. Modified Dice-squares (mean, the horizontal; N, sample size above the I-shaped vertical for observed range; standard deviation, the boldfaced I-shaped vertical; twice the standard error, the short thick, vertical. A, specimens from southwest Ontario; B, Outer Island, Apostle Islands, Wisconsin; C, Stockton Island, Apostle Islands; D, Drummond, Wisconsin; E, Lake Michigan: St. Martin Island, Rock Island, Washington Island (early years); F, Possible *P. leucopus* from Washington Island; G, *P. leucopus* from Portage County, Wisconsin.

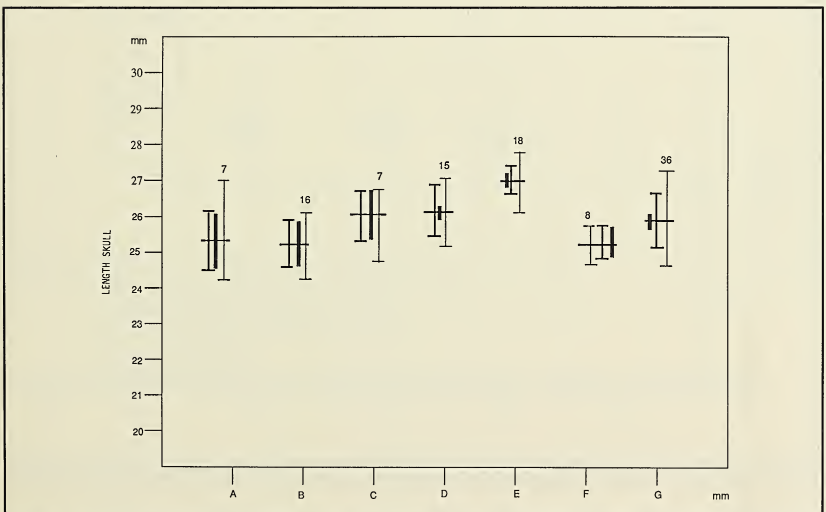

Fig. 5. Transect of deer mice localities based on total length of skull (see Fig. 4 for explanation).

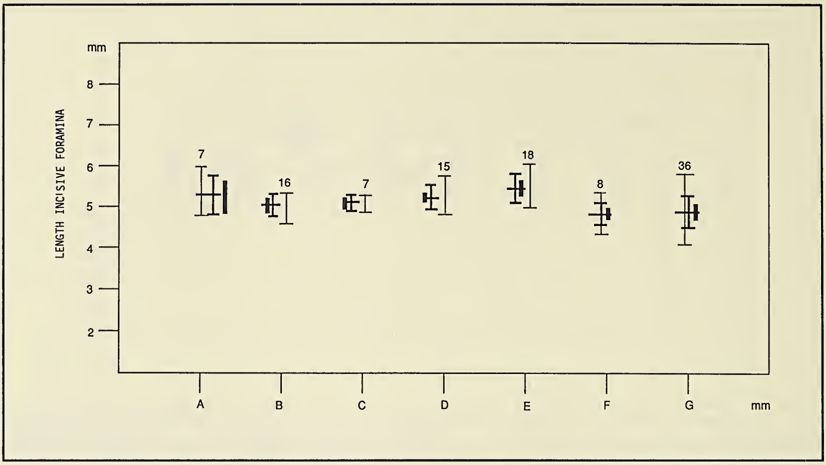

Fig. 6. Transect of deer mice localities based on length of incisive foramina (see Fig. 4 for explanation).

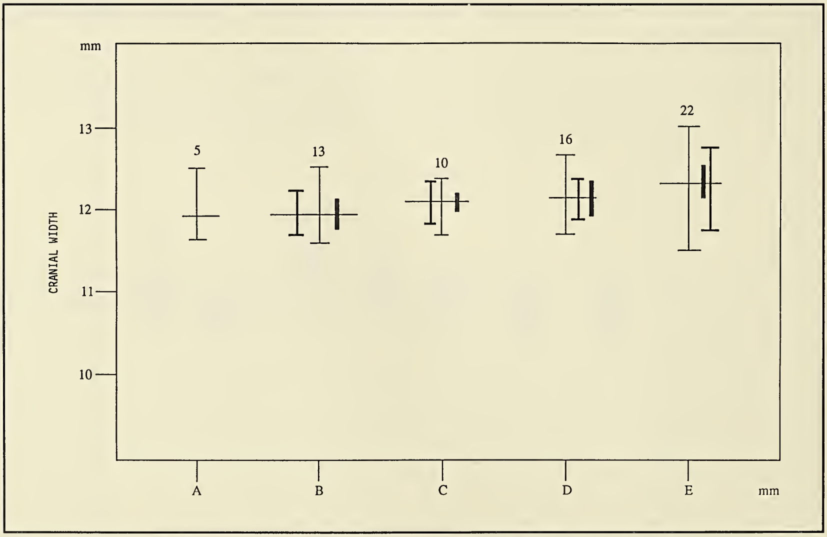

Fig. 7. Transect of deer mice localities based on cranial width (see Fig. 4 for explanation).

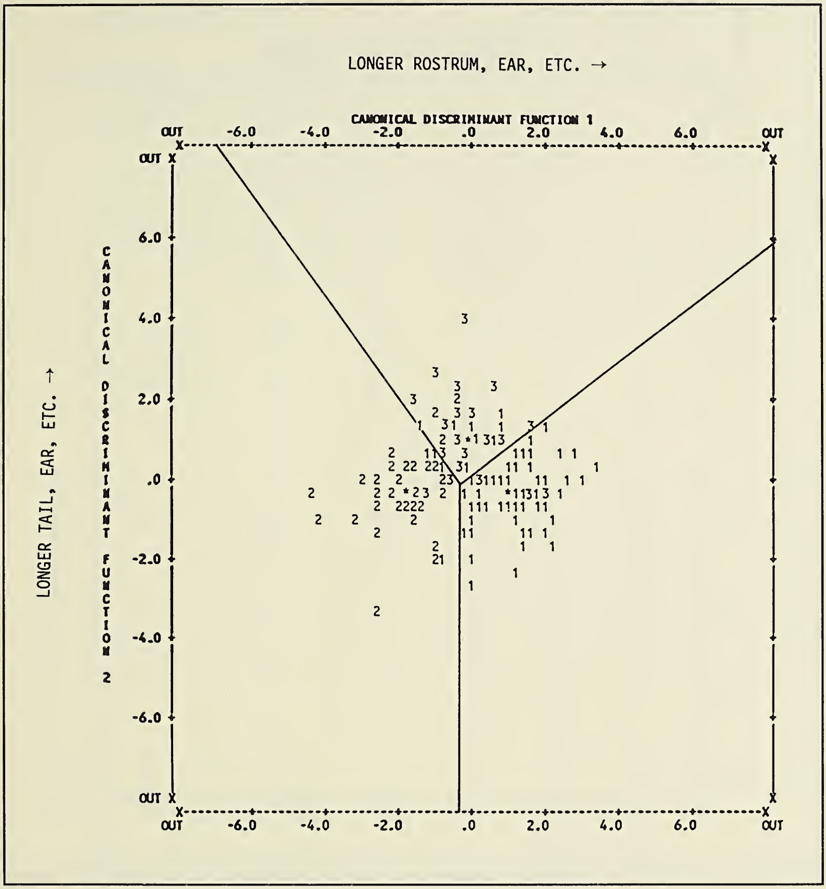

Fig. 8. Scatter plots of *Peromyscus* groups 1-3.

1 = Lake Michigan Isles

2 = Central Wisconsin (*leucopus*)

3 = Lake Superior

Values are canonical variates of discriminant functions. Asterisks are centroids.

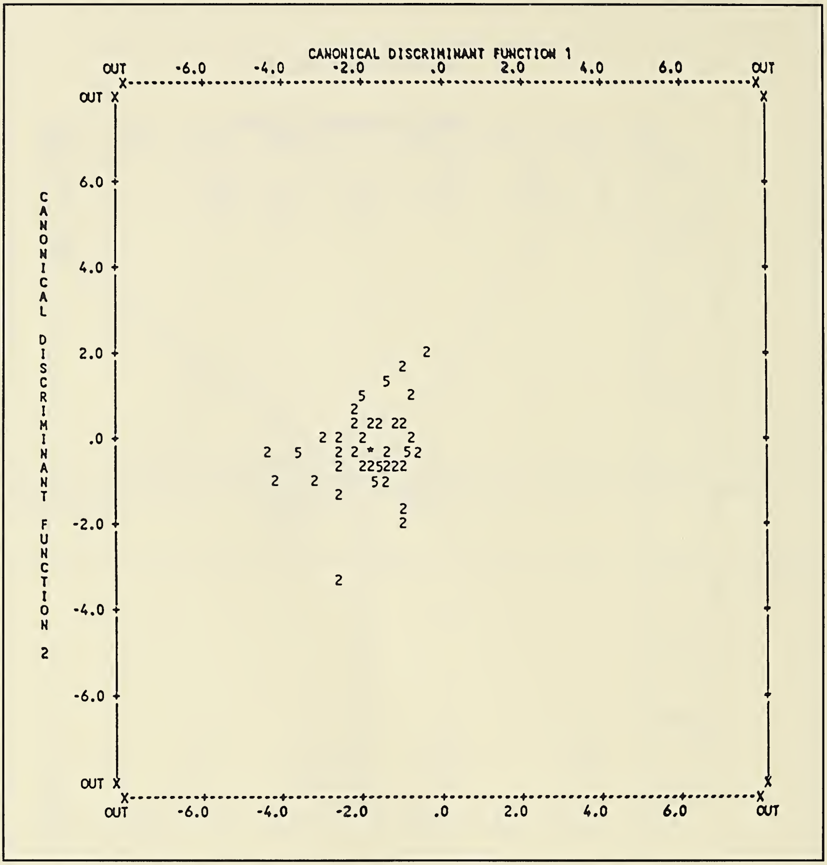

Fig. 9. Scatter plot for *P. leucopus*. Values are canonical variates, *P. leucopus* of Portage County, Wisconsin, comprising group 2. The six 5s were tentatively identified as *P. leucopus* from Washington Island, and this grouping confirms the identity.

Table 1. Mean lengths ± standard deviation of *Peromyscus* specimens from Wisconsin and Michigan

Group	*Locality*	*Ear*[1]	*Rostrum*[2]	*Tail*[3]	*Skull*[4]	*Incisive foramina*[5]	*Cranial width*[6]	*Rostral width*[7]
1	Lake Michigan Isles	18.85 ± 1.8	9.14 ± .42	83.13 ± 4.6	26.59 ± .52	5.15 ± .41	12.32 ± .43	4.54 ± .16
2	Central Wisconsin*	15.23 ± .93	8.32 ± .44	74.0 ± 7.0	25.96 ± .75	4.86 ± .4	——	4.60 ± .2
3	Lake Superior	16.96 ± 2.1	8.85 ± .43	83.6 ± 5.4	25.78 ± .73	5.20 ± .28	11.95 ± .24	4.29 ± .3

* (Portage County) *leucopus*

[1] N = 78, 42, 25 [2] N = 96, 35, 39 [3] N = 77, 42, 25 [4] N = 95, 35, 38 [5] N = 97, 36, 37 [6] N = 22, 13 [7] N = 18, 20, 14

Table 2. Analysis of variance of five measurements of *Peromyscus* spp.

	Linear measurement	*F*
1.	ear	53.37*
2.	rostrum	40.69*
3.	tail	33.02*
4.	total skull	13.60*
5.	incisive foramina	9.47*

* significant at $p < 0.05$

Acknowledgments

We wish to thank Drs. David Hillier and T. A. Neuhauser for helping with the computing. John Yost helped C. A. Long arrange specimens of deer mice. The University of Wisconsin–Stevens Point supported C. A. Long's sabbatical leave enjoyed at St. Olaf College. Dr. Eric M. Anderson and Adrian Wydeven gave appreciated advice on revising the manuscript.

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Table 3. Fisher's Linear Discriminant Functions. These classification coefficients may be applied to other samples.

	Lake Michigan Isles	*Central Wisconsin*	*Lake Superior*
Tail	0.640	0.483	0.766
Ear	1.340	0.310	0.459
Skull	72.225	73.331	71.062
Rostrum	-15.797	-20.279	-16.733
Incisive foramina	-0.019	0.188	1.965
Constants	-928	-889	-894

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John Lyons

Status and biology of Paddlefish (Polyodon spathula) *in the Lower Wisconsin River*

Abstract *The paddlefish* (Polyodon spathula) *is a Threatened Species in Wisconsin. Historically, paddlefish occurred over 224 km of the Lower Wisconsin River, from its mouth at the Mississippi River upstream to Wisconsin Dells. Paddlefish have not been reported from the 76 km between Wisconsin Dells and the Prairie du Sac Dam since the 1950s. A large population, possibly the largest remaining in Wisconsin, exists below the Prairie du Sac Dam, but further downstream, paddlefish are uncommon. From 1988 through 1990, several thousand paddlefish occurred in the 6-km stretch below the Prairie du Sac Dam. Paddlefish were most abundant in the 20-ha tailwater pool below the dam. Almost all paddlefish observed below the dam were large, with mean sizes of 15 kg and 134 cm total length, and maxima of 29.5 kg and 168 cm. Mean total length increased from 127 cm in 1988 to 139 cm in 1990. No young-of-year paddlefish and only one paddlefish under 5 kg were among the 237 paddlefish captured and weighed. The scarcity of small fish may have been merely a sampling bias or the result of poor spawning success and recruitment during the mid to late 1980s. Most paddlefish had evidence of recent parasitism by silver lampreys* (Ichthyomyzon unicuspis), *but lampreys probably did not cause substantial paddlefish mortality. Collisions with boats and snagging by anglers had injured many paddlefish. I recommend that management of paddlefish in the Lower Wisconsin River focus on: 1) improved understanding of reproduction and recruitment; 2) maintenance of a natural river flow regime; 3) continued prevention of illegal harvest; 4) re-establishment of a population above the Prairie du Sac Dam.*

The paddlefish (*Polyodon spathula)*, one of the largest and most unusual of Wisconsin fishes, was once much more widespread and abundant in Wisconsin than it is today (Becker 1983; Gengerke 1986). Before the beginning of intensive European settlement of the state 150 years ago, paddlefish were common in the Mississippi River and the lower reaches of its major tributary basins, the St. Croix, Chippewa, and Wisconsin. Small populations were also present in Lakes Michigan and Superior. Over the last 150 years, paddlefish have become far less abundant, disappearing from the Great Lakes by the early 1900s, and declining greatly in the Mississippi and its tributaries. Declines of paddlefish populations in Wisconsin and elsewhere have been attributed to habitat degradation, dam construction, water pollution, and possibly overharvest (Becker 1983; Pasch and Alexander 1986; Sparrowe 1986; Unkenholz 1986). The paddlefish is a Threatened Species in Wisconsin.

Paddlefish persist at only a few locations in Wisconsin (Becker 1983; Fago 1992). What may be the largest population occurs below the Prairie du Sac Dam on the Lower Wisconsin River in southwestern Wisconsin. Since 1988, I have studied the paddlefish below the dam, with the goal of collecting basic biological information necessary for preserving and increasing the population. In this paper, I report on the distribution and population status of paddlefish in the Lower Wisconsin River, and provide recommendations for managing the population. The data I present may serve as a baseline against which to judge future efforts to rehabilitate paddlefish populations throughout the state.

Study Area

The Wisconsin River originates at Lac Vieux Desert on the Wisconsin-Michigan boundary and flows 684 km south and west to the Mississippi River (Fig. 1). Since creation of the Lower Wisconsin State Riverway in 1989, the Lower Wisconsin River has usually been defined as the 148-km segment between the Mississippi River and the Prairie du Sac Dam, the first dam encountered upstream from the mouth of the Wisconsin (WDNR 1988). However, for purposes of this paper, I also include in my discussion of the Lower Wisconsin River the 76-km segment from the Prairie du Sac Dam upstream to the next dam, the Kilbourn Dam (river kilometer [RKM] 224) at Wisconsin Dells (Fig. 1). Historically, the biota of this segment were similar to those of the segment downstream from the Prairie du Sac Dam.

The Prairie du Sac Dam and the Kilbourn Dam are used for hydroelectric power. They are both impassable to fish moving upstream, although fish may be able to move downstream through them. The Prairie du Sac Dam has a head of 12.5 m and was constructed during 1911–1914, and the Kilbourn Dam has a head of 7.9 m and was constructed during 1907–1910 (Wisconsin Power and Light Corporation [WPLC], unpublished data). Presently, both dams are operated on a "run-of-the-river" basis, and water discharges through them are not regulated to any great extent. Dams further upstream on the Wisconsin River regulate river flows much more, and discharge patterns from these upstream dams can influence discharge patterns through the Kilbourn and Prairie du Sac dams.

The Lower Wisconsin River had mean annual discharges of 192 m^3/sec at the Kilbourn Dam in 1934–1990 (Holmstrom and Erickson 1990), 224 m^3/sec at the Prairie du Sac Dam in 1950-1989 (WPLC, unpublished data), and 246 m^3/sec at the Muscoda gaging station (RKM 71) in 1913–1990 (Holmstrom and Erickson 1990). Downstream from the Prairie du Sac Dam, the river is generally wide (> 200 m) and relatively shallow (< 3 m), with a primarily shifting sand bottom. Unique conditions exist immediately below the Prairie du Sac

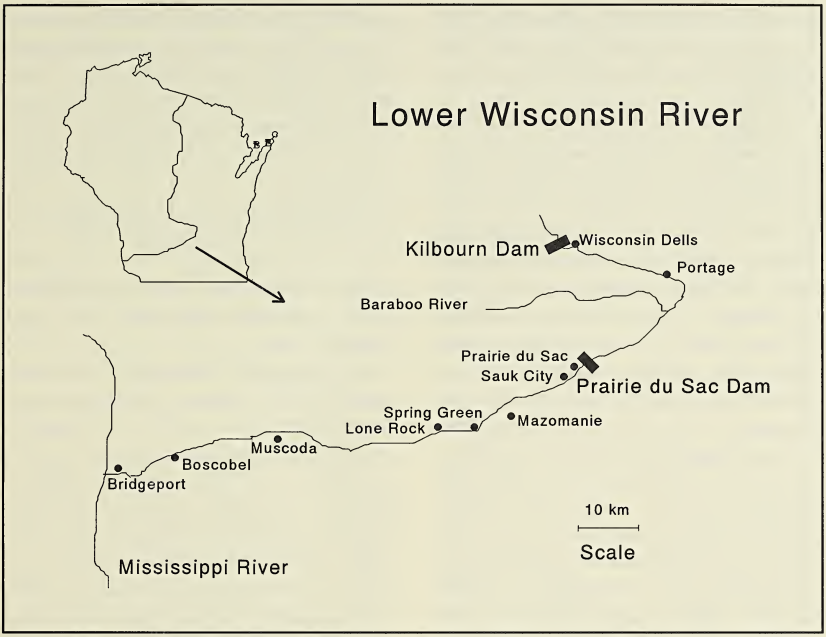

Fig. 1. Map of the Lower Wisconsin River, showing locations mentioned in the text.

Dam, where scouring has created a 20-ha tailwater pool that is over 12 m deep in places. The bottom in and adjacent to this pool contains relatively large amounts of gravel and cobble, although sand still predominates.

Methods

I obtained historical distribution and abundance data on paddlefish in the Lower Wisconsin River from published accounts, the Wisconsin Department of Natural Resources (WDNR) Fish Distribution Survey Database (Fago 1988), and unpublished records associated with paddlefish specimens preserved at the University of Wisconsin Zoological Museum (UWZM) in Madison and the University of Wisconsin Museum of Natural History (UWSP) in Stevens Point.

Current distribution and abundance data came from recent WDNR electroshocking surveys of the Lower Wisconsin River. The electroshockers used were standard WDNR two- or three-person, boat-mounted, pulsed direct-current "boom shockers," powered by either a 2500 watt or 5000 watt generator (Novotny and Priegel 1974). Between March and November 1985–1990, one to ten surveys per year were conducted in the area immediately below the Prairie du Sac Dam. Many paddlefish were observed during all of these surveys, but paddlefish were collected only from 1988 to 1990. Additional electroshocking surveys were conducted at sites closer to the Mississippi River on one date each in July 1985, April 1987, and June 1991, and on eight dates in October 1989.

During electroshocking surveys, efforts were made to minimize mortality of captured paddlefish. Paddlefish stunned by the electroshocker were quickly removed from the river and placed in a horse trough filled with river water. There they were measured to the nearest cm, weighed to the nearest 0.5 kg, checked for physical damage and lamprey parasitism, and then allowed to recover before being released. Normally, only one paddlefish was captured and processed at a time, and each captured fish was handled as little and as gently as possible. Most fish recovered from the electric shock within minutes, swam away strongly when released, and, presumably, survived. However, in each survey, some paddlefish (5 to 15%) died as a result of capture and handling. I took tissue and organ samples from 10 of the paddlefish that died between late March and early June 1990, and provided these samples for use in a nationwide paddlefish genetics study (Epifanio et al. 1990). I also examined stomach contents from these 10 paddlefish.

In previous studies, paddlefish size has been characterized by different length measurements (Russell 1986). To allow Lower Wisconsin River data to be compared with results from these earlier studies, four length measurements were made on most paddlefish captured: body length—the distance from the anterior edge of the eye to the caudal fork; mouth-fork length—the distance from the anterior tip of the jaw to the caudal fork; rostrum-fork length—the distance from the tip of the rostrum (paddle) to the caudal fork; and total length—the distance from the tip of the rostrum to the posterior tip of the upper caudal lobe. I used linear regression (SAS 1988) to develop equations to convert one measurement to another. I also used linear regression to develop quantitative length-weight relationships. I compared paddlefish total length distributions among different sampl'ng periods with the Kruskal-Wallis test (SAS 1988). I estimated the approximate age of Wisconsin River paddlefish based on the total length-age relationship developed for paddlefish in Pool 13 of the Mississippi River (Gengerke 1978). I did not determine age directly because paddlefish must killed to be aged (Russell 1986).

In October of 1988 and 1989, I made mark-recapture estimates of the number of paddlefish in the area below the Prairie du Sac Dam. For two days each year, captured paddlefish were marked with a length of brightly colored plastic flagging tape that was wrapped around the caudal peduncle (13 in 1988; 29 in 1989). Within 48 hours of marking, the sampling crew made up to four electroshocking recapture passes in the vicinity of the dam, counting, but not netting, all paddlefish that surfaced between the electrodes (770 in 1988; 471 in 1989), and noting whether any of these paddlefish were marked (2 in 1988; 2 in 1989). The bright flagging tape was easily seen on paddlefish in the water. I estimated population size using the modified Petersen formula, with asymmetric confidence intervals calculated under the assumption that recapture probabilities for marked fish followed a Poisson distribution (Ricker 1975).

In 1989, I began an annual paddlefish abundance monitoring program. I established a standardized electroshocking circuit for paddlefish around the tailwater pool below the Prairie du Sac Dam. The circuit was about 1.6 km long and took up to 25 minutes to shock. In October 1989 and October 1990, the field crew shocked this circuit, counting, but not netting, all paddlefish observed, and noting whether each one appeared to be more or less than 100 cm in total length (a length at which paddlefish weigh approximately 5 kg). I used the total number observed in each circuit as an index of paddlefish abundance.

Historical Distribution and Abundance

The first reports of paddlefish from the Lower Wisconsin River date from the early 1900s, the period when the first scientific surveys of the fishes of the Wisconsin River were undertaken. Greene (1935), Becker (1966, 1983), and Fago (1992) summarized these surveys, and recorded paddlefish from the Wisconsin River at Prairie du Sac in 1924 and 1937 and at Wisconsin Dells in 1931. Wisconsin Dells probably was the historic upstream limit for paddlefish in the Wisconsin River. No paddlefish have ever been reported upstream from this point. Before completion of the Kilbourn Dam in 1910, a large rapids occurred in the Wisconsin Dells gorge (Stark 1988), and this rapids may have been impassable to paddlefish. Between the mid 1800s and 1910, a low-head (2 to 3 m), wooden logging dam was also present at Wisconsin Dells (Stark 1988), further impeding paddlefish upstream movement.

The last record of paddlefish from the stretch between the Prairie du Sac Dam and Wisconsin Dells came in 1950 (Becker 1983), when a large individual was found in the Baraboo River, a tributary that enters the Wisconsin River at RKM 181, near the city of Portage (Fig. 1). Fish surveys of this stretch of the Wisconsin River during the 1970s, 1980s, and 1990s failed to find paddlefish (Tim Larson, WDNR Fish Manager, Poynette, personal communication; David Morrow, fisheries biologist, Mead and Hunt, Inc., personal communication; personal observations). Causes of the disappearance of paddlefish are unknown, although I speculate that poor water quality in the river from the 1940s through the 1970s may have played a role. During this period, discharges from upstream industries, particularly paper mills, caused major declines in dissolved oxygen levels and were responsible for several large fish kills in the Lower Wisconsin River (Poff and Threinen 1965; WDNR 1976; WDNR, unpublished data). By the late 1970s, pollution abatement had greatly reduced water quality problems in the Lower Wisconsin River, but by then paddlefish were gone. The Prairie du Sac Dam prevents paddlefish from moving upstream and recolonizing this stretch of river.

Only eight confirmed records of paddlefish, all large individuals, exist from the Lower Wisconsin River below Sauk City (RKM 142) (Becker 1966, 1983; Fago 1992; UWSP Specimens; WDNR Fish Distribution Survey Database). Two records were from the early 1960s, when two dead paddlefish were found near Muscoda. The remaining six records were from extensive electroshocking and netting surveys that were carried out during the 1970s. One of these records (one fish) was from near the mouth of the Wisconsin at Bridgeport (RKM 10), and the other five (eight fish total) were from between Spring Green and Mazomanie (RKM 108 to 135) (Fig. 1). During these same 1970s surveys, over 125 paddlefish were captured from the 6 km of river between Sauk City and the Prairie du Sac Dam. In the 1980s, more than 2000 paddlefish were captured or observed in 38 days of electroshocking in the three kilometers immediately below the dam. Conversely, no paddlefish were observed in 11 days of shocking areas further downstream—one day upstream of Mazomanie (RKM 136–

142), one day near Lone Rock (RKM 95), and nine days from near the mouth up to Boscobel (RKM 3 to 45) (Fig. 1).

Paddlefish have been common in the area below the Prairie du Sac Dam for at least the last 50 years. During March 1945, "over a ton" of dead paddlefish was observed at Sauk City, presumably killed by poor water quality (UWZM, unpublished data). During the 1960s, large numbers of paddlefish were regularly observed directly below the powerhouse of the Prairie du Sac Dam (Poff and Threinen 1965; Becker 1966; UWZM, unpublished data; Lyle Christenson, WDNR Fisheries Research Biologist, Monona, personal communication).

From 1985 through 1990, numbers of paddlefish observed during surveys below the Prairie du Sac dam were typically 10 to 30 times higher in and adjacent to the tailwater pool than in areas further downstream. However, groups of 10 to 20 paddlefish were sometimes observed downstream from the tailwater pool, usually in the vicinity of the State Highway 60 Bridge in Prairie du Sac (RKM 146) or the railroad bridge in Sauk City (RKM 142).

Recent electroshocking surveys and discussions with anglers and scuba divers indicated that large numbers of paddlefish were present in the tailwater pool in all months of the year. At least 75 paddlefish were observed during each monthly electroshocking survey of the tailwater pool between March and November 1989. Anglers who fished the pool reported observing or accidently snagging paddlefish during all months of the year. In February 1982, scuba divers in the pool observed numerous large paddlefish (Mike Talbot, WDNR Fisheries Management Biologist, Madison, personal communication).

Although data are limited, there is no evidence that large numbers of paddlefish migrate to or from the area immediately below the dam. There are few confirmed records of paddlefish from the Lower Wisconsin River below the Prairie du Sac Dam or from Pool 10 of the Mississippi River at the mouth of the Wisconsin River (Becker 1966, 1983; WDNR Fish Distribution Survey Database), although a few commercial fishermen say that they regularly catch paddlefish in Pool 10 (Cecil Jennings, U.S. Fish and Wildlife Service Fisheries Biologist, LaCrosse, Wisconsin, personal communication). Moreover, genetic differences exist between the Prairie du Sac Dam paddlefish population and Mississippi River paddlefish populations (Epifanio et al. 1990), suggesting little mixing between paddlefish from the Wisconsin and Mississippi rivers.

The tailwater pool area of the Prairie du Sac Dam appears to have all the necessary habitats for paddlefish to complete their life cycle. Although paddlefish have not been observed spawning in Wisconsin waters, the gravel bars immediately below the tailwater pool conform to descriptions of good paddlefish spawning habitat (Purkett 1961; Pasch et al. 1980; Russell 1986; Crance 1987). The deep, slow-moving waters of the tailwater pool itself appear to constitute excellent summer feeding and winter resting habitat for both juveniles and adults (based on descriptions in Southall and Hubert 1984; Russell 1986; Crance 1987), and the lentic environment above the dam provides a source of crustacean zooplankton (personal observations), a primary food of paddlefish (Rosen and Hales 1981).

Abundance and Size Structure Below the Prairie du Sac Dam

During the late 1980s, several thousand paddlefish lived in the Prairie du Sac Dam tailwater pool. In October 1988, the estimated population size was 3600 (95% confidence interval: 1320–9000), and in October 1989 it was 4720 (95% confidence interval: 1730–11800). These may be overestimates, because only two marked paddlefish were recaptured in each month. Mark-recapture population estimates based on less than three recaptures tend to be biased, typically yielding estimates that are too high (Ricker 1975). Nonetheless, a population of several thousand paddlefish seems reasonable. Throughout the study period, it was normal to observe hundreds of paddlefish during two or three hours of shocking the tailwater pool.

No population estimate was made in 1990, but the abundance of paddlefish may have been less than in 1988 and 1989. The number observed along the standardized electroshocking circuit was 133 in 1989 and 78 in 1990. Generally, fewer paddlefish were observed during 1990 surveys than during 1988 and 1989 surveys.

Almost all of the paddlefish observed or captured were large. Of 237 paddlefish weighed, only one was less than 5 kg (4 kg; 97 cm total length [TL]). Of the hundreds of other paddlefish observed but not netted, only four appeared to weigh less than 5 kg. The mean size of captured paddlefish was 15 kg and 134 cm TL, and the maximum size was 29.5 kg and 168 cm TL (36 paddlefish with damaged upper caudal lobes or rostrums were not included in total length statistics). Nineteen percent of the captured paddlefish weighed 20 kg or more.

Based on the distribution of total lengths, most paddlefish were probably 8 to 14 years old, with the smallest individuals aged 4 to 7 years and the largest individuals greater than age 18 (Table 1). By age 8 to 12, all male paddlefish and most female paddlefish are likely to be mature (Gengerke 1978; Russell 1986), hence mature adults dominated catches in the Lower Wisconsin River from 1988 through 1990.

The average total length of captured paddlefish increased from 1988 to 1990 (Table 1). Over the period October 1988 through April 1989, paddlefish mean TL was 127 cm (I assumed no growth occurred between October and April). By October 1990, mean TL was significantly greater at 139 cm (chi-square = 28.7; p = 0.0001). During the period October 1988 through April 1989, 36% of captured paddlefish were less than 125 cm TL, and only 2% were greater than 145 cm. From October 1989 through April 1990, 14% were less than 125 cm and 34% were greater than 145 cm. By October 1990, only 3% were less than 125 cm and 38% were greater than 145 cm.

Sampling bias might account for the near absence of small paddlefish in electroshocking catches. In other river systems, young-of-year paddlefish have usually proven more difficult to capture than larger individuals (Purkett 1961; Pasch et al. 1980; Russell 1986). Boom shockers effectively sample only the top 2 m of the water column, and if small paddlefish occupy deeper water, they would not be vulnerable to capture. However, little is known about habitat use by small paddlefish (Russell 1986). Small paddlefish might occupy some other part of the Lower Wisconsin River and only move into the area below the Prairie du Sac Dam after they grow to a relatively large size. Although small paddlefish have never been captured in surveys of the Lower Wisconsin River outside of the Prairie du Sac Dam area, many kilometers of the river remain unsampled.

Conversely, the scarcity of small paddlefish in electroshocking samples might represent a real scarcity in the Lower Wisconsin River population. The increasing aver-

Table 1. Numbers of paddlefish captured, by total length (TL) class, from below the Prairie du Sac Dam, Lower Wisconsin River, 1988–1990. Only fish without damaged rostrums or upper caudal lobes are included. Paddlefish captured between October and April are combined because I assumed that no growth occurred during this time interval. Approximate age ranges are based on data from Mississippi River paddlefish (Gengerke 1978).

TL Class (cm)	All Months, Years Combined	October through April Only			Age Range
		88–89	89–90	90–91[a]	
<100	1	1	0	0	4–7
100–104	0	0	0	0	4–7
105–109	1	0	0	0	5–7
110–114	6	2	1	0	6–9
115–119	10	3	4	1	7–10
120–124	23	10	3	0	8–12
125–129	36	13	4	6	8–12
130–134	29	6	7	6	9–13
135–139	34	7	10	4	9–14
140–144	18	2	8	1	12–18
145–149	19	0	6	5	14–18
150–154	14	0	6	3	16–18
155–159	8	1	4	1	≥18
160–164	4	0	2	2	≥18
165–169	1	0	1	0	>18
Totals	204	45	56	29	
Mean TL	134	127	139	139	
Standard Deviation	12.1	9.5	12.6	11.0	

[a]High flows prevented effective sampling for paddlefish in March & April 1991.

age lengths of captured paddlefish suggest that there was little recruitment to the adult population during the study period. Poor reproductive success during the mid to late 1980s could explain the low numbers of young paddlefish.

The time of paddlefish spawning in Wisconsin waters is unknown (Becker 1983), but based on preferred water temperatures for reproduction (15 to 22°C), and the spawning season in states to the south (mid to late April in Missouri and Tennessee—Purkett 1961; Pasch et al. 1980; late April to late May in Iowa—Southall and Hubert 1984), paddlefish in the Lower Wisconsin River probably spawn in May. Water temperatures below the Prairie du Sac Dam range from 11 to 17°C in early May and 18 to 22°C in late May (Don Fago, WDNR Fisheries Research Biologist, Fitchburg, unpublished data for 1987–1990). Paddlefish reproductive success tends to be highest in years when river flows are at or near flood levels during and for at least a week after spawning (Purkett 1961; Russell 1986). The specific flows required to provide good spawning conditions at a site depend on the morphometry of the river channel; paddlefish normally spawn on submerged gravel bars with water velocities greater than 0.4 m/sec and depths greater than 2 m (Crance 1987). Thus, river flows in May probably determine paddlefish reproductive success in the Lower Wisconsin River.

I hypothesize that river flows in May at the Prairie du Sac Dam might have been below the optimum for paddlefish reproduction during most of the 1980s. Based on my extensive observations of the Lower Wisconsin River over a wide range of flows and an examination of the discharge vs. water level relationship below the dam, I have found that large areas of submerged gravel bars with depths deeper than 2 m and water velocities greater than 0.4 m/sec occur in the vicinity of the dam only when river flows are greater than 400 m^3/sec. Mean flow in May at the Prairie du Sac Dam was 306 m^3/sec in 1950–1990 (WPLC, unpublished data). Since 1950, flows in May have exceeded 400 m^3/sec for more than seven consecutive days (and hence been best for paddlefish spawning) in nine years: 1951, 1954, 1960, 1965, 1972, 1973, 1975, 1979, and 1984 (WPLC, unpublished data). Thus, flows likely to produce optimal spawning conditions occurred only once during the 1980s. Seven of the years in the 1980s had mean May flows below the long-term average. The 8- to 18-year-old paddlefish that dominated catches in 1988–1990 were hatched between 1970 and 1982, a period in which four years of optimal flows occurred.

Miscellaneous Observations

The four length measurements made on paddlefish from the Lower Wisconsin River were strongly correlated with each other. Regressions relating each measurement to total length and body length, the most common measurements in the literature, are as follows:

Total Length = 20.384 + (1.271 x Body Length)
(N = 202; F = 1639; p = 0.0001; r^2 = 0.89)

Total Length = 22.231 + (1.242 x Mouth-Fork Length)
(N = 203; F = 1760; p = 0.0001; r^2 = 0.90)

Total Length = 3.421 + (1.074 x Rostrum-Fork Length)
(N = 203; F =3294; p = 0.0001; r^2 = 0.94)

Body Length = 2.747 + (0.963 x Mouth-Fork Length)
(N = 217; F = 10106; p = 0.0001; r^2 = 0.98)

Body Length = -6.480 + (0.789 x Rostrum-Fork Length)
(N = 205; F = 2537; p = 0.0001; r^2 = 0.93)

Paddlefish weight was also strongly correlated with both total length and body length:

Log_e(Weight) = -12.706 + (3.132 x Log_e [Total Length])
(N = 202; F = 484; p = 0.0001; r^2 = 0.71)

Log_e(Weight) = -10.408 + (2.902 x Log_e [Body Length])
(N = 213; F = 686; p = 0.0001; r^2 = 0.76)

Nearly all paddlefish from below the Prairie du Sac Dam suffered from parasitism by silver lampreys *(Ichthyomyzon unicuspis)*. Of 240 paddlefish examined, 231 (96%) had either an attached lamprey or a fresh lamprey wound. Individual paddlefish had up to 11 attached lampreys and 28 fresh wounds; the mean number of lampreys attached was 1.2 and the mean number of fresh wounds was 6.1. Most paddlefish also had healed wounds from previous lamprey attacks.

I do not believe that lampreys cause substantial mortality of paddlefish in the Lower Wisconsin River. Lamprey parasitism has been common on Lower Wisconsin River paddlefish since at least the 1940s (UWZM, unpublished data), and yet a large paddlefish population persists. The prevalence of healed wounds on paddlefish shows that paddlefish survive lamprey attacks. The ratio of paddlefish biomass to attached lamprey biomass is typically much more than

50 to 1. In experiments involving sea lampreys (*Petromyzon marinus)* feeding on lake trout *(Salvelinus namaycush*) and rainbow trout (*Oncorhynchus mykiss*), Farmer et al. (1975) found that lampreys caused direct mortality of their host only when the ratio of host biomass to lamprey biomass was less than 40 to 1.

Some paddlefish had injuries or tissue damage not caused by lampreys. Twelve of 240 paddlefish (5%) had damaged rostrums, and 55 (23%) had external damage to some other part of the body. In some instances paddlefish had lost most or all of their rostrum. Much of the damage clearly had been caused by fishing hooks and lines or by boat motor propellers. Paddlefish often swam just below the surface, and on several occasions I saw motor boats collide with them. Although fishing for paddlefish is illegal, I sometimes saw anglers deliberately trying to snag them. When anglers did catch paddlefish, they would often handle them roughly and keep them out of the water for long periods.

The frequency of tissue damage for paddlefish from below the Prairie du Sac Dam was similar to that observed elsewhere. In Pool 13 of the Mississippi River, Gengerke (1978) reported that 30 (5%) of 603 paddlefish had damaged rostrums. However, only 91 of 1543 paddlefish (6%) had damage from fishing hooks and lines or boat propellers. In the Missouri River in South Dakota, 46 of 458 paddlefish (10%) had damaged rostrums, and an additional 118 (26%) had damage to other parts of their body (Rosen and Hales 1980). Most of this damage was attributed to fishing hooks and lines or to boat propellers.

Paddlefish appeared to travel in schools below the Prairie du Sac Dam. Paddlefish were usually observed in groups of 10 or more. It was common to electroshock an area of the tailwater pool and observe no paddlefish, only to return several hours later and observe many paddlefish. However, paddlefish distribution in the tailwater pool was not random. Certain areas, particularly eddies adjacent to fast current, consistently had higher numbers of paddlefish than elsewhere.

Based on limited data, it appeared that paddlefish from below the Prairie du Sac Dam fed largely on crustacean zooplankton. All 10 of the paddlefish stomachs examined between late March and early May 1990 contained primarily *Daphnia*, a crustacean zooplankter that was present in high densities in the tailwater pool during this period (personal observations). The amount of food in the stomachs was impressive; several contained more than 1 kg (wet weight) of *Daphnia.* Other studies have reported that crustacean zooplankton are a major food of paddlefish (Wagner 1908; Rosen and Hales 1981; Becker 1983; Russell 1986).

Management Recommendations

I believe that a priority in management of the paddlefish population of the Lower Wisconsin River should be to learn more about the distribution and abundance of small (i.e., < 5 kg) paddlefish. Until the reason for the scarcity of small paddlefish in electroshocking samples can be explained, management efforts will be hampered by uncertainty about the size and abundance trends of the population. I recommend a two-part study to clarify the status of small paddlefish. The first part should determine whether electroshocking is biased towards larger paddlefish. A variety of methods that effectively sample deep water, such as trammel and gill netting, seining, and trawling, should be compared with electroshocking in the tailwater pool and in areas further downstream. If these other techniques capture small paddlefish in good numbers, then they should be used together with electroshocking in the annual abundance monitoring program.

The second part of the study should determine where, when, and under what conditions paddlefish reproduce successfully in the Lower Wisconsin River. Efforts to preserve and increase the paddlefish population below the Prairie du Sac Dam would be enhanced by a better understanding of factors that dictate spawning success and subsequent recruitment to the adult population. Because optimal conditions for paddlefish spawning might occur only a few times each decade, this part of the study could take many years to complete.

The likelihood that paddlefish need high river flows for successful spawning suggests that paddlefish reproduction might be enhanced if the Prairie du Sac Dam and upstream dams artificially increased flows during May. However, I recommend against this for several reasons. First, there are no actual data on paddlefish spawning in the Lower Wisconsin River. As a result, it is impossible to provide precise recommendations as to when, how much, and for how long flows should be augmented. The river flow conditions that I have suggested were optimal for paddlefish reproduction represent a hypothesis that needs to be confirmed with field data before changes in dam operations are considered. Second, neither the Prairie du Sac Dam nor the Kilbourn Dam have substantial water storage capacity, and it is unlikely that they could be used to increase flows without unacceptable declines in the levels of the impoundments behind them. Moreover, the Prairie du Sac Dam is in the process of being licensed by the Federal Energy Regulatory Commission (FERC), and a condition of the license will be that the dam continue to operate in run-of-the-river mode. The WDNR will also recommend continued run-of-the-river operation of the Kilbourn Dam if it is licensed by FERC (Bob Hansis, WDNR Water Management Specialist, Fitchburg, personal communication). Several dams upstream from the Kilbourn Dam have large storage capacity, but using them to increase flows below the Prairie du Sac Dam would be complicated. Finally, although artificial high flows might benefit paddlefish, they might harm other species. The biotic community of the Lower Wisconsin River is complex, and modification of natural flow patterns, however well intentioned, might have unforeseen negative consequences. I recommend taking a conservative management tack and changing natural river flows as little as possible.

Illegal harvest is a threat to the paddlefish population in the Lower Wisconsin River. Paddlefish eggs make excellent caviar and fetch high prices. The potential to earn large amounts of money by selling paddlefish eggs has led to considerable organized illegal harvest in some areas, and caused serious harm to paddlefish populations in some waters (Missouri Department of Conservation and U.S. Fish and Wildlife Service, unpublished data). Although there is no evidence of substantial illegal harvest in the Lower Wisconsin River, the year-round concentration of paddlefish below the Prairie du Sac Dam makes the population vulnerable to illegal snagging and netting. The area below the dam is regularly patrolled by WDNR Law Enforcement personnel, but if evidence of substantial illegal harvest comes to light, the patrols should be increased.

Recreational use of the area below the Prairie du Sac Dam clearly causes injuries to many paddlefish, although the effect of these injuries on the paddlefish population is uncertain. Two actions could be taken to reduce the number of paddlefish injuries. First, the tailwater pool area could be declared a "no wake" zone. Boaters would be required to travel slowly when in the area, allowing them and the paddlefish more time to see each other and avoid collisions. Second, educational signs and pamphlets could be developed to urge anglers to avoid trying to snag paddlefish, and to release quickly and carefully any paddlefish they caught accidentally.

I recommend that an attempt be made to re-establish paddlefish in the stretch of river between the Prairie du Sac Dam and the Kilbourn Dam. Water quality in the area below the Kilbourn Dam has improved markedly since the 1960s and 1970s, and the habitat there appears to have depth, velocity, and substrate characteristics suitable for paddlefish. The best source of paddlefish for reintroduction would be from below the Prairie du Sac Dam. The paddlefish from here are probably part of the same stock that once inhabited the area below the Kilbourn Dam, and by using them, the potential for introducing genetically unsuitable fish would be minimized (Epifanio et al. 1990). The population of paddlefish below the Prairie du Sac Dam is large enough that removal of some individuals (< 250) for stocking upstream probably would not be harmful.

Acknowledgments

I thank the many people who helped me observe and collect paddlefish in the Lower Wisconsin River. I am indebted to those biologists who allowed me access to their unpublished data and observations. Lyle M. Christenson, Philip A. Cochran, and two anonymous reviewers provided useful comments on an earlier draft of this paper. Electroshocking surveys during which paddlefish were collected were funded in part through the Sport Fish Restoration Program, Project F-83-R, Study 044.

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Bruce Taylor

An "Education into Gladness": Ron Wallace's The Makings of Happiness *and "The Mid-life Progress" narrative*

As Director of Creative Writing at the University of Wisconsin–Madison and Editor of the annual Bittingham Award for poetry from the University of Wisconsin Press, Ron Wallace, both as a practitioner and a promoter, has been for many years a major voice of and for poetry in Wisconsin. As author of three previous books of poetry, three books of criticism, and as editor of the anthology *Vital Signs: Contemporary American Poetry from the University Presses*, Wallace's national reputation has been firmly established for quite some time. However, with the publication of *The Makings of Happiness*, Wallace has emerged squarely among the very best of the mid-generation poets in America.

The Makings of Happiness is a book of broad appeal that can be enjoyed on many levels and from many different perspectives, a book for the general reader as well as the most seasoned poetry aficionado. An hour, an afternoon, a day, or many days can be spent wallowing in this book's sumptuous pleasures. The more a reader puts into it, the more he or she gets out of it—and that, after all, is the hallmark of great literature.

To even the casual reader of Ron Wallace's poems there is much wit and music to be found, great humor and many words at wonderful play. First, on this most available level, there is all the beautiful noise, all the language which delights the reader by delighting in itself.

I'm lifting the oysters
up from the ice chips,
scooping the slippery pap
loose with a spoon,
dripping the sliver of lemon, the ripe
island of tabasco, and then
flipping it all up to my lip and sipping
it in, the rough texture of shell
on incisor, the limp liquidy tongue
poised for the pleasure
of soft palate and swallow . . .
"Fresh Oysters & Beer"

Limp-wristed and slithery
she spins full around
and falls to the ground
dizzy, a fizzle.
"Wiffle Ball"

Breezy with bees
apple pulp rises under the grinder,
shreds of flesh and skin glistening,
the amber liquid dripping
into the tin acidic bucket.
"Apple Cider"

the tin stars pinned
in the tenpenny wind.
"February Thaw"

Even more simply, though no less elegantly, Wallace displays an impeccable diction, illuminating again how the difference between a word and the "right" word is, as Mark Twain has always told us, the difference between "lightning" and a "lightning-bug." Wallace gives us the "*rampantly* adolescent daughter" of "Fresh Oysters & Beer"; a "*puff* of nuthatch" and "roadside mud *quick* with rivulets" in "February Thaw"; in "Prayer," "the *wick* of your own breath *aflutter*," as well as the exquisitely assonantial

Or the votive candles of snow
over which one crow,
cowled in its shadow, lengthens?[1]

Then there is the deft ability Wallace has for reinventing the language with phrases to which he has restored original meaning by forcing them within the context of the poem back through the colloquialisms, clichés and euphemisms, the commonplaces of homely discourse to reassume their original power as metaphor. For example, in "Early Brass" the brass section of the New York Cornet & Sacbut Ensemble, "in long-tailed tuxedos / rise to the *bright occasion*." Marjorie, the quadriplegic "information manager of a chin operated wheelchair company," composes in "Fan Mail" a "chin-operated missive, / its five good-tempered sentences / tapped out with what *intensive care* . . . ."[2]

In "Basketball" the poet is shooting baskets with his six-year-old daughter who is dawdling:

Hurry up, I shout.
We don't have all day.
And we don't.
The next time I look,
she's sixteen . . .[3]

Wallace is capable of many wonderful lines and of many master-crafted individual poems. Yet, as enticing as it is to remain at this level, if the reader considers *The Makings of Happiness* merely as a collection and not as a progression with a beginning, middle and end, then that reader will miss the full scope and profundity of what, when read in sequence, reveals itself as a remarkable narrative—the slow, often sad, but ultimately miraculous story of many of us.

With this book meticulously arranged in three incremental sections, Wallace leads the reader through a progression of poems that ultimately achieves an equilibrium between richness and loss, regret and ease. Through the sequence of these wryly, often ironically bemused, superbly wrought poems, *Makings* shares much with the recent American fiction described by Margaret Morganroth Gullette in *Safe at Last in the Middle Years* as "mid-life progress narratives "(xiv). Gullette voices the recognition that "rescuing them [the protagonists/subjects] from . . . depletion seems to be one of the . . . unspoken spiritual or ethical functions" (xiv); and that these kinds of narratives utilize their "resistances, strengths, or sly timely weaknesses, ingenious mental feints" to achieve a resolution in which the author can begin even "to think the kind of sentence" that would have been impossible before (xiv.31). So, near the end of Wallace's book we find lines such as

> How ease inhabits our lives.
> "The Fox in the Berry Patch"

and in the same poem,

> . . . O the gladness
> that only a family understands . . .
> "The Fat of the Land"

Standing as they do above, out of context and in isolation, these lines could be dismissed as glib and self-serving by a less than attentive reader. But by the time the careful reader gets to these lines, and the poems they are part of, the poet has earned the right to such statements. Though what damns us saves us, and all that can save us from ourselves is time and change, here, according to Gullette, there is "no necessary contradiction between gladness and the self as it lives in time." Here then for both the poet and the reader is an enticement into hopefulness, or as Gullette calls it, an "education into gladness" (146).

> If a man can't be happy on a little farm
> in Wisconsin,
> he hasn't the makings of happiness in
> his soul.
> Nick Englebert, artist-farmer,
> 1881–1962

The conditional "if" of the title epigram, with which Wallace's book both begins and ends, raises the central question of the collection. The question is not, what is happiness, not exactly; but more, of what and how is happiness made? What, if you will, is the recipe? What are the ingredients?

Early Brass

The poems of the first section, "Early Brass," are both strident and timid, full of failures feared or perceived and all the initiatory anxieties of youth "duped by dazzle and subterfuge, / shimmer and flick" ("Bluegills") where "desire and longing could inspire / the unlikeliest situation" ("Love and Sex").[4]

Wallace seeks in the past (our memory, our *makings* of the past) some distant prophecy of what the future has become. The speaker, even in this first section, simultaneously assumes the voice of both child and father: the early awkward lover and practiced husband, the tentative young poet looking hopefully ahead and the master crafter looking back, however helplessly, towards the past which in its own way seems as mysterious now as the future did then.

Change and perspective are the major ingredients introduced in the first section, and time is the catalyst. The future from this "early" view seems always "somewhere overhead, . . . / stretched out filmy and seductive" ("Smoking"). The past, on the other hand, can be realized only in retrospect as "a vast doorway" ("Fan Mail"), ". . . one more / phantasmagoric invention we use / to fool ourselves into someone else's shoes" ("Off the Record").

In "Speeding":

> Some damn fool kid
> is racing his three-speed
> down the hill in front of our house
> . . .

and later,

> spring flashing its bright green signals,
> although, approaching fast from a
> side street,
> the future is looming,
> preparing to barrel through.
> *Look out! I* shout. But it's too late.
> The kid has been gone for years,
> pedaling for all he was worth
> into me, into you.

The events of these "early" poems, while they were happening, seemed to be all ". . . heading for the future / just as fast as the mind can see" ("Camp Calvary"); yet the same events seen in retrospect, the stance that the mature artist is allowed by the art itself, assume the slow motions of the inevitable, of ". . . the ball slowly / rolling out the door / and down these many years" ("Rebounding"). The difference in perspective is the result of the change time has brought to the poet, and the attempt to fix the events themselves within the artistic frame of the poems.

Breakdown

The second section of the book, "Breakdown," is one of crises and passages, accidents and escapes, close calls and catastrophes. The possibilities of luck and the fact of evil itself must at least be "gotten by," if not "gotten through."[5] Again, it is the meliorations of art that make such a passage possible.[6] If "Turning Forty" (the title of one of the poems) is "over the hill," then being "At Forty" (the title of another) is the hump; and once again it is the act of the poems, the learning of the *makings* of them, that allows the "getting over."[7]

"Breakdown," the title and first poem of this section, begins with that moment before a seemingly inescapable accident which, however, does not happen: "When you finally know / you are not going to make it," and ends with an escape, with ". . . nothing changed

> except for this small uncertainty,
> this fist in your gut, this sneer
> twisting your lips, as if
> you knew something true and awful,
> something you could never, never
> confess.

The accident which is ultimately avoided is middle-age with its intimations of mortality, its chances lost or not taken, with more doors closed behind than ever able to be opened ahead. As in the first section of this book, the initial motion seems to be forward, often out of control, as in "Hairpin":

> in the bright slow deceptions of the day,
> you race toward that sudden
> appointment
> you never quite planned on,
> the journey you didn't mean to take.

Or, in "Headlines":

> . . . morning careening just around the
> corner, your own spring flagging, the
> drought burning on?

Yet, there is also a pause here, a slow progression to the realization that we both lose and gain as we grow, that, as is noted in "Turning Forty":

> Time doesn't speed up like a train
> with somewhere to get to, railing
> on that Augustinian straight line,
>
> so much as it spirals, silent, circling
> back on itself, an old dog, settling
> on the same tired spot again . . .

and that there is a certain joy to all this when

> In the country of stumble and drag
> time settles, its bald tail a-wag.

In the first section of the book there were poems such as "Early Brass," "Rebounding," and, particularly, ""Birdsong Anyway" where the subject was the poet early at his art, the first few fumblings, the initial impulses which brought the poet to that art at all. In the second section, in poems such as the "Poetry Report," "State Poetry Day," and "The Dinner Party," it is the distractions of the pseudo-settled (the middle-aged, middle-class, and middle-brow), the temptations of the hack and the poetaster, that threaten the poet's progress towards the authentic.

In "State Poetry Day" (surely the most cacophonous villanelle ever written), poetry threatens not even to survive, as Auden once demurred, "in the valley of its saying," when, "In the legislative chambers with their dactyls and caesuras / the local poet laureates sing in praise of cheese and beer," and where

> No one mentions Nicaragua, acid rain,
> cocaine or Star Wars,
> as the couplets and quatrains maintain
> a pleasant atmosphere.
>
> The mayor couldn't be here, but he
> sends his grand whereases.
> Another year closes with a villanelle's
> razzmatazzes.

In the next poem, "The Dinner Party," a sestina, the poet, in another room, becomes aware that

> Everyone out in the living room's
> concerned
> about groundwater and nuclear war,
> their voices a warm glow in the dark,
> the familiar country of engaging
> party talk,
> and I'm here in the kitchen with
> my spinach
> and my eggs, my vinegar and oil,
> worrying
>
> about how to make a salad. . . .

It seems, then, no accident that these poems are followed by another pair, "The Hell Mural: Panel I" and "The Hell Mural: Panel II" which are also sestina and villanelle, that profoundly and majestically address those same subjects that the previous pair so trivially if artfully avoid. The poet moves from the light, almost parodic tone of the first pair to the high seriousness, the elegiac thunder of the second. (Both poems take as their subject The Hell Mural, impressions of the Hiroshima holocaust painted by Iri and Toshi Maruki.)

Thus this section of the book ends with two confrontations of an ultimate evil, each in the strictest of forms, as if those restrictions can contain the horror—the scope too large, the cast too numerous in its sufferings, the implications too gigantic to comprehend.

The Makings of Happiness

Is it escape then, that drives the poet to the "small farm in Wisconsin" of the Engelbert epigraph? Is it the world too much to handle, the realization of the impossibility of hanging on to anything except yourself and your own, to the few people that there is no doubt you belong to, and to a place, however imperfect, of your own making?

Yes, but not just. In this third and final section, the poet, full in the flourish of his talent, takes the way in to find the way out. He attempts, as poets almost always have, the ultimately universal through the deeply personal, struggling though the only life each of us has towards those other lives around us and toward the Life that surrounds and supports us all: the life of nature and the life of place, the life of family and work—which in this case is the poet at his craft.

The place is, of course, essential to this last section of the book. The farm, away from the bustle of the city and distractions of a larger society, allows the poet the time and space to focus and concentrate—quite literally, to see.

> Far from the city with its bright
>   deceptions,
> we lie down in the damp grass and
>   await whatever
> blast of heat or radiance is on its way
>   to take us
> out of ourselves into the future that
>   couldn't be.
> Tomorrow, the papers will claim
>   aurora borealis,
> a rare display for those with dark
>   enough to see.
>
> "Night in the Country"

The farmhouse itself, full of the immediate family, when viewed from the outside on a cold winter night, achieves the perspective of rebirth and renewal:

> . . . the warm house brightens
> as if the click of the refrigerator
> and the slow breathing of the children
> could call up the whippoorwill,
> cicada, spring peeper, and cricket,
> could fill us beyond loss or doubt.
>
> "February, Full Moon"

Family is key here. It is the "glue," if you will, that holds the place together. In "The Fat of the Land" it is the extended family gathered for a reunion primarily, it seems, to eat, to partake of, not just food, but of each other:

> . . . one big happy family, back from
> wherever we've spread ourselves too thin.
> A cornucopia of cousins and uncles,
>   grand-
> parents and aunts, nieces and nephews,
>   expanding.

and later,

> O the loveliness of so much loved flesh,
> the litany of split seams and puffed
>   sleeves,
> sack dresses and Sansabelt slacks,
> dimpled knees and knuckles, the jiggle
> of triple chins. O the gladness
> that only a family understands . . .

and finally,

> . . . huge and whole of this
>   simmering night,
> battened against the small skinny
> futures that must befall all of us,
> the gray thin days and the
>   noncaloric dark.

Ultimately, however, it is the poet, and the poet's craft learned and practiced, that provides the last ingredient for Wallace's recipe for happiness: to love and enjoy the moment, the day, and the world, the people who are yours in it, and to do good work.

In the first section of the book, in "Birdsong Anyway," the young poet attempts the metaphor of poem as birdhouse and fails, at least at the constructing of the house itself. In the first poem of the third section, "Building an Outhouse," a wryly, nearly perfectly diswrought sonnet which is also about "building" poems, the poet can concluded with confidence:

> . . . it's up! Functional. Tight as
>   a sonnet.
> It will last forever (or at least for awhile)
> though the critics come sit on it, and
>   sit on it.

How else to get through the day and the life, both past and future, however tenuous, that this day is a part of, but to bring it to the poem and there allow the connections to be made between the aging, changing self and the family and place the self finds itself a part of. The poem, of course, cannot capture the moment, but can fix it and frame it, shape it into one of those, as Wordsworth called them, "spots in time," or in Frost's words, "momentary stays against the confusion," in which the self, glad in the present, experiences grace.

This is, however, a grace more Frost than Wordsworth, for it is a condition, though perhaps given, only available to the poet active and aroused at the makings of poetry. The classic metaphor of Walt Whitman also comes to mind here, of the "Noiseless Patient Spider," "isolated / Mark'd how to explore the vacant vast surrounding, / It launched forth filament, filament, filament, out of itself" compared to the Soul/Poet, "detached in measureless oceans of space, / Ceaselessly musing,

> venturing, throwing, seeking the spheres
> to connect them,
> Till the bridge you will need be form'd,
> till the ductile anchor hold,
> Till the gossamer thread you fling
> catch somewhere . . .

It is in the final, title poem, "The Makings of Happiness," that these connections are most obviously made. The poem is based upon a painting by Nick Englebert, "*The Photographer,*" which also provides the epigraph for this book. The literal subject of the painting, as the title implies, is not primarily a "small Wisconsin farm" but a visiting turn-of-the-century French photographer taking a picture of a Wisconsin farm family. This was an event at that time of great wonder, rarity and delight. The necessity of the role of the artist then is inherent in the progressive tense of the poem's, and book's, title, the "*Makings.*"

It is not, as the poem tells us, "Until you have looked at something so long / it grows so familiar you can't see it," that you can "know the soul's work." The expressive role of the artist here—painter, photographer and poet—is to reveal the miraculous in the daily, homely and commonplace,

> the alp that all but disappears in dailiness;
> the sea that common routine conceals;
> the little farm in Wisconsin that seems
> painted in oil on your long picture
> window . . .

and to create

> the barn more like a hearth than a barn,
> a mother, who could be your mother,
> in the doorframe across the way,
> bread in the oven and time on
> her hands,
> the little girl, who could be a boy,
> roped to her calf, which could be a dog,
> waving to her cat, which could be
> a stoat,
> apples in her cheeks and honey in
> her hair,
> the church in the permanent center,
> the townspeople happy as larks . . .

What is important to keep in mind are the layers of references the poem has established. It is not the farm or the family itself, not the photographer's picture of it and them, not even the painter's picture of the photographer taking his picture, but the poem of the poet that pulls it all together and keeps

> . . . the man floating, the girl
> smiling, the calf changing, the cow
> rolling
> its eyes, the blue Frenchman tipping
> his hat at you who live so far off
> in the vanishing point of the future.

Notes

[1] Italics in this paragraph are mine.
[2] Italics in this paragraph are mine.
[3] Italics are in the original.
[4] "To feel good about the middle years it is helpful to have had a miserable young adulthood . . ." Gullette observes, while later adding that from the advantage of the "later, . . . safer middle years, . . . young adults [are regarded] with detached sorrow, pity, and compassion—as if . . . we now understand how the young are obliged to navigate a perilous crossing with rudimentary equipment before getting to the other side" (6–7).
[5] "Suddenly we see what must be the basic psychological situation, and it's the same whether the plot trouble is sex or parents or children or war. Whatever it is, the characters fear that for some reason they don't understand, they can't create a self-chosen, more self-confident, happier future —they can't progress in the life course as they must and want to." For this reason, I believe, dangerous-age novels contain more than their share of shrieks, blows, accidents, and death" (Gullette 15).
[6] "Meliorism is the narrative message of mid-life *Bildungsromane*" (Gullette 150).
[7] "The ability to recognize that the middle years can be welcomed as a relief by some people may depend on our traversing the dangerous age imaginatively, in however truncated and inevitably detached a way" (Gullette 18–19).

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Poet and Editor ***Bruce Taylor*** *is Professor of English at the University of Wisconsin-Eau Claire. His most recent essays include "The Vietnam War Movie: Voyeur and Witness" and "Draft Dodger Rag" in* The Highground, *published by the Wisconsin Vietnam Memorial Project Inc., and "Betrayed and Abandoned: The Divorced Male in the Short Fiction of John Updike" in* Wisconsin Dialogue.

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ISSN 0084-0505

Telephone (608) 263-1692

TRANSACTIONS

of the Wisconsin Academy of Sciences, Arts and Letters

Volume 82 • 1994

ERRATA

Elisabeth R. Deppe and Richard C. Lathrop. 1993. "Recent changes in the aquatic macrophyte community of Lake Mendota." ***Transactions of the Wisconsin Academy of Sciences, Arts and Letters*** **81: 47-58.**

Because of a change in font made by the printer at the final typesetting, the $\leq$ symbol was lost, causing a major problem in data interpretation on page 55.

Please note the corrections indicated on the proof reproduced on the back of this sheet and transcribe them onto page 55 of your 1993 *Transactions* volume so that future problems with data interpretation can be avoided.

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Uncommon Species

In the three survey years, six species were found very infrequently and at very low densities in Lake Mendota: *Potamogeton crispus* L., *P. richardsonii* (A. Benn.) Rydb., *P. zosteriformis* Fern., *P. foliosis* Raf., *Nelumbo lutea* (Willd.) Pers., and *Nymphaea tuberosa* Paine (Table 1). In 1989 and 1990, *P. crispus* was found at low densities on transects off the eastern and northern shorelines, while in 1991 it was found almost exclusively along the west and south shorelines. In all three years, *P. richardsonii* was found in moderate abundance at transect 45 and more sparsely at a few other transects during 1989–91. For all three years, the two floating-leaved lily species *Nelumbo lutea* and *Nymphaea tuberosa* grew densely at ≤1.0 m in University Bay at transect 39, and elsewhere in the bay at varying densities from 1989–91. These species were also found along the east shoreline at transect 47 in 1989. *P. foliosis* was found at scattered sites in 1990–91, and *P. zosteriformis* was found at only one station in 1989.

Depth Limit of Growth

The depth limit of plant growth in Lake Mendota was somewhat variable between transects but generally occurred between 3.0 and 4.0 m for 1989–91 (Table 3). Depth limits shifted to slightly shallower ranges in 1990, but returned to near-1989 levels in 1991. Depth limit decreased by 0.5 m from 1989 to 1990 at all transects in University Bay and along the northwest shoreline where plant growth was densest.

Depth limit of plant growth in Lake Monona generally occurred at 3.5 m in 1990, but at 2.5 m in 1991. Similarly, in Lake Waubesa these figures went from 3.0 m in 1990 to 2.0–3.0 m in 1991. In Lake Kegonsa, depth limits increased from 2.0–2.5 m in 1990 to 3.0 m in 1991.

Because most plant growth occurred at ≤3–4 m in Lake Mendota, it is noteworthy that 10% of stations ≤3 m in 1989 were devoid of plants, while 20% had no vegetation in 1990 and 1991. In 1990, 7% and 1% of stations ≤3 m were without vegetation in Monona and Waubesa, respectively, but this increased to 30% and 48% for the two lakes in 1991. In Lake Kegonsa, 58% of stations ≤3 m were without macrophytes in 1990, but only 21% in 1991.

Discussion

Depth Distribution

In our 1989–91 surveys in Lake Mendota, macrophytes were found almost entirely at water depths between 0.5 and 3.5 m, while certain depths favored growth of particular species. *Ceratophyllum* and *Myriophyllum spicatum*, tall-growing plants with biomasses heaviest near the water surface, grew most densely between 2.0 and 3.0 m. The common species, tending not to grow as tall, were found largely between 0.5 and 2.0 m, where they can receive adequate light. Their infrequent occurrence in water depths >2.0 m suggests that they may be shaded by algal blooms and dense growths of *Ceratophyllum* and *Myriophyllum*. Lack of macrophyte growth at the 0.5 m contour is probably due to one or more of the following reasons: rocky substrate, more pronounced wave action, ice shifting in winter, and the controlled lowering of the lake level over the winter months.

Macrophyte Community of University Bay Since the 1960s

Myriophyllum spicatum dominated the plant community from its introduction in the

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TRANSACTIONS of the Wisconsin Academy of Sciences, Arts and Letters

Volume 82 • 1994

Transactions welcomes articles that explore features of the State of Wisconsin and its people. Articles written by Wisconsin authors on topics other than Wisconsin sciences, arts and letters are occasionally published. Manuscripts and queries should be addressed to the editor.

Submission requirements: Submit three copies of the manuscript, double-spaced, to the editor. Abstracts are suggested for science/technical articles. The style of the text and references may follow that of scholarly writing in the author's field, although author-year citation format is preferred for articles in the sciences, author-page number format for articles in the humanities. Please prepare figures with reduction in mind.

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Contents

TRANSACTIONS

Volume 82 • 1994

From the editor v

Development of Brussels Hill Pit Cave, Door County, Wisconsin: Evidence from flowstone and sediments 1

Jim Brozowski and Michael J. Day

Brussels Hill Pit Cave is the deepest vertical cave in Wisconsin and contains a valuable suite of historic and prehistoric sediment, faunal, and floral assemblages. The sediments at the -15 m level appear to be post-glacial in age.

Occurrence and significance of sea lamprey (Petromyzon marinus) *in the lower Fox River, Wisconsin* 17

Philip A. Cochran

Improved water quality led to concern about the potential for sea lampreys to ascend the Fox River and gain access to the Lake Winnebago watershed. The controversial closure of the Rapide Croche lock in 1988 has been justified by subsequent collections of sea lampreys in the lower river.

Observations on the white perch (Morone americana) *early in its invasion of Wisconsin* 23

Philip A. Cochran and Peter J. Hesse

White perch are native to the Atlantic Coast but have recently invaded the Lake Michigan drainage in Wisconsin. This paper documents the dramatic increase of white perch in the Fox River and discusses various aspects of their biology.

History of the fishes of the Bois Brule River System, Wisconsin, with emphasis on the salmonids and their management 33

Robert B. DuBois and Dennis M. Pratt

The Bois Brule River has had a rich and colorful history from its early days as an important water route to its present status as one of Wisconsin's premier trout streams. The authors present an historical sketch of the fishes of the river system along with the factors that have affected them over the last two centuries.

Social behavior of adult jaguars (Panthera onca *L.*) *at the Milwaukee County Zoo* 73

Thomas F. Grittinger and Deborah L. Schultz

Social behavior between two jaguars was described and analyzed in a four-year study at the Milwaukee County Zoo.

Vesicular-arbuscular mycorrhizal fungi of Wisconsin's sandy soils 83

Richard E. Koske and Leonard L. Tews

Sandy soils of Wisconsin were surveyed for the first time for vesicular-arbuscular mycorrhizal (VAM) fungi.

The plant communities of Nine-Mile Island – past and present 89

David J. Post

The article details a brief history of the vegetation and human impact upon Nine-Mile Island since the original land survey of the 1840s and presents a phytosociological analysis of the present vegetation patterns and community distribution. Current successional trends are examined to predict possible future vegetation changes on the island with a call to maintain the island in its present state for the enrichment of future generations.

Analysis of black bear habitat in northeastern Wisconsin 109

Keith T. Weber

The article reports the results of field studies and roadside counts used to analyze black bear population and habitat in northeastern Wisconsin. An earlier version of the paper was awarded the Forest Stearns award for excellence in the biological sciences at the WASAL annual conference in 1992.

Errata

Transactions of the Wisconsin Academy of Sciences, Arts and Letters
Volume 81, 1993

Because of a change in font made by the printer at the final typesetting, the ≤ symbol was lost, causing a major problem in data interpretation on page 55 of the article "Recent changes in the aquatic macrophyte community of Lake Mendota," by Elisabeth R. Deppe and Richard C. Lathrop. For a copy of the corrected page, please contact the Wisconsin Academy.

From the editor

All of us who read *Transactions*, whether for the first time or as old friends well acquainted with this journal, cannot help but notice that the content of articles published year after year leans heavily toward the natural sciences. While *Transactions* extends a broad invitation welcoming scholarly articles "that explore features of the State of Wisconsin and its people" and while the Wisconsin Academy is devoted to arts and letters as well as to the sciences, it is a fact that *Transactions* has been a publishing vehicle of choice for those who write about the land and waters of Wisconsin, its geology, geography, and the diversity of its life forms. This is explainable in some measure insofar as historians, artists, poets, and creative writers often choose to write for our sister publication, the *Wisconsin Academy Review*, a journal of Wisconsin culture.

This 1994 issue of *Transactions* is no exception to the rule. Some of our articles feature studies of jaguars at the Milwaukee Zoo and black bear habitat in northeastern Wisconsin, the plant communities of Nine-Mile Island in the Chippewa River and the mycorrhizal fungi of Wisconsin's sandy soils, and a look at the Brussels Hill pit cave in Door County. Other articles explore the occurrence of sea lamprey in the lower Fox River, the recent invasion of white perch into the Fox River, and the history of the fishes of the Bois Brule River system. Together these many fascinating studies alert us to the changing natural environment of Wisconsin and to the ongoing parade of "visitors" who keep coming to our state, on their own (like the white perch and sea lamprey) or not on their own (like the jaguars in the zoo).

As I write this column in mid-August, I am preparing to teach an adult-education class next week at The Clearing, one of my favorite Wisconsin institutions, located in a spectacular natural setting on the bluffs above Ellison Bay. Currently an affiliate of the Wisconsin Academy, The Clearing was founded by the famous landscape architect and environmentalist Jens Jensen back in 1935 as a sort of outdoors "school of the soil." Over the years it has evolved into an independent association, supported by its many members and friends. During its summer residential program, The Clearing offers one-week courses on nature, the arts and humanities.

My course will be on "The Poetry and Message of the Psalms." Among the Psalms that will certainly feature prominently in our discussions will be Psalms 8 and 104. I expect some lively and interesting debate on whether or not these ancient religious poems have anything to say about current relationships between humanity and the natural environment. In my mind there is no doubt that, if the writers of these two psalms could be transported forward to our own day and could read the sort of selections contained in this current issue of *Transactions,* they would be confirmed anew in their appreciation for the world of nature, their sense of awe before its vast sweep and their feeling of interconnectedness with all its creatures.

Perhaps, if he could also be educated into the momentous ecological developments of our time—the Biology Department at UW Oshkosh teaches about "Ecosphere in Crisis"! — the poet of Psalm 8 would wish to reconsider or at least nuance the idea that humans are to exercise "dominion" over all other living things. Then again, if Hebrew Bible scholar James Limburg is on the right track in his reading of these two psalms, their ancient composers might ask us with deepened urgency, "Who cares for the earth?" "Who loves and treats gently this place that is home to so many relatives, human and non-human?"

It is clear to me, through my correspondence with our authors in this issue of *Transactions* and with the many fine reviewers who offered them valuable professional criticism and advice prior to publication, that there are many who undertake their scientific research precisely because they care for the earth. As a member of the Wisconsin Academy who has spent a lifetime of study and teaching in the humanities, I took great interest in reading these several articles devoted to the natural sciences and in discovering more about all the life around me in Wisconsin. As a biblical scholar, I found extra delight in playing off these articles against the appreciation for nature evident in some of the Psalms. I hope all of you, our readers, whether you lean more towards the sciences, arts or letters, will find similar enjoyment in reading the 1994 *Transactions.*

Now, as I look ahead to selecting manuscripts for future issues of *Transactions,* it is my pleasure to repeat the invitation for scholarly research and criticism on all aspects of science, arts and letters featuring the state and people of Wisconsin.

Bill Urbrock

The Wisconsin Academy of Sciences, Arts and Letters was chartered by the State Legislature on March 16, 1870, as a membership organization serving the people of Wisconsin. Its mission is to encourage investigation in the sciences, arts and letters and to disseminate information and share knowledge.

Jim Brozowski and Michael J. Day

Development of Brussels Hill Pit Cave, Door County, Wisconsin: Evidence from flowstone and sediment

Abstract *Brussels Hill Pit Cave is a joint-controlled vertical cave developed to a depth of 28 m in the Silurian-age Niagara Dolomite of the Door Peninsula in northeastern Wisconsin. Sediments and flowstones in the cave are post-glacial, with deposition beginning around the end of the Greatlakean substage, approximately 10,000 B.P. The cave sediments differ both physically and mineralogically from those on the surface. The cave is potentially older than the sediment infill and flowstones, possibly having formed in the late Cenozoic. Dating of cave flowstones using paleomagnetic and radioisotopic techniques suggests that initial deposition of these formations occurred approximately 11,000 B.P. From dissolution rate calculations (Palmer 1980) and paleomagnetic evidence we infer that the cave itself developed contemporaneously with sediment and flowstone deposition. The cave also contains significant early Holocene mammalian remains which are currently under investigation (Kox 1988).*

The Door County karst landscape is one of the few glaciated karst areas in the United States. Brussels Hill Pit Cave is a vertical cave formed along a dissolutionally widened joint in an outlier of the Niagara Dolostone Escarpment (Figs. 1a and 1b). Such caves are an integral part of the karst terrain of the Door Peninsula (Rosen 1984; Stieglitz 1984; Rosen et al. 1989; Johnson and Stieglitz 1990; Rosen and Day 1990). Recent paleontological work (Kox 1988; Robert Howe, pers. comm. 1992) has focused on a rich faunal suite within the cave. Previously excavated organic sediments from 28 m depth have been ^{14}C dated at 671 and 1820 B.P. (Howe, unpubl. data).

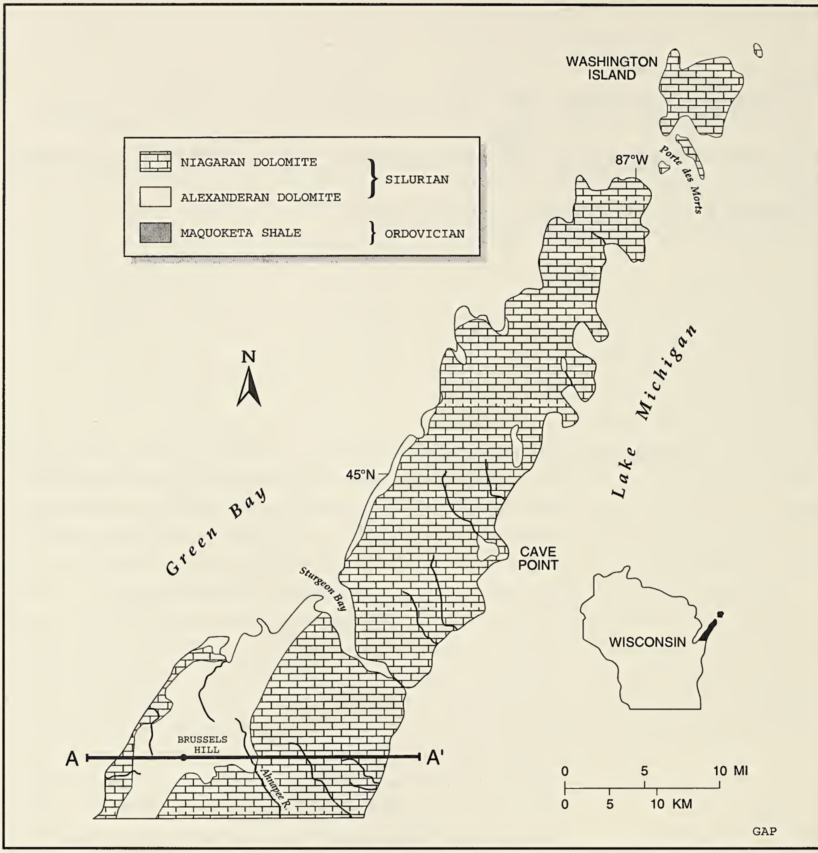

Fig. 1a. Geologic map of Door County (adapted from Sherrill 1978)

The primary objective of this study was to establish the chronology of sediment deposition within the cave. Determining the age of the flowstones and the source of the sediments would also provide information about the age and development of the cave itself.

Clastic sedimentary deposits and flowstone in caves are a tool for reconstructing the climatic history and geomorphic evolution of karst terrains (Milske et al. 1983). Lively (1983), Milske et al. (1983), and Lively et al. (1984) have presented flowstone and flowstone-sediment chronologies based on Uranium-series disequilibrium dating and have demonstrated that the flowstone deposition rate was significantly reduced during glacial periods in southeastern Minnesota. Gascoyne (1977) determined that, in general, speleothem deposits represent rela-

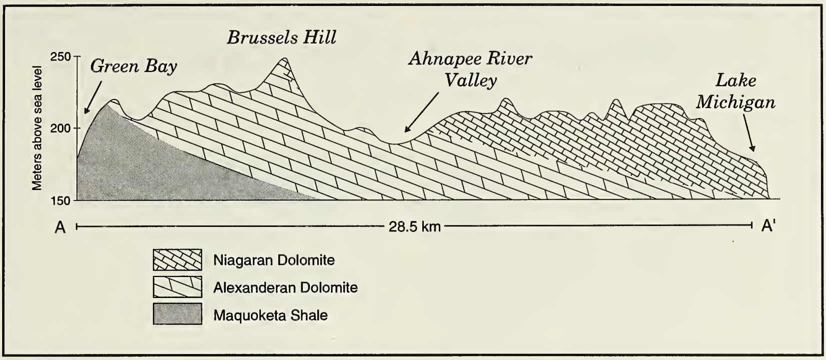

Fig. 1b. Generalized cross section of A – A'

tively warmer paleoclimatic periods, although speleothem growth may not always directly reflect surface conditions. Flowstone dating allows for a minimum estimation of cave age as the flowstone must be younger than the cave itself.

Cave formation age can also be estimated using carbonate dissolution rate calculations (Palmer 1980). Maximum rates under phreatic conditions are roughly 0.14 cm/yr or about 3 m every 1000 years. Extrapolating this rate calculation to vadose cave development, the 28 m depth of Brussels Hill Pit Cave suggests a maximum age of about 10,000 B.P., which coincides approximately with the deglaciation of the Door Peninsula.

The research presented here is used to test a developmental hypothesis for Brussels Hill Pit Cave and the associated sediment deposition. Based on Ford's (1977) four-part classification of glaciated karst areas, the cave is glaciokarstic or more specifically, karstiglacial, i.e., a karst process that has accentuated jointing which originally had resulted from glacial loading on the bedrock surface. Glaciokarst reflects the cumulative effects of karst formation and glacial activity (Ford 1977). We hypothesize that Brussels Hill Pit Cave is karstiglacial, based on the glacial history of the Door Peninsula (McCartney and Mickelson 1982). Cave formation commenced after glacial loading and unloading had accentuated bedrock jointing. Subsequent dissolution enlarged the joints and led to sedimentation followed by speleothem deposits.

Regional Geology and Geomorphology

The Door Peninsula is primarily an upland ridge with morphology controlled by the Niagaran Dolomite cuesta (Sherrill 1978). The bedrock geology of the Door Peninsula is outlined by Chamberlin (1877), Thwaites and Bertrand (1957), Klussendorf and Mikulic (1989), and Stieglitz (1984, 1989). The Niagaran Series is approximately 107 m thick and includes, from oldest to youngest, the Burnt Bluff Group, the Manistique Dolomite, and the Engadine Dolomite (Sherrill 1978; Stieglitz 1989). The rocks are mainly dolostones, thinly bedded in the lower formations and thinly to massively bedded in the upper formations. The rocks are fossiliferous, medium to coarse grained, and

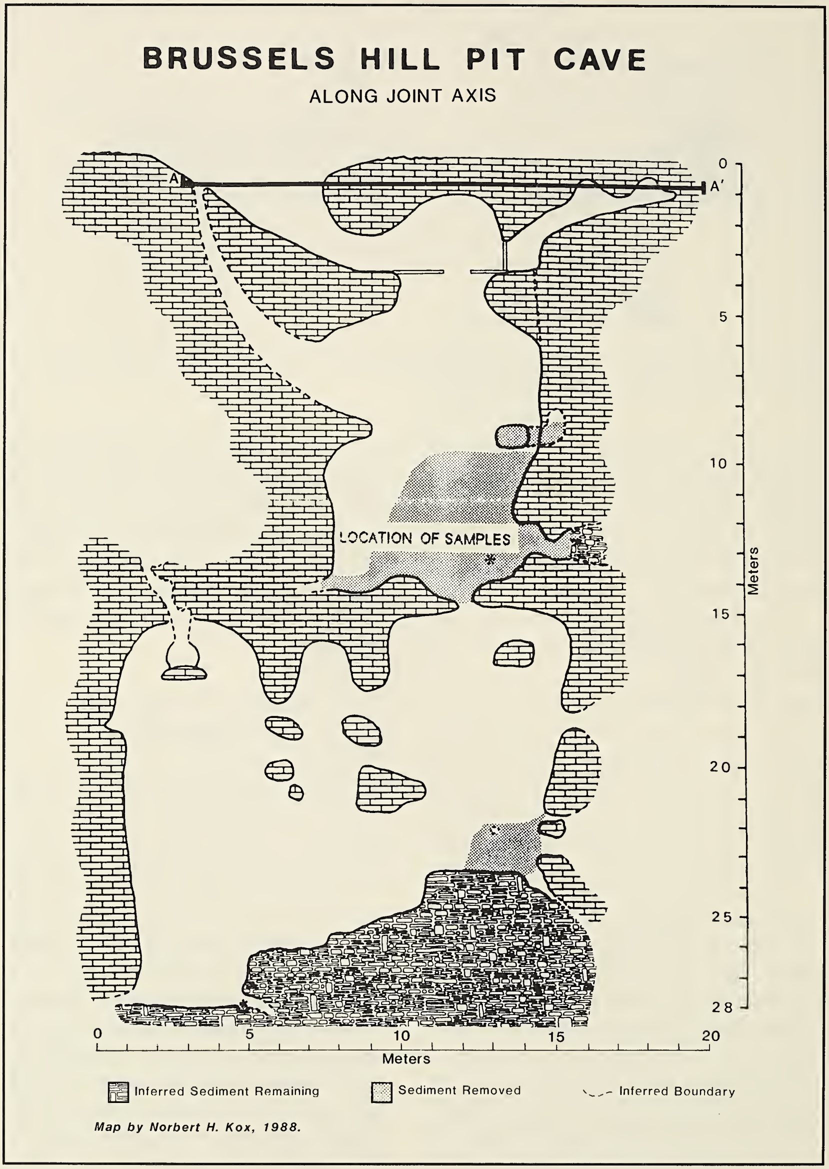

Fig. 2. Planar view of Brussels Hill Pit Cave

mostly buff gray colored. Dip of the bedrock is less than one degree to the southeast.

The Niagaran rocks form the Niagara Escarpment along the western edge of the Door Peninsula in Door County. West of the escarpment are several outliers of the Niagara Formation including Brussels Hill (Figs. 1a and 1b). Brussels Hill is a glaciated but erosionally resistant biohermal (reefal) structure; erosional resistance is attributed to the unstratified reef groundmass (Stieglitz 1984). The base of Brussels Hill is at 215 m; the summit is at 260 m.

Glaciation of the Door Peninsula occurred most recently during the Woodfordian (22,000 to 13,000 B.P.) and the Greatlakean (11,500 to 9500 B.P.) advances. These were separated by the Twocreekan interstadial between 13,000 and 11,500 B.P. (McCartney and Mickelson 1982). Deglaciation of the Door Peninsula coincided with the general retreat of the Lake Michigan and Green Bay lobes of the Laurentide Ice Sheet (Bryson et al. 1969; Hansel et al. 1985).

Although there were at least three major stages of Pleistocene glaciation in Wisconsin, it is not known specifically how frequently and for what duration the Door Peninsula was over-ridden by ice. Thus it is not known how many times karst processes on the Peninsula were disrupted.

Brussels Hill Pit Cave

The sinkhole entrance to Brussels Hill Pit Cave is at approximately 256 m above mean sea level and opens into a vertical drop of 28 m (Figs. 2 and 3). Brussels Hill Pit Cave is the deepest cave in Wisconsin and is developed along a joint oriented approximately 62 degrees east of north. Other prominent joint sets on Brussels Hill are at 25 and 155 degrees east of north (Rosen 1984). On the basis of altitude, location, and bedrock character, the cave is probably developed in the Manistique Dolomite.

In horizontal cross-section, the cave consists of two crude ellipsoids along the cave's vertical axis (Fig. 4). The three levels are apparently vadose, showing no evidence of phreatic development. Cave walls at the middle and lower levels are covered by flowstone drapery starting at bedding plane seepages 6 m below the cave entrance and extending to -28 m. Drapery samples for paleomagnetic determinations reported in this paper were collected at -15 m (Fig. 2). Prior to June 1986, only the cave above the -15 m level was known; excavations revealed a lower cave that descended to -28 m. Although some sediments have been removed from the lowest level, this study focuses on sediments at the -15 m level.

Paleontological analyses of the faunal remains from the -15 m level have identified short-tailed shrew (*Blarina brevicus*), common shrew (*Sorex* sp.), little brown bat (*Myotis licifugus*), white-tailed deer (*Odecoileus virginiana*), black bear (*Ursus americanus*), beaver (*Castor canadensis*), muskrat (*Ondatra zibethicus*) and otter (*Lutra canadensis*) (Howe, unpubl. data).

At -15 m, a flowstone ledge has formed over clastic sediments (Fig. 5). The flowstone consists of several layers of calcite mixed with bones, leaves, wood, fine organic material, and clasts of varying size and lithology. The ledge is approximately 15 cm thick and extends laterally for 150 cm to the southwest. It dips and pinches out near the lower room opening. The clastic sediments beneath the composite layer consist of layers of fine sand and silt about 25 cm thick. Based on their graded deposition and mixed igneous, metamorphic, and sedimentary mineralogy, the sediments are probably reworked surface glacial deposits. Samples for

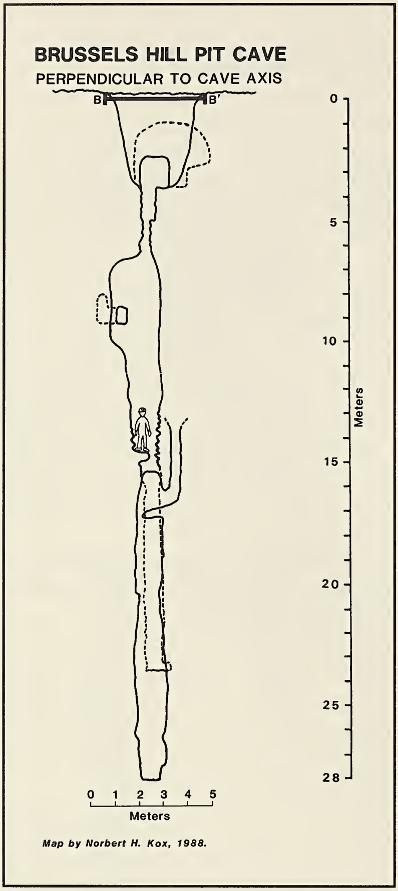

Fig. 3. Perpendicular cross-section of Brussels Hill Pit Cave

particle size and paleomagnetic analyses were removed from this relatively inorganic layer. Although some of the fine sandy and silty cave sediment is laminated, the laminae probably result from sediment reworking within the cave.

Below the fine sand layer is a variegated layer of coarse sand and fine gravel also about 25 cm thick (Fig. 5). This deposit includes several layers of coarse sediment cemented by crystalline calcite precipitate. The coarse basal sediments probably predate initial calcite deposition.

Beneath the cemented coarse sediment is a clay loam layer (Fig. 5) which contains several striated clasts and large (>30 cm) pieces of dolostone breakdown. Several of the clasts are well rounded, polished, and fluted indicating glacial transport.

In order to elucidate the relationship between surface soils and cave sediments, two soil pits approximately 15 m north and 15 m south of the cave entrance were opened, sampled, and analyzed. The Namur silt loam is the dominant regional soil (Link et al. 1978).

Methodology

Analytical Transmission Electron Microscopy (TEM) and Energy Dispersive X-Ray Analysis (EDXA) were used for visual and elemental analysis of the soils and sediments. Soil and cave clay mineralogy was determined using standard X-ray diffraction at the University of Wisconsin–Milwaukee. Soil particle size determination and pH measurement of the cave sediments and surface soils were performed using standard hydrometer methods and a calibrated laboratory pH probe.

Two flowstone cores were extracted for analysis from drapery on the north wall of the cave; each was physically abutting the Niagaran bedrock and retained a trace of dolostone patina when removed. Although there is no way to obtain perfect rotational alignment, every effort was made in the field and laboratory to maintain the closest possible alignment. Sediment cubes were obtained similarly.

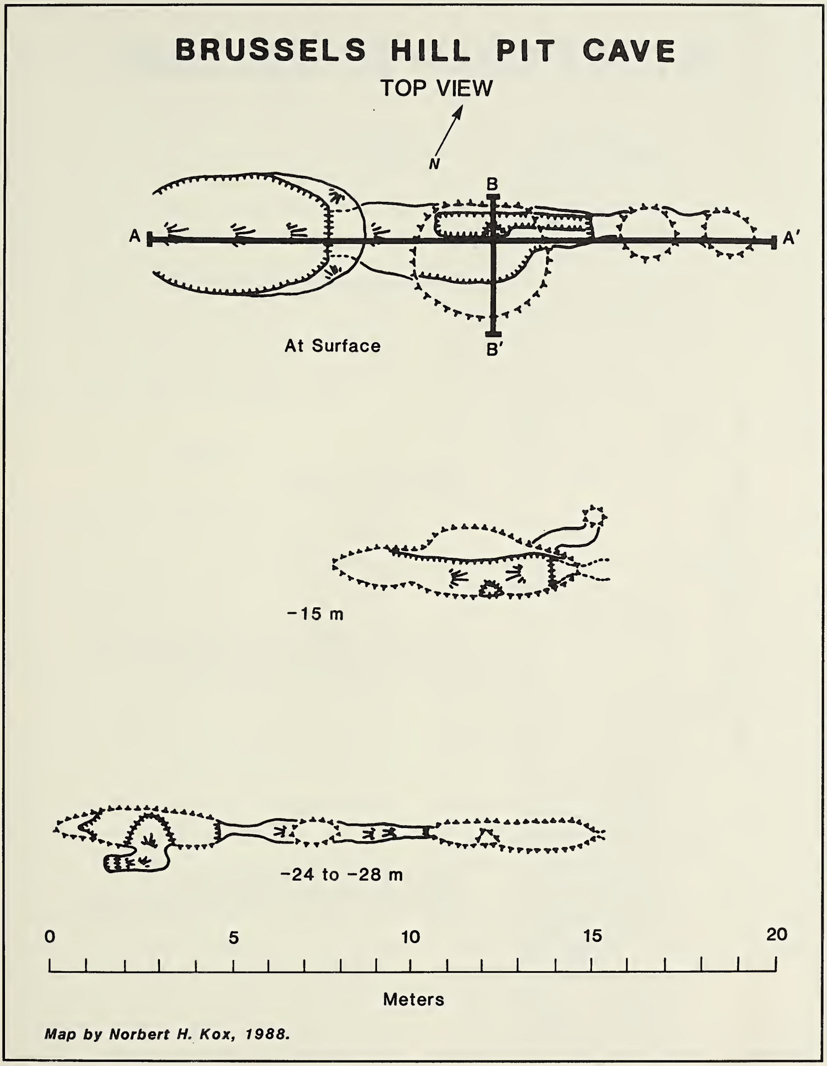

Fig. 4. Vertical top-view of Brussels Hill Pit Cave

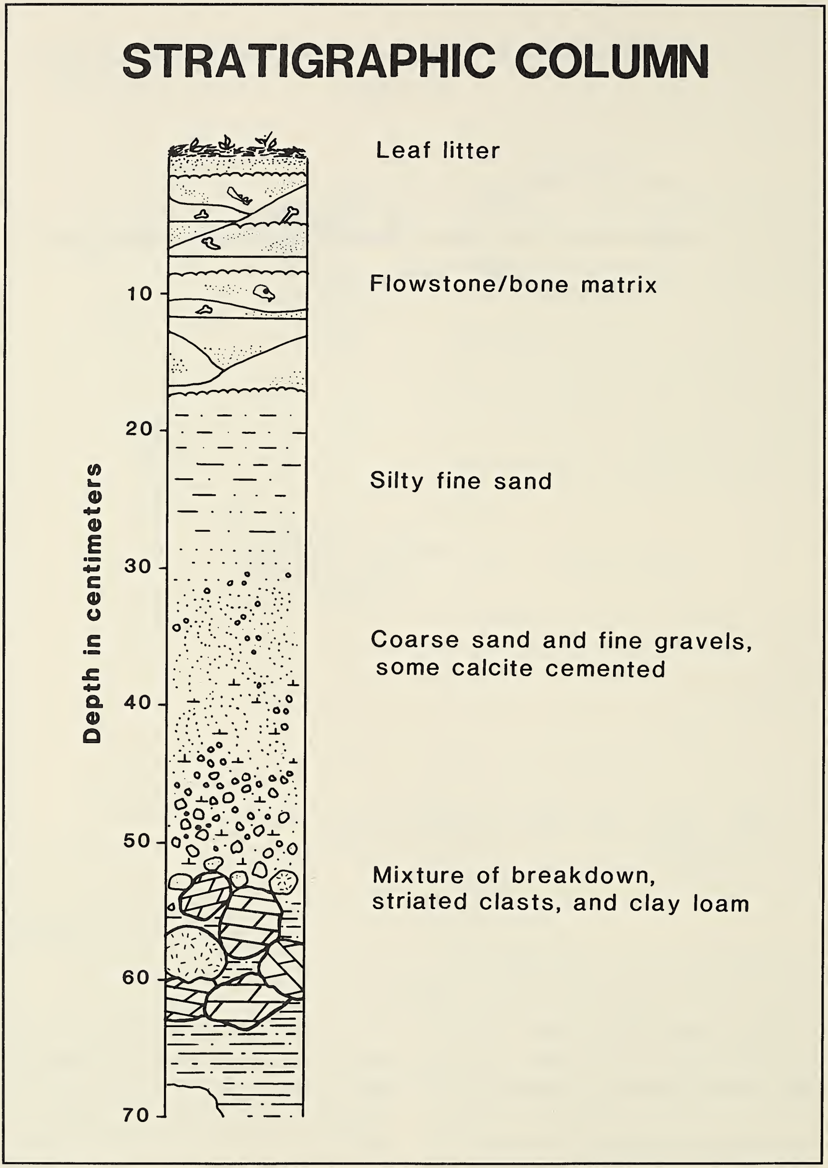

Fig. 5. Generalized stratigraphic column for the -15 m level

Paleomagnetic analysis was performed on a Superconducting Technology model C102 two-axis cryogenic magnetometer. The natural remnant magnetism (NRM) of each sample was measured first, then each was demagnetized using alternating fields stepwise up to 100 millitesla (25 to 1000 oersted). Sample remanence was measured after each demagnetization step; moment directions and intensities were calculated utilizing Fischer (1953) statistics. The paleomagnetic data for the cave were matched with a master curve generated from data sets for the Great Lakes area (Creer and Tucholka 1982; Kean and Klebold 1981).

Results

The Namur silt loam horizons are composed of the major elements aluminum, silicon, potassium, and iron, and the minor elements calcium, magnesium, and zinc. Clay minerals include illite, smectite, and chlorite. Soils sampled near the bedrock contact contain a high percentage of sand-sized grains (Fig. 6).

The sample from 40 to 56 cm in Soil Pit 2 contained smectite (montmorillonite) clays. Smectite forms in neutral to alkaline environment containing relatively high concentrations of calcium and magnesium (Brady 1974; Birkeland 1984). The Niagaran Dolomite, $CaMg(CO_3)^2$, has sufficient calcium and magnesium for smectite clay formation.

Cave clay loam analyses indicate the presence of silicon, iron, potassium, aluminum, calcium, magnesium, and zinc. Minerals include calcite, dolomite, quartz, and the clay minerals kaolinite and illite. Kaolinite is of interest because it forms primarily by the complete weathering of alkaline feldspars, through hydration at low pH (Klein and Hurlbut 1985). Generally, illites are the most common clay minerals in caves (Bull 1983; Sweeting 1973); they are formed by the loss of potassium and possibly aluminum from the mineral layers through hydration.

The Namur soil pHs vary from slightly acidic to neutral, pH 5.0 to 7.0, while the cave clay-loam is relatively alkaline, at pH 8.3. This suggests that the solvent capacity of percolating surface water, in contrast to Barden (1980), is not effectively neutralized by carbonate clasts, at least in this location. The pH of each soil horizon is moderated by proximity to the dolostone bedrock (Fig. 7). Contemporary dissolution may thus be expected on dolomitic bedrock or within caves beneath the Namur silt loam. No glacial striae were observed at either of the test pit soil/bedrock contacts beneath the Namur silt loam, and no striae were detected on any bedrock exposures examined in the immediate area. A sample of seepage water from the -15 m level had a hardness of 130 ppm (mg/L) total calcium and magnesium.

Paleomagnetic analysis results were correlated with the type-curve data provided by Creer and Tucholka (1982). Flowstone core inclination and declination values were 58° and -60°, respectively, indicating deposition between approximately 9830 and 11,260 B.P. For the cores, inclination correlations occur about 9700, 10,200, and 11,000 B.P. and declination correlations between 9000 and 11,260 B.P. (Figs. 8 and 9). Sediment cube correlations (declination and inclination values of 13° and 70°, respectively) occur several times for declination at about 7000, 9000, and 10,000 B.P.; inclination correlations occur at about 7000, 9000, and 9800 B.P.

Flowstone samples submitted to the Minnesota Geological Survey for U-series dating proved too porous and chalky for a reliable analysis. During a previous flowstone dating attempt the isotopic results showed evidence of post-depositional alteration in the calcite. The uranium concentration was very

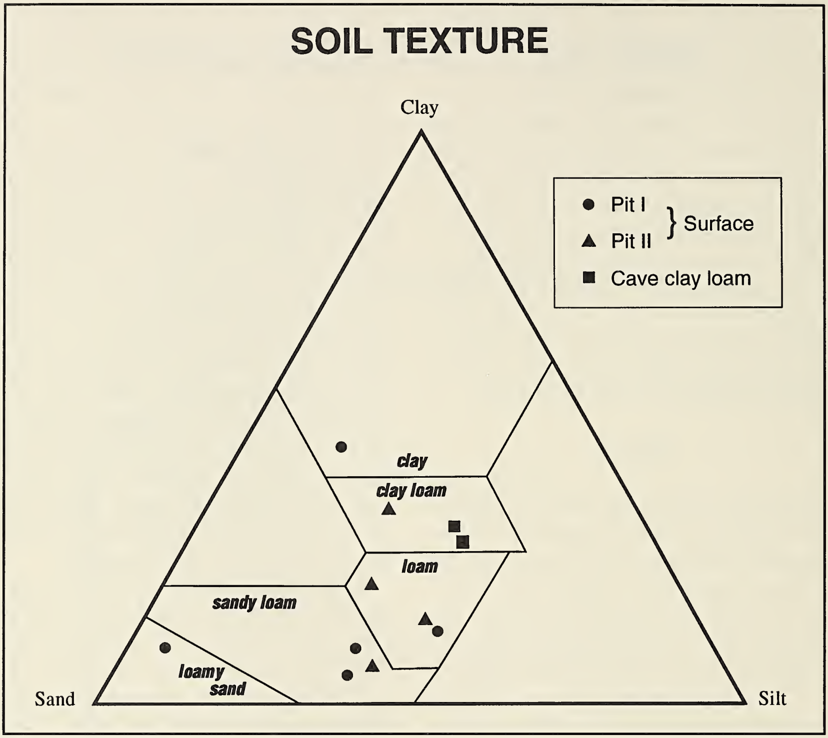

Fig. 6. Soil textural triangle

low (0.08 ppm) and the $^{230}Th/^{234}U$ activity ratio was greater than unity. Chemical recovery of Th from the sample was less than 5% (Richard Lively, pers. comm. 1992).

Discussion

The area around Brussels Hill Pit Cave is a glaciated karst terrain in which karstiglacial or post-glacial development of karst, sediment, and soil is related to the effects of Wisconsinan glaciation. The cave serves as a depository for allochthanous organic and mineral debris brought in directly through the cave opening and indirectly through percolation.

There are few mineralogical similarities between the surface soil horizons and the cave clay-loam; minerals notably present in the Namur soils and very limited in the cave clay-loam are zinc and iron. Elements present in the cave clay-loam and not in the soil are calcium and magnesium. The magnesium and calcium in the cave clay loam are probably derived by dolomite dissolution. Chemical analyses of the dolostones approximates a 1:1 (Ca:Mg) ratio (Johnson and Stieglitz 1990). Although the specific

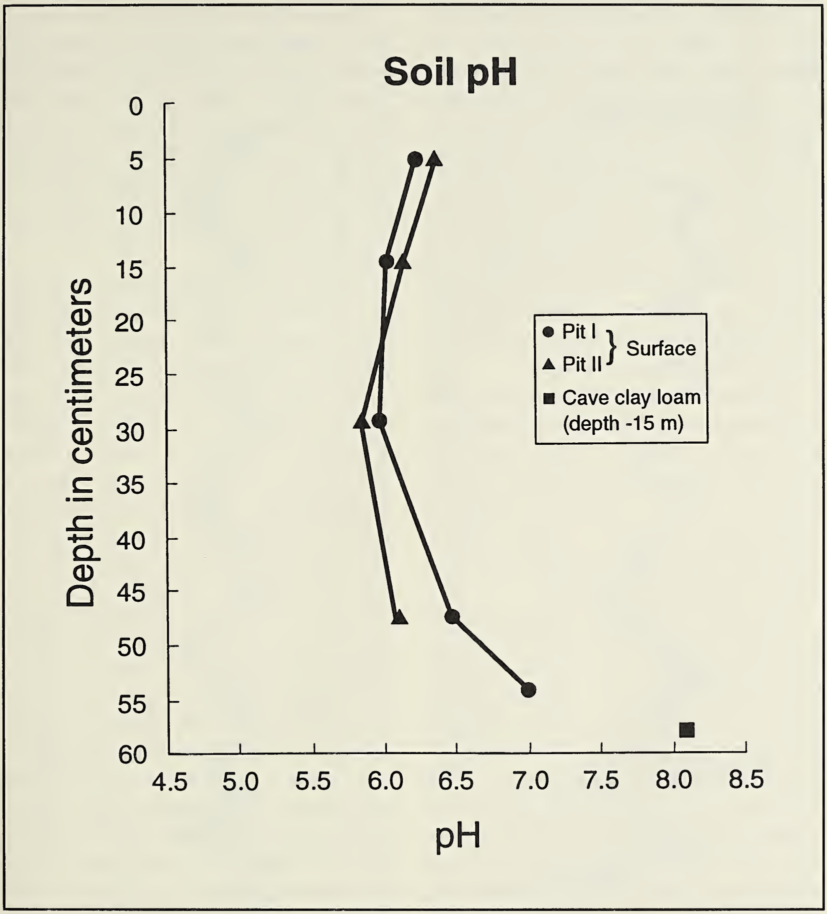

Fig. 7. Soil pH values

mechanism of cave clay deposition is not known, it may predate the surface soil formation, having been deposited either as loess or in a slurry during deglaciation.

Mineralogically, illite in the cave and smectite at the surface are not unexpected. Illite is the dominant clay mineral in unweathered till and loess as well as the most common clay mineral in caves (Bull 1983; Sweeting 1973); it forms under leaching conditions with high K concentrations. Small amounts of kaolinite and smectite may also appear (Grim 1968). Smectite formation may be related to tundra or boreal climates in the Door Peninsula during glacial recession.

Kaolinite and illite genesis are dissimilar, the former being formed under acidic conditions and the latter under alkaline conditions. Kaolinite formation could not have occurred in the cave under current pH conditions. The kaolinite may have been eluviated from the overlying Namur soil where it developed at a lower pH. Alternatively, kaolinite may have developed within an earlier pre–Late Wisconsinan soil profile, or it may have been derived from a nearby bog, marsh, or wetland. Illite probably developed *in situ* by the alteration of alkaline feldspar or mica under alkaline conditions.

In terms of particle-size distribution, only the lowest horizon of Soil Pit 2 is similar to the cave clay loam (Fig. 6). The increase in grain size with depth in the lowest horizon of Soil Pit 1 may be attributed to mechanical illuviation but is more likely to reflect granular material incorporated from dissolution of the dolomitic bedrock.

Since the cave clay loam is near the bottom of the cave sediment profile, it was either deposited before the rest of the sediment in the profile or it represents fines eluviated from overlying cave sediments. The relocation of coarse sand and fine gravel fractions probably occurred prior to the flowstone deposition. The origin of the coarse sand and fine gravel has not been determined, but these may have been introduced during deglaciation. Soil particles may have moved from the surface into the cave along joints and other fractures, with the joint width acting as a natural sieve, screening out larger particles. As Rosen (1984) states, the thin surficial deposits facilitate seepage concentration at or along joints and joint intersections. Karstic development is accelerated along the joints as is allochthanous sediment movement into the subsurface.

Based on paleomagnetic results, the flowstones were determined to have formed between approximately 9000 and 11,000 B.P. (Figs. 8 and 9). Although the established date is relative, there is a clear correlation with the results of previous Great Lakes paleolimnetic studies (Vitorello and Van der Voo 1977; Creer and Tucholka 1982) and the deglaciation of the Door Peninsula (Bryson et al. 1969).

Upper portions of the flowstone incorporate numerous bones, while the wall flowstones contain either burned or chemically reduced wood fragments. Howe (pers. comm. 1992) suggests that the wood remnants may be from the 1871 Peshtigo Fire which burned portions of the Door Peninsula. Because the flowstone formation is stratigraphically superior to the mineral sediments, it is assumed that the latter were deposited prior to flowstone deposition, during or immediately after glacial retreat. It is not known whether the coarse sand and fine gravel are an initial deposit or the result of sediment reworking. The intrinsic variety and morphology of the granular cave sediments indicate reworking and relocation by surface runoff. Whether this was because of historical near-ice meltwater run-off or contemporaneous temperate run-off is unclear; however, the lack of organic material and the flowstone shelf with subordinate striated clasts strongly suggest the former. As the flowstone is resting on the sediment and appears to have remained physically and stratigraphically stable and is probably less than 10,000 years old, the underlying sediment tentatively correlates to the Greatlakean substage between 9000 and 10,000 B.P. Similar stratigraphic sedimentary profiles have been described in Mystery Cave in southeastern Minnesota (Milske et al. 1983).

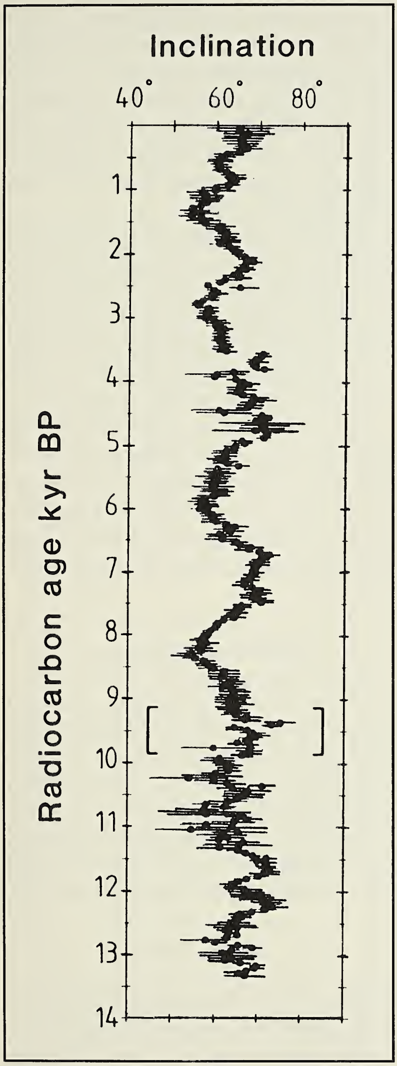

Fig. 8. Inclination type curve for east-central North America. Brackets indicate inclination value of 58° for flowstone cores which correlates to 9700 years B.P. (Modified from Creer and Tucholka 1982)

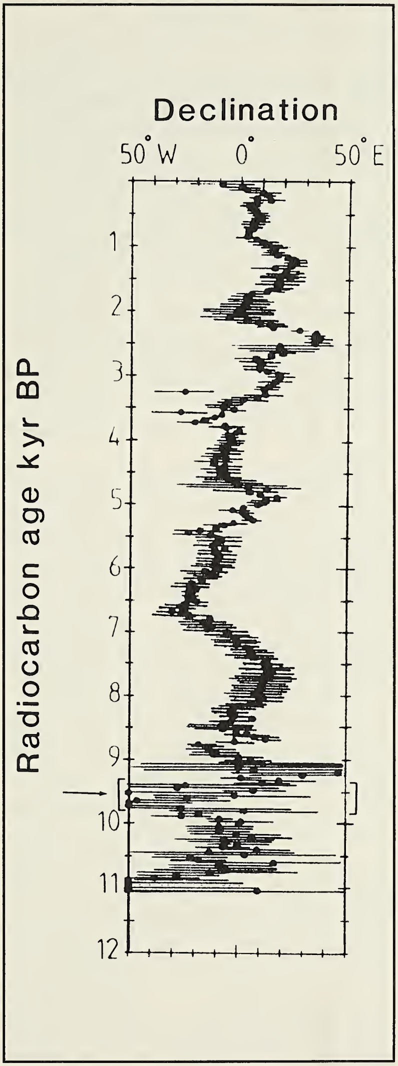

Fig. 9. Declination type curve for east-central North America. Brackets indicate inclination value of 58° for flowstone cores which correlates to 9700 years BP. (Modified from Creer and Tucholka 1982)

Conclusion

Based on our interpretation and following Ford's (1977) classification, Brussels Hill is a karstiglacial topographic feature. We further interpret the topographic morphology of the area as glacial in origin with subsequent post-glacial karstic modification. Jennings (1985, 239) defines karstiglacial forms as "forms thought to be virtually entirely glacial but [upon which] karst drainage characteristics have been superimposed." Brussels Hill may be a relict karstiglacial feature, having been formed during or prior to Wisconsinan glaciation with subsequent formation of the pit cave during interglacial conditions.

Interglacial or post-glacial warming produced meltwater which was responsible for sediment transport into the cave. Increased water flow would have enhanced dissolution of the Niagaran Dolomite. Flowstone and sediment ages in this report correlate with the general time of Wisconsinan deglaciation of the Door Peninsula but do not themselves reveal the initial date of cave formation.

Brussels Hill Pit Cave sediments are of post-glacial origin based on relative age determinations. Granular sediment in the cave differs in texture, pH, and mineralogy from surface materials. The cave itself pre-dates the sediment fill, and the available evidence and dissolution-rate calculations from Palmer (1980) indicate that cave development and sediment deposition could have begun at the end of the Greatlakean substage, about 10,000 B.P. Further research into the history of the lower cave levels will continue at the conclusion of the faunal studies.

Brussels Hill Pit Cave contains a post-glacial sediment sequence covered by later sediments and organic material of Recent (Holocene) age. The coarse sands and gravel may have been deposited during the initial stages of glacial recession when water was available to transport the coarser fractions; as water volume decreased with ice retreat, transport potential also decreased, depositing only finer sands and silts. Collapse of the cave sinkhole entrance probably occurred at a relatively recent time.

Sediment variety poses interesting questions about sediment deposition and mineralogical formation; physical and chemical alteration of minerals through changes in water and soil pH and possibly climatic transition could be examined further as could individual sediment particle mineralogy.

The record obtained from Brussels Hill Pit Cave assists in the analysis of Wisconsin's pre-settlement faunal assemblages (Howe, pers. comm. 1992) and also provides a valuable record of post-glacial geomophological events in northeastern Wisconsin.

Acknowledgments

Jim Brozowski wishes to thank the review editors for their insight and constructive comments. Thanks to Drs. W. F. Kean and B. E. Brown, Dept. of Geoscience, UW–Milwaukee, for their assistance through the various analytical stages. Special thanks to Ms. C. A. Syrrakos for skillful cartographic and diagram preparation.

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Philip A. Cochran

Occurrence and significance of sea lamprey (Petromyzon marinus) *in the lower Fox River, Wisconsin*

Abstract *The Rapide Croche lock on the lower Fox River was sealed in the winter of 1987–1988 to prevent upstream passage of spawning-phase sea lamprey* (Petromyzon marinus) *into the Lake Winnebago watershed. This action was taken because of concern that improvements in river water quality made colonization by lampreys inevitable, even though sea lampreys had not been collected in the Fox River prior to closure of the lock. The collection of sea lampreys in the Fox River in 1991, 1992, and 1993 substantiates the initial concerns and justifies the closure of the Rapide Croche lock.*

The sea lamprey (*Petromyzon marinus*) had a devastating impact on fish assemblages in the Great Lakes (Smith 1971; Smith and Tibbles 1980; Coble et al. 1990) prior to initiation of effective chemical control in the early 1960s. Sea lamprey control remains largely predicated on chemical treatment of tributaries inhabited by ammocoetes, but the process is costly and labor intensive. As control costs rise, it becomes increasingly desirable to minimize the number and length of streams that must be chemically treated.

Sea lampreys typically spawn in water of relatively high quality. Although they have been known to ascend polluted rivers to spawn in cleaner tributaries, there are known cases in which lampreys have apparently been inhibited by poor water quality from ascending polluted rivers. Ironically, one result of pollution abatement and improved water quality has been an increase in the number of streams used by spawning-phase sea lampreys. For example, sea lampreys colonized the Peshtigo River following pollution abatement in the early

1970s, leading to increased lamprey abundance in Green Bay (Moore and Lychwick 1980).

In the latter half of the 1970s, fisheries biologists in the Wisconsin Department of Natural Resources (DNR) and elsewhere became concerned about the possibility of sea lampreys ascending the Fox River from Green Bay (Kernen 1979; Smith and Tibbles 1980). Although the river was historically subject to severe pollution, by the 1980s water quality had improved to the point that a walleye (*Stizostedion vitreum*) fishery was reestablished below the De Pere dam, spawning-phase silver lampreys (*Ichthyomyzon unicuspis*) ascended the Fox River from Green Bay each year (Cochran and Marks, in press), and several species of salmonids were present in the lower river during the spring when water temperatures were favorable. Concerns about sea lampreys in the Fox River reflect several possible scenarios, which are not mutually exclusive. First, if sea lampreys gained access to the extensive high quality tributary systems in the Fox River drainage above Lake Winnebago (e.g., the Wolf and Embarrass rivers), spawning would probably be successful. Lampreys produced in these tributaries might pose a threat not only to fisheries in Green Bay and Lake Michigan, but also to Lake Winnebago fisheries previously unexposed to sea lampreys. The sea lamprey's proclivity for size-selective attack (Farmer and Beamish 1973; Cochran 1985) would make Lake Winnebago's unique and valuable lake sturgeon (*Acipenser fulvescens*) population a likely first target. Second, sea lampreys conceivably might spawn in some reaches of the Fox River proper, much as they are known to spawn in the St. Mary's River between lakes Superior and Huron (Smith and Tibbles 1980). Regardless of where it occurred, reproduction in the Fox River system would greatly increase the cost and difficulty of chemical control, or, if unchecked, endanger valuable fisheries.

In 1987, the Wisconsin DNR recommended that a lock on the lower Fox River be sealed and the corresponding dam modified to prevent upstream migration by sea lampreys. This proposal drew protests, primarily from pleasure boaters accustomed to traveling the Fox River between Lake Winnebago and Green Bay. Nevertheless, the recommendation was reaffirmed by the Sea Lamprey Study Committee appointed by the governor of Wisconsin (1988), and the Rapide Croche lock at the third dam upstream from Green Bay was sealed during the winter of 1987–1988.

All of the previous developments occurred before any sea lampreys were collected in the Fox River proper. Beginning in 1979, the U.S. Fish and Wildlife Service had sponsored the placement and monitoring of a sea lamprey assessment trap below the De Pere dam each spring during the lamprey spawning season, but no sea lampreys had ever been collected in the trap. Critics of the closure of the Rapide Croche lock pointed to the lack of evidence that sea lampreys had ever entered the river. Proponents of the closure argued that sea lampreys had been taken in Green Bay at the mouth of the Fox River and that by the time sea lampreys were detected in the river itself, it might be too late to prevent their spread into the Lake Winnebago system.

In light of the controversy surrounding the closure of the Rapide Croche lock, the subsequent capture of sea lampreys in the Fox River is noteworthy. The purpose of this report is to describe the lamprey collections and discuss their significance. Because of inaccuracies in accounts presented through the popular media, it is important that an accurate record be provided.

Methods

A portable sea lamprey assessment trap (Schuldt and Heinrich 1982) has been set each year since 1979 below the east end of the De Pere dam, approximately 12 km upstream from Green Bay. Additionally, a trap was set in 1988 and 1989 in the Osen millrace just east of the De Pere lock. Traps were checked five days per week from early April to mid-June. Measurements of total length (TL) and body mass (BM) reported here were collected from live animals anesthetized with tricaine methanesulfonate or from dead specimens prior to preservation.

Results and discussion

Lamprey assessment trapping and other fish collecting during the years 1979–1990 yielded no sea lampreys, but five individuals were collected from 1991 through 1993. In 1991, the trap was first lifted on April 5 after being set the previous day, and it contained an adult male sea lamprey (University of Wisconsin–Madison Zoology Museum, UWZM 9975; TL – 587 mm, BM - 365 g). Water temperature was 5°C. Subsequently in 1991, two additional specimens were collected by the Wisconsin DNR in fyke nets set in the Fox River between the De Pere dam and Green Bay. In 1992, an adult female sea lamprey (TL – 600 mm, BM – 505 g) was trapped on April 6 at a water temperature of 5°C. No sea lampreys were trapped in 1993, but the Wisconsin DNR, while electrofishing below the De Pere dam on October 12, collected a lake trout (*Salvelinus namaycush*) bearing a parasitic-phase individual (TL – 353 mm, BM – 84 g).

The relatively large sizes of the lampreys captured in the trap is typical of sea lampreys collected in tributaries to Green Bay (Johnson 1982). However, collection of upstream migrants in early April is relatively unusual in northeastern Wisconsin. For example, during 1987–1989, the first sea lampreys were captured in assessment traps in the East Twin River, Manitowoc County, on April 23, May 7, and April 26. Johnson (1982) trapped most of the lampreys he collected in the Peshtigo River during the period May 16–31. Sea lampreys began entering the Peshtigo River traps after the water temperature reached 10°C, and peak catches occurred between 15.6°C and 21.1°C.

Contrary to certain accounts in the popular media, sea lampreys in the lower Fox River do not constitute a threat to fisheries in Lake Winnebago at this time, because the Rapide Croche lock remains sealed to prevent their upstream passage. However, sentiment to reopen the Fox River waterway to unimpeded boat traffic persists in some quarters, and documentation that sea lampreys occur in the Fox River helps legitimize opposition to that sentiment. Any future arrangement for boat passage at the Rapide Croche dam must involve a boat lift or some other terrestrial transport. This will prevent upstream passage not only by sea lamprey, but also by white perch (*Morone americana*), an exotic species that was first captured in Green Bay and the lower Fox River in 1988 (Cochran and Hesse 1994). Closure of the Rapide Croche lock may fortuitously have prevented the white perch from gaining access to Lake Winnebago.

It remains to be seen whether increasing numbers of sea lamprey will ascend the lower Fox River during subsequent spawning seasons. Whether such an occurrence is biologically significant depends on whether spawning is successful and whether the burrowing ammocoetes can survive in the lower river or Green Bay for the duration of the larval phase (roughly four to five years). It has been suggested that walleye reproduction in the lower Fox River is limited by the availability of chemically suitable substrate (Auer and Auer 1990), and it may be tempting to extend that conclusion to sea lamprey. However, although Auer and Auer (1990) cited a lack of evidence of natural recruitment by walleye in the Fox River, juvenile walleye of yearling size are collected with regularity in the sea lamprey trap in De Pere, despite the fact that the Wisconsin DNR discontinued stocking after 1984 (Schneider et al. 1991). Moreover, the recent occurrence of adult *Hexagenia bilineata* mayflies along the Fox River at the De Pere dam (Cochran 1992) indicates that conditions at the sediment-water interface have improved to the point that *Hexagenia* naiads can once more complete their development in a microhabitat similar to that used by sea lamprey ammocoetes.

At this time, the significance of sea lampreys in the lower Fox River is primarily symbolic. They are symbolic, for example, of the improvements in water quality that first permitted them to become an issue. More importantly, they provide an historical footnote to a case in which foresight and proactive measures prevented the contamination of a watershed by exotic species. Such cases are all too rare and warrant documentation.

Acknowledgments

Sea lamprey assessment trapping below the De Pere dam was supported by contracts with the U.S. Fish and Wildlife Service. Manuscript revision was completed while I was funded by the National Oceanic and Atmospheric Administration's Office of Sea Grant, Department of Commerce, through an institutional grant to the University of Wisconsin. I am grateful to the many undergraduate students from St. Norbert College who have assisted with the trapping over the years and to Kristen Lucier for assistance with manuscript preparation. I am also thankful to Terry Lychwick, Dave Bougie, and Lee Meyers of the Wisconsin Department of Natural Resources for sharing their field data with me.

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Philip A. Cochran and Peter J. Hesse

Observations on the white perch (Morone americana) *early in its invasion of Wisconsin*

Abstract *White perch* (Morone americana) *were first reported in the Green Bay/ Fox River system in Wisconsin in 1988. Total spring catches in sea lamprey assessment traps below the De Pere dam increased until 1990, decreased in 1991, and then increased sharply in 1992 and 1993. These collections are believed to represent at least in part the result of upstream movements related to spawning. White perch were not trapped in large numbers each spring until water temperature exceeded 17–18°C, and males were collected on average slightly earlier than females. Several age classes were present among fish captured as early as 1989. Growth rates were relatively high and were comparable to those in other locations in the Great Lakes where populations are expanding. Growth declined, however, with increasing age. Relationships between weight and length were similar between the two sexes. Although the spread of the white perch up the Fox River appears to have been blocked by the sealing of the Rapide Croche lock in 1988, more information is needed to assess its impact in the lower Fox River and Green Bay, and care must be taken to minimize its chances for invading Wisconsin's inland waters.*

The white perch (*Morone americana*) invaded the Great Lakes from the Atlantic Coast in the 1940s and 1950s by way of the Erie and Welland canals (Johnson and Evans 1990). It was first identified in the Lake Michigan drainage in the lower Fox River of Wisconsin in May 1988 (Meyers 1988), and in September 1988, it was collected in Belmont Harbor in Chicago (Savitz et al. 1989). Collections from inland waters in Illinois (Blodgett 1993), including the Illinois River, indicate that it has spread from Lake Michigan through the Upper Illinois Waterway, which connects the Great Lakes and the Mississippi River drainages.

Concern about the colonization of Wisconsin waters by white perch stems from (1) the possibility for it to compete with more desirable native species (Schaeffer and Margraf 1986a), (2) its potential impact as a predator on the eggs of other species (Schaeffer and Margraf 1987), and (3) the potential for it to interbreed with the white bass (*M. chrysops*). In this paper we present data on the biology of the white perch early in its invasion of Wisconsin waters. Our results can serve as a basis for comparison with future data collected after the white perch presumably becomes fully established. Our experience also provides insight into the effectiveness of programs to monitor the spread of other exotic species, such as the sea lamprey (*Petromyzon marinus*).

Methods

White perch were collected with other fishes in portable sea lamprey assessment traps (Schuldt and Heinrich 1982) set below the De Pere dam on the Fox River, Brown County, Wisconsin, 12 km upstream from Green Bay. In 1988 and 1989, one trap was set below the eastern end of the dam spillway and another below a small spillway associated with a hydroelectric generator in a building east of the lock channel. The latter spillway is situated at the head of a millrace which enters the Fox River below the lock channel. Data from the two traps were pooled. From 1990 to 1993, a single trap below the dam spillway was monitored. Trapping was conducted for ten weeks from early April to mid-June in all years according to a protocol dictated by contract with the U.S. Fish and Wildlife Service. In addition, we trapped during the periods October 4–11, 1992, February 8–13, 1993, and June 12–October 29, 1993. Traps were emptied five days per week at intervals of no greater than 48 hours. Water temperature was recorded each time the traps were emptied. During the years 1989–1991, white perch were enumerated and, on most days, taken to the laboratory to be weighed and sexed (1990 only) and measured for total length (TL). In 1989 and 1990, scale samples for age determination by the junior author were collected from the upper left side between the lateral line and the second and third dorsal fin spines.

We occasionally collected fishes in the Fox River upstream from the De Pere dam by electrofishing with a boat-mounted generator (pulsed DC current). Samples were collected in 1988, 1989, 1992, and 1993, most often in the vicinity of the St. Norbert College campus.

Voucher specimens (UWZM 9726) have been deposited in the University of Wisconsin–Madison Zoology Museum.

Results

White perch were first detected in the Fox River in 1988 during the interval that the sea lamprey traps were operated (Meyers 1988), but no white perch were collected in the traps that year. Twelve individuals were captured in the two traps monitored in 1989 (Table 1). During the period 1990 to 1993, when a single trap was operated, total spring catch ranged from a low of 21 in 1991 to a high of 1196 in 1992 (Table 1). In October 1992, six trap days yielded a total of 20 white perch (22% of the combined catch of all species). No white perch were collected during four trap days in February 1993.

In most years trapping ended in mid-June, but in 1993, it was extended through the summer and into autumn. The high catches of late May and early June (Fig. 1) declined through late June and July. Monthly totals for June and July were 465 and 60, respec-

Table 1. Total yearly trap catch of white perch, percentage of total catch for all fish combined, mean date of capture, and mean temperature of capture. Means are followed by standard errors in parentheses.

Year	Number of White Perch	Percentage of Total Catch	Mean Date of Capture	Mean Temperature of Capture (°C)
1988	0	0	—	—
1989	12	0.3	May 27 (1.7)	19.0 (0.2)
1990	189	6.9	May 9 (0.5)	16.8 (0.2)
1991	21	0.7	May 30 (2.0)	19.8 (0.7)
1992	1196	17.7	May 28 (0.3)	18.4 (0.1)
1993	823	24.3	May 25 (0.4)	15.4 (0.1)

tively. No white perch were collected from August 1 through October 29.

Differences among years in the timing of spring trap catches may have been related to water temperature (Fig. 1). The dates of first capture in 1989 (May 21) and 1991 (May 19) were similar, but the date of first capture in 1990 (April 26) was much earlier. In each of the three years, white perch did not appear in the traps until after the water temperature first reached 18°C, but that occurred earlier in 1990 than in 1989 or 1991 (Fig. 1). In 1992, only 17 white perch were collected prior to May 11. On that date, when water temperature first measured 17°C, 75 individuals were collected (Fig. 1). In 1993, an unusually cool, wet spring with high discharge, high catches were recorded at cooler temperatures than in previous years, but the highest daily catch (93) occurred on June 11 when the water temperature first reached 19°C. Analysis of variance revealed that weighted mean temperature of capture (Table 1) differed significantly among years ($F_{4,2236}$ = 300.6, P = 0.000), as did weighted mean date of capture ($F_{4,2236}$ = 126.8, P = 0.000).

In 1990, sex was determined for 171 of 189 white perch. The numbers of males (100) and females (71) were significantly different from what would be expected under the null hypothesis that the two sexes were equally abundant and equally susceptible to capture (normal approximation to the binomial test, P < 0.05). Although there was great overlap between the two sexes, the mean date of capture for males (May 6) was significantly different from that for females (May 9) (t = -3.58, P = 0.0006), indicating that males move upriver slightly prior to females.

Ages were estimated from scales of 10 fish collected in 1989 and 170 fish collected in 1990 (Table 2). In both years, several age classes were present, but age IV+ fish were most abundant. Based on the 1990 data, there was no difference between sexes in the relative numbers of individuals of different ages (chi-squared test of independence, with age II pooled with III and age V pooled with VI to keep all expected values greater than five, x^2= 0.769).

The size distributions of white perch collected in the traps differed among years (Fig. 2). In 1989, one fish with a TL of 115 mm was collected, and nine were in the TL range of 192–230 mm. In 1990, TL ranged from 162 mm to 242 mm, but most individuals fell within 180–210 mm (body mass in 1990 ranged from 53 g to 246 g). In 1991,

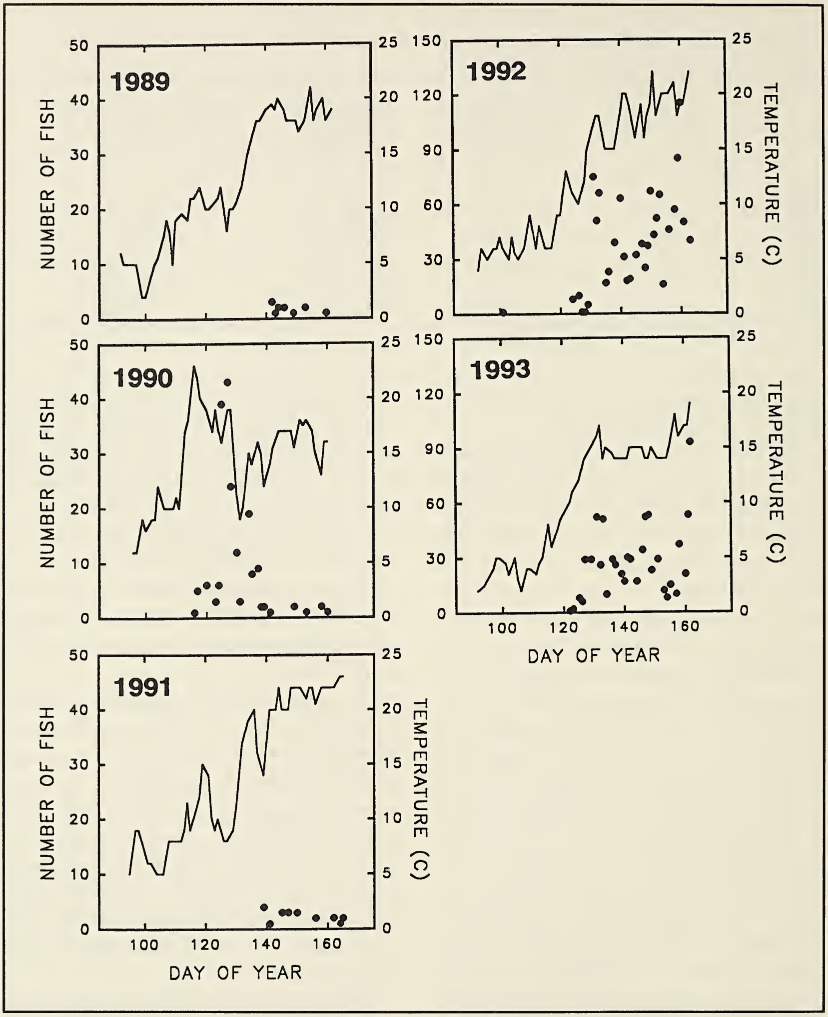

Fig. 1. Number of white perch collected in sea lamprey assessment traps and water temperature versus day of year during 1989–1993. Note that the left vertical scale for the years 1989–1991 is different from that for 1992–1993.

Table 2. Ages of ten of twelve white perch collected in 1989 and 170 of 189 white perch collected in 1990, followed by mean total length in millimeters and mean body mass in grams. Means are followed by standard errors (SE) in parentheses and associated sample sizes. 1990 data are partitioned by sex. Not all fish were measured for both length and body mass.

Age	*1989*	*1990*		
		Males	*Females*	*Unsexed*
Total Sample Size				
I	1	0	0	0
II	0	1	0	0
III	1	29	21	3
IV	6	56	37	0
V	1	11	10	0
VI	1	0	1	1
Total Length (mm), SE, Sample Size				
I	-	-	-	-
II	-	188 (0) 1	-	-
III	-	187 (1.6) 29	190 (2.3) 21	187 (1.45) 3
IV	-	193 (1.2) 56	200 (1.3) 37	-
V	-	212 (6.2) 11	204 (2.9) 10	-
VI	-	-	205 (0) 1	196 (0) 1
Body Mass (g), SE, Sample Size				
I	-	-	-	-
II	-	-	-	-
III	-	102.0 (3.67) 19	97.8 (6.39) 13	86.7 (2.66) 3
IV	-	107.8 (1.84) 47	127.8 (4.00) 16	-
V	-	149.6 (13.40) 11	131.0 (10.10) 6	-
VI	-	-	129.0 (0) 1	105 (0) 1

twelve fish ranged in TL from 103 mm to 126 mm and nine fish ranged from 185 mm to 231 mm.

Based on ages estimated from scales of fish collected in 1989 and 1990, growth rate declined with age (Fig. 3).

Linear regressions of the natural logarithm of body mass (LNWT) on the natural logarithm of total length (LNTL) were calculated with 1990 data for both sexes pooled and for each sex individually. For all fish, LNWT = -10.7 + 2.92 LNTL (r^2 = 0.866, n = 116). For males, LNWT = -10.3 + 2.85 LNTL (r^2 = 0.869, n = 80), and for females, LNWT = -11.6 + 3.08 LNTL (r^2 = 0.891, n = 31). Analysis of covariance failed to reveal a significant difference between the regressions for the two sexes.

Although we occasionally electrofished above the De Pere dam throughout the course of this study, we collected no white perch above the dam until September 23, 1993, when two small individuals (TL: 64 and 72 mm) were captured along the St. Norbert College shoreline. These were probably young-of-the-year.

Discussion

If the catch of white perch in the lamprey assessment trap is a reliable index of their abundance, then the white perch population increased dramatically from 1988, when they were first discovered in the Green Bay/ Fox River system, until 1993, when they represented 24% of the total spring fish catch (Table 1). In at least one location in the Great Lakes, the Bay of Quinte of Lake Ontario, white perch rapidly became a dominant component of the fish assemblage within a few years of their invasion, only to undergo a dramatic decline attributed either to severe winter weather or to increased piscivore abundance (Hurley 1986). In Lake Erie, however, white perch first invaded in the 1950s but did not increase in abundance substantially until the 1970s (Schaeffer and Margraf 1986b). Johnson and Evans (1990) suggested that the Great Lakes distribution of white perch is limited by low tolerance of cold temperatures. They pointed out that the current distributional limit approximates the -5°C winter air isotherm. Since Green Bay lies slightly outside that isotherm, its white perch populations might be expected to fluctuate in response to year-to-year climatic variability.

We interpret at least part of our spring catch of white perch to represent the result of an upstream spawning migration, although our samples and reports by local anglers indicate that at least some white perch are present in the river outside of the spawning season. Sea lamprey assessment traps are positioned to capture fish whose movement upstream has been blocked by a dam or other barrier. At least some of the white perch we captured in this manner were in spawning condition (i.e., milt was freely expressed by some males), and they displayed the bluish cast reported on the lower jaws

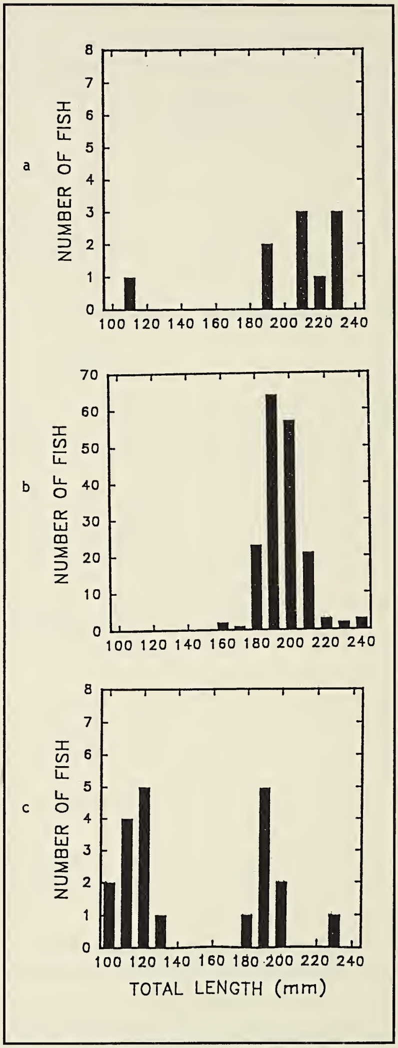

Fig. 2. Frequency histograms of total length of white perch collected in (a) 1989 (n=10), (b) 1990 (n=176), and (c) 1991 (n=21). Note that the vertical scale for the 1990 histogram is different from that for 1989 and 1991.

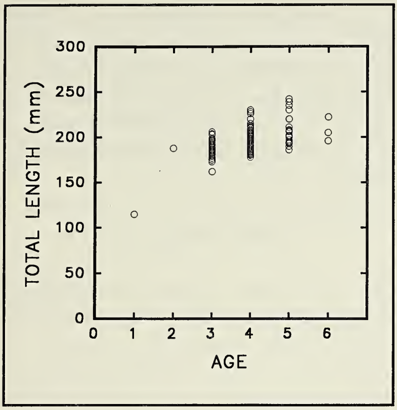

Fig. 3. Total length versus estimated age of white perch collected in 1989 and 1990

of spawning adults (Scott and Crossman 197; Smith 1985). Moreover, both Smith (1985) and Schaeffer and Margraf (1987) indicated that spawning peaked when water temperature reached 18°C, the approximate temperature at which white perch first appeared in abundance in our traps. Most of the fish we captured were above the size and age of maturity reported for white perch in Lake Erie (Schaeffer and Margraf 1986b). The modal group of smaller fish in 1991 (Fig. 2) may have been prereproductive, but in 1992 we noted fish as small as 112 mm from which milt was freely expressed.

Our interpretations of age and growth must be accepted with caution until the use of scales for aging white perch in this system has been validated. Nevertheless, our results indicated that white perch in the Green Bay system grow relatively quickly, especially early in their life, and that growth is comparable to that by white perch in Lake Erie (Schaeffer and Margraf 1986b). However, this species tends in freshwater habitats to become overpopulated, resulting in slower growth and an abundance of stunted individuals (Scott and Crossman 1973).

The presence of several age classes of white perch in the Fox River in 1989 and 1990 (Table 2) suggests either that white perch were present in the area and reproducing for several years prior to their discovery in 1988 or that their initial colonization involved large numbers of individuals, perhaps by multiple introductions (e.g., bilgewater release by freighters). In either case, the lamprey assessment trap did not capture white perch until a year after they were known to be present in the Fox River. This lapse between the occurrence and detection of an exotic species is especially relevant to the operation of the lamprey trap in the Fox River. The trap has been monitored each spring since 1979 because of concern that water quality improvements might be followed by the movement of spawning-phase sea lampreys up into the river. Indeed, a sea lamprey was collected in the trap for the first time in 1991 (Cochran 1994), but in light of our experience with white perch, it is quite possible that sea lampreys occurred in the river in prior years.

Although white perch were present in the lower Fox River as early as 1988, we did not collect them above the De Pere dam until 1993. During part of the spring spawning period, the De Pere lock channel is not yet open to boat traffic (it typically is opened at the end of May), and this may have delayed dispersal past the dam. We have, however, trapped white perch below the dam on dates after the locks were in operation. Spawning white perch from Lake Erie move at least 45 km up into tributary streams (Schaeffer and Margraf 1987), and it would seem inevitable that white perch would eventually traverse the 48 km between Green Bay and Lake Winnebago, where their presence could have substantial effects on important fisheries. Fortuitously, however, upstream movement by white perch toward Lake Winnebago has been blocked by the sealing of the Rapide Croche lock at the third dam upstream from Green Bay. This action was somewhat controversial when it was undertaken early in 1988 in anticipation of an invasion by sea lampreys. In retrospect, it may have been just in time to stop white perch.

Dams may eventually play an important role in limiting dispersal by white perch into other parts of Wisconsin. Now that they have invaded the Mississippi River in Illinois (Blodgett 1993), white perch can be expected to re-enter Wisconsin through the Mississippi River and its tributaries, some of which are impounded by impassable dams. For example, upstream dispersal in the Wisconsin River will be blocked by the Prairie du Sac dam, preventing access to a large area in north central Wisconsin.

At present, white perch in Wisconsin are apparently concentrated in the lower Fox River and southern Green Bay. They have not been collected in sea lamprey assessment traps operated in Green Bay tributaries other than the Fox River (i.e., the Menominee, Peshtigo, and Oconto rivers). Moreover, although they have been collected in Lake Michigan near Chicago (Savitz et al. 1989), they have not been taken in lamprey traps in the East Twin River, a tributary to Lake Michigan in Manitowoc County.

More information is needed to fully evaluate the ecological impact of white perch on the Green Bay/Fox River system, including their effects on the recently revitalized walleye (*Stizostedion vitreum*) and yellow perch (*Perca flavescens*) fisheries. In particular, the extent to which white perch feed on walleye eggs should be assessed, because they are known to feed on walleye eggs in the Lake Erie basin (Schaeffer and Margraf 1987). In addition, the extent to which walleye and other piscivores use white perch as forage should be investigated. Finally, efforts should be made to minimize the spread of this exotic species within Wisconsin's inland waters.

Acknowledgments

Our yearly spring trapping was funded by contracts with the U.S. Fish and Wildlife Service. Additional trapping, manuscript revision, and analysis of data for 1992 and 1993 were enabled by support from the National Oceanic and Atmospheric Administration's Office of Sea Grant, Department of Commerce, through an institutional grant to the University of Wisconsin. We thank Doug Basten, Joe Cochran, Eric Golden, Brian Jones, Adam Leisten, Joe Marks, Marty Sneen, and Rick Wagner for assistance with the collection of white perch, and James Hodgson for aid in the preparation of the figures. We appreciate the support of St. Norbert College for undergraduate research.

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History of the fishes of the Bois Brule River System, Wisconsin, with emphasis on the salmonids and their management

Abstract *The Bois Brule River in Douglas County is one of Wisconsin's largest, best known, and most intensively studied trout streams. A diverse fish fauna of at least 63 species (11 of which are exotic, plus one cultured hybrid) has been collected from the watershed. However, only 21 are coldwater, riverine species with viable populations; the remainder are either lentic, warmwater forms found in lakes Minnesuing and Nebagamon, are Lake Superior species that only occasionally enter the lower river, or are locally rare. The fish fauna has been profoundly altered by species introduced both intentionally and accidentally, and by control efforts directed at the exotic sea lamprey* (Petromyzon marinus), *which have caused severe density and distribution reductions in two species of native lampreys. Once sustaining a population of native brook trout* (Salvelinus fontinalis) *as the only angling target, the river now provides angling opportunities for four species of exotic salmonids as well. Declines in several of the salmonid populations, especially during the last two decades, may be attributable to over-exploitation; consequently, fishery regulations have become increasingly restrictive. Top priority, however, will continue to be maintenance of excellent habitat and water quality. With fine riparian stewardship practiced by private landowners, coupled with the state stewardship land acquisition program within state forest boundaries, this focus appears to be sustainable. Other habitat management efforts have included in-stream habitat enhancement techniques, beaver* (Castor canadensis) *control and dam removal, dredging projects, and bank stabilization efforts in red clay areas prone to slippage.*

The Bois Brule River (hereafter referred to as the Brule River) in Douglas County is perhaps the most famous trout stream in Wisconsin (O'Donnell 1944). Its fame is related both to its rich history as an important water route, linking Lake Superior and the upper Mississippi River drainage, and its historic reputation for excellent trout fishing (O'Donnell 1944; Marshall 1954). Additionally, the river has long been renowned for its beauty and an intangible mystique that repeatedly draws anglers and canoeists alike back to its waters. Today the Brule River provides habitat for a diverse array of coldwater organisms in addition to the salmonids. As one of the larger spring-fed streams in the Midwest, it is a regionally unique resource deserving the highest level of protection.

The original renowned trout fishery of the Brule River bore little resemblance to the current fishery for five salmonid species. During the middle and late 1800s the river was widely acclaimed for its native brook trout (*Salvelinus fontinalis*) fishing; this fishery was comprised of both stream-resident and anadromous, or coaster[1], components. Unfortunately, this fishery had begun to decline sharply by the turn of the century (Jerrard 1956), probably from a combination of over-exploitation, habitat loss, and logging dam effects (O'Donnell 1944). However, subsequent introductions of steelhead (anadromous rainbow trout, *Oncorhynchus mykiss*), brown trout (*Salmo trutta*), and various brook trout strains, in combination with increasingly restrictive angling regulations and termination of extensive logging, helped bolster the fishery back into prominence. High quality trophy fisheries for anadromous brown trout, steelhead, and more recently, coho salmon (*Oncorhynchus kisutch*) and chinook salmon (*Oncorhynchus tshawytscha*) have since developed and are augmented by challenging upper river and tributary fisheries for stream-resident brook trout and brown trout.

Throughout the recorded history of this river, anglers have often voiced complaints related to perceived dips in the quality of fishing. In 1983 an advisory task force (the Brule River Committee) was formed in response to perceived declines in populations of both steelhead and brown trout. The committee was formed of Wisconsin Department of Natural Resources (WDNR) personnel and concerned citizens representing area sports clubs. Objectives for the committee were to identify and prioritize the most pressing fishery problems and formulate suggestions for remedial actions. Most of the problems identified pointed to a common need: to promptly initiate a long-term, comprehensive research project to provide quantitative data about the salmonid populations. Although the river had been the focus of much investigation since the 1940s (see section on ecological investigations), the descriptive information obtained was of limited value for guiding management actions. Late in 1983 the WDNR initiated a broadly based research initiative to provide the information on salmonid population dynamics needed to optimize management of the fishery.

This report grew out of the research effort initiated in 1983 and presents an historical sketch of the fish populations of the Brule River system along with the factors that have affected them over the last two centuries. Our emphasis regarding these objectives is focused primarily on the salmonids and their management, and secondarily on the exotic sea lamprey (*Petromyzon marinus*), because these species have received the most management and research attention. However, because these species are just part of a diverse fish community, we also summarize the information available, both historical and recent, for all fish species within the river system.

Methods

This report represents a compilation of information taken from a variety of sources including data collected by the authors during various phases of a multifaceted salmonid research project on the Brule River during 1983–93, file data from the WDNR Brule Area and Superior offices, and numerous published sources. Works by O'Donnell (1944), Holbrook (1949), Marshall (1954), and Jerrard (1956) were instrumental in providing information about human development within the Brule River Valley and the historic trout fishery. Physical and chemical information for the mainstem[2] and tributaries were summarized from several sources. Fish distribution information was obtained either during WDNR fishery surveys over the last decade or from the sources acknowledged in Table 1. Both WDNR file data and published accounts of species distributions were used except in a few cases where they were clearly inconsistent with established information on statewide distributions (Becker 1983; Fago 1992). Collections from 44 sampling stations located throughout lotic areas of the river system during 1987–91 (DuBois et al. in press) targeted juvenile and stream-resident salmonids and were made with standard WDNR stream electrofishing units using 220 volt direct-current generators; electrofishing surveys prior to about 1980 used less efficient (on salmonids) alternating-current generators. Spawning runs of anadromous salmonids were examined with a viewing window and sea lamprey trap at the sea lamprey barrier/fishway (hereafter referred to as the barrier/fishway – Fig. 1). Smolts were studied with an inclined-screen trap (DuBois et al. 1991) below[2] the barrier/fishway.

Sport fishery statistics were summarized from WDNR creel surveys conducted in 1973, 1978–79, 1984, and 1986 on the mainstem from Stone's Bridge to the mouth, in 1990 on the lower river[2] only, and in 1992 on the upper river[2] only. Random, stratified, timed-interval designs—also known as bus route designs (Jones and Robson 1991)—were used to obtain completed trip interviews at major access points in 1986, 1990, and 1992; earlier access-point surveys were not stratified according to anticipated angling pressure. Information requested from each angler included the length of time fished, fishing methods used, data about the catch, and perceptions of the fishing experience. Creeled salmonids were measured to the nearest 0.1 inch and scale-sampled as needed for age analysis.

The Physical Setting

The 47-mile-long Brule River drains a watershed of about 130 square miles and flows north into Lake Superior (Fig. 1). The average discharge near the WDNR Brule Area Headquarters on the river's midsection is 169 ft^3/sec with extremes ranging from 67 to 1,520 ft^3/sec (Niemuth 1967); this flow regime is relatively stable for a large stream in Wisconsin (Bean and Thomson 1944; Sather and Johannes 1973). The upper sections of river originate in, and flow through, a large conifer bog surrounded by a sandy outwash plain known as the "pine barrens." This area acts as a sponge by absorbing a high percentage of the rainfall entering the region, and then delivering it to the stream through numerous springs at a uniform rate (Bean and Thomson 1944). The high input of spring flow is the defining feature of the river system. This uniform source of abundant ground water creates stable flows and a moderated thermal regime, which is cooler

Table 1. Relative abundance and distribution of fish species of the Brule River system

Common Name	*Scientific Name*	*Origin*	*Relative Abundance1*	*Information sources2*
PETROMYZONTIDAE				
Silver Lamprey	*Ichthyomyzon unicuspis*	Native	R	AU; SG; LB; MC; US
Northern Brook Lamprey	*Ichthyomyzon fossor*	Native	R	CH; OD; US
Sea Lamprey	*Petromyzon marinus*	Exotic	C	AU; LB; MC; MO; WI
LEPISOSTEIDAE				
Longnose Gar	*Lepisosteus osseus*	Native	R	MO; WI
ANGUILLIDAE				
American Eel	*Anguilla rostrata*	Exotic	R	AU; FB
CYPRINIDAE				
Common Carp	*Cyprinus carpio*	Exotic	R	LB
Golden Shiner	*Notemigonus crysoleucas*	Native	O	AU; FB; GR; LB; MC; MO; WI
Creek Chub	*Semotilus atromaculatus*	Native	C	AU; FB; GR; LB; MC; MO; OD; WI
Pearl Dace	*Margariscus margarita*	Native	U	AU; FB; MO; WI
Finescale Dace	*Phoxinus neogaeus*	Native	R	MO; WI
Northern Redbelly Dace	*Phoxinus eos*	Native	O	AU; FB; MO; OD; WI
Lake Chub	*Couesius plumbeus*	Native	C	MC, MO, OD; WI
Blacknose Dace	*Rhinichthys atratulus*	Native	C	AU; FB; GR; LB; MO; OD; WI
Longnose Dace	*Rhinichthys cataractae*	Native	A	AU; FB; GR; LB; MC; MO; OD; WI
Hornyhead Chub	*Nocomis biguttatus*	Native	C	MC; LB; MO; WI
Common Shiner	*Luxilus cornutus*	Native	C	AU; FB; LB; MC; MO; OD; WI
Emerald Shiner	*Notropis atherinoides*	Native	R	FB; LB; MO; OD; WI
Spottail Shiner	*Notropis hudsonius*	Native	O	AU; GR; LB; MC; MO; WI
Mimic Shiner	*Notropis volucellus*	Native	U	AU
Blacknose Shiner	*Notropis heterolepis*	Native	R	FB; MO; WI
Brassy Minnow	*Hybognathus hankinsoni*	Native	U	AU; FB; MO; WI
Bluntnose Minnow	*Pimephales notatus*	Native	O	FB; GR; MO; WI
Fathead Minnow	*Pimephales promelas*	Native	U	AU; FB; GR; MO; WI
CATOSTOMIDAE[3]				
Silver Redhorse	*Moxostoma anisurum*	Native	O	AU; MO; OD; WI
Shorthead Redhorse	*Moxostoma macrolepidotum*	Native	O	AU; LB; MC; MO; OD; WI
White Sucker	*Catostomus commersoni*	Native	A	AU; FB; GR; LB; MC; MO; OD; WI
Longnose Sucker	*Catostomus catostomus*	Native	C	AU; LB; MC; MO; OD; WI
ICTALURIDAE				
Black Bullhead	*Ameiurus melas*	Native	U	AU; FB; LB; MC; MO; OD; WI
Brown Bullhead	*Ameiurus nebulosus*	Native	R	MO; WI
Yellow Bullhead	*Ameiurus natalis*	Native	R	FB; MO; WI
Tadpole Madtom	*Noturus gyrinus*	Native	R	OD
Stonecat	*Noturus flavus*	Native	O	AU; MC; MO; WI
ESOCIDAE[4]				
Northern Pike	*Esox lucius*	Native	C	AU; FB; GR; LB; MC; MO; OD; WI
UMBRIDAE				
Central Mudminnow	*Umbra limi*	Native	C	AU; FB; GR; MO; OD; WI
OSMERIDAE				
Rainbow Smelt	*Osmerus mordax*	Exotic	O	AU; MC; MO; OD; WI
SALMONIDAE				
Atlantic Salmon	*Salmon salar*	Exotic	R	AU; LB
Brown Trout	*Salmo trutta*	Exotic	A	AU;FB;GR;LB;MC;MO;OD;SC;WI
Chinook Salmon	*Oncorhynchus tshawytscha*	Exotic	C	AU; LB; SC; WI
Coho Salmon	*Oncorhynchus kisutch*	Exotic	A	AU; LB; SC
Steelhead	*Oncorhynchus mykiss*	Exotic	A	AU;FB;GR;LB;MC;MO;OD;SC;WI

(Taxonomic names and order of families follows Robins et al. [1991].)

Main Areas of Distribution

lowest mile of the lower river; greatly reduced by lampricide treatments that began in 1959
lower two thirds of the mainstem and several tributaries prior to lampricide treatments that began in 1959; now Minnesuing and upper Nebagamon creeks
much of the mainstem and larger tributaries until restricted by the lamprey barrier in 1986; now below the barrier

one specimen reported from the lowest mile of the lower river

specimens reported from the estuary and Lake Nebagamon

lower river up to the lamprey barrier
the lowest few miles of the mainstem and Lake Minnesuing
scattered throughout the lower river; most common in slow water in the larger tributaries
lower river, Casey, Blueberry, and Wilson creeks, West Fork, and Lake Minnesuing
the lowest several miles of the lower river
lower river and most of the tributaries
lowest mile of the lower river
entire mainstem and Trask, Casey, and Blueberry creeks
riffle areas throughout the mainstem and in the larger tributaries
lowest mile of the lower river
lower river up to the lamprey barrier and Trask Creek
lower river up to the lamprey barrier and Lake Minnesuing
lower river up to the lamprey barrier
estuary
lowest mile of the lower river and Lake Minnesuing
lower river and larger tributaries
lowest mile of the lower river, Blueberry Creek, and Lake Minnesuing
lowest several miles of the lower river, Casey and Wilson creeks, Rocky Run, and the East Fork

lowest several miles of the lower river
lowest several miles of the lower river
entire mainstem and the larger tributaries
most common in the lowest several miles of the lower river but occasionally as far upstream as Winneboujou

slow, deep sections of the mainstem, Nebagamon Creek, and lakes Nebagamon and Minnesuing
lowest mile of the lower river
lowest mile of the lower river and Lake Minnesuing
one specimen reported from the lower river at McNeil's Bridge
lower river below the lamprey barrier

lakes Nebagamon and Minnesuing, uncommonly reported from scattered lotic sections

midsection and lower river except for extreme lowermost section and most of the tributaries

lowest mile of the lower river

occurrence/extent of reproduction in the Brule River system is unknown; probably strays from others waters
the larger tributaries and most of the mainstem, except for the extreme uppermost and lowermost sections
midsection of the mainstem and Nebagamon and Blueberry creeks
upper river mostly above Stone's Bridge, Rocky Run, Blueberry Creek, Jerseth Creek, East Fork
entire mainstem (but less common in the extreme uppermost and lowermost sections) and the larger tributaries

Table 1 continued

Common Name	*Scientific Name*	*Origin*	*Relative Abundance1*	*Information sources2*
SALMONIDAE (CONT.)				
Pink Salmon	*Oncorhynchus gorbuscha*	Exotic	R	SC
Brook Trout	*Salvelinus fontinalis*	Native	A	AU; FB; GR; LB; MC; MO; OD; WI
Lake Trout	*Salvelinus namaycush*	Native	R	LB
Splake	Lake trout X Brook trout	Exotic Hybrid	U	LB
Lake Herring	*Coregonus artedi*	Native	R	MO; WI
Round Whitefish	*Prosopium cylindraceum*	Native	U	AU; LB; MO
PERCOPSIDAE				
Trout-perch	*Percopsis omiscomaycus*	Native	U	AU; LB; MC; MO; OD; WI
GADIDAE				
Burbot	*Lota lota*	Native	O	AU; LB; MC; MO; WI
GASTEROSTEIDAE				
Brook Stickleback	*Culaea inconstans*	Native	C	AU; FB; GR; MO; OD; WI
Ninespine Stickleback	*Pungitius pungitius*	Native	R	MO; WI
COTTIDAE[5]				
Mottled Sculpin	*Cottus bairdi*	Native	A	AU; FB; GR; MC; MO; OD; WI
Slimy Sculpin	*Cottus cognatus*	Native	A	AU; GR; MO; WI
CENTRARCHIDAE				
Smallmouth Bass	*Micropterus dolomieu*	Native	C	AU; FB; GR; LB; MC; MO; WI
Largemouth Bass	*Micropterus salmoides*	Native	C	AU; FB; GR; MO; WI
Pumpkinseed	*Lepomis gibbosus*	Native	A	AU; FB; GR; MC; MO; WI
Bluegill	*Lepomis macrochirus*	Native	A	AU; FB; GR; LB; MO; OD; WI
Rock Bass	*Ambloplites rupestris*	Native	C	AU; FB; GR; LB; MC; MO; OD; WI
Black Crappie	*Pomoxis nigromaculatus*	Native	A	AU; FB; MO; WI
PERCIDAE				
Walleye	*Stizostedion vitreum*	Native	C	AU; FB; LB; MC; MO; OD; WI
Yellow Perch	*Perca flavescens*	Native	A	AU; FB; GR; LB; MC; MO; OD; WI
Logperch	*Percina caprodes*	Native	O	AU; LB; MC; MO; OD; WI
Johnny Darter	*Etheostoma nigrum*	Native	C	AU; FB; GR; MC; MO; OD; WI
Iowa Darter	*Etheostoma exile*	Native	R	AU; FB; GR; MO; WI
Ruffe	*Gymnocephalus cernuus*	Exotic	C	LB; PR

[1]A = abundant – species often collected in large numbers.
C = common – species often collected in moderate numbers.
O = occasional – species occasionally collected in moderate or small numbers.
U = uncommon – species infrequently collected in small numbers.
R = rare – species collected at rare intervals in very small numbers.

[2]AU – authors collections; CH – Churchill 1945; FB – WDNR Fisheries Management file data (Brule Area Office); GR – Greene 1935; LB – WDNR lamprey barrier trap 1986 – 1993; MO – Moore and Braem 1965; MC – McLain et al. 1965; PR – Pratt et al. 1992; OD – O'Donnell and Churchill 1954; SC – Scholl et al. 1984; SG – Schuldt and Goold 1980; US – USFWS data files (J. Heinrich, pers. comm.); WI – Wisconsin Fish Distribution Study (cited by Fago 1992).

[3]O'Donnell and Churchill (1954) reported the golden redhorse (*Moxostoma erythrurum*) to be common in the estuary; based on current distribution information this is likely to have been a misidentification—their specimens probably were shorthead redhorse or silver redhorse.

Main Areas of Distribution
not consistently reproducing in the Brule River system since 1979; rarely strays from other waters
upper river and most of the tributaries
transient from Lake Superior into the lower river up to the lamprey barrier
transient from stocking programs elsewhere in Lake Superior
lowest mile of the lower river
lowest several miles of the lower river
lower river, becoming increasingly common towards the mouth
lower river below the lamprey barrier
scattered throughout the mainstem and most of the tributaries in weedy, slow-water areas
lowest mile of the lower river
entire mainstem but least common in cold, headwater areas; Trask, Blueberry, and Nebagamon creeks
colder tributaries and headwater areas; present but less common throughout most of the mainstem
lakes Nebagamon and Minnesuing; rarely reported from scattered mainstem and tributary areas
lakes Nebagamon and Minnesuing; rarely reported from scattered mainstem areas
lakes Nebagamon and Minnesuing; rarely reported from scattered mainstem and tributary areas
lakes Nebagamon and Minnesuing, and Nebagamon Creek; rarely reported from scattered mainstem areas
lakes Nebagamon and Minnesuing, and Nebagamon Creek; rarely reported from scattered mainstem areas
lakes Nebagamon and Minnesuing; rarely reported from scattered mainstem and tributary areas
lakes Nebagamon and Minnesuing; uncommonly reported from the lower river below the lamprey barrier
lakes Nebagamon and Minnesuing, and Nebagamon Creek; rarely reported from the lower river below the lamprey barrier
lower river up tp the lamprey barrier
entire mainstem, Trask and Blueberry creeks, East Fork, West Fork, and Lake Minnesuing
lowest mile of the lower river, Blueberry Creek, and Lake Minnesuing
lower river below the lamprey barrier; most common in the estuary

[4]In the early 1900s, some specimens of grass pickerel (*Esox americanus*) were reported from Lake Nebagamon (Fago 1992). These reports were probably erroneous because Lake Nebagamon is well outside of the known range of this species, and in early years northern pike were sometimes referred to as grass pickerel and walleye were often called pickerel. It is possible that true grass pickerel were introduced into Lake Nebagamon, but that a viable population failed to become established.

[5]There appear to be overlapping distributions of mottled and slimy sculpins throughout the mainstem and in the tributaries, with mottled sculpins predominating in the mainstem and the warmer tributaries and slimy sculpins predominating in the colder tributaries. Although the limited data collected are consistent with this pattern, the conclusion is tentative because separation of these species in the field is difficult and specimens from relatively few sites were examined in the laboratory.

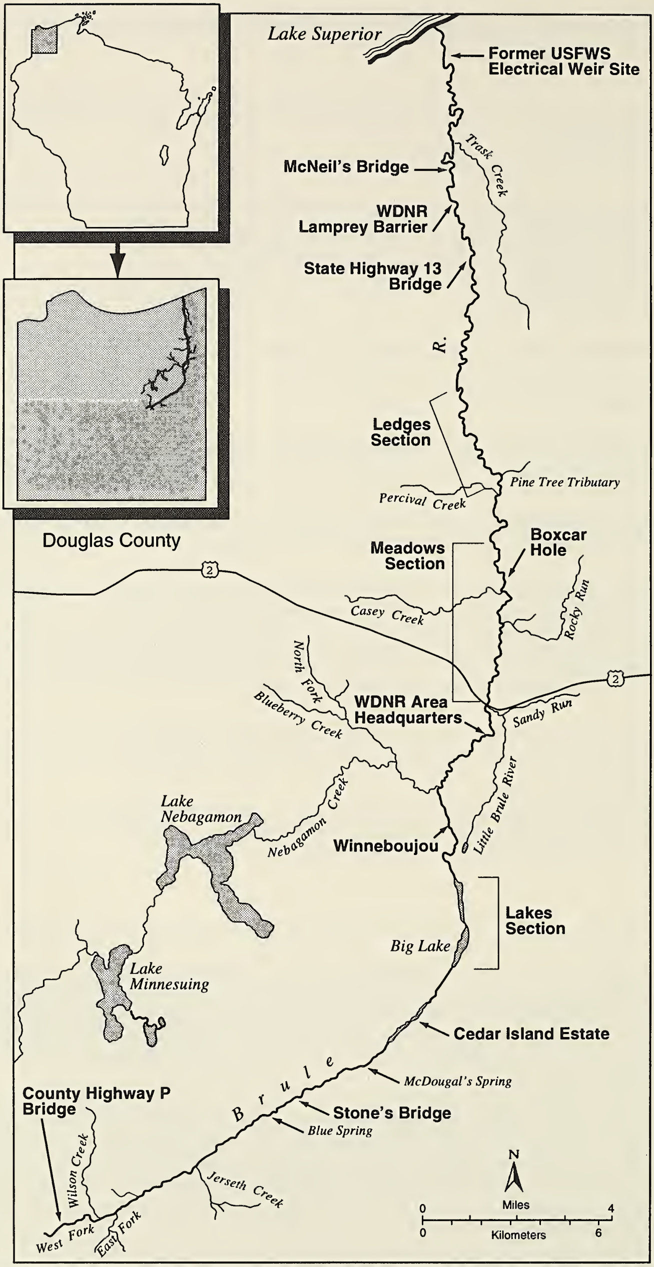

Fig. 1. Map of the Bois Brule River study area including major tributaries

in summer and warmer in winter than most streams its size (both characteristics are most evident in the upper reaches). The lower river flows through a region of red clay that contributes high runoff and associated turbidity and siltation to this section during pluvial periods. A longitudinal gradient of water temperature consists of less thermal moderation as the river proceeds to its mouth. In winter, the lower river is heavily ice-covered, and during warm summers, water temperature in the lowest section is marginal for salmonids. Patterns of spring flow and water temperature probably existed historically much as they do today. The physical and chemical characteristics of the river system are summarized in Table 2; more detailed descriptions of the geology and topography of the watershed (Bean and Thomson 1944; Dickas and Tychsen 1969), the forest cover types within the Brule Valley (Fassett 1944; Thomson 1945), and the chemical aspects of the river system (Bahnick et al. 1969) are also available.

History of Human Activity Within the Brule River Watershed as Related to the Fish Community

The Brule River is renowned for its relatively undisturbed natural setting, and indeed it has weathered human encroachment with less disturbance than most large streams in Wisconsin. Nonetheless, changes to its physical setting have occurred during the last century that may have affected the fish community. Early accounts of explorers' journeys up the Brule River mention the presence of one hundred or more beaver (*Castor canadensis*) dams that had to be broken through (Marshall 1954). Locations of these dams are not given, but they were probably most abundant in the upper river above the Cedar Island estate area (Fig. 1). Beaver were heavily trapped in 1803–04, and the dams were subsequently removed by the military to facilitate use of the river as a water route between the Great Lakes and the Mississippi River prior to the development of a military road network (Marshall 1954). These dams may have hindered brook trout movement to spawning areas (Marshall 1954), and accounts reporting excellent trout fishing are commonly found only after removal of most dams in about 1830 (O'Donnell 1944; Marshall 1954; Jerrard 1956).

Aboriginal fish harvest from the Brule River for centuries had undoubtedly been modest; recent research indicates that the Chippewa who settled along the southern littoral of Lake Superior did not rely on fish for their primary subsistence (Kaups 1984). Access to the river for European settlers prior to about 1850 was by water along Lake Superior, mostly from the city of Superior (Marshall 1954). Travel upriver was time-consuming and arduous, and the bark canoes used required skillful handling and frequent repair from damage caused by striking rocks. Hence, the brunt of early fishing probably took place near the mouth of the river. The first record of fish caught from the Brule River comes from the journal of Michel Curot who set two gill nets near the mouth of the river in 1804 and caught eight unidentified fish (Wisconsin Historical Society 1911).

Increased angling pressure on other sections of river began when overland access improved following the cutting of a crude wagon trail from St. Paul to Bayfield in 1850 (Marshall 1954). This trail passed through the town of Gordon (then called Amik), and an early road cut from Gordon to the Brule River about two miles south of Cedar Island soon followed (Marshall 1954). As early as 1855, canoes and Mackinaw boats complete with crews for fishing were advertised for

Table 2. Mean physical and chemical characteristics of the lower Brule River[1], the upper Brule River[2], and 14 tributaries for which reliable fish distribution information exists (compiled from data collected by the authors, from Fisheries Management files [Brule Area and Superior Offices], or from Sather and Johannes 1973; n/a means no data available).

Mainstem Section Or Tributary	*Mean Width (ft)*	*Mean Depth (inches)*	*Estimated Normal Discharge (ft3/s)*	*Mean Gradient (ft/mile)*	*pH*	*MPA (ppm)*	*Specific Conductance @ 77°F (umhos)*	*Approximate Maximum Summer Water Temperature (°F)*
Lower River	66	30	221	13	7.7	66	119	high 70's
Upper River[3]	54	30	97	6	7.5	45	106	high 60's
Trask Creek	7	6	2	55	7.6	123	237	at least mid 70's
Casey Creek	10	7	1	40	7.0	49	106	at least mid 70's
Percival Creek	4	2	<0.5	111	7.3	100	213	n/a
Pine Tree tributary	3	4	<0.5	264	n/a	n/a	n/a	n/a
Rocky Run	10	7	2	90	7.5	105	142	low 60's
Sandy Run	7	6	7	47	7.4	99	161	low 60's
Little Brule River	17	10	12	20	7.3	66	91	mid 60's
Nebagamon Creek	21	10	20	20	7.1	41	91	high 70's
Minnesuing Creek	20	10	3	2	7.3	45	98	at least high 70's
Blueberry Creek	11	10	5	29	6.4	26	70	low 70's
Jerseth Creek	5	4	1	71	7.2	43	84	high 50's
Wilson Creek	4	5	2	50	7.0	36	80	mid 60's
West Fork	15	6	2	5	7.3	66	134	low 70's
East Fork	15	14	4	23	7.3	42	83	high 50's

[1]Lower river refers to the stretch of river from U. S. Highway 2 north to Lake Superior

[2]Upper river refers to the stretch of river from U. S. Highway 2 south to the confluence of the East and West forks

[3]excluding Big Lake

hire in the Superior newspaper (*Superior Chronicle*, August 28, 1855). A fishing excursion on the Brule River in 1862 was reported to have caught "a lot of trout weighing from four to five pounds each" (*Superior Chronicle*, August 23, 1862).

The period from 1870 through 1890 is noteworthy in the history of the Brule River because means of transportation for reaching the river improved dramatically, the countryside around the river was rapidly "filling up with immigrants" (Marshall 1954), and recreational use of the river steadily increased from that time on (Holbrook 1949; Marshall 1954). In 1870, the Bayfield trail was cut from Superior to Bayfield, and it quickly became an important artery (Marshall 1954; Jerrard 1956). Near the Brule River the Bayfield trail followed the Copper Range and crossed the river about two miles south of the present County Highway FF bridge. At first, this trail was usable by wagon only in winter until it was improved in 1876. During the early 1870s, Alexander McDougall caught bushels of trout through the ice from the Cedar Island spring ponds and shipped them by dogsled to the Bayfield trail, then by horse team to markets in Duluth (Marshall 1954). Several articles in the *Superior Times* during the mid-1870s indicated that angling parties were making fine sport catches from the river. During the 1880s another wagon trail was cut from the town of Solon Springs (then called White Birch) to the Blue Spring area of the upper river just south of Stone's Bridge. Access to the river was eased further by the development of a railway system. The Northern Pacific rail line from Duluth to Ashland was laid in 1883; this train crossed the river at the newly established town of Brule (Marshall 1954). In 1892, the laying of the Duluth and South Shore Railroad crossed the river at Station Rapids just south of the present County Highway B bridge (Marshall 1954). By 1884, Joe Lucius was operating a guiding service for anglers on the river, and by 1900, the river had been "well discovered by anglers" (Marshall 1954). Roads in the Brule area were first passable by automobile in 1914.

Much of the virgin timber within the Brule River valley was clear-cut beginning in the early 1890s; this activity ushered in a new era of human perturbation and development in the region (Jerrard 1956). Two logging dams (also called splash dams), one near the mouth of the river and the other about two miles north of the town of Brule (near the present Boxcar Hole), were built to facilitate movement of logs downriver (Marshall 1954; Jerrard 1956). These dams, although thought to be short-term, appear to have blocked the migration route of coaster brook trout at critical times and contributed to decline of the fishery (O'Donnell 1944). Also significant was damage caused to the streambed and shoreline areas when the dams were breached and large numbers of logs were run swiftly downstream (Marshall 1954). The extent of siltation, erosion, and subsequent flooding caused by timber cutting in riparian areas is uncertain but likely was substantial. Clearly, the logging dams and lumbering operations negatively affected the fishing, and fishing improved when these activities were terminated (O'Donnell 1944; Jerrard 1956). The late 1800s and early 1900s also saw increasing human activities regarding agriculture, road construction, and delivery of utilities within the watershed; the extent to which these activities may have harmed the fish populations is unknown.

The written record of human dwellings in the Brule River Valley begins with a Chippewa village at the mouth of the river during the late-1850s that exported large quantities of Lake Superior fish by sailing sloop

(Marshall 1954). At about the same time, several commercial fishers of European descent also maintained their fishing stations there, and exported large quantities of whitefish (*Coregonus clupeaformis*), siscowet (a "fat" morph of lake trout, *Salvelinus namaycush*), and lake trout (*Superior Chronicle*, May 1, 1859; also *Superior Times*, July 15, 1875). In 1880, Samuel Budgett established the town of Clevedon at the same location, but this community persisted for only about five years. Land on the present Cedar Island Estate was purchased in 1877 by two Minnesota men for the purpose of using the series of spring ponds on the property to commercially raise brook trout (*Superior Times*, January 27, 1877). In the late 1870s Frank Bowman built a cabin on this property (Marshall 1954). During the early 1880s, Henry Clay Pierce added to the now extensive Cedar Island Estate, and the first of the Winneboujou Club cabins were built. These were the first of the long-term dwellings that sprang up along the banks of the Brule River during the 1880s (Marshall 1954; The Winneboujou Club 1990). By the early 1900s, most of the permanent dwellings that now exist along the upper river had been completed. On the entire length of river, about four dozen permanent dwellings can now be found; this number is slowly shrinking as properties become available for public ownership through the state's land acquisition program.

In 1905, Pierce created a large fish hatchery at Cedar Island by blocking off the extensive system of interconnected spring ponds from the river; this action greatly reduced the amount of spawning area for the upper river brook trout population. These spring ponds had gravel bottoms with areas of upwelling ground water that provided excellent spawning habitat. Early accounts (summarized by O'Donnell 1944) affirm that these spring ponds were the primary spawning grounds of the original brook trout population. A major decline in the brook trout fishing apparently started about 1910, about five years after this spawning area was separated from the river proper (Jerrard 1956). Early reports by WDNR fishery workers (O'Donnell 1944; O'Donnell and Churchill 1954) recognized the tremendous spawning potential represented by the Cedar Island spring ponds and recommended state acquisition of the ponds to make them accessible once again as natural spawning grounds.

The State of Wisconsin built a fish hatchery on the Little Brule River, at about its midpoint (Fig. 1), in 1928. Still operating, this hatchery has always been used to meet statewide demands for domestic salmonids. It uses the entire flow of the Little Brule River for its water supply and creates a complete barrier to upstream fish movement. Run-of-the-river fish hatcheries like the ones on the Little Brule River and at Cedar Island, in addition to the positive effect of producing fish, have the potential to affect ecosystem health in negative ways as well. They can cause localized habitat destruction by their placement, downstream water pollution by their operation, and present a risk for disease outbreaks that can spread to adjacent wild populations. Although they have reduced critical habitats, there is no evidence to suggest that either hatchery within the Brule River system has negatively affected ecosystem health through disease outbreaks or substantial pollution.

The Brule River ecosystem is subject to considerable recreational activity apart from fishing, the byproducts of which could conceivably impact the fish community. Recreational canoe and kayak use is seasonally heavy, averaging about 13,000 people annually over the last ten years on the upper river alone, and use on the lower river is probably similar in magnitude (C. Zosel, WDNR, pers. comm.). The relatively pristine setting of the upper river, having two stretches exceeding eight miles in length without road crossings, provides a rare canoeing experience. Litter resulting inadvertently from spills is substantial given the volume of boat traffic. Tubing was a popular activity on the Brule River before it was banned in 1981 because of conflicts between tubers and other river users, and a myriad of other concerns. Issues of crowding and potential conflicts between anglers and recreational canoers have frequently surfaced and may ultimately need to be addressed by managers through some sort of usage allotment system as increases in both activities continue. Campgrounds on the middle and lower sections of river also draw numbers of recreationists into the watershed.

Ecological Investigations on the Brule River Watershed

While the Brule River has received fame as a quality trout stream, its history has been interspersed with perceived declines in fishing quality (Schneberger and Hasler 1944). Consequently, the river has been the focus of many studies to preserve and restore the fishery. These efforts have compiled a wealth of information about physical, chemical, and biological aspects of the river.

In the early 1940s, the Brule River and its watershed were subjected to one of the most exhaustive interdisciplinary studies ever done on a Wisconsin stream. The intent was to evaluate the physical, biological, and chemical characteristics of the watershed so that an efficient and well-balanced management plan could be developed by the WDNR (then the Wisconsin Conservation Department, WCC). Eleven technical papers were subsequently published in the *Transactions of the Wisconsin Academy of Sciences, Arts and Letters*; these were later reissued as one collection (Wisconsin Conservation Department 1954). Topics covered included: topography and geology of the Lake Superior basin (Bean and Thomson 1944); vegetation of the watershed (Fassett 1944; Thomson 1945); a history of fishing (O'Donnell 1944); a survey of the aquatic plants and bank flora (Thomson 1944); parasites found on fishes (Fischthal 1945); results of a four-year creel census (O'Donnell 1945); bottom sediments (Evans 1945); biology of the northern brook lamprey, *Ichthyomyzon fossor* (Churchill 1945); and physical, chemical, and biological attributes of the river as habitat for trout (O'Donnell and Churchill 1954). In 1946, a brief summary of fishery recommendations emerged which constituted the first WDNR management plan for the river. Recommendations included stocking guidelines, public acquisition of the Cedar Island spring ponds, an extended autumn season on the lower river, initiation of creel and trout population surveys, and several riparian protection and erosion control measures.

Early efforts by the WDNR to sample fishes using weirs occurred at Stone's Bridge and near the WDNR Ranger Station in 1943 (O'Donnell and Churchill 1954) and again at Stone's Bridge in 1958–60 (Fallis and Niemuth 1962). During 1961–64, intensive investigations of the anadromous brown trout and steelhead populations by the WDNR (Niemuth 1967, 1970) provided the first substantial data set from which management applications could be drawn. Field work included operation of fish weirs with two-way traps during much of the open-water seasons, electrofishing sampling of some mainstem reaches using mark/recapture techniques to obtain population estimates, and documenting upper river spawning sites. The weir locations were initially below Winneboujou and later just north of U.S. Highway 2. A similar investigation was repeated in 1978–79 (Scholl et al. 1984). This study also included electrofishing surveys of several Brule River tributaries. From 1957 to 1979 the U.S. Fish and Wildlife Service (USFWS) operated an electrical weir one mile above the mouth of the river in an effort to control spawning of sea lamprey. However, in the later years of its use, the TFM (3-trifluoromethyl-4-nitrophenol) lampricide program had been developed, and this weir served primarily to monitor the effectiveness of chemical control. Some data on anadromous salmonid populations were obtained from the operation of this weir (Scholl et al. 1984); however, its operation caused an increased incidence of spinal deformities to the salmonid populations as the downstream-migrating smolts passed through the electric field (Devore and Eaton 1983) and may have contributed to mortality of adult spawners as well. Unfortunately, reliable quantitative information about the salmonid populations was difficult to obtain from any of the fish weirs because of malfunctions caused by high water or vandalism during portions of virtually every operating season.

Studies by two University of Wisconsin–Madison graduate students also added to knowledge about Brule River trout. Hunt (1965) studied the importance of surface-drift insects in the trout diet, and Salli (1962, 1974) reported on the early life history of trout species in the lakes sector[3] (Fig. 1).

Efforts to assess the sport fishery were made in 1936, 1940, and in 1943–44 (O'Donnell 1945); in 1948–49 (Brasch 1950); in 1954 (Daly 1954); in 1962–64 (Niemuth 1970); in 1973 (Swanson 1974); in 1978–79 (Scholl et al. 1984); and in 1984, 1986, 1990, and 1992 (this report). Some of these were partial surveys with limited objectives, while others were intended to be comprehensive surveys of the river's mainstem. However, the size of the river, difficulty of access to some areas, and multiple uses by the public (which can render car and canoe counts unreliable as indicators of pressure), have created difficulties in obtaining reliable estimates of total angling pressure and harvest. Furthermore, comparisons among surveys are difficult because of changing open seasons, daily bag limits, size limits, stocking policies, and survey techniques over time. Results show that angling pressure on the upper river has remained fairly stable during recent years, but pressure has decreased on the lower river since the late 1970s (Table 3). On the upper river, catch rates have increased in recent years, while harvest has declined because of more restrictive regulations and an increased tendency by fly-fishers to voluntary release their catch (Table 3). On the lower river, catch rates have remained fairly stable or declined, while harvest of steelhead and brown trout have declined substantially (Table 3).

The WDNR Bureau of Research initiated a two-year pilot research study in 1983, which was followed by a long-term research initiative (1986–93). Both were carried out jointly with the WDNR Bureau of Fisheries Management. Topics addressed during this research, and the reporting status of the studies, are described in Table 4. This cooperative effort, in conjunction with direction supplied by the Brule River Committee, has contributed to improved management of the Brule River ecosystem.

History of the Fish Community

At least 63 fish species, including 11 exotic species plus one cultured hybrid, have been collected from the Brule River system (Table 1). Important shifts in the fish community from the historical condition have unquestionably occurred. These shifts appear to be primarily related to establishment of exotic species (additions of exotics or reductions in populations of native species attributable to sea lamprey control), although the loss of coaster brook trout could be attributed to over-exploitation or blockage of migration routes. Many species have not experienced demonstrable changes in their populations over the last 50 years, suggesting little (if any) change in habitat conditions. These conclusions were reached through a comparison of the fish fauna of 1987–91 with that described from surveys done during the mid-1940s (O'Donnell and Churchill 1954). However, the comparison is valid only for common species because of differences in equipment, survey techniques, and survey effort between the two time periods. Early surveys were less intensive than surveys done from 1987–91, and early electrofishing gear was less efficient. Hence, we have assumed that uncommon species not reported by O'Donnell and Churchill (1954) were missed by their sampling (as opposed to not being present).

Among the lampreys (Petromyzontidae) the differences between time periods are striking, with two species of native lampreys suffering from greatly reduced distributions and population densities. Northern brook lamprey were abundant in the 1940s (Churchill 1945), but we found no specimens during electrofishing surveys in the Brule River system in recent years. Silver lamprey (*Ichthyomyzon unicuspis*) were once plentiful in the lower river (McLain et al. 1965), but only a few specimens were found there in the 1970s (Schuldt and Goold 1980). The only silver lamprey we have seen in the Brule River was a specimen attached to a migratory brown trout that could have originated elsewhere. Using specialized gear and techniques developed for sampling lampreys, USFWS personnel have collected three adult northern brook lampreys from one mainstem area and Minnesuing Creek over the last thirty years (J. Heinrich, USFWS, pers. comm.). They have also collected moderate numbers of ammocoetes of *Ichthyomyzon* from Minnesuing Creek and the upper section of Nebagamon Creek, as well as small numbers of specimens from scattered mainstem areas. These specimens could be northern brook lamprey, silver lamprey, or some combination of the two. (It is not presently possible to identify *Ichthyomyzon* ammocoetes to species.) These species were seriously impacted by lampricide treatments aimed at controlling the sea lamprey (Table 1 – see also section on the sea lamprey and the effects of control efforts). Sea lamprey are now common downstream of the barrier/fishway, but were not yet established in the 1940s.

The most common minnow species (Cyprinidae) do not appear to have changed in either relative abundances or distributions since the 1940s. A number of occasional, uncommon, or rare species reported here (Table 1) were not reported by O'Donnell and Churchill (1954), but this difference is attributed to less efficient sampling during the 1940s. Shifts in population distributions of two less-common minnow species may have occurred. The northern redbelly dace (*Phoxinus eos*) occurred in the upper part of the mainstem in the 1940s, but in 1987–91 was confined to the lower river and tributaries. Similarly, the common shiner (*Luxilus cornutus*) was found in deeper sections of the upper river in the 1940s, but we found it only in the lower river below the barrier/fishway.

Among the salmonids no major changes in distributions of brook trout or steelhead between time periods were apparent. Brown

Table 3. Angling pressure, catch, and harvest statistics for upper and lower sections meaningful comparisons). Steelhead throughout the river system and brown trout from marily of anadromous adults, whereas the < 13" categories are primarily stream-resi- (reported in the "all brown trout" category only).

	Lower River				
Category	*1973*	*1978–79*	*1984*	*1986*	*1990*
Angling Pressure					
Trips per Mile	n/a	1,440	1,183	887	739
Hours per Mile	n/a	5,314	4,365	3,274	2,726
Total Hours	n/a	132,847	109,122	81,856	68,140
Catch per Hour					
Brook Trout	n/a	n/a	0.007	0.009	0.002
Steelhead (≥ 13")	n/a	n/a	n/a	0.030	n/a
Steelhead (< 13")	n/a	n/a	n/a	0.037	n/a
Steelhead (all)	n/a	n/a	0.098	0.067	0.100
Brown Trout (≥ 13")	n/a	n/a	n/a	0.007	n/a
Brown Trout (< 13")	n/a	n/a	n/a	0.013	n/a
Brown Trout (all)	n/a	n/a	0.015	0.020	0.004
Pacific Salmon	n/a	n/a	0.001	0.005	0.002
All Species	n/a	n/a	0.121	0.101	0.108
Harvest per Hour					
Brook Trout	n/a	n/a	0.004	0.007	0.002
Steelhead (≥ 13")	n/a	0.056	0.033	0.019	n/a
Steelhead (< 13")	n/a	0.027	0.002	0.007	n/a
Steelhead (all)	n/a	0.083	0.035	0.026	0.032
Brown Trout (≥ 13")	n/a	0.003	0.002	0.004	n/a
Brown Trout (< 13")	n/a	0.004	0.008	0.003	n/a
Brown Trout (all)	n/a	0.007	0.010	0.007	0.001
Pacific Salmon	n/a	n/a	0.001	0.005	0.002
All Species	n/a	n/a	0.050	0.045	0.037
Harvest per Mile					
Brook Trout	1.8	n/a	15.5	21.4	4.8
Steelhead (≥ 13")	189.0	299.6	143.5	63.8	n/a
Steelhead (< 13")	89.0	141.0	10.0	22.7	n/a
Steelhead (all)	278.0	440.6	153.5	86.5	86.4
Brown Trout (≥ 13")	16.5	17.7	9.7	14.7	n/a
Brown Trout (< 13")	8.4	19.7	36.6	9.4	n/a
Brown Trout (all)	24.9	37.4	46.3	24.1	4.1
Pacific Salmon	4.2	n/a	4.2	17.7	4.6
All Species	308.9	n/a	219.5	149.7	99.9

[1]See section on regulations for daily bag and size limits in effect during each survey year; sampling periods for the surveys included the entire regular open seasons on the upper river in 1973, 1984, 1986, and 1992, and the regular open seasons plus extended early and late seasons on the lower river in 1973, 1984, 1986. In 1990 the survey period on the lower river coincided with the spring and autumn anadromous salmonid runs and was not extended through the summer; also sampled was the time interval 1 July 1978 – 30 June 1979 during the regular and extended seasons on the upper and lower sections of river.

of the Bois Brule River since 1973[1] (n/a = data not available or insufficient to provide the lower river are reported in two categories; the ≥13" categories are comprised pri- dent or juvenile anadromous forms. This distinction is invalid for upper river brown trout

Upper River				
1973	*1978–79*	*1984*	*1986*	*1992*
n/a	284	436	297	310
n/a	1,354	2,081	1,414	1,482
n/a	17,599	27,054	20,108	19,271
n/a	n/a	0.208	0.296	0.650
n/a	n/a	n/a	0.004	0.018
n/a	n/a	n/a	0.195	0.190
n/a	n/a	0.097	0.199	0.208
—	—	—	—	—
—	—	—	—	—
n/a	n/a	0.057	0.067	0.149
n/a	n/a	0.002	0.007	0.021
n/a	n/a	0.364	0.568	1.028
n/a	n/a	0.105	0.095	0.059
n/a	0.014	0.001	0.001	0.006
n/a	0.026	0.028	0.021	0.001
n/a	0.040	0.029	0.022	0.007
—	—	—	—	—
—	—	—	—	—
n/a	0.043	0.032	0.037	0.022
n/a	n/a	0	0.005	0.002
n/a	n/a	0.166	0.159	0.090
73.6	n/a	218.7	147.2	88.2
4.1	19.5	2.0	1.4	8.8
148.8	34.5	58.8	32.6	0.8
152.9	54.0	60.8	34.0	9.6
—	—	—	—	—
—	—	—	—	—
66.9	58.6	66.1	56.8	33.2
0	n/a	0	7.2	2.3
293.4	n/a	345.6	245.2	133.3

Table 4. Topics addressed during the 1984–93 research initiative

Topic	*Reporting Status*
A bibliography of fishery-related references	DuBois 1989
Fecundity of steelhead from western Lake Superior	DuBois et al. 1989
Annual monitoring of adult anadromous salmonid run sizes, age structure, and migration timing using a fish trap at the lamprey barrier	file data in the WDNR Superior Office (D. Pratt contact) will be formally reported at a later date
Investigation of density, biomass, age and growth, and species composition of stream-resident and juvenile anadromous salmonids within discrete habitat zones	DuBois et al. in press
Sampling wild salmonid smolts	DuBois et al. 1991; other reports in preparation
Experiment to determine the effectiveness of planting hatchery-reared steelhead smolts of Brule River origin	file data in the WDNR Superior Office (D. Pratt contact), file report forthcoming
Evaluation of recent and historical habitat improvement efforts	DuBois and Schram 1993; this report summarizes all efforts to date
Creel surveys done in 1984, 1986, 1990, and 1992	unpublished file report in preparation; this report
Status of the aquatic insect community	DuBois 1993; DuBois and Rackouski 1992
The effects of lampricide treatments on the salmonids and their aquatic invertebrate food source	DuBois and Plaster 1993; DuBois and Blust 1994

trout were reported to be most abundant in the lower half of the river system in the 1940s (O'Donnell and Churchill 1954); however, based on the habitat needs and present distribution of this species we doubt this observation was accurately recorded. More recently, brown trout have been most common in the middle and upper reaches of the river. Populations of Pacific salmon have become established only since the early 1970s. Among the Esocidae, the northern pike (*Esox lucius*) was reported as being moderately common in some upper river areas (O'Donnell and Churchill 1954), whereas we encountered them only rarely from 1987–91. However, we did not effectively sample the areas having the best habitat conditions for northern pike (the lakes section[3]). The reasons for these apparent population shifts are unknown, but do not seem to be habitat-related.

Exotic species have changed the complexion of the fish community of the Brule River in major ways. Exotic salmonids have diversified the predator complex and, consequently, the angling opportunities. These salmonids gained access either through deliberate introductions to the river itself (brown trout, steelhead) or to other Lake Superior areas (Atlantic salmon [*Salmo salar*], chinook salmon, coho salmon, pink salmon [*Oncorhynchus gorbuscha*]). Other species gained access to the river unintentionally through a variety of avenues including the opening of the St. Lawrence Seaway via the Welland Canal (sea lamprey, American eel [*Anguilla rostrata*]), population expansion from introductions to connecting waters of the Great Lakes (rainbow smelt [*Osmerus mordax*], common carp [*Cyprinus carpio*]), or from the release of ballast water from transoceanic vessels in the Duluth/Superior harbor (ruffe [*Gymnocephalus cernuus*], Pratt et al. 1992). The establishment of exotic species in the Brule River has had mixed effects that have sometimes been difficult to assess, with some additions regarded positively (the salmonids), but others causing concern. For example, the sea lamprey has been the focus of expensive control efforts in Lake Superior tributaries for over thirty years, and the ruffe, while viewed as a limited threat to the Brule River ecosystem, may ultimately warrant control efforts in some areas of Lake Superior.

Of 52 native species, only 21 (40%) are primary riverine species with viable populations in lotic areas. The remainder are species that either are primarily found in the lentic habitats of Lakes Nebagamon and Minnesuing, are residents of Lake Superior that occasionally move into the lowest section of the lower river, or are locally rare forms that stray into the river. The longnose gar (*Lepisosteus osseus*), collected once from the river (Table 1), is at the northern periphery of its range in Lake Superior. Lake sturgeon (*Acipenser fulvescens*) have not been reported from the Brule River, but may have entered it historically since they are present in western Lake Superior and are known from nearby rivers. Arctic grayling (*Thymallus arcticus*) were not mentioned in any of the early accounts about the Brule River, but a population (now extinct) existed in Michigan waters of Lakes Superior, Michigan, and Huron (Scott and Crossman 1973). Therefore, Arctic grayling could have strayed into the Brule River, and they are mentioned along with brook trout in regulations pertaining to the river in the early 1890s.

Because the salmonids and the sea lamprey have received the majority of research and management attention, their life histories and interactions in the Brule River ecosystem are described in more detail in the remainder of this section.

Brook Trout

Reports of tremendous fishing for brook trout in the Brule River abound, particularly for the period 1830–1900 (O'Donnell 1944; Holbrook 1949; Marshall 1954). Historical records of angling catches can be unreliable, and must therefore be interpreted cautiously, but the consistency of the early angling records pertaining to brook trout is impressive (summarized by O'Donnell 1944). For example, a U.S. Infantry Lieutenant wrote in 1831 that "the river is exceedingly clear and cold and is filled with thousands of real mountain brook trout." And in 1846, a geologist charting the region in the interest of mining companies wrote, "It surpasses all other streams in its brook trout, some of them, . . . weighing ten pounds. Its waters colder and clearer, if possible than any other river."

The only salmonid native to the Brule River, brook trout sometimes grew to a large size with reports of 6- to 10-pound fish not uncommon (O'Donnell 1944). That a part of the original brook trout population was of the coaster variety is virtually certain (O'Donnell 1944). This conclusion is consistent with historical information about the life history of brook trout in other Lake Superior tributaries (Bullen 1988). Coasters appear to have been common along the south shore of Lake Superior during the 1800s (Shiras 1935), and the Brule River may have been a major producer.

However, by the 1870s evidence of public concern about overharvest of brook trout in the region was beginning to surface. A quote from the *Superior Times* (February 24, 1876) is illustrative: "while our legislature is devoting time and money to the propagation of fish within the state it is a pity they do not stop the wholesale slaughter of brook trout through the ice in the Lake Superior counties." By the early 1890s, the Brule River brook trout fishery had begun to decline (O'Donnell 1944). Excessive angling catches undoubtedly occurred frequently during the late 1800s and early 1900s as regulation of recreational angling was very liberal with no daily bag in effect until 1905 (see section on regulation of the fishery). This history of substantial and at times excessive harvest has continued to the present as increases in angling pressure have accompanied increasing harvest restrictions. Hence, over-exploitation is a major factor implicated in the reduction of the brook trout population.

Lumber interests started cutting the virgin timber in the Brule Valley in 1892, and the logging dams they built allegedly damaged the coaster population by blocking their migration route at critical times (O'Donnell 1944). A law was on the books at that time requiring a fishway at any dam or obstruction on the Brule River (Chapter 251, Laws of 1891). Unfortunately, noncompliance was rife, and a 1906 article (quoted by O'Donnell 1944) explicitly states that there were no fishways at the logging dams on the Brule River. Siltation associated with poor forestry practices likely also contributed to the decline of the fishery (Holbrook 1949; Marshall 1954). Interspecific competition with heavily stocked brown trout and rainbow trout during the 1920s and 1930s may have also negatively affected the brook trout population. Coaster brook trout were apparently extirpated from the river by the mid-1940s, with the latest reliable record being of a 24-inch fish observed spawning in the upper river in 1944 (O'Donnell and Churchill 1954).

Efforts to bolster the sagging brook trout fishery included supplemental stocking of domestic strains, which began in 1894 and continued steadily for over 80 years, and introductions of exotic species (early plantings summarized by O'Donnell 1945). Stocking of brook trout was terminated in 1979 because of emerging evidence from the fisheries literature, now even more firmly established, that stocking domestic strains of trout on top of healthy wild populations often has more negative than positive effects (White 1989; Goodman 1990). This represented a major change in management policy which may have contributed to some recent recovery of the brook trout population.

Early records about the strains of brook trout stocked in the Brule River are sketchy, and undocumented plantings by wealthy private citizens or citizen groups may have occurred. Domestic brook trout strains, which have been systematically selected from fast-growing, early-maturing brood stocks, can have a significant reproductive advantage over wild fish. Gene flow from these strains may have altered, to an unknown degree, the genetic structure of the original brook trout population, which was uniquely adapted to the physical setting of the river.

The present brook trout population is largely confined to the upper (southern) half of the river and most of the tributaries (Fig. 2) where ice-free conditions for long stretches during winter provide evidence of abundant spring flow. They exist sympatrically with populations of exotic salmonids

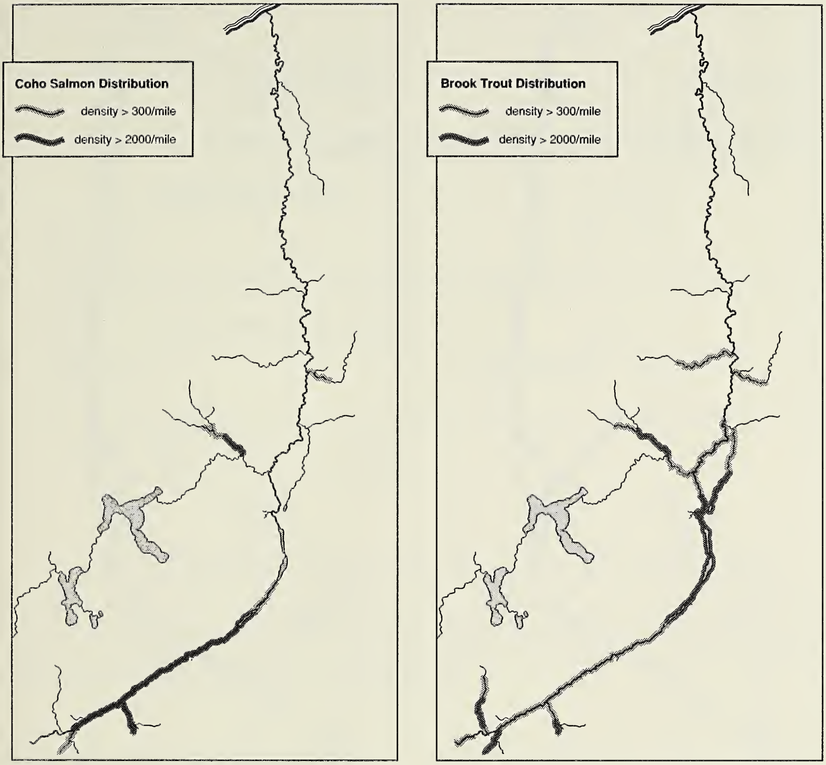

Fig. 2. Present distribution of juvenile coho salmon and brook trout of all age classes in the Bois Brule River system showing areas of highest population density

in sufficient numbers and sizes to provide acceptable fishing. The Brule River contains the largest population of brook trout of all Wisconsin streams draining into Lake Superior. However, they are the least abundant of the three primary salmonid species in the Brule River system (DuBois et al. in press). Brook trout spawn in slower-flow areas, often near springs where small-sized gravel and the upwelling ground water conditions they require are suitable. Spawning areas in the Brule River have not been well documented, but are probably scattered widely throughout the upper river and several tributaries in spring pond areas and other areas of reduced flow. Spawning likely could be enhanced by dredging spring pond areas adjacent to the main channel along the upper river (Carline 1980).

Steelhead

Steelhead were first introduced to the Brule River in 1892 (O'Donnell 1944), and stocking of a variety of Pacific Coast strains continued periodically through 1981 (see

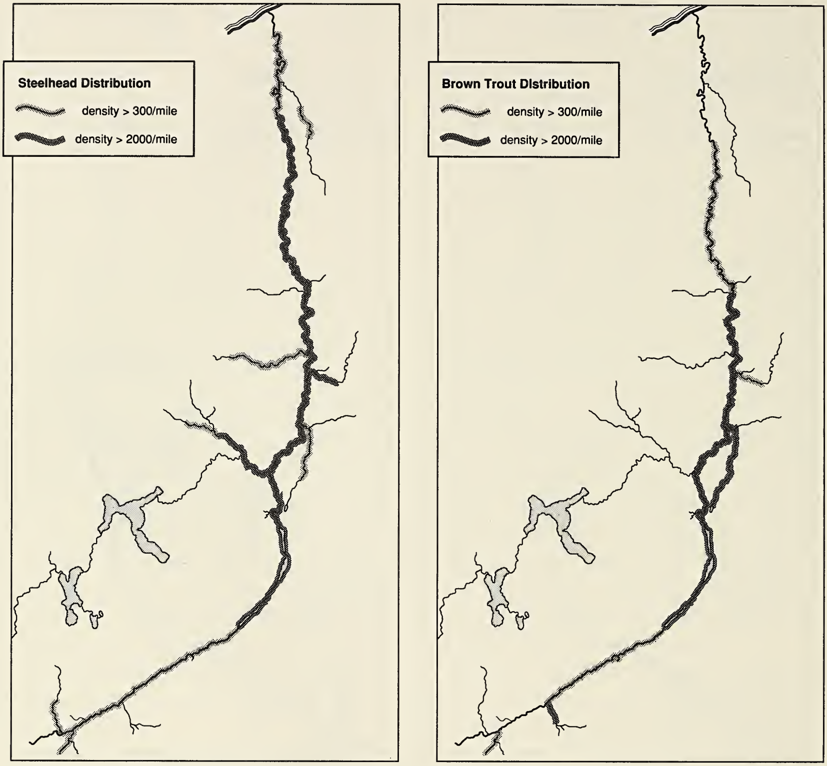

Fig. 3. Present distribution of juvenile steelhead and brown trout of all age classes in the Bois Brule River system showing areas of highest population density

MacCrimmon and Gots 1972, and Krueger and May 1987a). Steelhead have become the most abundant salmonid in the river system (DuBois et al. in press). This species has a strong migratory tendency, and it appears that the entire Brule River population is anadromous, although this apparently was not the case originally (O'Donnell 1944). Steelhead inhabit most of the river system as juveniles (Fig. 3), but descend into Lake Superior as smolts after one, two (usually), or three summers in the river. Once in the lake, these fish grow to a large size and then return to the river to spawn after one, two, or three more years. Upon reaching maturity they spawn annually (Swanson 1985), with a few spawning every other year (Seelbach 1993).

About 15 major spawning areas used by steelhead were identified by O'Donnell and Churchill (1954) and Niemuth (1967, 1970) in riffle areas between Stone's Bridge and Winneboujou. Spawning in the lower river is even more significant, but it is more diffi-

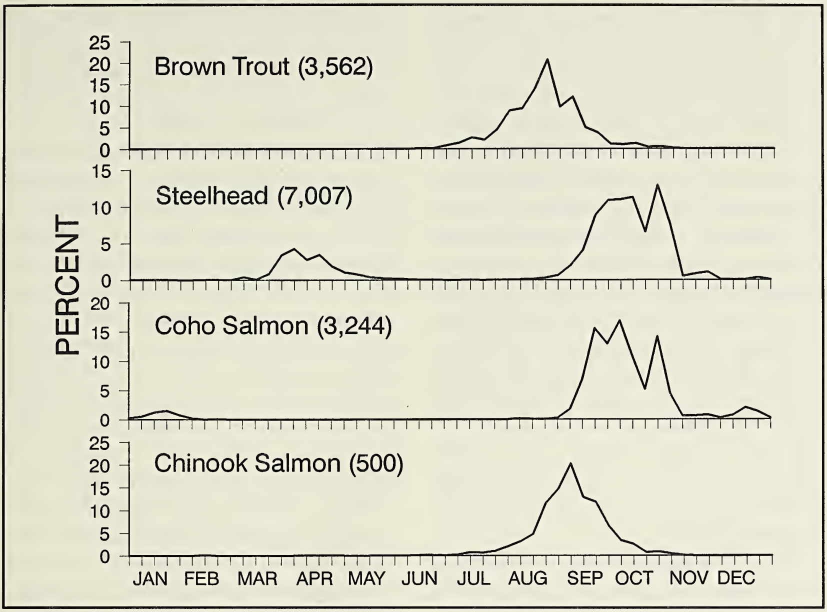

Fig. 4. Five-year (1989–93) mean weekly distribution of anadromous salmonids ascending the Bois Brule River on annual spawning runs (mean number per year for each species during 1989–93 in parentheses)

cult to document the specific locations used and hatching success because of higher turbidity and deeper water. Year-class strength of juvenile steelhead has been stable in the upper river, but highly variable in the lower river (DuBois et al. in press). This variation has apparently resulted largely from environmental factors and may not be closely related to numbers of spawning adults. The lower river is less stable than the upper river in terms of both its flow and temperature regimes. We speculate that a critical factor associated with year-class strength in the lower river pertains to spring flooding, which may have a devastating effect on eggs and newly hatched fry (Seegrist and Gard 1972). The limited data available suggest that when there is little flooding in the spring when the young-of-the-year are small (less than about 2 inches), survival is high. Also, during warm springs, growth is faster, allowing young fish to grow more quickly through the critical "window of time" when they are vulnerable to spring flooding.

Though all steelhead spawning apparently occurs in the spring (some autumn spawning is possible but unlikely), two distinct migration patterns have emerged: a larger autumn run of fish ascends the river from September through December and overwinters in deeper holes throughout the mainstem of the river, and a smaller spring run begins to ascend the river in February or early March and continues through May

(Fig. 4). A study to investigate the possible genetic distinctness of these runs did not show significant differences (Krueger and May 1987a). It is therefore probable that the autumn and spring spawning runs are actually one extended run interrupted by a temperature-related cessation of migration cues during winter. The large autumn run on the Brule River is unique among Wisconsin's tributaries to Lake Superior, the others having substantial spring runs and only small autumn runs (if any). The reason(s) for this difference among streams is not clearly understood, but the availability of suitable overwinter holding areas in the Brule River, the relative seasonal stability of its flow, and the moderated thermal regime that contributes to its becoming ice-free earlier in the spring than most other streams, may all be important factors.

Evidence mounted during the early and mid-1980s that the steelhead population of the Brule River had declined disturbingly since the late 1970s and may now be at only a small fraction of its former abundance. For example, the estimated steelhead harvest during 1978–79 (about 7,000) was roughly similar in magnitude to the estimates of the entire run sizes in recent years (Fig. 4). Other tributaries along Wisconsin's Lake Superior shoreline showed a similar pattern of declining runs since the 1970s suggesting that the western Lake Superior steelhead stocks were collectively declining and may have been approaching a collapse (B. Swanson, WDNR, pers. comm.). Causes of this decline (which unfortunately coincided with a year-round open season on the Brule River during 1983–85) were unknown, but overharvest in Lake Superior as well as in the streams was strongly suspected.

In response to this perceived threat to the steelhead stocks, the WDNR enacted more restrictive size and bag limit regulations in 1989, and embarked on a limited-term steelhead stocking experiment for the Brule River to bolster its population. The stocking plan called for an annual egg-take operation (about 100,000 eggs annually) from wild Brule River steelhead and subsequently raising these juveniles to smolt size (approaching or exceeding 7 1/2 inches). The goal of the stocking program was to release 50,000 functional smolts at various locations on the lower river each May until the program was no longer needed. Anglers have also responded by practicing more catch-and-release angling for steelhead on a voluntary basis (D. Pratt, unpubl. data). In 1993, the minimum legal size was further increased to 26 inches to allow maiden spawners to spawn at least once before entering the harvest (see section on regulations for complete description of steelhead sport harvest restrictions). At least several years will be required to assess the effectiveness of these measures. The wisest course of action for steelhead is to manage with conservative regulations; however, highly variable year-class strength related to environmental factors outside of management control will lead to large variations in annual angling quality, regardless of best management practices. Additional descriptive aspects of the Brule River steelhead population have been reported by Niemuth (1970) and Scholl et al. (1984).

Brown Trout

Brown trout were introduced to the Brule River by the WCC in 1920 (O'Donnell 1945). However, they may have already become established in the river from stockings elsewhere in the Lake Superior basin (Krueger and May 1987b). Many domestic strains of brown trout were undoubtedly stocked before stocking of this species was terminated in 1974. A self-sustaining population of brown trout developed early on, and they are now common throughout much of the river system (Fig. 3).

Two ecologically distinct groups of autumn-spawning brown trout coexist: a stream-resident component provides a challenging upper-river fishery and an anadromous (lake-run) component exhibits a life history strategy similar to steelhead. Anadromous brown trout spawning runs begin in July, peak in August, and extend into October (Fig. 4). Juveniles reside in the river for one (usually), two, or rarely three years before smolting in the spring or autumn. They then usually spend two years in the lake before returning to the river to spawn at age three or four. Although spawning need not result in the death of brown trout in an obligatory sense, as is the case with Pacific salmon, repeat spawning is relatively uncommon, and high natural mortality appears to be associated with spawning.

Brown trout sampled from western Lake Superior tributaries were found to differ genetically among drainages, between anadromous and stream-resident life histories, and among locations within the Brule River drainage (Krueger and May 1987b). Anadromous brown trout provide a rare trophy fishery, but have been generally less popular than steelhead because they are often harder to catch. Additionally, they are susceptible to mortality from furunculosis, caused by the bacterium *Aeromonas salmonicida*. Some fish carry the disease without symptoms, but outbreaks of furunculosis have sometimes reached epidemic proportions in the Brule River. Although furunculosis was observed prior to intensive weir study (Niemuth 1967), stress associated with handling large numbers of brown trout at weirs may have aggravated the prevalence of the disease. Warm river temperatures in August when most anadromous brown trout ascend the river have also been implicated in activating symptoms.

Resident and anadromous brown trout spawn in many of the same mainstem areas used by steelhead, but are more spatially restricted than steelhead in the lower river and the tributaries. This restriction may be related to the difficulty posed for overwintering eggs by anchor ice in the less-thermally-moderated lower river and by typically lower water levels in the tributaries during their autumn-spawning period. Information on size and age structures and other descriptive aspects of the anadromous brown trout stocks have been reported by Niemuth (1967) and Scholl et al. (1984).

Pacific Salmon

Three species of Pacific salmon have been found in the Brule River in recent years; all are strays from stockings by neighboring states and the Province of Ontario. Their sudden appearance serves as a reminder that the Brule River is not an isolated system, but rather, is intimately tied to the ecology of the surrounding region. Scott and Crossman (1973) described the life histories of Pacific salmon in the Great Lakes, and Scholl et al. (1984) provided early information about the population characteristics of these autumn-spawning species in the Brule River.

First documented in the Brule River in 1973, coho salmon have established a viable though widely fluctuating population. Their life history strategy involves one year of stream residency for juveniles, outmigration as smolts in May, and growth in the lake for one or two years before returning to the stream to spawn and die. Adults have contributed significantly to the sport catch in recent years. Coho salmon have so far shown a three-year cycle of abundance in the order of a small-run year, an intermediate year, and a large-run year. Numbers of spawners and the resulting young are strongly correlated. Spawning runs have peaked in mid to late September, but substantial movement has occurred throughout autumn and extended into winter (Fig. 4). Coho salmon spawn successfully throughout the upper river and tributaries, favoring smaller riffles near headwater areas (Fig. 2). Juveniles fare well in the slow, deep, alder-choked sections of the upper river south of Stone's Bridge; because these areas are extensive, the Brule River will likely remain a strong coho salmon producer.

Establishment of a viable chinook salmon population has developed more slowly than that of the coho salmon, although the first adults were also documented in 1973. During the late 1970s and early 1980s, small numbers of juveniles were found only in Blueberry and Nebagamon creeks and in mainstem riffles close to the confluence with Nebagamon Creek (Fig. 1). Since 1988, chinook salmon have spawned over a slightly wider range of locations, although still centered in the same general area. Year-class strength has also shown modest increases (DuBois et al. in press). Chinook salmon in the Brule River smolt mostly as young-of-the-year in May and June, with the remainder smolting during autumn or the following April/May. After smolting, chinook salmon spend up to five years in the lake (four years is most common) before returning to the river to spawn. Spawning runs, which have peaked from mid-August through September (Fig. 4), have contained modest numbers of spawners; the extent to which their population size or distribution may change is unknown.

Pink salmon have also been found in the Brule River, although not in appreciable numbers since 1979 (Scholl et al. 1984). Their potential for establishment in the Brule River appears limited.

The Sea Lamprey and Effects of Control Programs on Other Fishes

Sea lamprey were introduced to the upper Great Lakes through the opening of the Welland Canal and were first reported in Lake Superior in 1938 (Becker 1983). Although early records of their spawning in the Brule River are sketchy, they had developed a viable population in western Lake Superior by the mid-1950s. Primary spawning areas in the Brule River are not well known but likely included both mainstem and tributary riffles near silt beds for ammocoete habitat. Sea lampreys quickly caused serious damage to the salmonid populations of Lake Superior (National Research Council of Canada 1985). The Brule River was one of the largest tributary producers of sea lampreys in the Lake Superior basin, yielding approximately one-third of the entire catch from Lake Superior streams (McLain et al. 1965). Beginning in the mid-1950s, control programs initiated by the USFWS began to dramatically reduce sea lamprey recruitment to Lake Superior by disrupting their spawning and larval phases through use of mechanical weirs, electrical weirs, and later, selective lampricide treatments (Smith and Tibbles 1980). In the Brule River, sea lamprey control has included an electrical weir one mile upstream from the mouth of the river from 1957 through 1979, selective lampricide treatments using TFM at three-year intervals in the entire mainstem and throughout most of the tributaries from 1959 through 1986, and a mechanical barrier used in conjunction with chemical treatment only below the barrier since 1986.

Although TFM treatments of the Brule River successfully reduced sea lamprey recruitment, deleterious effects on some non-target organisms were observed, and the monetary cost of treatments was high

(Gilderhus and Johnson 1980). Concern about these negative aspects led to the construction in 1984 of a sea lamprey barrier, located about seven miles upstream from the mouth of the river (Fig. 1). Initially, a low-head dam with jumping pools to allow migratory salmonids to pass upriver was built. However, this structure did not pass salmonids during all water conditions, and plans for remodeling were formulated. A reconstruction, including an effective fishway, was begun in 1985 and completed in March of 1986. The fishway included a viewing window which has proven to be a valuable research tool to obtain data on salmonid run numbers and other population statistics. This barrier system functions via use of a low-head dam with an overhanging metal lip within the fishway of a height surmountable by leaping salmonids but insurmountable to sea lampreys. The primary barrier which crosses the entire width of the river is higher than the fishway barrier and is impassable by all sea lampreys and most migratory salmonids. During autumn when no sea lamprey movement occurs, the fishway barrier is removed, allowing free upstream access to all fish species. The USFWS will periodically monitor the entire river and tributaries for presence of ammocoetes to determine any need for further treatment of upriver areas. Because the barrier appears to stop all sea lamprey movement, routine TFM treatments will now be made only downstream of it. Sections of the Brule River above the sea lamprey barrier were last treated in 1986 to kill ammocoetes produced before its completion.

All species of lampreys are highly sensitive to TFM, and populations of three species of endemic lampreys have been greatly reduced or eliminated from treated streams within the Lake Superior basin (Schuldt and Goold 1980). In the Brule River, the silver lamprey and the northern brook lamprey were once abundant, and their populations have been greatly reduced by repeated treatments (Table 1). It is not known if silver lamprey were historically indigenous to sections of the Brule River above the sea lamprey barrier.

Other groups of aquatic organisms are affected to different degrees by TFM. Lampricide treatments usually have substantial negative effects on a relatively few forms of invertebrate life (Gilderhus and Johnson 1980; Dermott and Spence 1984; MacMahon et al. 1987), and they do not usually have severe direct effects on salmonid populations (Dahl and McDonald 1980). Secondary effects on salmonids due to a reduced invertebrate food supply also are unlikely to be severe (Merna 1985; DuBois and Blust 1994). However, other families of fishes, particularly ictalurids (catfishes) and catostomids (suckers), are quite sensitive to TFM. Stonecats (*Noturus flavus*) in the lower Brule River and in other western Lake Superior tributaries were so severely affected by TFM treatments that it was initially feared that they might have been eliminated from Lake Superior (Dahl and McDonald 1980). Fortunately, untreated refugia apparently existed for a portion of the stonecat population. Populations of other fishes indigenous to the Brule River may have been reduced because of TFM treatments. Dahl and McDonald (1980) provide a thorough discussion of the known effects of sea lamprey control on non-target fishes in the Great Lakes.

Control of sea lamprey spawning in the Brule River will remain an important fisheries management priority. Although research on alternative methods of sea lamprey control is ongoing, mechanical barriers and chemical treatments remain the most successful of the practical options.

Habitat Management

The history of the Brule River is dotted with numerous efforts to preserve the integrity of the physical habitat, enhance habitat for salmonids, and stabilize riparian areas. These efforts fall into five categories: (1) preservation of riparian areas, (2) in-stream habitat enhancements, (3) beaver control and dam removal, (4) bank stabilization in red clay areas subject to slippage, and (5) dredging projects.

Preservation Efforts

A major factor in the preservation of the Brule River ecosystem has been the protection afforded by state stewardship acquisition of land bordering the river. The Brule River State Forest was established in 1907 when Frederick Weyerhauser deeded 4,320 acres to the state. Land acquisition since has added to that total as funds have allowed. In 1959, the boundaries of the Brule Forest were extended to include the entire Brule River corridor. Presently about 40,000 acres of land are under state ownership, which represents about 80% of the total acreage within the boundary of the Brule River State Forest and includes about 50% of the river frontage (C. Zosel, WDNR, pers. comm.).

Another major factor contributing to preservation of the Brule River ecosystem has been the excellent stewardship practiced by private riparian landowners over many years (Holbrook 1949). Brule River Preservation, Inc., is a public nonprofit corporation including over 20 landowners from the upper river dedicated to preserving the Brule River and fostering sound ecological management for its use. The Nature Conservancy (TNC), an international organization dedicated to preserving unique natural areas, has a Conservation Easement Grant Program in effect on much of the upper river between Blue Spring and the WDNR Brule Area Headquarters (Fig. 1). This program features agreements between individual landowners and TNC whereby the landowners voluntarily restrict certain rights of use and development on their lands in perpetuity in order to ensure that these lands are protected against unwise commercial development and ecological degradation.

In-Stream Habitat Enhancement

The WDNR has been at the forefront nationally in the development of in-stream habitat enhancement techniques for salmonids. Consequently, much is now known about the identification of environmental deficiencies and the application of appropriate structural remedies to Wisconsin's streams (White and Brynildson 1967; Hunt 1988, 1993). Techniques used in the Brule River have included wing deflectors and bank covers, debrushing and installation of brush bundles, and removal of downed trees and other debris. Unfortunately, most of these efforts were undertaken before knowledge about effective techniques had been refined. A project of "stream improvement" was started in 1936 using Works Progress Administration labor. A total of 286 structures were installed in the river including deflectors, bank covers, and other stream enhancement devices, many of dubious value for creating trout habitat (O'Donnell 1944; Holbrook 1949; Marshall 1954). This effort appears to have been focused on making the river easier to canoe (O'Donnell 1944). Some of these structures still exist, either complete or as remnants, below County Highway P, below Stone's Bridge, in the Winneboujou area, and near the WDNR Area Headquarters. Additionally, the Civilian Conservation Corps installed structures, planted willows, and "clean[ed] out large amounts of down trees and other materials" at about the same time (O'Donnell 1944, p.29). The beneficial role of large, downed timber in shaping stream morphology and creating salmonid habitat has only been realized in recent decades (Harmon et al. 1986; Bisson et al. 1987). Current thinking now favors adding large woody debris to the stream to compensate for wood removed by earlier enhancement efforts or lost for other reasons[4]. During the 1960s, a series of rock deflectors was installed below the State Highway 13 bridge by the Brule River Sportsmen's Club, Inc. Also in the 1960s, the Douglas County fish and Game League (under cooperative agreement with the WDNR) constructed rock wing deflectors in several lower river locations to provide cover for salmonids and deflect current away from red clay banks. No follow-up evaluations were made of any of these early efforts.

Habitat enhancement efforts by the WDNR within the Brule River watershed since the 1960s have focused on riparian debrushing and installation of brush bundles on inside bends in some tributary areas choked with speckled alders (*Alnus rugosa*). Riparian debrushing lets sunlight into the stream for aquatic plant growth and encourages physical improvements in the stream channel, while brush bundles provide cover for trout fry and accelerate a favorable channel-constriction process (Hunt 1979). Such efforts on the East and West forks of the Brule River appear to have improved trout habitat, but were not evaluated to document their impact on trout populations. During 1978–91, a project on the Little Brule River below the state trout hatchery to remove all beaver dams and riparian alders and install brush bundles was conducted and evaluated (DuBois and Schram 1993). Natural reproduction in both treatment and control sections improved during the post-treatment period. However, numbers of legal-size brown trout declined markedly in both treatment and control sections following treatment, a result that could have been due to increased fishing pressure brought on by publicity surrounding the project, the improved fishability of the debrushed stream segment, or movement of large brown trout out of the stream.

Beaver Control and Dam Removal

Effects of beaver dams on trout habitat have generally been regarded as negative in Wisconsin although they are considered beneficial in small, high-gradient streams. Negative effects are most likely to occur on streams of low-to-moderate gradient where dams may contribute to warming of water, hinder salmonid movement and spawning, cause silting-in of gravel areas important for producing insects, and produce poor channel characteristics (summarized by Avery 1983). Traditionally, beaver have been regulated by trapping because of the value of their fur. For example, heavy trapping of beaver on the Brule River in 1803–04 drastically reduced their numbers (Marshall 1954). However, beavers are prolific, and animals from surrounding areas tend to recolonize trapped-out areas, creating an unceasing cycle. Furthermore, intensity of trapping effort fluctuates because of unstable fur prices. Recent low fur prices and excellent habitat have resulted in a large beaver population in northern Wisconsin. The Brule River and tributaries have been on various special extended beaver trapping seasons since the early 1960s, including a liberal open season since the mid-1980s. The Brule River watershed was included in a WDNR beaver subsidy program from 1986–88 that provided a financial incentive for trappers to control populations in designated areas. Since then, a trapper from the Animal Plant Health Inspection Service of the U.S. Department of Agriculture has worked under WDNR direction to remove beaver from within the Brule River watershed and other salmonid tributaries to Lake Superior.

Beaver dams on the Brule River generally occur only in the upper river above Stone's Bridge and in several tributary areas. Although historically these were probably also the areas of heaviest beaver activity, dams may have occurred further downstream as well. Numerous recent excursions to remove beaver dams from the upper Brule River have been made by WDNR workers, members of area sports clubs, and other citizens, but results have been short-lived, especially if beaver were not also removed. A recent habitat development project on the Little Brule River evaluated the effects of beaver dam removal and riparian debrushing on the physical conditions of the stream channel and on the salmonid populations (DuBois and Schram 1993). Although physical changes in channel morphometry following these manipulations were impressive, salmonid population responses were mixed, and the beneficial aspects could not be attributed solely to dam removal.

Bank Stabilization

The clay soils in the Brule River watershed appear to be geologically young and undergoing a high rate of natural erosion. When Europeans settled in this area, their lumbering, road construction, and agricultural activities removed the established mixed-conifer forest cover type and altered drainage patterns in ways that accelerated this pattern of erosion. Present-day activities, although more carefully controlled, continue to aggravate the erosion process.

Erosion of the red clay soils of the lower Brule River Valley has the potential to negatively affect salmonid populations. The potentially most damaging effect is from sedimentation, which can inhibit aquatic invertebrate life and reduce salmonid spawning success by causing high egg and larval mortality. In extreme cases, turbidity can also reduce feeding success of visually feeding salmonids and inhibit proper gill function (Berg and Northcote 1985). However, turbidity is probably not an important limiting factor for salmonids in the lower Brule River because other tributaries to Lake Superior in Wisconsin are known to have longer-term turbidity episodes yet have contained robust salmonid populations in recent decades.

A red clay interagency committee was formed of state and federal agencies in 1955 to investigate land-use problems on the red clay soils of northwestern Wisconsin. The goals of this committee were to determine the causes of red clay sedimentation in area lakes and streams and to study means of erosion and sedimentation control. Experimental work to reduce clay erosion was done on the Brule River in a few areas using gabions and riprap to stabilize bank slippage. Some successes were achieved in areas of less extreme slippage, but the efforts were expensive and the results obtrusive in a natural setting. Various mulchings and plantings were also tried in localized areas. State forest management goals now call for specialized timber management in steeply sloped red clay areas, with the long-range objective of returning the area to mixed-conifer forest. This plan may eventually lead to reduced bank erosion and slippage, but decades will be required to assess the results.

Dredging Projects

Dredging of spring ponds in Wisconsin can benefit brook trout spawning (Carline 1980), but indiscriminate dredging of streams can produce harmful physical changes such as degradation of the streambed (headcutting) and bank erosion (Kanehl and Lyons 1992). Several dredging projects have been carried out on the Brule River with the goal of enhancing trout habitat by creating deeper pools and exposing gravel substrates for spawning and increased invertebrate production. In the late 1920s, the WDNR dredged the east side of Big Lake. Blue Spring and a short stretch of river above Stone's Bridge were dredged by a private interest in the late 1960s. These projects were never evaluated to document benefits that may have accrued. In 1967, Douglas County and the Douglas County Fish and Game League tried to deepen and straighten the mouth of the Brule River by dredging. The attempt was futile, however, as the river quickly reverted back to its original form.

Regulation of the Fishery

Restrictions on fishing on the Brule River have usually followed the regular statewide trout and salmon regulations, with various extended special seasons on the lower river. In the early 1900s the four northern counties bordering Lake Superior were sometimes subjected to different open seasons on trout than the rest of the state. The many changes occurring over the history of regulation in open season dates, daily bag limits, and minimum sizes are described below in chronological order.

Open Seasons

Regular Season. The first restriction on trout fishing enacted in Wisconsin was a reduction in the length of the statewide open season from 12 months to 8 months in 1858. In 1878, the open season was further reduced to 5 months. From 1891 through 1898 the open season on the Brule River was greatly reduced to just 26 days in August (Chapter 138, Laws of 1891). Reasons for this restriction were not stated, but we note its concurrence with the era of intensive logging and use of logging dams to transport logs downriver en masse; release of these dams would have created serious hazards for anglers downstream. The length of the open season has varied since, but has usually been between 4 and 5 months. The season opener has varied between mid-April and mid-May; the closing date for the regular season has also been variable, occurring sometime between August 20 and September 30.

Special Extended Seasons. Various extended seasons have been enacted for the lower river between U.S. Highway 2 and Lake Superior to allow increased angling opportunities during anadromous salmonid spawning runs. These seasons have included a special early season, starting in spring sometime prior to the regular season and running to the regular season opener, and a special late season, starting in autumn after the regular open season and extending for various periods of time. Season extensions began in 1935 with a special early season starting on May 1 (at that time the regular season opener was on May 15). The starting day for the special early season has since varied, but has most often been the Saturday nearest April 1. Special regulations for the autumn season began in 1954 with an extension through November 15 and a further extension to December 31 in 1974. In 1983, a year-round open season was created from U.S. Highway 2 to Lake Superior to spread out fishing pressure and create additional angling opportunities. This year-round season was rescinded after the 1985 season because of public dissatisfaction and indications of excessive harvest. Present season extensions run from the Saturday nearest April 1 through November 15.

Daily Bag and Minimum Size Restrictions Prior to 1989

There was no statewide restriction on the daily bag for trout until 1905 when it was set at not more than 10 pounds. In 1909, the daily bag was changed to 45 trout; it was subsequently reduced to 35 trout in 1917, 25 trout in 1923, 15 trout in 1929, and 10 trout in 1949. From 1949 to 1989 the daily bag during the regular season remained at ten trout or salmon, sometimes with the stipulation that only five of those could be steelhead, or steelhead and brown trout in aggregate. Daily bag limits for the Brule River during the special extended seasons were more restrictive than during the regular seasons. From 1962 to 1989, the daily bag during the extended seasons was five trout or salmon in aggregate, with the stipulation for 16 of those years that only two of the five could be steelhead.

The first size limit enacted for trout in Wisconsin was a 6-inch minimum in 1905. In 1915 the statewide minimum length was increased to 7 inches; it was set back to 6 inches again in 1950, where it remained until 1989. The special extended seasons have been subject to higher minimum lengths, beginning with a 13-inch minimum for the late season in 1954. In 1970, the minimum length limit during the early and late seasons was reduced to 10 inches, where it remained until 1989.

Recent Changes in Daily Bag and Minimum Size Limits

Although anglers were increasingly practicing voluntary catch-and-release during the 1980s (Table 3), by 1989 it became apparent that additional restrictions on harvest of both adult spawners and presmolts of steelhead and brown trout were necessary to protect the fishery. Excessive harvest was strongly implicated in the declining numbers of spawning steelhead. Concern had also mounted that harvest of large, resident brown trout may have been dangerously high, especially during a popular, early-summer mayfly hatch (*Hexagenia limbata*) when trout are particularly vulnerable. An additional concern surfaced that harvest of presmolt steelhead and brown trout 6 to 10 inches in length may have been substantially reducing run sizes of adult spawners. Studies had shown smolt size to be positively correlated with survival to the maiden spawner stage (e.g. Ward and Slaney 1988), and that if steelhead survived their presmolt winter, they had an excellent chance to grow to trophy size (Seelbach 1987). Hence, larger presmolts were valuable and required protection from harvest.

New regulations in 1989 for the entire open season therefore included a reduced daily bag limit of five salmonids in total of which only one could be a steelhead 12 inches or larger and only two could be brown trout larger than 15 inches. Minimum sizes were increased to 10 inches on brown trout and 12 inches on steelhead and Pacific salmon to protect anadromous presmolts. The minimum size limit on brook trout was also increased to 8 inches to allow more fish to grow into a desirable size range. In 1993, the minimum size limit on steelhead was further increased to 26 inches for the Brule River and all other Wisconsin tributaries to Lake Superior to ensure that young adults would have the opportunity to spawn at least once before entering into the harvest. More time is needed to determine the extent to which these changes may have benefited the fishery.

Concurrent with the decline in the Brule River steelhead run in the mid and late 1980s were indications of reduced steelhead runs in other Wisconsin tributaries to Lake Superior (B. Swanson, WDNR, pers. comm.). Increasing harvest of steelhead in Lake Superior by anglers in charter and private boats was suspected of contributing substantially to this disturbing decline of steelhead in western Lake Superior. Hence, in 1990, regulations for the Wisconsin waters of Lake Superior were changed to allow daily harvest of only one steelhead over 28 inches in length.

Other Restrictions on Fishing

Gear restriction proposals for reducing harvest and post-release mortality of salmonids in sections of the upper river have periodically been voiced. However, the only gear restriction ever enacted was for "fly fishing only" for the stretch of river from Stone's Bridge to Winneboujou in 1938 in response to a petition by landowners. This restriction was rescinded shortly thereafter, following a storm of public protest that may have been politically generated (Holbrook 1949).

Other restrictions include no fishing from 1/2 hour after sunset to 1/2 hour before sunrise during the extended seasons on the lower river, and the establishment of small refuge areas closed to fishing where migrating fish tended to congregate and illegal snagging was known to have occurred (below the sea lamprey barrier, the Boxcar Hole and the Skid Mays area within the Ledges section[5]).

Voluntary catch-and-release is being practiced with increasing frequency, especially on the upper river, as the angling community re-evaluates the value it places on wild salmonids. Brule River Preservation, Inc., the Brule River Sportsmen's Club, Inc., and Trout Unlimited of Wisconsin have undertaken a collaborative signage project on the upper river that suggests the practice of voluntary catch-and-release to preserve good fishing. These types of voluntary initiatives have been shown to effectively shape angler behavior because many anglers are influenced by the ethics of their peers. Also, anglers are concerned about the future of their sport and typically respond well to education.

Management Implications

1. Continue the focus on riparian protection. A strong posture by the WDNR and private interests on protecting riparian areas has existed for decades and should continue. A healthy riparian zone is instrumental for maintaining water quality and instream habitat diversity, which are in turn critical for the continuing support of a diverse array of coldwater life. The state should continue its policy of land acquisition within State Forest boundaries from willing sellers where feasible. An enduring focus on cooperative ecosystem stewardship by riparian landowners, the Brule River Preservation, Inc., the Brule River Sportsmen's Club, Inc., and a broad range of WDNR functions will remain invaluable.

2. Focus for instream habitat maintenance and enhancement. Habitat maintenance and enhancement considerations for the river system should include beaver control and dam removal to maintain an unimpeded migration route, dredging of spring pond areas to increase brook trout spawning potential (however, dredging of the mainstem is not recommended), and addition of downed conifers, rootwads, and other forms of large woody debris throughout the system to compensate for wood removed since the late 1800s. Existing instream habitat improvement structures that seem to have been useful should be refurbished. Public acquisition of any part of the Cedar Island spring pond area to be again made accessible for wild brook trout spawning should be a high priority if that property becomes available; a substantial boost to the brook trout population would likely result given the apparent paucity of spawning areas for that species elsewhere throughout the upper river.

3. **Continue the trend for increasingly restrictive angling regulations.** Increasingly restrictive regulations have contributed to a brighter future for the salmonid fisheries, especially since over-exploitation was identified as one of their major threats. This trend should be maintained, and gear restrictions for sections of the upper river should be considered pending determination of the effects of the 1989 regulatory changes on the salmonid populations.

4. **Further monitoring of the stream biota.** The recent establishment of numerous exotic species serves to remind us that the Brule River is part of a larger ecosystem that will remain continually at risk from distant occurrences. Given the climate of uncertainty under which the system must be managed, there will be a need for periodic monitoring of the fish and aquatic insect communities to test for impacts of exotic animals on native species. Additionally, an abbreviated sampling schedule of the quantitative investigations into salmonid population dynamics initiated during the last decade should continue, as much as economically feasible, to ensure benefits to future fisheries management.

5. **Continue the research focus.** Many indications from the public including the admirable work of the Brule River Committee and the committee's strong support of the research efforts of the last decade suggest that status quo management of this river system is not acceptable. The public has a right to expect state-of-the-art management on a resource as valuable as the Brule River. Resource management policies have come under increased scrutiny from special interest groups and this trend will likely continue. Continuing research will be needed to satisfy the demand for sound management.

Acknowledgments

We extend special thanks to our technicians W. Blust, S. Plaster, and F. Stoll, without whose able assistance in the field this research would not have been successful, and to the many limited-term employees who contributed to the research in a variety of ways. We also thank R. Hunt and S. Schram for their roles in fostering this research. Review comments from M. Holbrook, R. Hunt, J. Lyons, M. Jennings, P. Seelbach, M. Staggs, W. Weiher, C. Zosel, and an anonymous referee improved the manuscript. M. Jesko and C. Olson assisted with the figures. L. Claggett, R. Lee, and personnel from the State Historical Society of Wisconsin helped unearth information about early regulation of the fishery. This research was supported in part with funds authorized by the Anadromous Fish Conservation Act (project WI-AFS-16), the Federal Aid in Sport Fish Restoration Act (projects F-83-R and F-95-P, study 415), and the Wisconsin Department of Natural Resources.

Endnotes

[1] Coaster brook trout apparently exhibited an anadromous life history strategy similar to that of the anadromous brown trout. Little scientific information on coaster brook trout in Great Lakes tributaries is available because most populations were extirpated before scientific data were collected. Bullen (1988) describes a remnant population in a Lake Superior tributary.

[2] Upper river refers to the river reach from U.S. Highway 2 south (upstream) to the con-

fluence of the East and West forks. Lower river refers to the river reach from U. S. Highway 2 north (downstream) to Lake Superior. Upper or above always refers to an upstream direction; lower or below always refers to a downstream direction. Mainstem refers to the main thread of the Brule River proper without the tributaries.

[3] The lakes section is composed of four widespreads of the Brule River (Sucker, Big, Lucius, and Spring lakes) located just south of the river's midsection (Fig. 1).

[4] There is likely much less large woody debris in the Brule River (and other rivers and streams in northern Wisconsin) than there was historically for several reasons in addition to the removal efforts of early fisheries workers. Woody debris has been systematically removed from our rivers and streams for more than a century to maintain open channels for human navigation, and during the intensive logging era of the late 1800s removal efforts were intensified to maintain smooth channels for the downriver transport of logs. Additionally, the clear-cutting of our northern forests at that time (which included steamside areas) temporarily interrupted the continual natural process of dying streamside trees falling into waterways.

[5] The ledges section is the reach of river having maximum gradient where it crosses the Copper Range (Fig. 1). The river descends 80 ft in 2¼ miles at that point (Bean and Thompson 1944).

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Thomas F. Grittinger and Deborah L. Schultz

Social behavior of adult jaguars (Panthera onca L.) *at the Milwaukee County Zoo*

Abstract *The purpose of this study was to describe and analyze social behavior between two captive jaguars* (Panthera onca *L.*), *a male and a female, at the Milwaukee County Zoo. Some one hundred eighty-nine bouts were recorded and analyzed over four years. These bouts consisted of numerous acts, some of which appeared to be sex-specific or at least individual- specific. The bouts varied considerably in duration; the mean duration of the bouts initiated by the male was significantly longer than that for bouts initiated by the female. Two-act sequences for each animal revealed a large number of complex grooming and wrestling acts, with much switching back and forth. Apparent sex differences were revealed in the two-act sequences of complex grooming and clasping, clasping and lying on, and wrestling and lying on. As the study progressed, the male spent a significantly greater percentage of bout time in sexual behavior during the bouts.*

The jaguar (*Panthera onca* L.) is one of the least studied large cats in the world (Rabinowitz and Nottingham 1986). Until recently, the only published information available on the jaguar came from anecdotal reports of explorer-naturalists, hunters, and surveyors (Crawshaw and Quigley 1991). The recent scientific papers focus on various aspects of jaguar biology, such as home ranges, movements, and daily activity patterns (Crawshaw and Quigley 1991; Rabinowitz and Nottingham 1986; Schaller and Crawshaw 1980). Other published works emphasize various aspects of their predatory behavior (Emmons 1986; Mondolfi and Hoogesteijn 1986; Rabinowitz 1986b; Schaller and Vasconcelos 1978). Despite this, little is known regarding jaguar social interaction patterns (Mondolfi and Hoogesteijn 1986). The purpose of this paper is to provide an ethogram ("a set of comprehensive descriptions of the characteristic behavior patterns of species" [Brown 1975]), in this case limited to social behaviors. This paper describes social interactions between two captive jaguars (a male and a female) at the Milwaukee County Zoo over a four-year period. In addition to the description of individual acts, the duration of interactions was examined, the sequences of acts was analyzed, and variation over the study period was monitored.

Methods

The subjects of this study were both captive born (male: February 10, 1983; female: September 22, 1982) and had been housed together since September 15, 1983. The period of observations extended from October 22, 1985, to July 17, 1990. During this time the male was sexually unaltered while the female was maintained on Melangesterol (a progesterone derivative) implants until July 1990, when an ovariohysterectomy (spay) was performed. The study was terminated at that time.

Observations were made two to three times per week during the snow-free months of the year in Milwaukee (from May to early December) when the animals were released into the outside enclosure, an area 40 x 60 ft (12.2 x 18.3 m) (Fig. 1). Observations lasted from 30 to 60 min, depending on the level of activity. Social interactions were recorded by means of a video camera with a built-in timer and were analyzed later. The interactions consisted of bouts, "relatively stereotyped sequence[s] of behaviors that occur in a burst" (Lehner 1979). A bout extended from first contact (an obvious act of initiation of social interaction such as a fixed gaze) to termination (when one or both animals withdrew and did not reunite within 30 s). The initiator of the bout was the individual that approached the other (receiver) or initiated first contact.

The bouts were recorded, and the sequences of motor acts or patterns within the bouts were obtained by replaying the video tapes on slow speed. Accurate analysis of rapidly changing events was facilitated by the fact that the male is black and the female spotted. Two-act sequences (Latour 1981) were presented to contrast the behavior of the male to that of the female, both as initiator and as recipient. Changes in relative frequencies of some of the more common acts were examined for the study period.

Results and Discussion

An ethogram is the starting point in any ethological research (Lehner 1979). Although the behaviors of various cats have been documented (e.g. Schaller's [1972] work on the lion [*P. leo* L.] Wasser's [1976] thesis on tiger [*P. tigris* L.] play, and Leyhausen's [1956] and West's [1974] papers on the domestic cat [*Felis catus* L.]), there are no reports describing jaguar social behavior.

In order to construct the ethogram, several hundred contact bouts were recorded, one hundred eighty-nine of which were unobstructed enough for analysis. The bouts were described by the acts they contained.

Non-Contact Acts and No Activity

Non-Contact Acts:

• Fixed gaze (FG) – The animal initiated the bout with its head and neck held low and oriented toward the recipient animal. The animal rapidly shifted weight from one front leg to another.

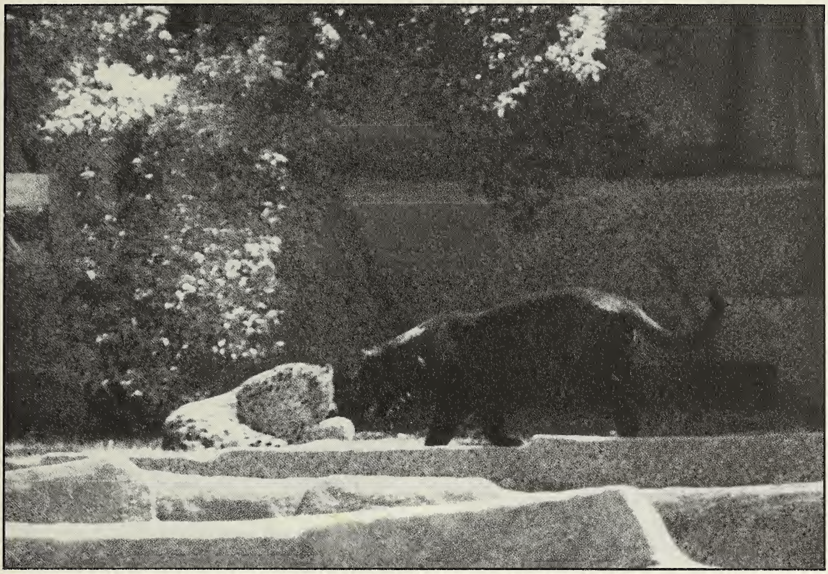

Fig. 1. The female jaguar (right) and the male jaguar in their outdoor enclosure

• Stalking (St) – The initiator moved slowly with a fixed gaze toward the recipient. The body was tense and held in a lowered manner; the forequarters were usually held lower than the hindquarters.

• Rushing (Rus) – One animal ran toward the other, who did not flee.

• Chasing (Ch) – One animal ran toward the other, who did flee.

• Approaching (Ap) – One animal simply walked toward the other.

• Facing off (FO) – The initiator's head was oriented toward the other animal, who would or would not do likewise. The animals were in close proximity to each other, usually about a body length or less apart.

• Walk/run away (WA/RA) – The animal walked or ran away, usually ending the bout.

No Activity (NA):

This category was probably more artificial than the rest. It ranged from the relaxed mode of behavior seen when one animal remained motionless while being licked by the other, to a lack of discernible activity on the part of both animals. This category involves no reciprocity of actions whatsoever.

Contact Acts

Playing Behavior:

• Rubbing (Rub) – Rubbing often was the first actual physical contact between the two animals. One animal would rub the other using its head or body.

• Holding (Ho) – Holding was accomplished by throwing either one front leg over the neck or shoulder of the subject, or by placing both front legs around the other's neck. In some cases it appeared to restrain, while in others it was less forceful.

• Grabbing (Gr) – Grabbing was done by the rapid thrust of one of the front paws out and around the leg of a fleeing animal.

• Jumping on Back (JOB) – The animal placed its forequarters on the other's back. The front legs were usually straddled over the subject, and the hind legs may or may not have been on the ground.

• Pawing (Pa) – The subject was struck with the forepaw. The intensity of pawing varied greatly.

• Biting (Bi) – Biting covered a range in activity from a brief mouthing to a much more sustained biting and pulling.

• Wrestling (W) – Wrestling ranged from a close embrace with combinations of pawing, biting, and kicking with the hind legs, to a loose relationship with one animal lying on its back and the other animal standing over or near it. The animal lying on its back would often paw or reach with its front feet while treading with its hind legs; the mouth was held open and the teeth were exposed. The standing animal's mouth was also open while it bit and pawed at the lying animal. The belly-up and stand-up positions were sometimes interchanged and often mixed with close contact wrestling. The intensity of wrestling varied considerably.

Grooming behavior:

• Simple licking (SL) – In this situation one animal simply licked the other, from either a standing or lying position. The recipient of the simple licking did nothing (listed as NA). Both animals did this.

• Complex Grooming (CG) – In this complicated act, the female straddled the male who was belly side up, and she would lick him. This behavior was more protracted than simple grooming, and the animals were always in the straddle-belly up positions. This was maintained as long as she continued to lick him. This belly-up position differs from the NA behavior insofar as he actively participated in the sequence of events. When she stopped, he would start wrestling and either she would resume grooming and he would again relax, or she would wrestle with him.

Sexual behavior:

• Clasping (Cl) – The male hugged the female closely while both were lying on their sides. The male would pull the female against his chest and pull her down toward his stomach while treading with the hind feet.

• Lying on (LO) – With her head at or below the level of his stomach, the male rested his body on the female. While doing this, he would often move back and forth over the recumbent female, sometimes displaying a partial erection.

• Mounting (Mo) – The male straddled the female who was sitting or lying on her belly.

The results of this study demonstrate that within the conditions of captivity jaguars socially interact in bouts. The data support the idea that playing, grooming, and sexual behaviors often are found in the same bout. Bout duration varied considerably, with a range of 1 to 1204 s (Fig. 2). The majority (57%) of the bouts were less than 1 min long. These short bouts often consisted of one of the approach acts, followed by one of the contact acts such as biting or pawing, and usually ended with a walk-away or run-

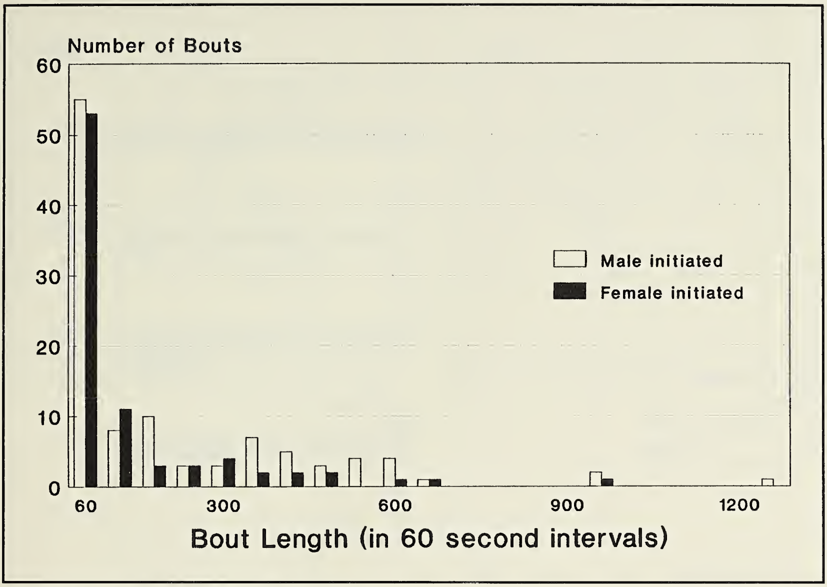

Fig. 2. Distribution of bouts by length

away. The longer bouts began and ended much as the shorter ones did, but contained a reciprocal switching of contact acts. The male initiated 106 bouts and the female initiated 83 bouts, with no significant difference between initiators (test concerning proportions, $z = \pm 1.67$, $P > .05$). The mean duration of the bouts initiated by the male (174 s) was significantly longer than that for the bouts initiated by the female (99 s) (t-test, $t = 2.51$, $P < 0.01$).

Bouts were each analyzed as being composed of a series of two-act sequences of successive acts by the same animal. The integration of individual acts and the differences between the two animals is seen in these two-act sequences (Figs. 3–6). The area of each box in Figures 3–6 is proportional to the total number of acts, and the arrow width is proportional to the total number of transitions between the acts. For the sake of simplicity, only those transitions of ten or more were included.

Complex grooming and wrestling were the most common acts seen in both animals, both as initiator and as receiver. As the arrows suggest, these two acts often switch back and forth during a bout. It is of interest that prolonged wrestling, a common play act seen here, did not occur in wild adult lions (Schaller 1972).

While most of the acts were performed by both animals, there were a few that appeared to be individual-specific or sex-specific. Complex grooming varied between the animals, with the female always straddling the belly-up male. The male's position was maintained as long as she continued to lick

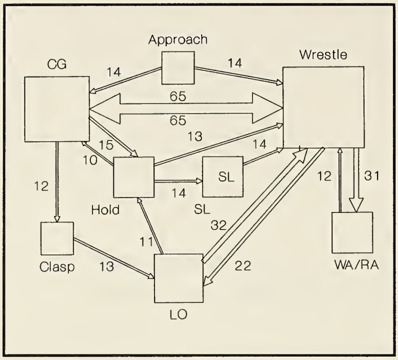

Fig. 3. Two-act sequences for male as initiator

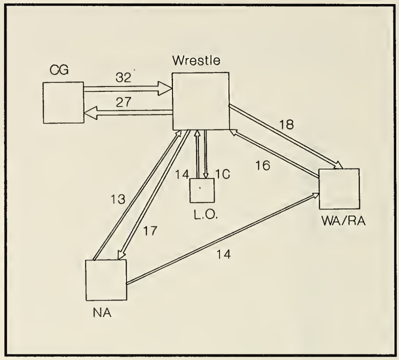

Fig. 4. Two-act sequences for male as receiver

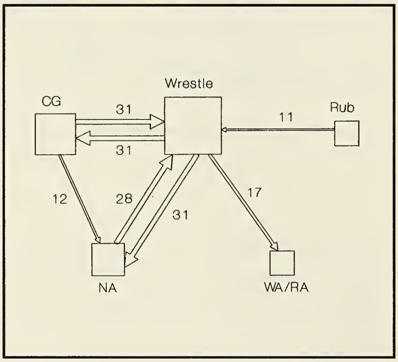

Fig. 5. Two-act sequences for female as initiator

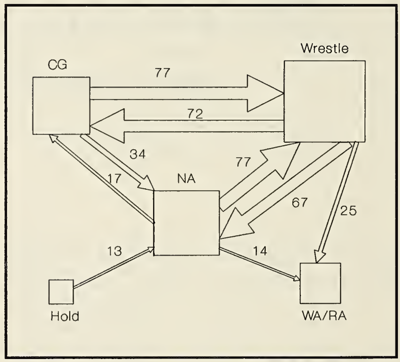

Fig. 6. Two-act sequences for female as receiver

him. If she stopped, he would start wrestling, and either she would resume the complex grooming and he would again relax or she would wrestle with him. A similar reaction was seen in the bite-lick-bite sequence in tigers (Wasser 1978) and in the use of social grooming as an interruption of playfight (Fagen 1981).

Only the male engaged in clasping, lying on, or mounting (all sexual) behaviors. As the study progressed, a shift was apparent (Fig. 7). There was a significant change in the proportion of time engaged in sexual behavior during the four years (the difference between proportions test was, for 1987–88, $z = -6.72$; for 1988–89, $z = -13.15$; and for 1989–90, $z = -6.82$, $P < 0.001$). His two-act sequences often included wrestle-lie on, lie on-wrestle, wrestle-clasp, and clasp-lie on; clasp appeared to be transitional between wrestling and lying on. When the male would either clasp or lie on the female,

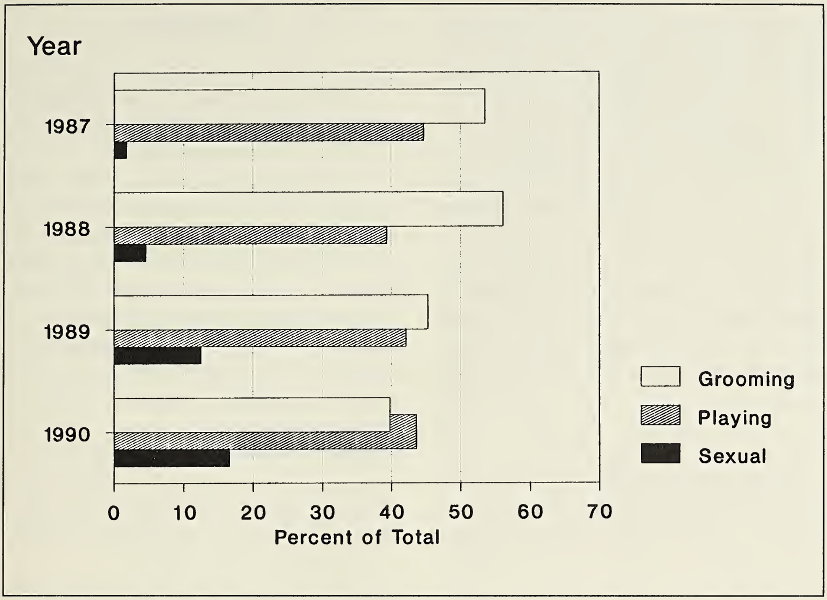

Fig. 7. Distribution of contact behaviors, 1987–1990

she would lie still (NA) or wrestle. Mounting was too infrequent to warrant placing in the two-act sequences; the female usually walked away from him as he attempted to do this. While Wasser's (1978) tiger bouts included contact behaviors such as paw, bite, wrestle, and lick, they lacked any sexual activity, possibly because his tigers included only one adult male and five of its offspring (one sub-adult and four cubs).

The progressive increase through the four years in the percentage of sexual behavior cannot be attributed to the development of sexual maturity. The animals were adults when the study started. He was 4.5 years and she was 5 years old, and they had produced a cub before the observations started. Rabinowitz (1986a) considered jaguars to be subadults at 2–3 years and mature adults at 4–10 years. Mondolfi and Hoogesteijn (1986) gave 2–2.5 years for sexual maturity in the female jaguar and 3–4 years for the male jaguar.

Unlike the complex grooming and the sexual behaviors, the acts that constitute play appeared not to show individual or sex differences. This is in agreement with Fagen's (1981) prediction that in carnivores, where both sexes display similar fighting skills, no differences should exist in play. In both animals the play demonstrated some accepted characteristics: exaggerated and repeated acts (Loizos 1966; Fagen 1981). Among the many functions attributed to play, expending excess energy (Bekoff 1976; Schaller 1972) and strengthening social bonds (Schaller 1972) were two that may have merit here. In confinement, male and female felids often live together in relative peace and may frequently play with each other, phenomena seldom recorded in the wild (Fagen 1981). In the wild, all felids, with the exception of the lion and the cheetah (*Acinonyx jubatus* Schreber), live solitary lives (Bekoff 1989). Hemmer (1978) suggested that carnivores are capable of a much greater plasticity in social behavior in zoos than they usually are in nature. He proposed that there are three factors that affect sociality in the pantherines: (1) environment, (2) relative brain size, and (3) temperament. He believed that the jaguar and the leopard (*P. pardus* L.) are capable of group living but, like the tiger, are forced by habitat conditions in the wild to forgo this.

Detailed longitudinal field observations of identified individual felids are still lacking (Bekoff 1989), and the evidence presented here is limited to only two captive jaguars; nevertheless, this study, which covers four years in the lives of two readily identified individuals, supports Ewer's (1973) contention that felids are not as asocial as commonly believed. The observations indicate that social behavior is organized into bouts of varying length and complexity and that the contact portion of the bout is dominated by play and complex grooming activity.

Acknowledgments

Support for this study was provided by a University of Wisconsin Centers sabbatical leave. We would like to thank Dr. Millicent Ficken for her ideas, Dr. Jack Hailman for suggestions on the manuscript and the treatment of data, and the Milwaukee County Zoo, especially Ralph Konrath and Valerie Werner, for their assistance throughout the project.

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Richard E. Koske and Leonard L. Tews

Vesicular-arbuscular mycorrhizal fungi of Wisconsin's sandy soils

Abstract *The root zones of beach grass,* Ammophila breviligulata, *of Wisconsin's Great Lake's dunes, and of other plants of sandy soils of the state were surveyed for the first time for vesicular-arbuscular mycorrhizal (VAM) fungi. The most frequently obtained were* Glomus etunicatum, Gigaspora rosea, Glomus geosporum, *and* Glomus macrocarpum. *Taxonomic characteristics of the obtained fungi are similar, in most cases, to those of VAM fungi found elsewhere.*

The soils of Wisconsin heretofore have been unexamined for vesicular-arbuscular mycorrhizal (VAM) fungi. Moreover, there have been only a few reports of VAM fungi being isolated from the lacustrine dunes of the Great Lakes region of North America (e.g., Koske et al. 1975; Koske 1985). Be that as it may, there have been numerous reports of VAM fungi from North America's maritime dune systems (e.g., for New England, Koske and Halverson 1981; Koske 1981; and for the Northwest, Gerdemann and Trappe 1974). It is of ecologic and taxonomic interest to know the VAM fungi of Wisconsin's soils, since they have potential in the improvement of crop production. Moreover, it is worthwhile to compare the VAM flora of the Great Lakes dunes to those of New England's dunes, especially since the higher plant flora, and therefore the ecology itself, is so similar.

Procedures

VAM fungi were collected from the root zones of plants at 53 sites at 21 different geographic locations (described with their sampling dates in Table 1). The sites included dunes of

Table 1. Collected species found in association with VAM fungi

Site	*Species Association*	*Date Collected*
1. Cornucopia (Bayfield Co.)	*Ammophila breviligulata* Fern. growing on Lake Superior dunes at Cornucopia's public beach	July 3, 1984
2. Rock Island (Door Co.)	*Agropyron dasystachum* (Hook) Scribn. growing on Lake Michigan dunes	July 22, 1984
3. Washington Island (Door Co.)	*A. breviligulata* growing on Lake Michigan dunes	July 22, 1984
4. Newport State Park (Door Co.)	*Calamovilfa longifolia* (Hook) Scribn. growing on Lake Michigan dunes	July 22, 1984
5. Bailey's Harbor (Door Co.)	*A. breviligulata* from Lake Michigan dunes at The Ridges beach (remnant arboreal forest)	July 21, 1984
6. Jacksonport (Door Co.)	*A. breviligulata* growing on Lake Michigan dunes at Jacksonport's public beach	July 21, 1984
7. Whitefish Dunes State Park (Door Co.)	*A. breviligulata* growing on Lake Michigan dunes	July 21, 1984
8. Kewaunee (Kewaunee Co.)	*A. breviligulata* growing on dunes at Kewaunee Pioneer Park	June 16, 1985
9. Two Rivers (Manitowoc Co.)	In the root zone of *A. breviligulata* growing on dunes at Two River's public beach	June 16, 1986
10. Kohler-Andrae (Sheboygan Co.)	*A. breviligulata* growing on Lake Michigan dunes at Kohler-Andrae State Park	July 21, 1984
11. Kohler-Andrae (Sheboygan Co.)	*A. breviligulata, Lathyrus maritimus* (L.) Bigelow, *C. longifolia*, and *Rosa* sp. growing on Lake Michigan dunes at Kohler-Andrae State Park	October 9, 1983
12. Harrington Beach (Ozaukee Co.)	*L. maritimus* and *A. breviligulata* growing on Lake Michigan dunes at Harrington Beach State Park	July 11, 1984
13. Sauk City (Columbia Co.)	In the root zone of *A. breviligulata* growing on a bank of the Wisconsin River in Sauk City	June 21, 1985
14. Lake Wisconsin (Columbia Co.)	Sedges and *Lythrum salicaria* L. growing on a sandbar in Lake Wisconsin	June 21, 1985
15. Plainfield (Waushara Co.)	Associated with the roots of *Z. mays* L. near an irrigated field near Plainfield	June 27, 1985
16. New Hope (Waupaca Co.)	From an unirrigated oat field near New Hope	June 27, 1985

Site	*Species Association*	*Date Collected*
17. New Hope (Waupaca Co.)	From an unirrigated field of *Z. mays* near New Hope	June 27, 1986
18. Red Granite (Waushara Co.)	*Poa pratensis* L. from a granite quarry near Red Granite	June 27, 1985
19. DeWitt Road (Sheboygan Co.)	*A. breviligulata* on Lake Michigan dunes at the end of DeWitt Road	July 11,1984
20. Plainfield (Waushara Co.)	From an irrigated and an unirrigated field of *Z. mays* near Plainfield	June 27, 1985
21. Columbia Co.	From an irrigated field of soybeans	July 9, 1985

Lake Michigan and Lake Superior, sandbars and banks of the Wisconsin River, and irrigated and unirrigated sandy soils of central Wisconsin. Sand-root samples were placed in plastic bags and stored at about 6°C until processed. Field notes regarding position, date, and vegetational cover were recorded.

Spores of the VAM fungi were separated from the soil by a technique of flotation and filtration (Koske and Halvorson 1981). Approximately 35 g of sand were added to about 500 ml of tap water in a 1 liter beaker and agitated vigorously. The suspension was filtered immediately, before settling, through a .5 mm soil sieve with the spores being collected on a No. 4 Whatman filter paper placed in a Buchner funnel with vacuum pressure. The filter paper was removed from the funnel and placed under a dissecting microscope where spores of the fungi were isolated to a drop of water on a glass slide with the aid of a fine forceps. A cover slip was placed atop the spores, and with gentle pressure, the spores were burst for better examination of spore wall structure. Spores were sometimes stained with Melzer's Reagent for diagnostic purposes. If a permanent slide was desired, spores were placed in a drop of polyvinyl alcohol solution and sealed with clear fingernail polish.

Results

Fifteen species of VAM fungi were collected from the sandy soils of Wisconsin (Table 2). All species are new records for Wisconsin. The fungus most frequently isolated from sand dunes was *Glomus etunicatum.* Other commonly obtained fungi are *Gigaspora rosea*, *Gl. geosporum* and *Gl. macrocarpum.*

The VAM fungi of Wisconsin's dunes were compared to those of other soils using a coefficient of similarity, C (Bray and Curtis 1957) (Table 3). The equation is: $C = 2w/a + b$ where w = the number of species common to both floras, a = the number of species of one flora, and b = the number of species of the other flora. The VAM fungi of Wisconsin's dunes are most similar to those of Wisconsin's non-dune soils, and somewhat more similar to those of Iowa than they are to those of the maritime dunes of Rhode Island or the prairie soils of Illinois.

One of the obvious differences between the VAM floras of Iowa, Wisconsin, and Rhode Island is that *Gigaspora-Scutellospora*

Table 2. VAM fungi collected from Wisconsin's Great Lake dunes and other sandy soils

Species	*Sites from which species were isolated**
Acaulospora scrobiculata Trappe	9,13
A. spinosa Walker & Trappe	11,14,16
Gigaspora rosea Schenck & Smith	9,10,11
Gi. gigantea (Nicol. & Gerd.) Gerd. & Trappe	9,13,14
Glomus aggregatum Schenck & Smith	4,11
Gl. caledonicum (Nicol. & Gerd.) Gerd. & Trappe	5
Gl. etunicatum Becker & Gerd.	3, 4, 5, 6, 7, 9,11,12,14,17,19
Gl. geosporum (Nicol. & Gerd.) Walker	9,11,18, 20, 21
Gl. macrocarpum Tul. & Tul.	11,18
Gl. microaggregatum Koske, Gemma & Olexia	1, 8
Gl. mosseae (Nicol. & Gerd.)	15, 20, 21
Gl. lamellosum Dalpe, Koske & Tews	5,10,11
Glomus sp. B.	10,11
Scutellospora calospora (Nicol. & Gerd.) Walker & Sanders	1,11
S. dipapillosa (Walker & Koske) Walker & Sanders.	15

*Numbers indicate the site from Table 1 from which the fungi were collected.

complex seems to be a more important component of Rhode Island's flora. (These genera are combined on Table 4 since the separation of *Scutellospora* from *Gigaspora* occurred after most of these studies were reported). In the Rhode Island dunes, 44% of the collected species are of the genera *Gigaspora-Scutellospora* whereas in the dunes of Iowa and Wisconsin this figure is much lower (Table 3). The relative importance of *Acaulospora* also differs. In the Rhode island dunes, only one species, *A. scrobiculatum*, was obtained. In the midwestern soils of Iowa and Wisconsin, 20 to 25% of the species belonged to the genus *Acaulospora.* In addition, the genus *Glomus* appears to be more important in the midwestern soils than it is in Rhode Island dunes.

Discussion

For the most part, VAM fungi collected from Wisconsin resemble those collected elsewhere. Nevertheless, there are some exceptions. The azygospores of *Acaulospora spinosa* are small, but fall within the range of Walker and Trappe's (1981) description. The spores and suspensors of *Scutellospora calospora* are smaller than those reported by Gerdemann and Trappe (1974), but probably this is not enough of a difference to warrant a new species. The walls of *Gl. aggregatum* did not exhibit the greenish tint previously reported as sometimes present (Koske 1985). The chlamydospores of *Gl. caldeonicum* fall below the range of those of Gerdemann and Trappe (1974). The walls are thicker than

Table 3. The VAM fungi of Wisconsin's Great Lakes Dunes compared to those of other soils using a coefficient of similarity, *C*

	C
Wisconsin non-sandy soils	.84
Iowa soils (Walker et al. 1982)	.44
Rhode Island maritime dunes (Tews and Koske 1986)	.30
Illinois prairie soil (Anderson and Liberta 1989)	.25

Coefficient of similarity, *C* is calculated by using the fomula $C = 2W/a + b$, where w is the number of species common to both populations, a is the number of species in one population, and b is the the number of species in the other population.

Table 4. The relative importance of the VAM Genera collected from four different areas in terms of the percent of species of each genus

Site	*% Gig-Scut*	*% Acaulopora*	*% Glomus*	*% Sclero*
Wisconsin dune	23	21	57	0
Wisconsin non-dune	25	25	50	0
Rhode Island dune	44	11	44	0
Iowa soils	26	20	53	0
Illinois soils	33	0	50	17

those reported earlier, and they are sometimes tinged with a pale pink, which may be the result of a bacterial invasion carrying the pigment. Again, these differences are not important enough to warrant naming a new species.

The chlamydospores "*Gl. tortuosum*" are about twice the size of these of Schenck and Smith (1982). The spore wall is about three times thicker. They reported a single laminate wall; four were observed here. The width of the attachment is three times that reported by Schenck and Smith.

The higher plant flora of the lacustrine dunes of the Great Lakes are similar to those of the maritime dunes of New England, but their VAM fungal flora vary greatly. In a study of Moonstone Beach (Tews and Koske 1986), a barrier dune in Rhode Island, only two of the nine species isolated, *S. calospora* and *Gl. aggregatum*, were similar to those of the present study. Three species in the Moonstone study had a frequency of over 50%: *A. scrobiculata*, *Gi. gigantea*, and *S. persica*. None of these appears in the present study. The most commonly isolated fungi in the present study are *Gl. etunicatum*, *Gl. macrocarpum*, and *Gl. aggregatum;* only the latter was isolated from Moonstone Beach.

The fungal flora of Wisconsin's Great Lakes dunes are at least as similar to that of the disturbed stream and river bank soils of central Iowa (Walker et al. 1982) as they are to the dunes of Rhode Island. There were three species in common with the Iowa study: *A. spinosa*, *S. calospora*, and *Gl. geosporum*. Nevertheless, the higher plant flora of the Iowa study (*Fraxinus americana* L., *Bromus inermis* Leyss, and *Setaria* spp.) differed greatly from that of the Great Lakes dunes. Furthermore, at one site the soils were not sandy but were composed of silt-loam.

If the flora of Wisconsin sandy soils are compared to that of a sandy prairie of Illinois (Anderson and Liberta 1989), we find that there are three species in common: *Gl. geosporum*, *Gl. fasciculatum*, and *Gi. gigantea.* This prairie soil was dominated by little blue-stem grass (*Schizachyrium scoparium* [Michx.] Nash).

Acknowledgments

The authors wish to express their appreciation to Dr. Neil Harriman for his assistance in identifying the higher plants and to Ms. Jackie Bestler, Mr. Nathan Ihrcke, and Ms. Vicki Verbrick for their help in the laboratory.

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David J. Post

The plant communities of Nine-Mile Island – past and present

Abstract *Nine-Mile Island, in the Chippewa River, west-central Wisconsin, is currently under consideration for purchase as a natural area by the Wisconsin Department of Natural Resources. Logging and agricultural use would be limited while occasional controlled burning would be utilized in certain areas to maintain the prairies. Hunting and other public uses of the land for enjoyment would still be permitted. A description of the vegetation of Nine-Mile Island is presented. Land Office survey records from 1848–49 indicate at that time the island was about 35% floodplain forest, 25% oak openings, and 40% mesic forest. Settlement was limited to a single small farm. 1990 quadrat sample data were used to trace changes that occurred since that time. Little change was found to have occurred in the extent and composition of the forests, and the overall vegetation pattern now present appears to be similar to that found on the island in the 1800s. Size class distribution suggests little change in the composition of vegetation for the foreseeable future.*

Nine-Mile Island of the Chippewa River in west-central Wisconsin provided an opportunity to investigate the interactions between the vegetation and environmental factors in a relatively natural and undisturbed setting. Although human activities have exerted and continue to exert some influence on parts of the island, much of the original vegetation consisting of oak openings, oak forest, floodplain forest, and prairie is present at this time.

In 1991, the Wisconsin Department of Natural Resources (WDNR) acquired a 23.5 ha (63 acre) tract on the island, which is to be designated a natural area. This area is to be preserved intact as an example of lowland forest habitat. In addition, the WDNR has proposed the purchase of about 2145.75 ha (5300 acres), including the remainder of the island and some of the adjacent floodplain. This natural area will preserve the plant communities as well as bird and reptile species that are considered rare in Wisconsin.

In the establishment of a natural area it is important to determine "baseline" conditions and to integrate current data in describing the extent, distribution, and condition of existing vegetation types (Noss 1989). The purpose of this study was to describe the plant communities of the island and to identify environmental factors responsible for their presence. The original survey records of 1848–49 were used to reconstruct the vegetation of that era. The present vegetation was sampled using quadrats. Standard phytosociological analytical techniques were used to compare present community types with those of the past and to draw inferences about future compositional changes.

Study Site

Nine-Mile Island is located in the Chippewa River in southern Dunn and northern Pepin counties, Wisconsin. The island is located in sections 35 and 36 of Township 26 N and Range 13 W in Dunn County and sections 1, 2, and 3 of Township 25 N, Range 13 W in Pepin County (Fig. 1). It is about 56.5 km (35 mi) upstream from the Mississippi River, approximately 6.5 km (4 mi) north of the City of Durand, Wisconsin. The island is about 4.3 km (3 mi) long and 4.0 km ($2^1/_2$ mi) at the widest place, with a total area of about 1012 ha (2500 acres). The topography is basically flat with elevations ranging from 1.2 to 3 m (4 to 10 ft) above the normal level of the river. The channel is characterized by eroding banks of sand and gravel. The island is situated about 1.6 km (1 mi) below the confluence of the Chippewa and Red Cedar rivers and was formed by the presence of a back channel commonly referred to as Nine-Mile Slough. The back channel carries less water than the main channel and may be nearly dry when the river level is low, leaving much of the sand and gravel bed exposed. Changes have taken place in the river channel surrounding the island since about 1965. The meander on the southwestern part of the island was cut off, decreasing the size of the main island (Fig. 1). Also, the meander at the northeastern corner of the island was cut off at about the same time, causing another change in the configuration of the island. Figures depicting aspects of the island's vegetation prior to the changes in the river channel include the areas formerly considered a part of Nine-Mile Island.

Loose, river-deposited sand and gravel called "riverwash" occurs along the banks and shorelines (Fig. 1). The vegetation is sparse because the water level changes frequently and often floods the shoreline. At higher elevations the island is mostly sandy alluvial land with an isolated area of loamy alluvial land. The soils are nearly level sandy loams to silt loams and in places are nearly level and poorly drained with a silty clay-loam subsoil (USDA 1964, 1975). Frequent flooding occurs on the western one-third of the island where the average elevation is about 1.2 m (4 ft) above the normal level of the river. The normal level of the river was determined as the line of demarcation where terrestrial vegetation began (Peterson and Gamble 1968). Swamp hardwood vegetation and low land (below 4 ft above the normal level of the river) are prevalent on the western one-third of the island. The remainder of the island has an average eleva-

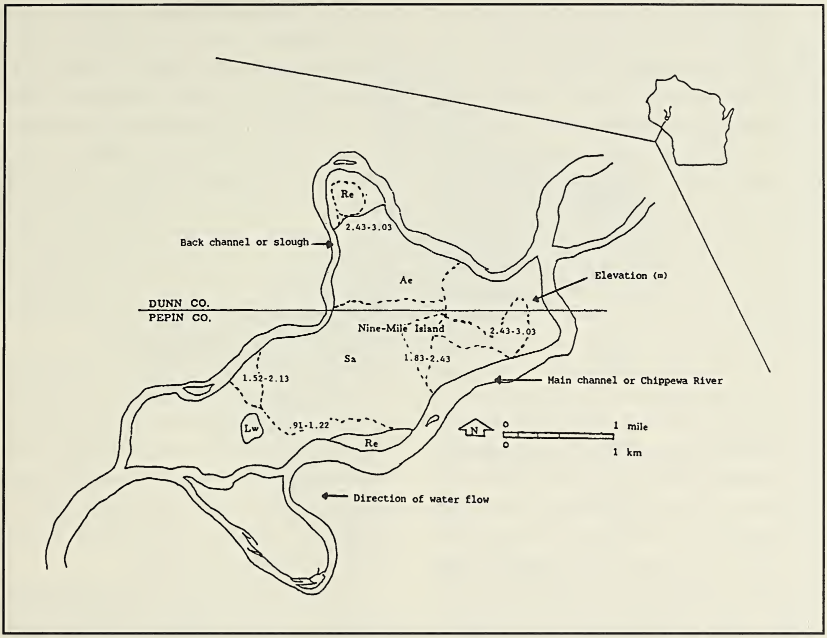

Fig. 1. Nine-Mile Island in its geographic setting on the Chippewa River, west-central Wisconsin. Soil types: Ae, alluvial land, sandy; Lw, loamy alluvial land, wet; Sa, sandy alluvial land; Re, riverwash. The dashed lines show elevation contours.

tion of about 1.8 to 3 m (6 to 10 ft) above the normal level of the river. Oak forests, scattered oak openings interspersed with remnants of prairie vegetation, and some mesic forest vegetation occur on these soils.

Flood frequency data for this region of the Chippewa River was obtained from an analysis that used a United States Geological Survey (USGS) method (USDA 1975). The mean annual flood is defined by the USGS as a flood having a recurrence interval of 2.33 years and occurring at an elevation of .9 m on this island. An elevation of 1.2 m can be expected to flood every five years; at 2.1 m, a flood can be expected every ten years. The entire island may be inundated once in about every 60 to 80 years. About 60% of the floods occur during the months of March and April (Barnes 1989).

History of Settlement

The original land survey of Nine-Mile Island and the surrounding area was conducted in 1848–49 prior to settlement. The surveyor described the island as level with second-rate sandy soils. The timber was described as black, white, bur, or red oak on the level and as maple, ash, elm, birch, aspen, and lind in the bottoms. Much of the vegetation was described as either timber, scattered timber, or simply as “bottoms.”

The first settlers came to the island during or soon after the original survey was completed. During the late 1840s and as late as the 1850s there was a small wood-cutting operation located on the central part of the island. It provided fuel for the steamboats that periodically traveled on the Chippewa River between the Mississippi River and Eau Claire. Although there is no record of extensive use of the land for crops, hay and grasses were raised for forage, especially during the depression years (1930s) when farmers used all available land. The hay was often hauled across the ice during the winter. Also, cattle grazed on the island in a fenced pasture that encompassed at least 202 ha (500 acres) during the depression and in the years following. Remnants of the old fence as well as old mowing machinery are still present. There are accounts of an old ferry measuring about 4 x 10 m, connected to the island by ropes and cables, that was in service as late as the 1940s. This ferry was used to transport a team and wagon to the island to haul hay or to transport livestock. The only dwelling presently on the island is an old hunting cabin. On the same site are the remnants of an old barn foundation purported to date back to the 1850s as part of a small farmstead. This small farm was apparently occupied until the 1940s and was used to raise crops (Hubbard 1991). Finally, sportsmen use the island today to hunt an evidently ample deer population and other small game.

Original Vegetation

Data from microfilm copies of the original field notebooks were used to determine the approximate distribution and composition of plant communities present at the time of the original survey. Corner points were established at .8 km (.5 mi) intervals where east-west and north-south transects intersected (corners). A post was driven into the ground at each corner, and the distance and bearing to the four nearest trees was recorded along with their common names and diameters. If no trees were nearby, the surveyors constructed a mound of earth as a corner reference and so recorded it (Barnes 1989). A chain was used to measure the distance between section corners; about 80 chains is equivalent to 1.7 km (1 mi). The distances to the trees nearest the corner point were recorded in links (0.66 ft in a link).

Areas in which the trees were calculated to be more than 15 m apart were mapped as oak openings (<65 m) or prairie (>65 m) (Curtis 1959), while the remaining areas were mapped as either bottomland hardwoods or mesic hardwood forest (Fig. 2). Survey data used were from twenty corners that lie on Nine-Mile Island.

Eighteen of the twenty corner points were ascertained by the original surveyors to have trees less than 15 m (45 ft) apart, indicating that the island was about 93% forested in 1848. Three basic community types were present on the island as interpreted from the surveyors records: floodplain forest, mesic hardwood forest, and oak openings within which some small prairie occurred.

Floodplain forest comprised what was then about 33% of the entire island. Silver maple (*Acer saccharinum*), basswood (*Tilia americana*), and green ash (*Fraxinus pennsylvanica*) were the most common species, each occurring in 50% of the corner points. Also abundant in the floodplain forest were American elm (*Ulmus americana*) and black willow (*Salix nigra*) (Table 1). Butternut (*Juglans cinerea*) was also recorded in parts of the floodplain forest.

Oak openings occupied about 20% of the island at the time of the 1848–49 survey. (This includes land area that is no longer

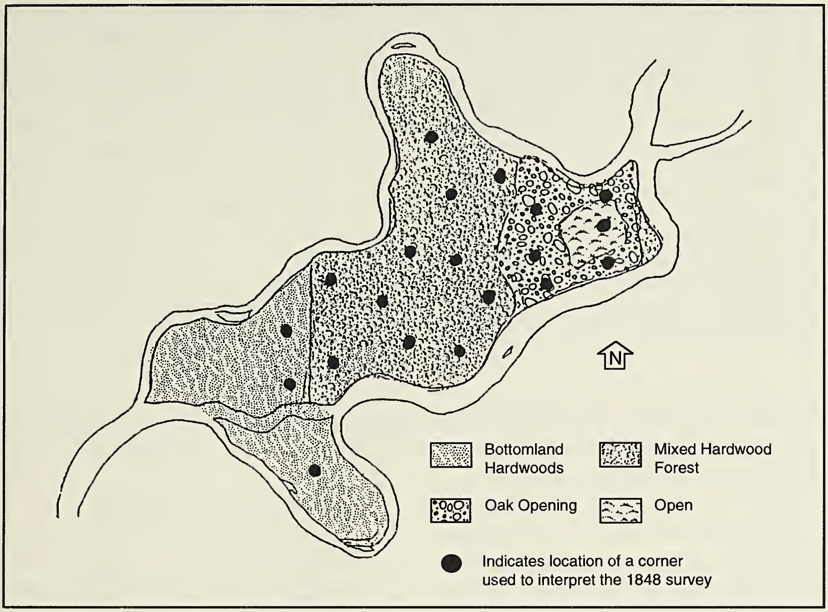

Fig. 2. The vegetation of Nine-Mile Island in 1848 as interpreted from the original survey records

part of the island proper.) "Black Oak," as listed in the survey records, was the most common species occurring in the oak opening community, being witnessed at 60% of the corner points. This may have been red oak (*Quercus borealis*) or Hill's oak (*Quercus ellipsoidalis*). White Oak (most likely *Quercus alba*) was also common here, occurring at 40% of the corner points. Other species present in the oak openings were American elm, hackberry (*Celtis occidentalis*), *Populus* sp., and river birch (*Betula nigra*) (Table 2). At one point along a line in this area of the island (between sections one and two in Pepin County) the surveyor recorded "entering prairie" but did not list prairie plant species. It may be possible to make an inference about the species that occurred in this area from Buss's (1956) study on the nearby Meridean prairie. He found that the most abundant plants occurring on undisturbed sites were big bluestem (*Andropogon gerardi*), spiderwort (*Tradescantia ohiensis*), and flowering spurge (*Euphorbia corollata*). Little bluestem (*Andropogon scoparius*), indian grass (*Sorghastrum nutans*), and purple prairie clover (*Petalostemum purpureum*) are species that Buss listed as being scattered.

A "mesic hardwood" forest, as inferred from the survey records, comprised about 45–50% of what remains the main part of the island. Here, the number of individuals of each species was more equal, although

Table 1. Frequency (%F), average diameter ($\bar{x}$dbh), and relative density (%RD)* of trees of the Floodplain Forest at the time of the original land survey (1848–1849) (5 corners, 12 trees)

Species	*%F*	*$\bar{x}$dbh (cm)*	*%RD*
Juglans cinerea	25	22.5	16
Acer saccharinum	50	25	33
Salix nigra	25	22.5	8
Tilia americana	50	25	10
Ulmus americana	25	45	12
Fraxinus pennsylvanica	50	22.5	20

*Relative Density (%RD) = % of total of all trees.

Table 2. Frequency (%F), average diameter ($\bar{x}$dbh), and relative density (%RD) of trees of the Oak Openings at the time of the original land survey (1848–1849) (6 corners, 11 trees)

Species	*%F*	*$\bar{x}$dbh (cm)*	*%RD*
Betula nigra	20	30	12.2
Populus sp.	20	27.5	12.2
Celtis occidentalis	20	30	8.3
Ulmus americana	40	32.5	18.2
Quercus alba	40	30	18
Quercus borealis	60	35	31.1

Table 3. Frequency (%F), average diameter ($\bar{x}$dbh), and relative density (%RD) of trees of the Mesic Hardwood Forest at the time of the original land survey (1848–1849) (9 corners, 12 trees)

Species	*%F*	*$\bar{x}$dbh (cm)*	*%RD*
Tilia americana	44.4	25	33
Acer saccharinum	33.3	45	16.6
Fraxinus pennsylvanica	11.1	22.5	8.3
Quercus macrocarpa	11.1	30	8.3
Ulmus americana	33.3	25	16.6
Quercus alba	11.1	22.5	8.3
Celtis occidentalis	22.2	27.5	8.3

basswood, typically listed as "lind," was the most abundant at 44.4% of the corner points. Other species that occurred frequently in the mesic hardwood forest were American elm at 33.3% of the corner points, maple (presumably silver maple) at 33.3% of the corners, and hackberry at 22% of the corners. In addition, some green ash, white oak, and bur oak (*Quercus macrocarpa*) were witnessed (Table 3).

The land throughout the island was described in the survey records as "surface level" with "second rate" soils. The vegetation pattern coincided with the present description in most respects except that there seemed to be less open land around the oak openings in 1848.

Present Vegetation

The vegetation was sampled during the autumn of 1990 using 1/100 ha (1/40 acre) circular quadrats to sample trees and 1/40 ha (1/1/00 acre) circular quadrats to sample herbaceous vegetation. One hundred seventy (1/100 ha) quadrats were placed along north-south transects established by a compass bearing at .32 km (.2 mi) intervals along the entire width of the island. Adjacent transects were spaced .32 km apart, so that the entire island was divided into a nearly regular grid pattern of quadrats. Tree diameters greater than 10 cm (4 in) at diameter breast height (dbh) were recorded using a diametric caliper, and sapling species were recorded as present or absent. Herbaceous species were also recorded as present or absent within the quadrats. Soil samples were collected at every tenth quadrat beginning with the fifth and continuing throughout the entire island. A consistent practice of collecting a sample of the top six inches of soil, after removing the leaves and other duff, was followed. The soil samples were analyzed for percentages of water-retaining capacity, sand, and organic matter. Elevation above the normal water level was estimated using a level and stadia rod.

Simpson's Diversity Index was used to calculate the degree of species diversity within each community. This index assigns a value between zero and one to a community; the closer the number is to one, the higher the diversity. A definition of biological diversity is "the variety and variability among living organisms and the ecological complexes in which they occur" (Noss 1989).

A two-dimensional polar ordination was performed using the importance values of the tree species to determine the difference in composition between the communities. The degree of compositional dissimilarity between each of the community pairs was determined using the 1 - (2w/a + b) index. Beal's (1960) geometric method was used to position the five communities in the plane defined by the first two axes.

A histogram was constructed for the major species in each community type to reveal their distribution of size classes. Trees were divided into size classes ranging from 10 cm (4 in) dbh to 30 cm (12 in) dbh.

A relative peak value method was used to infer possible successional changes in the mesic forest and floodplain forest. Succession may be defined as the replacement of some species by others through time. The end result of succession is a community in which the member species perpetuate themselves through reproduction, are in a dynamic balance with one another, and are in equilibrium with the prevailing environmental conditions (Buckholz and Pickering 1978). This technique plots the relative number of stems of all important species in a community against relative size classes. Using relative numbers removes the effect of numerous species having higher peaks. Using relative size classes (i.e., each size class is expressed as a percentage of the largest size class for the species) reduces the risk of misinterpretation because different species attain different maximum heights. The resultant line graphs show the peak number of a given species in each size class. The position of a peak number for a species relative to other species allows inferences to be made about possible successional trends in a stand. Young species will peak on the left side of the graph while older species will peak on the right side of the graph. A species with a peak value on the right side of the graph in a large size class is likely to be eventually replaced by a species with a peak value closer to the left side of the graph in a smaller size class.

Community Descriptions

Five community types were identified on the island: two oak openings, an oak forest, a mesic forest, and a floodplain forest (Fig. 3). Hill's oak and red cedar (*Juniperus virginiana*) were the most abundant trees of the seven species in Oak Opening I, which occurs at an average elevation of about 2.7 m (8 ft) above the normal level of the river (Table 4). This community occurs on sandy soil on the eastern end of the island and is mostly inland. White oak was also prevalent in this community, and basswood and green ash were the most common associates of the oak species. This oak opening had a density of 83.5 trees/ha, a compositional index of 397, and a Simpson's Diversity Index of .827. Silver maple and American elm trees and saplings were common, but were restricted to the low areas closer to the river. Green ash and basswood saplings were common throughout the area. In Oak Opening I, white oak was present primarily in the 25 to 30 cm (12 to 13 in) size range (Fig. 4). There were no small individuals and few saplings of white oak; most of the saplings and small trees were basswood and green ash, suggesting a change in future dominance and possibly a change from oak opening to forest. Fire was responsible for maintaining the oak openings in Wisconsin (Curtis 1959) and may be necessary to maintain this community type on Nine-Mile Island.

Table 4. Frequency (%F), mean diameter ($\bar{x}$dbh), relative density (%RD), and importance values (IV)* of trees in Oak Opening I (26 quadrats, 22 trees)

Species	*%F*	*$\bar{x}$dbh (cm)*	*%Rd*	*IV**	*Sampling Frequency (%)*
Juniperus virginiana	19.2	23.8	9.1	12.5	25
Quercus ellipsoidalis	15.4	62.5	4.6	15.2	35
Tilia americana	15.4	14.4	36.4	21.7	65
Quercus alba	11.5	36.7	13.6	17.2	40
Fraxinus pennsylvanica	11.5	28.8	18.2	18.3	65
Acer saccharinum	7.7	21.3	9.1	7.3	45
Ulmus americana	7.6	17.5	9.1	7.3	30

*Importance value (IV) is the number assigned to a tree species in a stand relative to other trees in that stand. It is an average of the relative density (how many trees are present), the relative dominance (size of the trees present), and the relative frequency (how often a tree occurs).

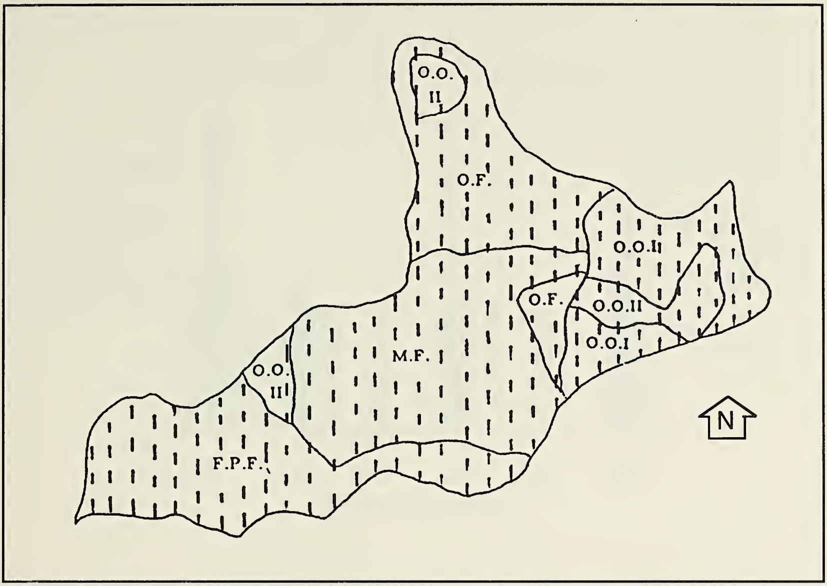

Fig. 3. The present vegetation of Nine-Mile Island as interpreted from sampling with quadrats and aerial photographs (Oak Opening I, O.O.I.; Oak Opening II, O.O.II.; Oak Forest, O.F.; Mesic Forest, M.F.; Floodplain Forest, F.P.F.). The dashed lines indicate north-south transects along which 1/40 acre circular quadrats were established at .32 km (.2 mi) intervals.

Shrubs present included prickly ash (*Zanthoxylum americanum*), prickly gooseberry (*Ribes Cynosbati*), and grey dogwood (*Cornus racemosa*), while staghorn sumac (*Rhus typhina*) was abundant in the open areas. Both big bluestem and little bluestem dominated in the oak openings along with abundant prairie smoke (*Geum riflorum*) and individuals of several species of goldenrod (*Solidago* spp).

Red oak, swamp white oak (*Quercus bicolor*), Hill's oak, and American elm were the most abundant of the eight species of trees in Oak Opening II (Table 5). This community is also located on the eastern end of the island and occurs at an average elevation of 2.4 m (8 ft) above the normal level of the river on sandy and poorly drained soils. White oak was also abundant in this community, and hackberry and green ash were common associates of the oak species. This community had an estimated density of 180 trees/ha, a compositional index of 506, and a Simpson's Diversity Index of .895. Green ash and hackberry saplings were relatively common as were pin oak (*Quercus ellipsoidalis*) and white oak saplings. The comparative size class distribution indicates a stable population of the dominant species with an abundance of red and white oak saplings as well as older, mature trees (Fig. 5). Prickly ash, grey dogwood, and staghorn

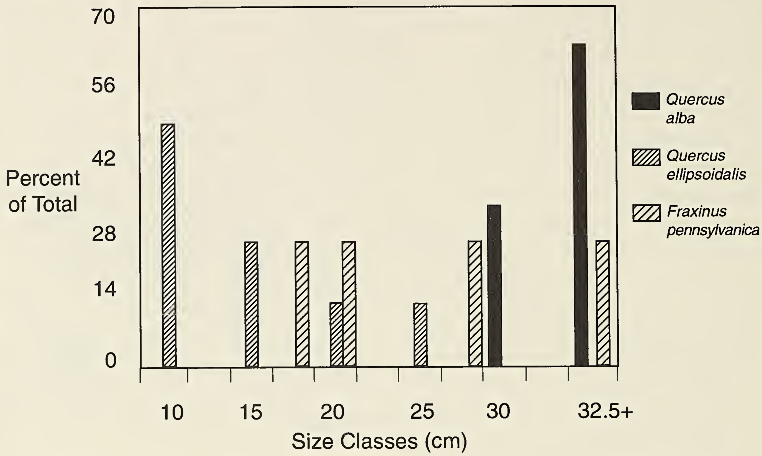

Fig. 4. Size class distribution of three important tree species in Oak Opening I

sumac shrubs were abundant in the open areas. Big bluestem, little bluestem, and rye grass (*Elymus canadensis*) were prevalent in this community along with abundant individuals of goldenrod. The two oak openings were distinguished by dominant oak species. Pin oak was dominant in the first oak opening while red oak and swamp white oak were dominant in Oak Opening II.

White oak was the largest and most abundant of the fourteen species of trees in the oak forest (Table 6). This community occurs toward the east-central part of the island at an average elevation of about 2.4 m (7.9 ft) above the normal level of the river, somewhat lower than the elevation of the oak openings. Red oak was also abundant, and to a lesser extent bur oak and Hill's oak were also present.

Yellowbud hickory (*Carya cordiformis*) and green ash were the most common associates of the oak species. The oak forest had an estimated density of 421 trees/ha, a compositional index of 543, and a Simpson's Diversity Index of .826. Hackberry, basswood, and black cherry (*Prunus serotina*) were abundant, although black cherry was found most often as a sapling. There were scattered individuals of large, older white pines near the north end of the island, and American elm, red cedar, and silver maple were common. A few individuals of sugar maple (*Acer saccharum*) were also found in the oak forest at the lower elevations. Yellow bud hickory saplings were abundant, and hackberry, cherry, and basswood saplings were also common. Red oak was the most common of the oak saplings present

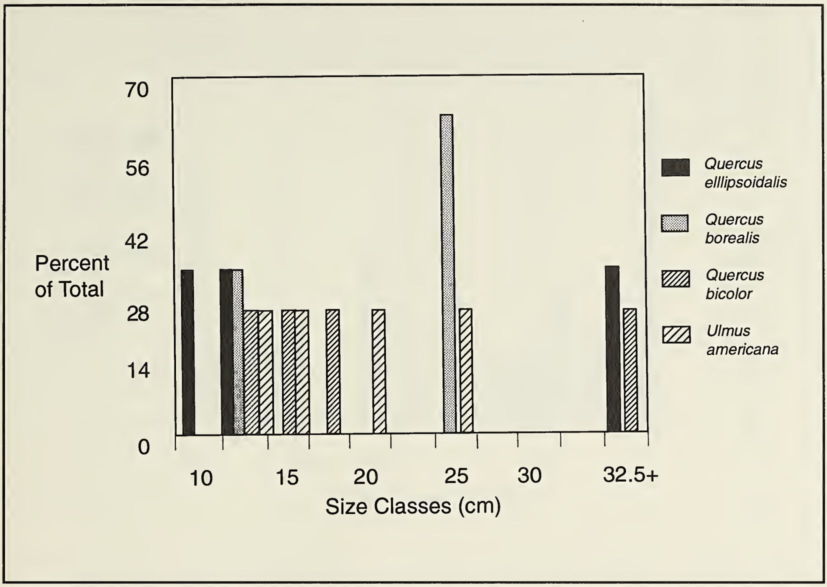

Fig. 5. Size class distribution of four important tree species in Oak Opening II

with fewer white oak and bur oak saplings. The comparative size distribution suggests continuation of the oak forest, but as shown by the numbers of young trees present, it appears that red oak may continue to dominate in the future (Fig. 6), and white oak and basswood populations appear stable. Prickly ash, prickly gooseberry, grey dogwood, and red osier dogwood (*Cornus stolonifera*) were common shrubs in the understory. Staghorn sumac was also present, although less abundant than in the oak openings. Rye grass and bottlebrush grass (*Hystrix patula*) as well as woodland nettle (*Laportea canadensis*), *Aster* sp., and wild geranium (*Geranium maculatum*) were abundant throughout the oak forests.

Hackberry and green ash were the largest and two of the most abundant of the fifteen species of trees in the mesic forest and had as close associates basswood (the most abundant tree species) and yellowbud hickory (Table 7). Curtis (1959) described basswood and red oak as dominant species of mesic forests. This community occurs over much of the central part of the island at an elevation of 1.5 to 2.1 m (4.9 to 6.5 ft) above the normal level of the river. There are some places where the land is low and contains marshes. The soil is sandy loam, with an isolated patch of silty loam, and has a high percentage of organic matter and a relatively high water-retaining capacity. This community had an estimated density of 338 trees/ha, a compositional index of 659, and a Simpson's Diversity Index of .828. American elm and white oak were also common. Hop hornbeam (*Ostrya virginiana*) occasion-

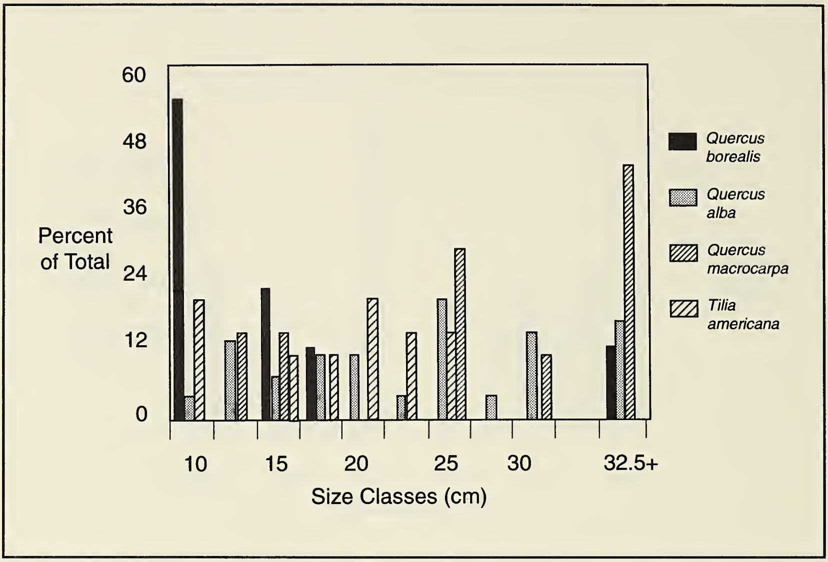

Fig. 6. Size class distribution of four important tree species in the Oak Forest

Table 5. Frequency (%F), mean diameter (x̄dbh), relative density (%RD), and importance values (IV) of trees in Oak Opening II (11 quadrats, 20 trees)

Species	*%F*	*x̄dbh (cm)*	*%RD*	*IV*	*Sapling Frequency (%)*
Quercus alba	45.5	21.3	10	14.8	54
Quercus bicolor	36.4	20.0	20	20.4	30
Quercus ellipsoidalis	36.4	20.0	15	17.8	60
Ulmus americana	18.2	18.1	20	15.3	25
Quercus borealis	18.2	20.8	15	13.7	50
Fraxinus pennsylvanica	18.2	22.5	5	6.8	60
Celtis occidentalis	9.1	16.3	10	7.3	60
Juniperus virginiana	9.1	12.5	5	3.9	20

Table 6. Frequency (%F), mean diameter ($\bar{x}$dbh), relative density (%RD), and importance values (IV) of trees in the Oak Forest (20 quadrats, 81 trees)

Species	*%F*	*$\bar{x}$dbh (cm)*	*%RD*	*IV*	*Sapling Frequency (%)*
Quercus alba	78.9	25.5	37.1	32.1	35
Carya cordiformis	42.1	12.5	1.2	4.5	75
Fraxinus pennsylvanica	36.8	29.5	6.2	8.3	50
Quercus borealis	31.6	14.7	11.1	8.2	45
Celtis occidentalis	31.6	32.5	3.7	6.3	60
Prunus serotina	21.1	13.7	2.5	3.1	55
Tilia americana	21.1	19.8	12.4	8.6	60
Quercus macrocarpa	15.8	30.4	8.6	8.9	30
Juniperus virginiana	15.8	16.3	4.9	3.8	50
Acer saccharinum	15.8	37.5	2.5	4.3	45
Quercus ellipsoidalis	10.5	27.5	4.9	4.7	60
Ulmus americana	10.5	17.5	1.2	1.6	55
Acer saccharum	10.5	12.5	1.2	1.5	60
Pinus strobus	5.3	48.8	2.5	4.2	30

Table 7. Frequency (%F), mean diameter ($\bar{x}$dbh), relative density (%RD), and importance values (IV) of trees in the Mesic Forest (83 quadrats, 284 trees)

Species	*%F*	*$\bar{x}$dbh (cm)*	*%RD*	*IV*	*Sapling Frequency (%)*
Celtis occidentalis	51.8	20.8	18.3	17.6	70
Fraxinus pennsylvanica	43.4	23.8	19.7	18.4	50
Carya cordiformis	40.9	12.1	8.8	9.2	90
Tilia americana	36.1	26.8	28.9	26.3	65
Ulmus americana	20.5	19.8	7.8	7.0	30
Quercus alba	16.9	27.9	5.6	6.6	30
Acer saccharinum	10.8	41.7	3.2	5.6	25
Ostrya virginiana	8.4	20.0	2.5	2.6	30
Quercus borealis	7.2	35.6	1.4	2.4	20
Quercus ellipsoidalis	2.4	24.2	1.1	1.0	25
Quercus macrocarpa	2.4	42.5	.7	1.2	25
Carpinus caroliniana	1.2	46.3	.7	1.1	—
Prunus serotina	1.2	13.8	.7	.5	30
Ulmus thomasi	1.2	12.5	.4	.3	10
Ulmus rubra	1.2	10.0	.4	.3	15

ally occurred as saplings or small trees, and silver maple was often found in low lying areas. Yellowbud hickory saplings occurred in almost every quadrat, while hackberry and basswood saplings were also common. In the mesic forest, it appears that green ash and basswood may replace silver maple (Fig. 7). Also, white oak is an important species, and while some of the older trees may be replaced, there are many white oak saplings present to suggest that white oak will remain an important species. Shrubs included prickly ash, prickly gooseberry, red and grey dogwood, and an occasional thornapple (*Crataegus* sp.). Blackberry (*Rubus allegheniensis*), raspberry (*Rubus* sp.), and the vining and climbing species virginia creeper (*Parthenocissus quinquefolia*) and grape (*Vitis riparia*) were abundant in the forested areas. Rye grasses were also common in the less shaded areas of the mesic forest.

Silver maple was the largest and most abundant of the nine species of trees in the floodplain forest (Table 8). Its major associates were green ash and American elm. Basswood was often abundant on higher ground while clumps of river birch were found in the lowest areas. Silver maple, American elm, or ash are often dominant in floodplain forests in Wisconsin (Curtis 1959).

The floodplain forest occurs primarily on the western end of the island with an isolated patch in the central part. The average elevation is from .9–1.2 m (2.9–3.9 ft) above the normal level of the river, which makes this community prone to frequent flooding. The soil is silty, poorly drained, and some-

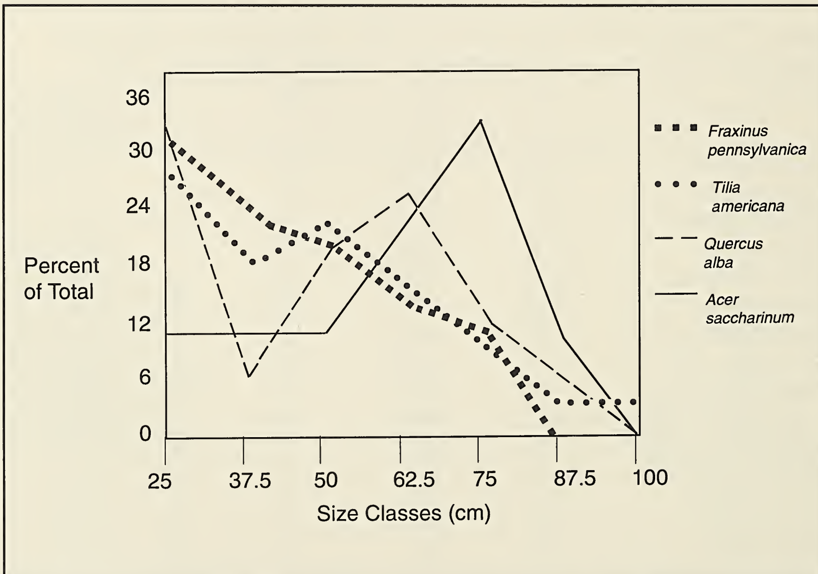

Fig. 7. Relative peak values of four important species of the Mesic Forest

what lower in organic matter than the mesic forest. These soils are higher in water-retaining capacity than the soils of other community types on the island. The floodplain forest had a lower number of tree species than the mesic forest and had an estimated density of 325 trees/ha, a compositional index of 507, and the lowest Simpson's Diversity Index of .712. It had a high estimated basal area per ha of 47,267 cm^3 because of the many large, apparently older trees. Hackberry and slippery elm (*Ulmus rubra*) were common, and occasional, mature individuals of bur oak were also present. Hackberry and basswood saplings occurred in almost every quadrat, while green ash and American elm saplings were also common.

In the floodplain forest, it appears that green ash may eventually be replaced by American elm, although that seems unlikely because of Dutch elm disease, and some of the large, older silver maples may be replaced by green ash (Fig. 8). Prickly ash was present throughout the area, although generally the floodplain forest was more open and had few shrubs. Rye grass was abundant in less shaded areas, and virginia creeper, wild yam (*Dioscorea villosa*), and grape were common vines.

Community-Environment Relations

The result of the ordination shows the distribution of the communities in a two-dimensional space (Fig. 9). The distance between the positions of communities along the x-y axes represents the degree of compositional difference between them. The five

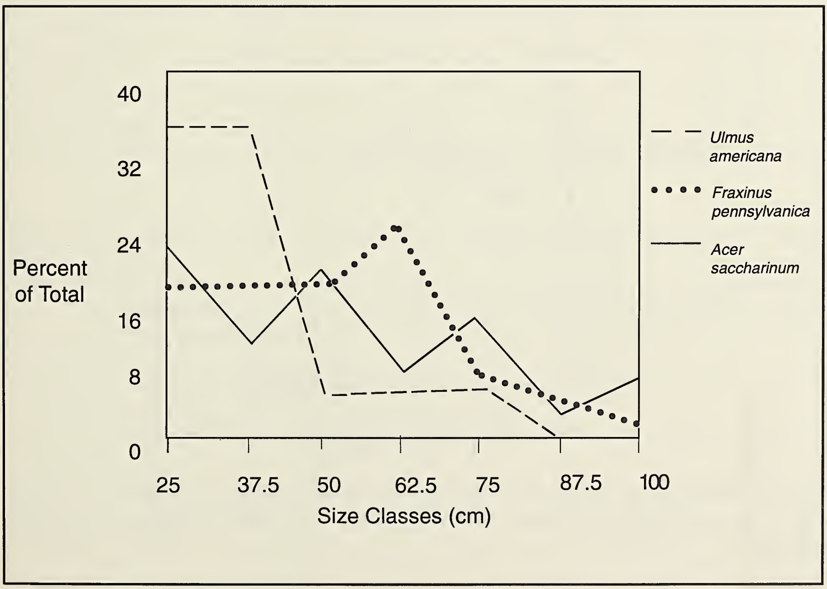

Fig. 8. Relative peak values of three important species of the Floodplain Forest

communities form two distinct groups, the oak openings and oak forest in one group and the mesic forest and floodplain forest in a second. The grouping appears to be related to several environmental factors. The oak openings and oak forest occur at the higher elevation where there is a lower water-retaining capacity and higher sand content, while the mesic forest and floodplain forest occur at the lower elevation where there is a high water-retaining capacity and lower sand content.

The communities at higher elevations have lower water-retaining capacities because of higher percent sand and lower organic matter content, while the mesic forest and floodplain forest at lower elevations have higher water-retaining capacities because of higher organic matter content and lower percent sand. The evident interrelationships between the environmental factors are shown in Table 9. The percentage of sand is positively correlated to elevation, and there is also a strong positive correlation between percent of organic matter and water-retaining capacity (Table 10). Elevation and percent organic matter do not appear to be correlated, while there is a negative correlation between increasing elevation and water-retaining capacity. It should be noted that there were only five sets of data, and with the resultant low number of degrees of freedom, none of the values obtained were found to be statistically significant above a 90% level of confidence.

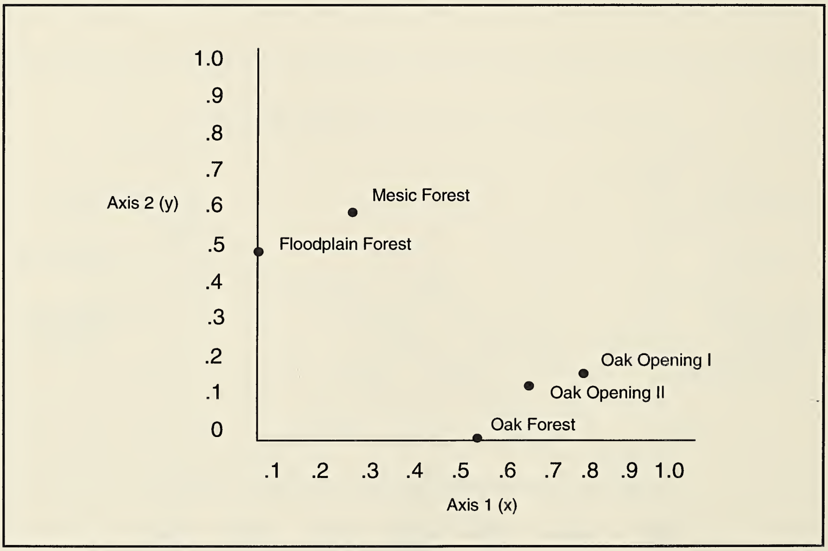

Fig. 9. A two-dimensional polar ordination of the five communities by importance values

Table 8. Frequency (%F), mean diameter ($\bar{x}$dbh), relative density (%RD), and importance values (IV) of trees in the Floodplain Forest (31 quadrats, 102 trees)

Species	*%F*	*$\bar{x}$dbh (cm)*	*%RD*	*IV*	*Sapling Frequency (%)*
Acer saccharinum	58.1	35.3	45.1	45.8	60
Fraxinus pennsylvanica	41.9	27.2	24.5	21.6	65
Ulmus americana	32.3	17.9	16.7	13.2	60
Celtis occidentalis	22.6	18.3	2.9	5.4	95
Tilia americana	9.7	33.3	2.9	3.7	95
Betula nigra	9.7	25.8	2.9	3.4	15
Quercus macrocarpa	6.4	47.5	1.9	3.3	25
Ulmus rubra	3.2	33.8	1.9	1.9	20
Populus deltoides	3.2	55.0	1.0	1.8	—

Table 9. Soil water-retaining capacity (% WRC), sand (% S), organic matter (% OM) and elevation (m) of each of the five communities (18 samples)

Community	*% WRC*	*% S*	*% OM*	*Elevation (m)*
Oak opening I	96.21	72.44	12.49	2.43–3.03
Oak opening II	103.61	80.0	18.66	2.43–3.03
Oak Forest	119.7	66.7	12.0	1.83–2.43
Mesic Forest	141.11	67.8	34.67	1.52–2.13
Floodplain Forest	160.03	63.42	30.80	.91–1.22

Table 10. Correlation coefficient values (r) for physical environmental factors examined in the study

	Elevation	% Sand	% WRC	% Organic matter
Elevation	1.0	.56	-.79	-6.4
% Sand	.56	1.0	-.78	-.69
% WRC	-.79	-.78	1.0	.65
% organic matter	-.0064	-.69	.65	1.0

Discussion

The original survey records indicate that the island was about 93% forested prior to settlement (Fig. 10). About 30% of the area was floodplain forest, 50% was mesic hardwood forest, and 20% was oak openings.

Early settlement and the limited use of the island for agriculture had little apparent impact on the forests. Human activities were limited to a small woodcutting operation on the central part of the island and use of the open prairie area for agriculture. There was a small farmstead on the eastern end of the island in the oak opening/prairie area on which crops were raised. This farm dated back to the late 1800s and was in use until the 1940s according to a personal account (Hubbard, pers. comm., 1991). Hay and grasses were raised for forage in the open areas, especially during the depression years and early 1940s. No other evidence suggests use of the open areas for crops although cattle grazed in a fenced pasture of about 202 ha (500 acres) on the prairie. Remnants of the old fence are still visible. Pasturing may account for what seems to be an increase in the extent of the oak openings/prairie area since the 1940s.

The present composition of the forests is similar to that of 1848. The same overall configuration of plant community types was observed on the island in the autumn of 1990 as were described in the original land survey records. The only change is that there appears to be more open land occupied by prairie vegetation. This may be a result of the use of the land for pasture or simply the lack of precision when working with the 1848–49 data.

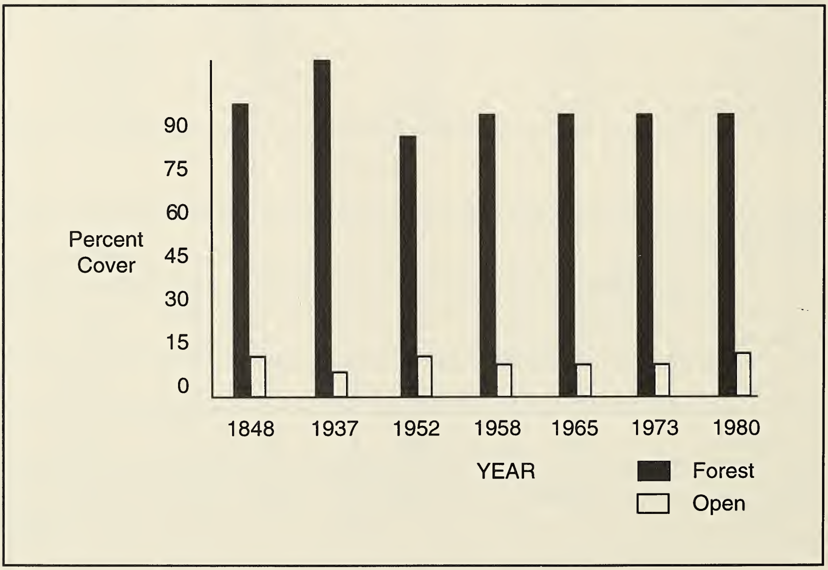

Fig. 10. Changes in vegetation cover from 1848 to 1980

Elevation appears to be the major influence on the development of plant community types on this island as it is related to flooding frequency and to soil texture as well as to organic matter content and water-retaining capacity of the soil. Major changes in the topography of the island are not likely to occur; thus, significant changes in the vegetation are unlikely in the future. Also, a high frequency of saplings and small trees of the most abundant species in the oak openings and oak forest suggests little probable change in their tree composition in the foreseeable future. In the mesic forest and floodplain forest relative peak value summaries of the dominant species suggest that there may be some successional changes. However, such changes are likely to be small and gradual and not have a pronounced effect on the overall type and extent of these forests.

There is a note of urgency to the WDNR's current process of acquiring the island as a State Natural Area. Parts of the original floodplain forest remain threatened by logging operations. In the past decade about 202 ha (500 acres) of floodplain forest timber currently owned by the Schlosser Lumber Company have been either select-cut or clear-cut, removing about 40–60% of the canopy cover (Epstein, pers. comm., 1990).

Most studies of vegetation history in Wisconsin have examined upland areas and have reported drastic changes in the vegetation as a result of man's activities (Gleason 1913; Curtis 1959; Stroessner and Habeck 1966; Barnes 1974). However, extensive changes in the nature of the vegetation of Nine-Mile Island have not occurred. The only effect of human impact in the past has been in the form of minor woodcutting for fuel (with available equipment, it is probable that only trees 20 cm dbh or smaller were harvested), pasture for dairy cattle in the open areas of the island, and crops raised on a small farm in the same area. Only the barn foundation of the old farmstead remains. The only human habitation on the entire island is a hunting cabin on the site of the old farmstead. Isolation on this island with its low elevation and undeveloped soil types have maintained these communities in their original state. Nine-Mile Island is a unique ecological resource containing rare plant and animal species and is a good example of a lowland forest habitat which should be preserved in its nearly pristine state for the enrichment of future generations.

Acknowledgments

I wish to thank James A. Reinartz, Resident Biologist and Manager of the University of Wisconsin–Milwaukee Field Station in Saukville, who reviewed the manuscript and offered valuable advice for its improvement. I also wish to thank Dr. William J. Barnes, Ecologist and Professor of Biology at the University of Wisconsin–Eau Claire, who provided technical assistance, comments, and suggestions for revision of the manuscript.

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Keith T. Weber

Analysis of black bear habitat in northeastern Wisconsin

Abstract *A study was performed in northeastern Wisconsin from June through December 1991 to analyze the regional habitat and density of black bear* (Ursus americanus). *Previously reported habitat requirements of the black bear were used to establish areas that might be successfully exploited by bears within a proposed 259.2 km² (100 mi²) study site. The field study area contained moderate to good black bear habitat estimated to carry a bear population density of one bear/6.1 km² based on roadside counts.*

Black bear (*Ursus americanus*) research by the Wisconsin Department of Natural Resources (WDNR) and the University of Wisconsin–Stevens Point has focused recently in the north-central and northwestern portion of the state (Kohn 1982; Anderson, pers. comm.). My study in northeastern Wisconsin was initiated to determine the present population of black bear and to assess habitat quality. The results of this study will aid in the understanding and management of the bear.

The study began on 1 June 1991 and terminated on 2 December 1991. Known black bear habitats with varying population densities from around the United States and Canada revealed several key features, including soil characteristics, forest type and age of stand, altitude, and the effects of timber harvest, agricultural activity, hunting pressure, human population density, and the road-to-forest ratio. Generally, black bears require habitat containing a soft-mast food source (e.g., berries) and a hard-mast food source (e.g., nuts and acorns) (Rogers and Allen 1987) accompanied by forested cover (Unsworth et

Table 1. Comparison of various black bear population studies

State	Forest Composition	Human Density (per km²)	Bear Density (1/X km²)	Reference
California	Pine and fir	0.93	1/1.3	Piekielek and Burton 1975
Idaho	Shrub and pine	0.95	1/1.3	Beecham 1983
Minnesota	76% aspen, 24% spruce	8.30	1/5.2	Rogers 1987
New York	Unavailable	29.10	1/17.1	McCaffrey et al. 1974
Wisconsin	N central, 90% forested	5.47	1/3.9	Kohn 1982
Wisconsin	NE, 87% upland, 7% lowland	11.00	1/6.1	(this study)

Human population density figures were taken from the U.S. Census Bureau reports and reflect the population at the time of the bear study. Bear densities are the mean of the estimated population range given in the study (e.g., a study performed by Rogers [1987] reported a black bear density of one bear/ 4.1–6.3 km². The value used above was the mean of 4.1 + 6.3 [$\bar{x}$=5.2]).

al. 1989). Bear populations range from one bear/1.3 km² in California (Piekielek and Burton 1975) to one bear/17.1 km² in New York (McCaffrey et al. 1974) (Table 1).

My research was conducted to (1) determine the population of black bear in a local study of northeast Wisconsin, (2) assess habitat quality, and (3) compare the study site with the findings from other black bear studies.

Study Area

Field work was conducted in a 259 km² (100 mi²) region in northeast Wisconsin, located in the southwest corner of Marinette County. Throughout this paper the study site will be called the Marinette County Study Area (MCSA) (Fig. 1). Elevation ranges from 412 m (1350 ft) above sea level to 229 m (750 ft), with the mean elevation extending from 274–305 m (900–1000 ft). Soils in this region are primarily sand, with the Menagha association (70%) and the Mancelona-Emmet Menagha associations (15%) being most prevalent. Seven percent of the region is a Seelyville Markey association with 2.5% each of the Sarona-Keweenaw and Ishpeming-Michigamee associations. The majority of these soils were created from glacial outwash and till (87.5%) (Lorenz 1991). The remaining 3% of soils is flooded by the High Falls reservoir and Thunder Lake. Several streams, small lakes, and ponds are not mentioned or included in the above data.

The rock outcroppings in the Ishpeming-Michigamee soil association can provide good den sites for the black bear (Lorenz and Thrall 1991), but bear usage of these rock outcroppings, while not common, is more typical of pregnant sows than boars (Jackson 1961; Fair 1990). Much of this area is wooded, providing the black bear with forage, the bulk of which can be found on well-drained uplands containing oak, hazelnut, and berries (*Quercus* spp., *Corylus* spp., and *Rubus* spp., respectively). The MCSA consists of 90% well-drained soils, of which 87% is forested uplands (*Populus* spp., *Pinus* spp., and *Quercus* spp.), 7% is lowlands (*Fraxinus nigra, Acer rubrum, Thuja occidentalis,* and *Picea mariana*), and 3% is rock outcroppings (Couvillion 1990) (Figs. 2 and 3).

Forest composition in the MCSA is similar to that published for the property within the MCSA owned by the regional utility company, Wisconsin Public Service Corporation (WPSC). The WPSC property adja-

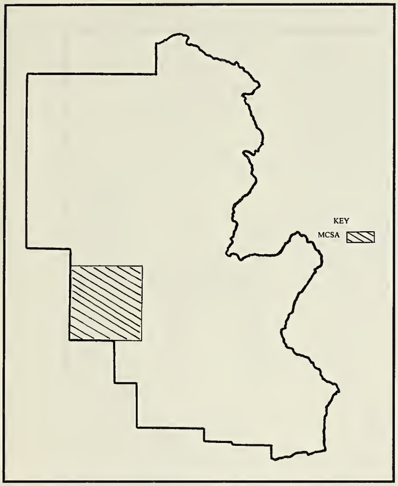


Fig. 1. The location of the Marinette County Study Area (MCSA) in northeast Wisconsin

cent to the High Falls reservoir is composed of 86.8% uplands and 6.7% lowlands; the balance is unforested (WPSC 1991). The MCSA exhibits homogeneity in soil features and forest composition.

Privately owned land accounts for 65% of the study area. Public land comprises 25% while the remaining 10% belongs to WPSC (Land Atlas and Plat Book 1985). Forest inventory maps were made available by the WDNR and WPSC for all public and utility land, respectively. Forest composition of the entire MCSA was approximated by correlating forest inventory maps with the Marinette County soils maps and topographic maps.

Agricultural land comprises 19% of the county (Decker, pers. comm.). A few large tracts of forest exist, but forest edge is extensive in the region because of substantial logging. Studies performed in Idaho suggest that black bears prefer 20–40-year-old stands of timber that have not been previously clear cut. Unsworth et al. (1989) and Fair (1990) found that bears tend to avoid those areas that have sustained a clear cut of 20 or more acres. The age of the stand was considered when evaluating habitat quality.

The use of sanitary landfills by bears has been noted in other papers (Kohn 1982; Rogers 1987), but such areas are absent in the MCSA. An intensive study zone of 30.72 km^2 (12.0 mi^2) was established within the MCSA to provide a better perspective of the study area. The intensive study zone is delineated in Figures 2 and 3. The majority of field research was conducted on public land. Nevertheless, I shall assume that the results found in the intensive study zone are applicable to the entire MCSA due to the homogeneous nature of the soil and forest features found throughout the region.

Materials and Methods

The research conducted in this study pertains to the *americanus* subspecies of the black bear (*Ursus americanus*) which occurs throughout northern Wisconsin and is typically of the black color morph (98%) (Rounds 1987). For this paper, adult bear refers to a bear at least four years old, subadult to one between the ages one and four, and cub to one less than one year old (Rogers 1987). Henceforth, a female will be referred to as a sow and a male as a boar.

Information on forest inventories was provided by the WDNR (mapped by Couvillion) and the WPSC. Supplementary forest surveys were conducted to provide an enhanced picture of the study area and to provide ground truth with the WDNR-Couvillion forest inventory. I used the point-quarter method (Smith 1974) to establish an independent description of vegetation which

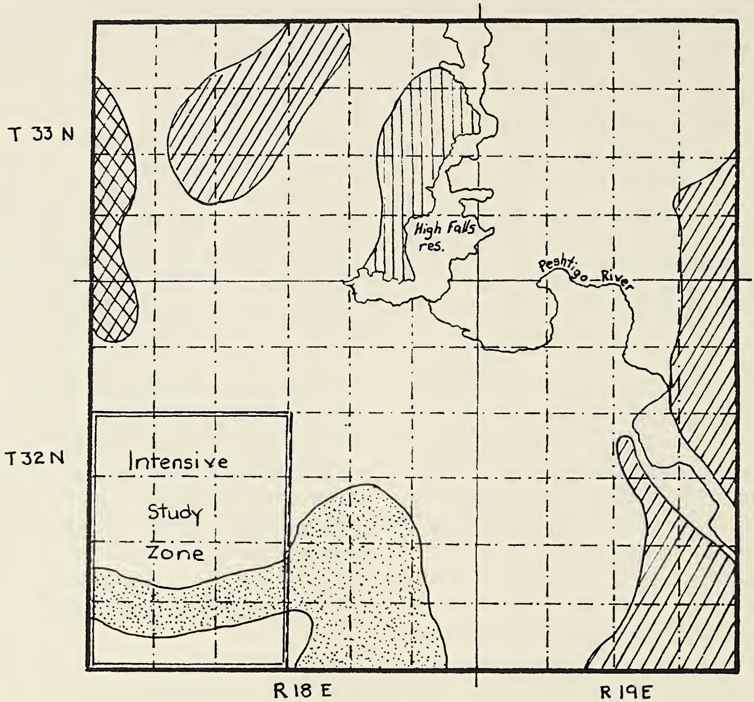
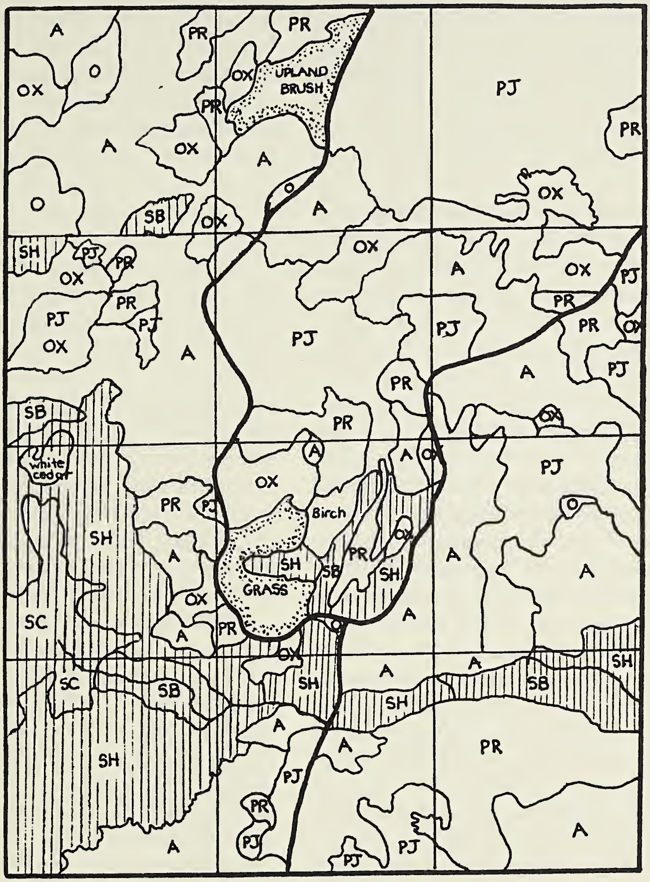


Table of Soil Percentages

	Well Drained	Poorly Drained	%
From Glacial till			
	Sarona Keewana		2.5
From Glacial Outwash and till			
	Mancelona Emmet Menagha		15.0
	Menagha		70.0
	Ishpeming Michagamee		2.5
Organic Soils			
		Seelyville Markey	7.0

Scale

Fig. 2. Map of soils found within the MCSA and the delineation of the Intensive Study Zone



Forest Inventory of MCSA (WDNR, WPSC)				
	%	Species	Upland	Lowland
(open)	87.0	Aspen(A), Jack Pine (PJ)	*	
		Scrub Oak(OX), R Pine(PR)		
(hatched)	7.0	Blk Ash/ Red Maple(SH)		*
		Cedar/ Spruce/ Fir(SC)		
		Blk Spruce(SB)		

Upland Forest Sampling	
Species	Rel Dens
Red Oak	22
Aspen	19
White Pine	16
Red Pine	13
Red Maple	13

Fig. 3. Map of forest composition found in the Intensive Study Zone and Forest Inventory Table for the MCSA

could then be compared with WDNR forest inventory maps; the results showed similarities between the two vegetation descriptions. Eighty quadrats were sampled along two transects, resulting in a 2.5 m (8.2 ft) mean point-to-plant distance and a mean area per individual of 6.25 m^2 (67.24 ft^2) (Fig. 3).

Bear populations were estimated by roadside count of tracks, droppings, and visual observation. Note that roadside counts do not generally represent actual populations but are an index to the population and are indicative of population trends. However, because of the characteristic low population density and sexual dimorphism of the black bear and the relationship between bear weight and track size (demonstrated by Piekielek and Burton [1975]), an estimate of the bear population in the intensive study zone could be made with ample time spent in the field. Counts were performed by vehicle once per week for twelve weeks over a 26 km route (n= 12, 25.9 km/ week [10 mi/ week]). The same route was driven on each occasion, although minor deviations were allowed and were sometimes necessary based on road conditions. The number of distinct bear sign observed was divided by the distance traveled. Only those tracks unquestionably made by a black bear were counted. When a set of tracks was found, the most distinct front and rear prints were chosen as samples, and measurements were taken of pad length, pad width, and width across the toes. The sum of the six values is the composite foot measurement and can be used to determine the approximate live weight of a bear (Piekielek and Burton 1975; Kohn 1982). Additional data collected included direction of travel, the soil type in which the track was made, the time when the track was found, and the precise location of the prints (Smith 1974). I estimated the age of the tracks, the distance the animal traveled on the forest road, and its speed of travel. The location of each bear was determined in the field and later plotted on a topographic map to help distinguish individuals and to better understand the home range of bears in the MCSA.

Results

The study of tracks located during the roadside count suggested that five bears (three adults/sub-adults, two cubs) inhabit the intensive study zone of the MCSA. This is the known minimum population (P_k), determined by comparing track size and weight estimates derived by using composite foot measurements. Individuals were recognized by variations in track size that could not be attributed to speed of travel or the soil medium. The P_k of five bears/30.7 km^2 yields a density of one bear/6.1 km^2 for the MCSA. Standard deviation of the road side counts was determined according to the formula

$$S = \sqrt{\frac{\sum (x_i - \bar{x})^2}{n - 1}}$$

where x_i represents the number of bears located in the intensive study zone during one time period, $\bar{x}$ is the mean number of bears located during the weekly count periods, and n is the total number of weekly roadside counts ($\bar{x}$ = 3.67, s = .58, n = 12).

Comparison of the P_k and the WDNR-estimated black bear population density for Wisconsin's bear range (P_p = 1/ 3.8 km^2 [1/ 1.5 m^2]) revealed a slightly lower population in the MCSA. The WDNR has created three black bear management zones within the bear's range across the northern third of the state (i.e., zones A, B, and C). The MCSA lies in management zone B, which the WDNR estimates to have a population density of P_p. The basis of the variation can be illustrated by examining several factors: (1) The MCSA is a relatively small region within bear management zone B. Therefore, various population density estimates should be anticipated when sampling subsets of a larger region (Amundsen, pers. comm.). (2) A higher human population weighs heavily against bear numbers, as a negative correlation seems to exist between the two factors (Kohn, pers. comm.). The general agreement between these patterns and the conditions in my study area supports the results obtained by this study.

Initially the results of the weekly counts (x_i) were alike, but as the autumn proceeded, bear sign diminished. This probably was due, at least in part, to the pressure exerted on the bears by hunting, perhaps causing them to avoid roads during the bear hunting season (September–October). The reduction could also be related to a diminished amount of available food and the onset of hibernation. A distinct drop in bear sign was evident on 14 October; this trend continued until the roadside counts were terminated on 28 October. For this reason, I have limited my calculations from roadside counts to the period prior to 14 October 1991. The roadside count index for 1991 is .217 bears per kilometer of road traveled.

At least one boar is known to inhabit the intensive study zone. A set of large tracks (length of hind print = 267 mm [10.5 in]) was discovered in mid-September and, due to size alone, the possibility of the tracks being made by a sow was eliminated. Research indicates that the hind print of a sow rarely exceeds 240 mm (9.5 in) (Trauba, pers. comm.; Jackson 1961). These tracks were no more than a few hours old (a strong downpour had occurred earlier that morning) and made in soft sand. The weight of the boar was approximated by employing the method detailed by Piekielek and Burton (1975) using composite foot measurement (800 mm [31.5 in]) to determine the live weight of the animal. The boar's weight is approximated at 147 kg (327 lb).

Discussion

Bears use forest roads as a means of travel. The observed tracks indicate that bears tend to follow the road for some distance (in one case for over 200 m) rather than simply cross the road. The bears that used the roads nearly always traveled on the road edge and in the same direction as vehicular traffic flow. This appears to contradict the findings of Unsworth et al. (1989) who reported that black bears rarely used roads as travel routes. However, since an estimate of the number of bears that avoided roads was not known, I cannot infer that all black bears in the study area regularly use roads.

Two possible den sites were located in the intensive study zone, both beneath the roots of upturned trees (*Tsuga canadensis* and *Thuja occidentalis* L.). One site was neatly cleaned and contained the tracks of a sow with one cub, believed to be the same family indicated earlier, although the tracks from her second cub were not found (Fig. 4). Black bears in the MCSA presumably use ground-level dens because the mean January temperature is -11.4°C (11.4°F) (Lorenz 1991) and excavated black bear dens occur less frequently unless the mean January temperature falls below -20°C (-4°F) (Tietje and Ruff 1980).

To evaluate the vitality of the bear population in the MCSA, data regarding reproduction was necessary. As mentioned previously, one sow is known to have given birth to two cubs that were still alive in early October 1991. Results of the 1991 mating season are unknown. However, signs of activity by area boars, including the presence of

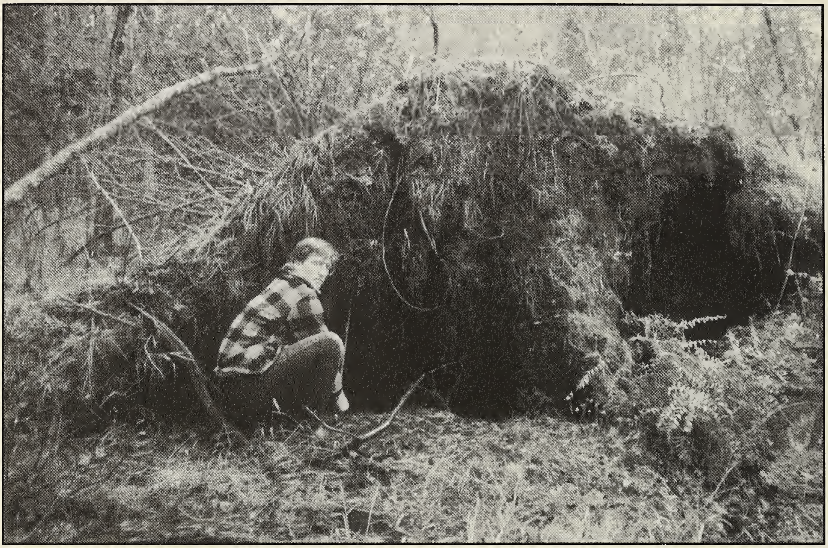


Fig. 4. The author is shown investigating an overturned cedar where the tracks of a sow and one cub were found. It is not certain if bears will use this site for denning purposes as it is susceptible to spring flooding.

"bear trees," indicates that some competition for mates may have occurred.

Black bears, especially adult boars (85%), use trees as marking posts during the June mating season, presumably to communicate their presence to other males (Laycock 1988; Rogers 1987). Further, Rogers found that utility poles were also used for marking purposes. The power line which cuts through the intensive study zone was closely examined for bear sign. All utility poles examined (n = 30) were constructed of large southern yellow pine (*Pinus palustris*), and one was positively identified as having been marked by a bear (Fig. 5). This determination is based on (1) the manner in which it is marked, which corresponds well with typical marking behavior (predominately openings or edges with markings toward the opening), (2) five individual claw marks evident in each stroke (width = 133 mm [5.25 in]) reaching a height of 2.12 m (83.25 in), and (3) six black hairs (length = 20–65 mm) removed from the pole between a height of .61–1.27 m (24–50 in). Because these hairs suffered little bleaching from the sun, one may conclude that this pole was marked during the 1991 mating season (Rogers 1987).

The availability of forage for bears in the MCSA was studied in the field to help determine the quality of black bear habitat provided by this area. Whereas an abundance of soft-mast food was available, oak mast (acorn) production for fall 1991 failed throughout the county, perhaps because of stress from previous years of drought, damage caused by the tent caterpillar (*Malacosoma constrictum*), and injury from oak wilt. The effect of oak mast failure is not known at this time, but the abundance of berries should alleviate this stress. A study by Elowe and Dodge (1989) indicates that if sows become nutritionally stressed, >66% of potential mothers could reabsorb the blastocyst and come into estrus again the following season. Another study (Fair 1991) suggests that reproductive synchrony could result from mast crop failure.

The mean age of the black bear population is a concern in bear management. Studies in Montana by Jonkel and Cowan (1971) reveal that the black bear does not reach sexual maturity until it is 3.5 years old. This is further supported by the findings of Rogers (pers. comm.) and Anderson (pers. comm.) in Minnesota and north-central Wisconsin, respectively. Furthermore, a sow may not breed until it is four years old and, in some cases, the sow will not successfully raise a litter until it is more than six years old. Therefore, a healthy bear population is expected to have a mean age of 4–5 years (Laycock 1988). While a relatively young population (mean age 4.1 years) presently exists in the MCSA (Kohn 1982), the number of sub-adults is estimated to be high, and these bears are projected to carry the population to an older mean age (Amundsen, pers. comm.). Thus, the age structure of the bear population in the MCSA appears to be healthy.

Bear populations can be affected by numerous factors such as development and road construction, which tend to fragment the population and produce "islands" of bear habitat isolated from one another by regions of unsuitable habitat. Research indicates that the "black bear cannot function as a population" when its density drops below one bear/25.9 km^2 (1/10 mi^2) (Fair 1990). The bear population density in the MCSA (one bear/6.1 km^2) is much higher than this

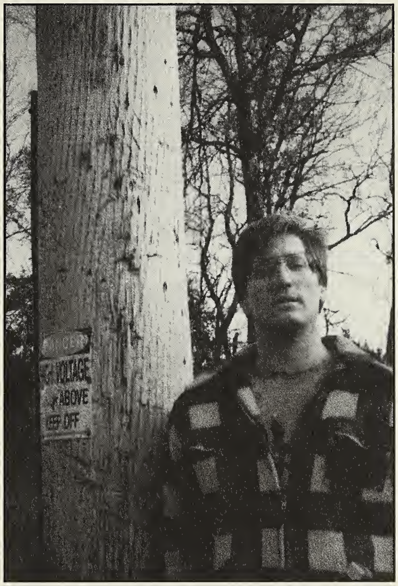


Fig. 5. This photograph shows a utility pole which was used by a boar, presumably to signal his presence to other bears. The author is shown here to better illustrate the height of the marks.

"threshold level," indicating that, currently, the black bear population in the MCSA is healthy and that the quality of habitat is adequate to support this population into the foreseeable future. This is based on the following evidence: (1) the bears are known to be reproductively active, (2) various forage exists in the region offering alternative food sources in the event that one source should fail, (3) the mean age of the population is 4.1 years (black bears in northeast Wisconsin are sexually mature at 3.5 years), and (4) estimated population densities are high enough to sustain a viable population as defined by researchers elsewhere (Fair 1990; Laycock 1988).

The population estimate of one bear/6.1 km^2 is lower than the WDNR estimate (one bear/3.8 km^2), probably because of the following factors rather than a decline in bear population or discrepancy in population estimates: (1) the MCSA is only a portion of bear management zone B, (2) different methods were used to arrive at the two population estimates, and (3) a higher human population exists in the MCSA (weighing against bear population density [Kohn, pers. comm.]) than in northwest Wisconsin.

Acknowledgments

I am grateful to W. J. Johnson, project advisor, UW Center–Marinette, R. Amundsen, J. Beecham, G. Egtvedt, B. E. Kohn, W. Kowalski, A. G. MacHutchon, D. Schad, S. Stubenval, S. D. Trauba, and the UW–Marinette County Extension Office for sharing their data and supporting this project. R. Howe and an anonymous reviewer aided greatly in the development of this paper. Field assistance was provided by S. Y. Weber. To all those involved in this project, I thank you.

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TRANSACTIONS

of the Wisconsin Academy of Sciences, Arts and Letters

Volume 83 • 1995

125th Anniversary Issue

TRANSACTIONS

of the Wisconsin Academy of Sciences, Arts and Letters

Volume 83 • 1995

125th Anniversary Issue

Transactions welcomes articles that explore features of the State of Wisconsin and its people. Articles written by Wisconsin authors on topics other than Wisconsin sciences, arts and letters are occasionally published. Manuscripts and queries should be addressed to the editor.

Submission requirements: Submit three copies of the manuscript, double-spaced, to the editor. Abstracts are suggested for science/technical articles. The style of the text and references may follow that of scholarly writing in the author's field, although author-year citation format is preferred for articles in the sciences, author-page number format for articles in the humanities. Please prepare figures with reduction in mind.

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Contents

TRANSACTIONS

Volume 83 • 1995

From the editor v

Part One: 125th Anniversary Articles

The Age of the Quartzites, Schists and Conglomerates of Sauk Co., Wis. 3
Roland Duer Irving
First appeared in *Transactions* 1 (1870–72) 128–137

Oconomowoc Lake and Other Small Lakes of Wisconsin, Considered with Reference to Their Capacity for Fish-Production 11
Increase Allen Lapham
First appeared in *Transactions* 3 (1875–76) 30–36

Copper Tools Found in the State of Wisconsin 18
James Davie Butler
First appeared in *Transactions* 3 (1875–76) 99–104

United States Sovereignty—Whence Derived, and Where Vested 25
William Francis Allen
First appeared in *Transactions* 3 (1875–76) 125–132

On the Extent and Significance of the Wisconsin Kettle Moraine 33
Thomas Chrowder Chamberlin
First appeared in *Transactions* 4 (1876–77) 200–234

The Larger Wild Animals That Have Become Extinct in Wisconsin 65
Philo Romayne Hoy
First appeared in *Transactions* 5 (1882) 255–257

Some Personal Recollections of Abraham Lincoln 69
John Wesley Hoyt
First appeared in *Transactions* 16 (1909–10) 1305–1309

Part Two: Current Articles

Dairying in an urban environment: The Milwaukee metropolitan area 75

John A. Cross

Urban expansion has displaced dairy farmers from the Milwaukee metropolitan area, with some farmers now relocating to other parts of Wisconsin.

Small mammal distribution associated with commercial cranberry production 87

Eric E. Jorgensen and Lyle E. Nauman

Small mammals are unevenly distributed in wetlands associated with commercial cranberry production.

The effect of manure management on phosophorus and suspended solids in the Lake Tainter, Wisconsin, watershed 91

Ken Parejko and Douglas Wikum

Fields near streams in Barron and Dunn Counties, Wisconsin, were spread with turkey litter before and after snowmelt in spring, 1993. Monitoring runoff by sampling the streams upstream and downstream from the fields did not detect significant loading of phosphorus or sediments.

The effect of picnic beetles on European corn borer larval mortality 105

Kamela K. Schell and John L. Wedberg

The picnic beetle is often found in the corn agroecosystem in close association with the European corn borer. This study demonstrates the reductive effects picnic beetles have on corn borer populations.

From the editor

And girlish April went ahead of them.
The music of her trailing garment's hem
Seemed scarce a league ahead. A little speed
Might yet almost surprise her in the deed
Of sorcery; for ever as they strove,
A gray-green smudge in every poplar grove
Proclaimed the recent kindling.

The lines are from the opening portion of John Neihardt's epic poem "The Song of Three Friends." They evoke the spring of 1822 when the famous band of one hundred trappers, the Ashley-Henry men, set out from St. Louis to the beaver country of the upper Missouri River. A sense of adventure, of new beginnings, and of still-unfolding springtime pervades Neihardt's lyric depiction of the scene.

In February, 1870, **Dr. John Wesley Hoyt** of Madison addressed several hundred people gathered in the Assembly Chamber of the Wisconsin State Legislature to consider the feasibility of forming a Wisconsin Academy of Sciences, Arts and Letters. As he describes the occasion in a letter of reminiscence written forty years later in February, 1911, this undertaking also was begun with a sense of new beginnings and of high adventure. Indeed, the embarkation was not without obstacles, especially the opposition of those who, while admitting that such an institution might be very useful, felt that the attempt to organize such a comprehensive society was quite premature at such an early stage in the history of the State. Undaunted, and lured, as it were, by "girlish April . . . scarce a league ahead," Hoyt presented a plea of such conviction, invoking the spirits of Christ and Emerson, that his dream for the immediate formation of the Academy carried the day. Accordingly, just a month later, on March 16, 1870, the Academy was formally chartered and incorporated by "the people of the State of Wisconsin, represented in Senate and Assembly." Hoyt was himself elected to serve as the Academy's first president from 1870–1875.

The Act of Incorporation charged the Academy with encouraging research in "the material, metaphysical, ethical, ethnological and social sciences," with undertaking "a progressive and thorough scientific survey of the State," with advancing both the fine and useful arts, including original invention, with fostering philological and historical research, with the formation of appropriate libraries and museums (!), and, finally, with "the diffusion of knowledge by the publication of original contributions to science, literature and the arts." Just two years after the Academy's incorporation the first volume of *Transactions* appeared. It reported on Academy proceedings for 1870–1872 and carried a lengthy presidential report on the founding of the Academy, lists of officers and members, the Academy's charter and constitution, and an impressive number of original scholarly articles.

In a commemorative address to those gathered at the Fiftieth Anniversary Meeting of the Academy in 1920, **Professor Thomas Chrowder Chamberlin** looked back at the Academy's heady beginnings. Then at the University of Chicago, Chamberlin had been another of the original incorporators of the Academy and had served as President of the University of Wisconsin and as president of the Academy from 1885–1887. In this address, Chamberlin noted how the Academy was formally inaugurated largely upon the ideals, fond hopes, and aspirations of those who planned it, and especially on the tenacious vision of Dr. Hoyt. "Scarcely a dozen of those who signed the call for the convention," he observed, "were productive workers in any of the fields embraced within the purposes of the Academy."

Among these dozen or so early contributors who were to set the tone for the future of the Academy, Chamberlin singled out **Dr. Increase Allen Lapham**, the first General Secretary of the Academy and editor of *Transactions*, who was "at once a botanist, a zoologist, an archeologist, a geologist, and a meteorologist. He was a distinguished example of the best order of the old school of all-around students of natural science." Lapham served as Wisconsin's state geologist; he collected what was to become the nucleus of the University of Wisconsin's enormous herbarium; and he was largely responsible for the establishment of the U.S. Weather Service.

Chamberlin also took special notice of such lights as Lapham's friend and co-worker, **Dr. Philo Romayne Hoy**, a person who "bubbled over with enthusiasm" for naturalistic investigations, and **Dr. William Francis Allen**, whose papers "set a high standard of true original investigation in humanistic lines"; of "the sprightly literary contributions of the inimitable **Dr. James Davie Butler**, and of the notable contributions of the Academy's fourth president, **Professor Roland Duer Irving**, who "took an active part in leading geological inquiry along sound scientific lines."

Upon completion of this anniversary address, Chamberlin himself was presented the honorary degree of Doctor of Science by President Birge of the University of Wisconsin. The citation noted Chamberlin's half-century of contributions to the Academy and to the State of Wisconsin, including his direction of the Wisconsin Geological Survey and praised the "spirit and temper of science" which he had embodied in his life and work.

1995 marks yet another significant milestone for the Academy, the 125th Anniversary of its founding. To commemorate the occasion, I have selected for this special anniversary issue of *Transactions* a colorful sampling of articles written by the illustrious founders and scholars identified above. All of the articles, except for Hoyt's reminiscence on Abraham Lincoln, appeared in the first five volumes of *Transactions.* Although necessarily limited in number, they represent some of the diversity of interest and expertise of the early contributing members of the Academy. They still make marvelously engrossing reading, whether for their pioneering scientific observations and insights (viz., the articles by Irving, Lapham, and Chamberlin), or their zoological (Hoy), anthropological (Butler), and political (Allen and Hoyt) interests. Like Neihardt's "gray-green smudge in every poplar grove," these articles proclaim "the recent kindling" of scholarly productivity by these and many other members in the earliest "Aprils" of the Academy. Moreover, the contribution by the ever-productive Lapham on Oconomowoc Lake seems peculiarly noteworthy, since its writing was completed during the afternoon of September 14, 1875, on the very evening on which Lapham died.

Also in this issue of *Transactions* we include four new contributions, all of which relate in one way or another to Wisconsin dairying and agriculture. John Cross writes about an "endangered species," dairy farming in the expanding Milwaukee metropolitan area. Kamela Schell and John Wedberg discuss the interactive effects of picnic beetles and corn borers on sweet corn, while Eric Jorgensen and Lyle Nauman document small mammal distribution associated with cranberry production in south-central Wisconsin. Finally, Ken Parejko and Douglas Wikum present results from their monitoring of manure runoff, resulting from two different management strategies, at five sites in the Lake Tainter watershed in Dunn County.

Special issues involve the special efforts of many. For helping to make this issue of *Transactions* possible, I wish to acknowledge especially the extra efforts of managing editor Patricia Duyfhuizen and her student interns Cynthia Barber, Jennifer Fandel, Sheri Jackson, and Gretchen Toth, and the valued advice and collaboration of Faith Miracle, editor of the *Wisconsin Academy Review.* Very special thanks are also extended to Academy staff members Gaile Burchill, Robert Lovely, Jean Sebranek, and Helen Vukelich, all of whom spent many hours word-processing the entire articles by Irving, Lapham, Butler, Allen, Chamberlin, Hoy, and Hoyt from the early issues of *Transactions* so they could appear in print once again. Finally, a word of appreciation to the State Historical Society for providing some of the photographs that accompany the reproduced articles.

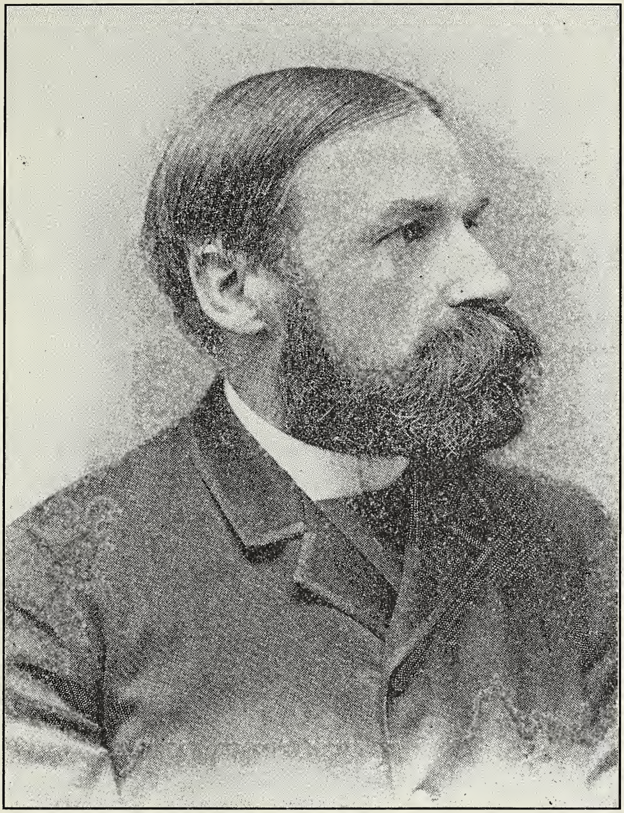
Now let me join all of those taking part in the Wisconsin Academy's many anniversary celebrations this year by offering a toast to the next 125 years and to many more springtimes, new beginnings, and adventures for the Academy and for *Transactions.* May "girlish April" always beckon with "the music of her trailing garment's hem," and may our collective efforts, year after year, continue to "proclaim the recent kindling."

Bill Urbrock

The Wisconsin Academy of Sciences, Arts and Letters was chartered by the State Legislature on March 16, 1870, as a membership organization serving the people of Wisconsin. Its mission is to encourage investigation in the sciences, arts and letters and to disseminate information and share knowledge.

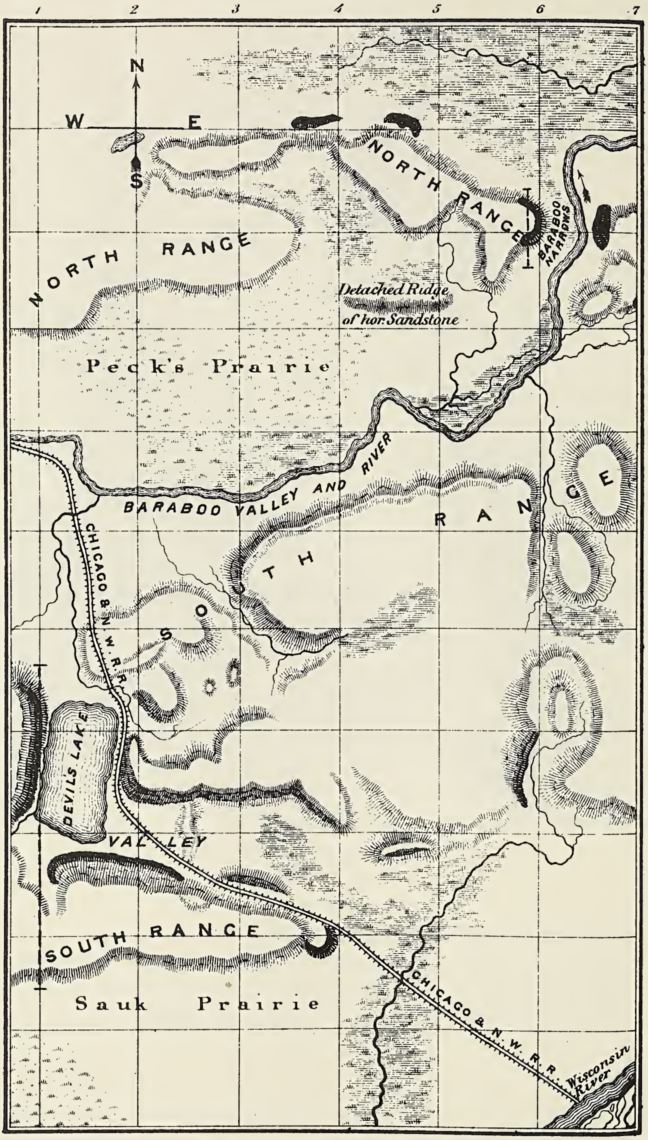
Part One:
125th Anniversary Articles

Managing Editor's note: We have prepared the anniversary articles to recreate the look of the originals, preserving their "old style" margins, headings, and punctuation. —T.A.D.



Roland Duer Irving, E.M., Ph.D.
(1847–1888)

Professor of geology, mineralogy, and metallurgy at the University of Wisconsin; comissioned geologist for Wisconsin Geological Survey and United States Geological Survey; fourth president of the Wisconsin Academy, 1882–1884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NORTH RANGE
BARABOO NARROWS
Detached Ridge of hor. Sandstone
Peck's Prairie
BARABOO VALLEY AND RIVER
CHICAGO & N.W.R.R.
SOUTH RANGE
DEVILS LAKE
VALLEY
SOUTH RANGE
Sauk Prairie
CHICAGO & N.W.R.R.
Wisconsin River

THE AGE OF THE QUARTZITES, SCHISTS AND CONGLOMERATES OF SAUK CO., WIS.*

BY ROLAND IRVING, E.M.

Professor of Geology, Mining and Metallurgy at the University of Wisconsin

Through the central portion of the county of Sauk, Wisconsin, run two ranges of hills or ridges, having an east and west trend, and a height varying from a mere rise above the general prairie to an altitude of five hundred feet. The width from north to south never exceeds three or four miles, and in places is much less than one mile. The total lengths from east to west, or rather, the exact points at which the peculiar rocks which make up the ridges give place to the ordinary country rock, are not as yet accurately known. These lengths, however, seem to be from fifteen to twenty miles.

The rock material of the ridges is mainly a hard dark-colored quartzite; with this in some places are siliceous and talco-siliceous schists, and two or three kinds of conglomerate. The dip of the strata, which, though in some places obscure, is in others very marked—and can *everywhere* be determined by careful observation—is *uniformly* toward the north. The angle varies from 20 deg. to 25 deg. in the south range, to 75 deg. to 80 deg. in the north.

The occurrence of these bold ridges in the midst of a prairie country, together with the marked contrast between their upturned and metamorphosed layers and the entirely undisturbed strata of the Potsdam and Calciferous epochs, which for miles around form the country rock, has caused much speculation and discussion. From time to time, during the past twenty years, brief notices have appeared in various journals and reports, but no careful investigation of the localities in question seems ever to have been attempted. In most of these notices, or rather in most of those that are not absurdly inaccurate in their statements and wild in their ideas, the main point under discussion has been the relative age of the metamorphic strata. Do they, or do they not, antedate the Potsdam period? Are they the results of local metamorphism on the Potsdam sandstones, or are they the remnants of pre-existing rocks? The advocates of the former theory have had the last word in the discussion.

* This paper has already been published, with some slight differences, in the American Journal of Science and Art for February, 1872.

The facts recorded in the present article are the results of a series of visits made to the localities by the writer, during the months of September, October and November of this year (1871), and they will, I think, be seen to prove beyond all doubt or cavil, that the quartzites and schists antedate entirely the Potsdam epoch, i.e., are either Huronian or Laurentian in age.

Of all of the notices mentioned, none are more than brief mentions and only a few seem to have any value at all. Dr. Shummard, in Owen's report on Wisconsin, Iowa and Minnesota, makes the first mention of the quartzite. He gives no opinion. Dr. James G. Perceval, in the report of progress of the Wisconsin survey for 1856, refers again to the quartzites, calling them merely "metamorphic sandstones," but intimating that they result from a change on the Potsdam sandstones. Mr. James Hall, in his report of progress to the Governor of Wisconsin for 1860, gives by far the most accurate description I have been able to find. He refers the quartzites unhesitatingly to the Huronian—but gives no proofs whatever. His pamphlet did not fall into my hands until after my own investigations were entirely completed. In the first volume of his final report, Mr. Hall again mentions the quartzites, but still more briefly, expressing the same opinion as before, and still giving no proofs. In 1864 there appeared in the American Journal of Science and Art (II, vol. xxxvii, p. 226) an article by Mr. Alexander Winchell of Michigan, in which he describes, among others, some fossils from the conglomerates overlying the quartzites; and upon them bases his claim that the quartzites are a downward continuation of the Potsdam sandstones. He himself never visited the localities. Finally, Mr. James H. Eaton of Beloit College, in a paper read before the Wisconsin Academy of Science, in February, 1871, expresses the same opinion though on somewhat different grounds. The foregoing list includes everything of any value that has been published on the subject.

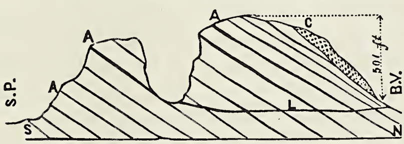
The accompanying map includes those portions of the two ridges where most of my observations have been made.

I. The South Range, to which my attention was first directed, presents, on approaching it from Sauk Prairie on the south, a bold, and, in places, precipitous rise from the plain of from 350–450 feet. The northern side of this ridge has however, in all places as yet studied, a much more gradual slope down to the valley of the Baraboo river, this slope being in many places determined by the northward dip. Running entirely through this ridge is a deeply cut valley, which has at first for about two miles, a direction slightly north of west, and then turns due north quite abruptly. This northern end holds the Devil's

Lake, which entirely fills the valley from side to side. Throughout its whole length the sides of this cleft are precipitous masses of quartzite rising everywhere more than four hundred feet above the bottom, and reaching at the lake an altitude of 501 feet above its level, and of 1,474 feet above the sea. The bottom of the valley is covered with a heavy mass of Drift material, and the lake is held in its position by low Drift hills at its northern and southeastern extremities. The bottom of the lake itself seems to be in a Drift sand, and is over most of its area about thirty feet below the surface of the water. The lake has no outlet; but draining as it does a very small amount of surface, the extraordinary evaporation caused by reflection from the cliffs above, together with the high winds of Wisconsin, is quite sufficient to account for its maintenance of level; whilst the character of the surrounding rock shows readily the reason for its not becoming saline.

The great exposures of cliff at this locality, and the deep rock cuttings on the newly-opened railroad, afford most excellent opportunities for study. The change of direction, too, of the valley, gives facilities for approaching the rocks from different sides, not elsewhere easily obtainable.

The rock here is mainly a hard, dark-colored, very compact quartzite, though the colors vary from a very light grey in places to deep brownish-red. The bedding joints of the quartzite are in some places rather obscure, but the railroad cuttings have so far exposed them, that with a little care I was able readily to ascertain the dip. This on both sides, and throughout the whole length, of the valley, is uniformly about 20 to 25 degrees a little west of north. Some of the writers mentioned, and notably Winchell, have described this valley as corresponding to an old anticlinal axis, but the uniform dip of the strata throughout its length proves, of course, that this is not the case.



SECTION 1.—North and south through the south range on section line 1 of map. A, quartzites; A′, quartzites with some schists; C, conglomerate; S.P., Sauk Prairie; B.V., Baraboo Valley; L, level of lake.

The quartzite, although often looking massive, shows in many places, on weathered surfaces, the lamination and cross-lamination of more modern sandstones. Many of the fallen masses show, too, on exposed surfaces of lamination, the most distinct ripple markings I have ever seen. On the shallow sandy bottom at the north end of the lake below, may be found their very counterparts. Between the beds of quartzite, in many places, are thin layers of a schist principally siliceous, but having always some talcose material. These correspond apparently to the clayey or shaly layers between the beds of sand now represented by the quartzite. In some places these layers seem to be merely a thinly laminated quartzite, with talcose films covering the laminae; in others, the talcose material pervades and gives character to the whole mass, the siliceous material, however, always being present.

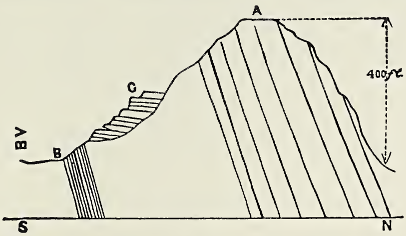
The most remarkable feature of this locality is, however, the very striking system of vertical joints which everywhere intersect the quartzite. The bearing of these joints, taken in some fifty or sixty different localities, I found to be uniformly N.E. and S.W. and S.E. and N.W., the variations in a few places being evidently due to local displacement. On the cliff sides, and more especially about the lake, these joints, together with the bedding joints, have so cut the rock into separate blocks, that these have from time to time been thrown down the bluff by frost and atmospheric agencies in huge rectangular masses, weighing by calculation from seventy-five to two hundred tons apiece.

In many places along the north flank of this ridge and lying always above the quartzite, are outcrops of a conglomerate, containing pebbles unmistakably from the quartzite below, always rounded, and in size varying from a few lines to four or five inches in diameter. In some few places there seems to be a second conglomerate in which the sandy cement itself appears altered to a quartzite. This is a point, however, deserving of further investigation. There are also places where distinct layers of coarse and fine conglomerate occur, the latter always above and graduating into a simple sandstone.

In this conglomerate are found in one locality just northeast of the lake, the Potsdam fossils described by Mr. Winchell in the article referred to, viz: *Scolithus linearis* Hall, *Orthis Barabuensis* Hall, *Delphinocephalus Minnesotensis* Owen, etc. I have examined a collection of these fossils from the above locality, in the possession of Dr. Lapham, of Milwaukee, and have seen the fossils and quartzite pebbles in the same fragments side by side.

II. The observations on the North Range were made about the Lower Narrows of the Baraboo river and westward from there about half a mile. This north range seems to be less continuous both as to elevation and as to the character of its rock material. I am told by

Dr. Lapham that it seems rather to be made up of detached masses of metamorphic rocks. The rising ground, however, never entirely disappears, and the quartzite seems to be found as far to the east and west as in the south range. At the Baraboo Narrows the metamorphic rocks are in great force, the cliffs on either side the river, which here makes a direct cut through the range from south to north, being as much as four hundred feet in height. The body of the bluff on the



Section 2.—Through North range at W. Bluff of Baraboo Narrows. A, thick-bedded dark colored quartzites, with some talco siliceous schist; B, siliceous schist; C, horizontal sandstone; B. V., Baraboo Valley.

west side is made up of heavy beds of quartzite, with, in places, intercalated beds of metamorphic conglomerate, and of a talcose schist like that in the south range. These beds all stand at a very high angle, between 75 and 80 degs. from the horizontal, the dip being north, with possibly a slight inclination to the east. At the bottom of the hill on the south side is an exposure of a peculiar light-colored siliceous schist, entirely different from any of the other rocks of the series. An old shaft sunk some thirty feet on the schist, affords most excellent opportunity for examination. The total thickness seen was about twelve feet, the layers varying in thickness from a few lines to four or five inches. Very thin films of a talcose material sometimes appear between the layers. Directly above this schist, I found a horizontal undisturbed sandstone, laid open for some distance by quarrying. The beds are generally a foot or two in thickness. In the loose pieces near by is found *Scolithus linearis*. The sandstone is, of course, the Potsdam of the surrounding valleys. Section 2 will serve to give a clear idea of the structure of this bluff.

The narrow detached ridge just to the westward, represented on the map, is also made up of horizontal Potsdam sandstone. There are many other such detached ridges along the Baraboo valley, bearing the same relation to the quartzite ranges, and showing the same horizontality of strata.

The following arguments in favor of the priority of these rocks to the Potsdam period will, I think, after what has been said, be admitted as valid. I give them in the order in which they became apparent to me.

1st. *The limited area of disturbance*; the undisturbed Potsdam and Calciferous strata being found north, south, and between the ridges, and in close proximity to them.

2d. *The absence of any anticlinal axes.* Dipping as the rocks do uniformly to the north, in order to place them in the Potsdam category, we must imagine a metamorphism of the strata, accompanied by a great fault, having on one side the unchanged sandstones, and on the other the tilted quartzites and schists, an idea new, I think, to geology.

3d. *The occurrence of rounded pebbles of quartzite in the conglomerate on the south side of the south range.* To suppose this conglomerate, which by its fossils is unmistakably Potsdam, to be of the same period as the quartzites below, we must suppose that period to have lasted long enough to cover the deposition of the quartzites as sandstones, their metamorphism, and the rounding of the pebbles by beach action, before the formation of the conglomerate; not to speak of the time sufficient to erase all signs of an anticlinal.

4th. *The occurrence of horizontal sandstones resting unconformably on the flanks of the tilted strata.* This last is, of course, absolutely conclusive as to the *north range*, but lest it might be claimed that the two are independent, I have given the others.

Mr. Winchell argues that, since Mr. Hall states that the fossils I have mentioned as occurring in the conglomerate are restricted to the Middle Potsdam, either this statement must be untrue or the quartzite must be the downward continuation of this formation. This argument, however, loses all force when we regard these ranges as high ridges in the Potsdam seas, never having been entirely covered by these seas, but having merely had the new sandstones and conglomerates deposited about their flanks. The place where these fossils were found must be *at least* 200 feet above the base of the sandstones of the surrounding country. A single glance at Dr. Lapham's geological map of Wisconsin will show this. The conglomerate is by no means necessarily the *base* of the Potsdam because it rests immediately on Huronian or Laurentian rocks.

In the final report of Mr. Hall already referred to, he mentions a low hill north of Baraboo, in which the middle of the hill is quartzite, and the flanks conglomerate and sandstones graduating upward into calcareo-sandy layers, without giving any further explanation. This statement, before somewhat unintelligible to me, now throws further light on my own results.

To my mind these ridges were unquestionably islands in the Potsdam sea, and a more beautiful illustration than is furnished by the sandstones and conglomerates of wave action on a rocky coast, can hardly be imagined.

There are many very interesting details of structure in these ridges which would repay thorough study. The points presented in the present paper are only those necessary to show the age of the rocks.

There are several more of these scattered quartzite ranges in Wisconsin, all but one of them occurring within the Potsdam and Calciferous areas. During the coming season I hope to be able to make a connected study of them.

UNIVERSITY OF WISCONSIN, November 18, 1871.

Courtesy The State Historical Society of Wisconsin WHi(x22)11

Increase Allen Lapham, LL.D.
(1811–1875)

Civil engineer; all-around student of natural science; author of first hardcover book published in Wisconsin, *A Geographic and Topographical Description of Wisconsin, etc.*, 1844; founder of the herbarium at the University of Wisconsin, 1849; founding member and president, State Historical Society of Wisconsin; charter member and first elected secretary of the Wisconsin Academy, and first editor of *Transactions*

OCONOMOWOC LAKE AND OTHER SMALL LAKES OF WISCONSIN, CONSIDERED WITH REFERENCE TO THEIR CAPACITY FOR FISH-PRODUCTION

BY I. A. LAPHAM

The Oconomowoc Lake in Waukesha county, on the line of the Chicago, Milwaukee and St. Paul Railway, is one of those beautiful sheets of clear, cold water that may be taken as a type or representative of hundreds of others within the State of Wisconsin. A few facts and observations in regard to this lake may therefore be of interest to the Fish Commissioners, and to all who desire to encourage the increase of fish-production.

As shown upon the plats of the government land surveys, it has a length of two miles; breadth, three fourths of a mile; a shore-line of six and a half miles; covering an area of 830 acres, or one and three-tenths square miles.

Its elevation above Lake Michigan, as ascertained many years ago, in making the survey of the Milwaukee and Rock River Canal, is two hundred and eighty-two feet. Its irregular form can best be seen by reference to the accompanying chart.

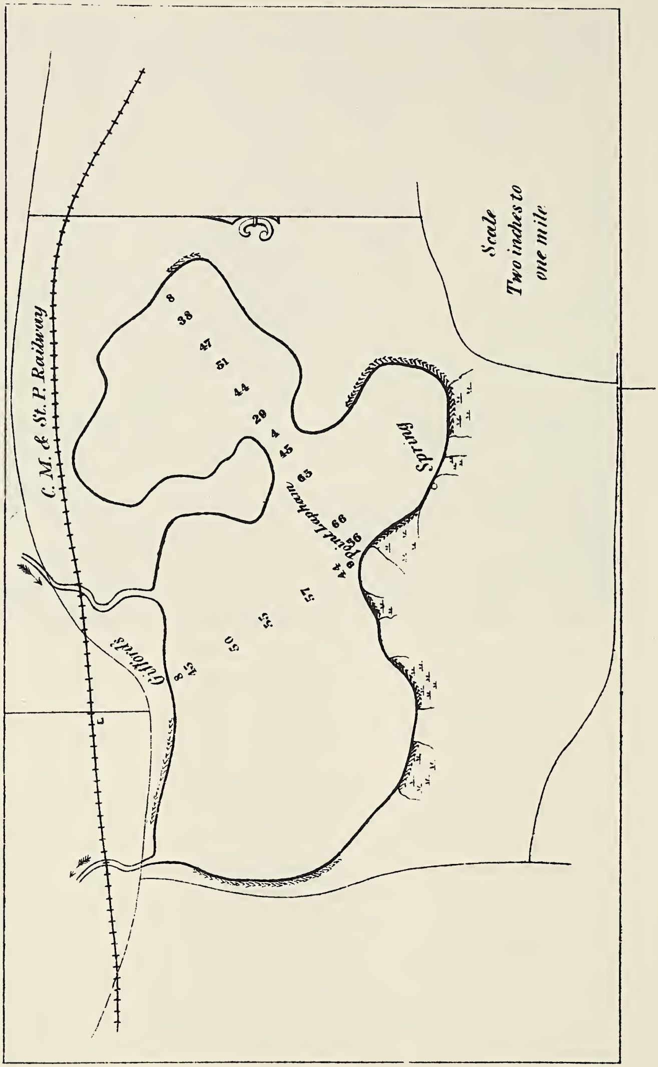
The Oconomowoc River, a small stream which is the outlet of several other lakes, enters it on the north shore and leaves it at the northwest corner. So irregular is the shape of this lake that it might be taken to illustrate geographical terms, as gulf, bay, point, cape, promontory, peninsula; it has also straits, channels, bars, shoals and its coast-line.

The banks of the lake consist mostly of high grounds which are selected as sites of beautiful, often costly residences, which, especially when duplicated by reflection from the smooth surface of the water, form landscapes worthy of the pencil of the painter.

The lines of figures on the accompanying chart show the depth of the water as measured in 1875. They indicate three principal depressions, the deepest being 66 feet,* the mean of all the soundings is 39 feet.

*The greatest depths measured in other lakes in the vicinity were:

	Feet.		Feet.
Nagowicka	100	La Belle	45
Upper Nashotah	55	Silver Lake	40
Lower Nashotah	50	Upper Genesee	39
Pewaukee	50	Lower Namahbin	34


C. M. & St. P. Railway
Scale
Two inches to
one mile
Spring
Point Lapham

There are several shoals with from two to six feet depth of water.

There is no deposit of mud or sand brought into the lake by the river; the water supply both from the river and from the numerous springs on the shore, being always clean and pure. One of these springs on the south shore, known by its Indian name Minnewoc, (place of waters) has been analyzed by Mr. G. Bode, of Milwaukee, Chemist of the Wisconsin Geological Survey, with the following result:

Chloride of sodium	0.129
Sulphate of soda	0.627
Bicarbonate of soda	1.041
Bicarbonate of lime	9.638
Bicarbonate of magnesia	6.138
Bicarbonate of iron	0.129
Alumina	0.067
Silica	0.879
Total (grains in one gallon)	18.648

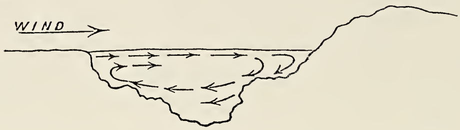
It will be seen that the chief ingredients, as in most Wisconsin waters, are lime or magnesia, derived doubtless directly from the magnesian limestone rocks and pebbles buried beneath the soil. This analysis also shows that the water does not differ essentially from those having great reputation for their medicinal virtues.

The lime from the springs is deposited, under favorable circumstances, upon the bottom of the lake forming beds of pure white marl; a process which is materially assisted by the secretions of mollusks and aquatic plants, especially the chara and algae.

The temperature of the water, being an important item in fish culture, was taken at different times near the surface, where it had considerable depth, with the following result:

In May	41°	Fahr.
In June	63	"
In July	72	"
In August	72	"
In September	72	"
In October, 1874	53	"

An attempt was made to find the temperature at the bottom in deep water and resulted in showing at some times no differences, at other times one or two degrees warmer or colder; though the deep water is popularly believed to be much colder than that at the surface.



The strong wind blowing over the lake causes a surface current which must be balanced by a counter current below, and thus by a constant interchange of water equalizes the temperature. If the day is warm with but little wind, the surface water will become the warmest; at night the surface cools down so that in the early morning it is colder than at the bottom.

The deep-water fishes do not, therefore, seek that locality on account of diminished temperature.

One lake is said to have remained open nearly all winter; the cold weather having been accompanied by high wind, which prevented the water from freezing.

When the surface is once covered with ice the currents cease, and ice is formed of great depth and of crystal transparency and purity.

The temperature of the spring-water along the shores remain [sic] nearly uniform throughout the year, varying from 47 to 49 degrees, which is not far from the mean temperature of this locality.

The currents caused by the wind blowing over the surface of the lake, act upon the bottom and shores, causing abrasions at some places and accumulations at others, very much as by the larger currents of the ocean. This is quite apparent at two points on the channel between the lake and the large bay at the northeast angle. The current flowing into the bay from the lake causes an eddy at these points from which are deposited long narrow bars projecting from the shore. This channel it will be seen is quite narrow and the water in it shallow.

These currents also cause accumulations of beach sand and gravel at certain points along the shore; separating and assorting the material upon a small scale, precisely as is done on a larger scale by the currents in the great lakes, and in the ocean.

While white shell marl is accumulating in some portions of the lake, soft muck resulting from the annual decay of aquatic vegetation is accumulating in others. Some of the lakes, especially those not connected with a stream of running water, are thus becoming rapidly filled with marl and peat, causing changes that become apparent after long intervals of time. Some small shallow lakes have thus been changed to meadows within the recollection of the first settlers of the county only 38 years ago.

The government plats represent some lakes in 1835, which are now only known as marshes or wet meadows. One called "Soft Water Lake," was a clean sheet of water only four years ago, but is now nearly covered with the leaves of the yellow pond lily (Nuphar) and other water plants. Soon it will cease to be known as a lake.

There are also some changes of the level of some of these lakes, indicating a less amount of water than formerly. Sand bars formerly covered with water are now dry, and in one case the bar extends quite across the lake, thus dividing it into two. Another proof of a diminished supply of water is afforded by the occurrence of ancient beaver dams in places where no pond could be formed at the present time, for want of running water.

The time may come when by the use of some simple, easily worked dredge, the marl, and muck may be removed from the bottom of some of the more important of these lakes, to be used as a fertilizer of the neighboring farms; especially as the beauty of the lakes would be increased by deepening the water, and by the consequent removal of the unsightly vegetable growth along their shallow margins.

Ice ridges are formed at certain places around the shore, some of them double, or triple, and varying in height up to ten feet. These ridges are formed by the expansion of the ice during the winter, pushing the materials of the beach in-land. They consist of sand, gravel, or boulders; in the latter case they constitute the so called "walled lakes." If the banks are high and steep at the edge of the water, no ridge can be formed, but wherever low grounds or marshes approach the lake, they may be looked for. Where springs enter the lake, no ridges are formed, the water remaining above the freezing point all winter. Trees are often found with their roots crowded inland by the ice expansion; their tops leaning over the water. These ridges make excellent road-beds, and are often used for that purpose.

The ancient mound-builders, that mysterious people who preceded the present Indian races, once occupied the banks of these lakes as is clearly shown by their numerous works; and they probably derived no inconsiderable portion of their subsistence from fish. No shell-heaps have been found to indicate their use of the abundance of Unio and Anodons found in these lakes. The works of the mound-builders are rapidly disappearing, being levelled by the plow of the farmer.

Besides the Unios, these lakes abound in other bivalve and univalve mollusks; crustaceans and worms, and the larvae of insects appear in wonderful numbers. These, with the innumerable minnows found in shallow waters, afford at all times an abundant supply of food for the larger fishes. Loons, geese, ducks, gulls, plover, and many other birds swim upon the waters or wade along the margin.

Among the fishes to be found are the following:

Perch, Perca flavescens, Cuvier.

Wall-eyed Pike, Lucoperca americana.

Striped Bass, Roccus chrysops, Girary.

Rock Bass.

Stone-Roller, Etheostonia.

Black Bass, Micropluas nigricans, Agassiz.

Sun-Fish, Pomotis.

Pumpkinseed.

Shiner.

Sheephead, Haploidonotus grunnieus.

Stickle-back, Applissinconstans, Kirtland.

Pickerel, Esox, Lesueur.

Sisco, Argysosomus sisco, Jordan Am. Nat., 1875, p. 135, Ind. Geol. rep. 1875, p. 190.

Sucker, Catastomus.

Red-Horse, Plychostonus.

Cat-fish, Amiurus catus, Cuvier.

Bull-Head.

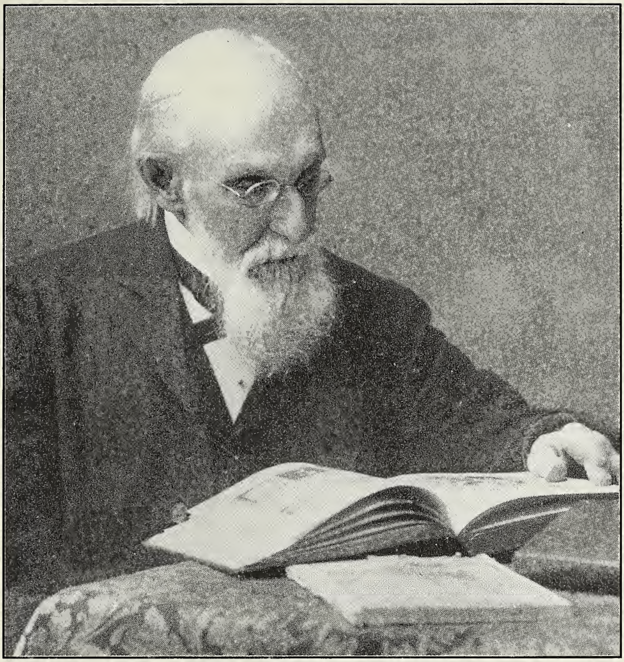
Bill-Fish, Lepidosteus oxyurus, Rafinesque.

The Salmon and Brook-trout are reared artificially, and have been introduced into some of the lakes.

Young salmon (Salmo salar) and the brook-trout (S. fontinalis) have been introduced into this lake, but so far as known they have not increased.

From the data given above one will be able to decide whether it would be advisable for the State to attempt to stock this lake with fish; and if so, the kinds best adapted to the conditions named.

The natural supply of fish has been drawn upon so heavily that the present yield is quite small, compared with what it was a dozen or more years ago; and hence the necessity of some effort for the restoration of the supply of the better kinds.



James Davie Butler, LL.D.
(1815–1905)

Student of theology and Congregational minister; seasoned worldwide traveller and popular travel lecturer; professor of Greek at Wabash College; professor of ancient languages and literature at the University of Wisconsin; curator of the Wisconsin Historical Society

COPPER TOOLS FOUND IN THE STATE OF WISCONSIN

BY PROF. J. D. BUTLER, LL.D.

Implements of unalloyed copper are among the most rare and curious of archaeological findings. The exhibit of these articles now made at the Philadelphia Centennial comprises the largest collection ever brought together. The copper age proper, in distinction from the age of bronze, forms a link in the chain of human development which according to Sir John Lubbock, "is scarcely traceable in Europe." The only European museum known to that distinguished archaeologist which contains any copper tools is the royal Academy at Dublin. The number there was thirty till within a year or two, when five were received from Gunjera—a province in India north of Bombay.

The articles now on view at the Centennial are as follows: In the Government building, from the Smithsonian Institution, seventeen real tools, besides casts of several others, and various copper trinkets. In the same building two articles, much corroded, owned in the State of Vermont.

In the mineral annex. From Ohio eight implements; from Michigan nineteen, and from Wisconsin, *one hundred and sixty four.* The whole number from all quarters is two hundred and ten.

I made notes regarding all the exhibits, but having lost them; can only describe the show from Wisconsin. But the coppers from that State are nearly four times as many as all the rest of the world has sent to Philadelphia, and they surpass others in size, variety, and perfection of preservation, as much as in number. The only instrument from any other source, not represented among Wisconsin Coppers, is a crescent about six inches long—perhaps intended for a knife, though it has no handle.

Among the varieties in the Wisconsin exhibit—which is made by the State Historical Society—are the following:

Ninety-five spear-heads. Of these the larger number are what some antiquarians called "winged," that is the sides of the base are rolled up towards each other so as to form a socket to receive a shaft. Some of these sockets are quite perfect, and all are ingeniously swaged. Sixteen of them are punched each with a hole, round, square, or oblong, for a pin to fasten the shaft, and one of the copper pins still sticks fast in its place. Twenty-three of the spear-blades swell on one side something like bayonets, the rest are flat. Three are marked with seven dents apiece, and one with nine; indentations which have been fancied to indicate the number of beasts, or men, the weapons had killed. Nine spear-heads have round tangs which are so long, smooth and sharp, that they may well have been used as awls and gimlets. The blades of these nine spears swell in the middle of each side. Their shape is a beautiful oval. The largest specimen of this class is about a foot in length. In the middle of its blade there is a hole as large as a pipe-stem, which may have been drilled for putting in a cord to recover the spear when it had been thrown into the water. One spear has a unilateral barb. This, meeting with unequal resistance, will not go straight in water, so we think it of an absurd pattern. But the truth is that if aimed at a fish where he looks to be, it will hit him where he is—though, owing to the refraction of light in water, he is not where he looks to be. One barb is then better than two, and we are the fools after all. Spears of a similar pattern, though of other material have been exhumed in France and California, and are still used in Terra del Fuego. Specimens in bone from Santa Barbara may be seen in the Smithsonian exhibit. Thirteen spears have flat tangs to thrust into shafts. Six of these tangs are serrated or notched like the necks of flint weapons for binding about with sinews. They seem to mark the very point of transition from one material to another—from mineral to metal.

There are fifteen knives. Most of these were intended to be stuck in handles, but one of them has a handle rolled out of the same piece of copper with its blade. Another has its copper handle bent into a hook. There are several gads, or wedges, to be driven. There are three adzes—tools beveled only on one side of their edges, and with broad sockets for handles. There are eleven chisels, some as heavy as those we now use. There are twelve axes, one weighing three and three-quarter pounds in exactly the weight of those common among Wisconsin lumbermen to-day. Another, which is a pound heavier, is the largest specimen of wrought copper that has even been brought to light. There is one hook, and a square rod. There are more than half a dozen borers of various sizes. One may be called an auger, being sixteen inches long and three in circumference. There is a dagger ten inches long with a blade an inch wide. These, with various anomalous articles, complete the catalogue.

For the conservation and display of this unique copper treasure the State of Wisconsin has set apart one of the towers of the Capitol in Madison. There they will be daily open for inspection, and will no doubt be a magnet attracting to themselves other curiosities of like nature.

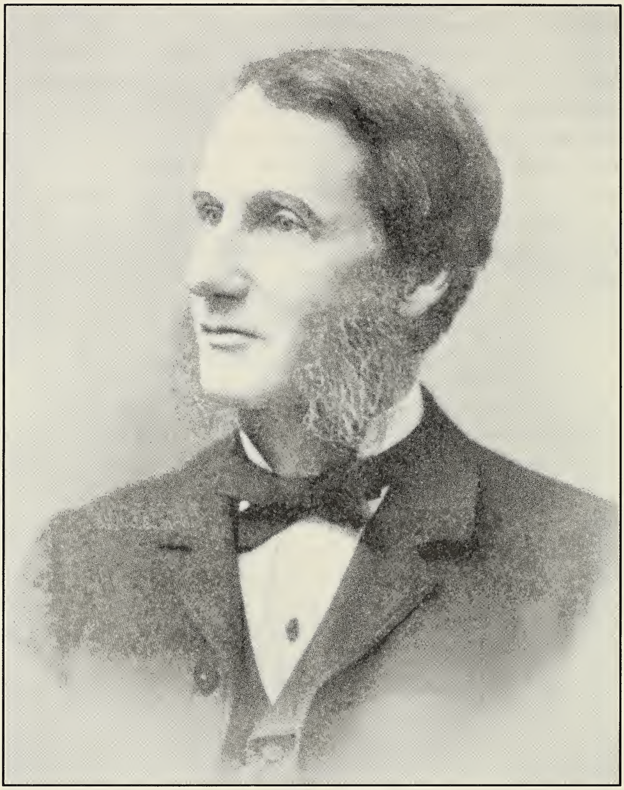
The question is always asked, "Where did these coppers come from?" It cannot be so definitely answered as is to be desired. Nevertheless something is known in respect to the finding of them. They were all discovered within the limits of Wisconsin—while the Smithsonian specimens—less than one eighth as many, were gleaned from eight different States. Nearly all of them have come to light in eleven southeastern counties of Wisconsin. Only in those counties has much search been made.

Most of the Wisconsin coppers were brought together into one collection by the zeal and perseverance of one single man, Frederick S. Perkins of Racine county. Five years ago this gentleman, though he had long been forming a museum of stone implements, had never seen one of copper. On the 25th of November, 1871, he was first shown such an antique. It was a large spear-head that had been exhumed three miles north of his residence in Burlington, Wisconsin. That November date marks the birthday of his interest in copper—or his transition from the stone to the copper age. His enthusiasm which had been great for the former became greater for the latter. He had leisure—or he made it, to ride over county after county on every road, waylaying every pedlar [sic], calling at every school, every store, at almost every house. He advertised in newspapers, he threw tempting baits abroad on all waters. He found what he sought, where no one else would have looked for such a prize, and where many proved to him that it could not be found. He has recorded the name and resident, by county and town, of one hundred and twenty-one persons from whom he obtained pre-historic coppers, as well as of three hundred and twenty-five others who furnished him stone antiques, but had no coppers to furnish. This record shows how thorough and wide-spread were his researches. Indeed, although the Wisconsin Historical Society has bought the bulk of his findings, some of them are scattered far and wide. Five of them are in the Central Park museum, others in the Metropolitan in New York, others I think have enriched the Smithsonian. A further question which must occur to every investigator, is, where were these implements obtained by those from whom Mr. Perkins obtained them? On this point my information is more scanty than it would be were not Mr. Perkins now in Europe, and than it will be on his return. Large numbers of the tools were turned up in plowing or hoeing. Others at greater depth in digging foundations of houses or sinking wells. Not a few have come to light in burial mounds close by skeletons. In one such mound at Prairie du Chien an axe weighing two and seven-sixteenths pounds and eight inches long was discovered lying on a large flint spade, fourteen feet below the top of the mound, and seven feet below the level of the earth around, and among human bones. Another axe, with other coppers, was taken from a similar mound in Barron county. The only socket spear-head which shows its rivet still in place, was found on a knoll in plowed land by James Driscoll in May, 1874, at Lake Five, Waukesha county. One knife was dug out of a mound by a dog while hunting, in 1860, in Troy, Waukesha county. One chisel was met with ten feet below the surface in cutting a road through a bluff at Cedarburg, Ozaukee county, in 1871. One of the most remarkable articles, a sort of copper pike, was dug up three feet under ground on the bank of Pike Lake, Hartford, Washington county, by Samuel Mowry in 1865. One massive celt, at first turned up in Merton, Waukesha county, a pedlar [sic] had preserved for twenty years. Several knives and other implements found near lakes and rivers appear to have been washed out of their banks. A lance-head found at Rubicon, Dodge county, in 1869, has a lump or stud of silver on one side of it.

But we cannot fail to ask, "who made these copper instruments? was it Indians or some pre-Indian race?" It has been argued that they are of pre-Indian origin because the skeletons with which they are discovered in burial mounds are not of the Indian type, but of a very different cranial development. Again, as the mounds, multitudinous and often of vast size, are beyond Indian industry, so the tools seem beyond Indian ingenuity. Most of them indeed, are hammered, and so show copper used rather as a mineral than as a metal. Others of the coppers betray no marks of hammering, no laminations or flaws. Practical foundrymen detect on them mould-marks where the halves of a flask united, and so declare them smelted. Others they hold were run in a sand-mold. These indications of casting are plainest on the largest piercer and on one of the chisels, except perhaps on certain implements which Mr. Perkins has carried abroad for the conversion to his views of trans-Atlantic skeptics regarding our pre-historic metallurgy. All proofs that our coppers were cast, tend to show that they are not the handiwork of Indians.

Our early annals indicate that our copper implements were a pre-Indian manufacture. They testify that the earliest travelers in Wisconsin found the Indians using copper, if at all, only for trinkets and totems, but not for implements either of war or of peace. Thus La Salle on his last expedition through this region, well nigh two centuries ago, says of the Indians: "The extremity of their arrows is armed, instead of iron, with a sharp stone or the tooth of some animal. Their buffalo-arrow is nothing else but a stone or bone, or sometimes a piece of very hard wood" Charlevoix, writing about 1720, mentions Indian "hatchets of flint which take a great deal of time to sharpen, as the only mode of cutting down trees." "To fix them in the handle," says he, "they cut off the head of a young tree, and make a notch in it in which they thrust the head of a young tree, and make a notch in it in which they thrust the head of the hatchet. After some time the tree by growing together keeps the hatchet so fixed that it cannot come out. They then cut the tree to such a length as they would have the handle." "Both their arrows and javelins," he adds, "are armed with a point of bone wrought in different shapes." According to Hennepin about 1680, (2.103) "the Indians, instead of hatchets and knives, made use of sharp stones which they fastened in a cleft piece of wood with leather thongs, and instead of awls they made a certain sharp bone to serve." The Jesuit Father Allouez, writing about 1660, says "I have seen in the hands of the savages, pieces of copper weighing from ten to twenty pounds. They esteem them as divinities or as presents made them by the gods. For this reason they preserve them wrapped up with the most precious things, and have sometimes kept them time out of mind." In none of these or other early chronicles do I find any mention of any copper tool whatever. Pre-historic mines about Lake Superior are a proof that our copper implements are not Indian work. No tradition of such mines was brought to light by early adventurers among Indians. But if excavated by them to such an extent as we see them, and for ages, how could they have been given up and even forgotten? On the whole the evidence now before us tends to show that our copper tools are the work of some pre-Indian race. The success of Mr. Perkins in unearthing coppers in unlooked for numbers should raise up a legion of copper-hunters. For encouraging such investigators still more, my last words shall be regarding the greater harvest than has crowned his labors which seems to me ripe for their sickles.

Indications are not wanting that our past prizes in copper-hunts, are all as nothing to what is in store for us. Pre-historic mining-pits honeycomb Isle Royal all over. Along the south shore of Lake Superior they are frequent for a hundred miles. They were every one rich pockets. Their yield of copper must have been many times enough for sheathing the British navy. What has become of this copper? It cannot have vanished like iron in oxidizing rust. It must still exist, and lurk all around us. At Assouan the quarries prove to a stranger that Egypt must be rich in granitic monoliths, for there we see the rock whence they were hewn. Spanish treasure-ships sunk in the Caribbean ages ago, still teach divers where to ply their sub-marine machinery for richest spoils. In Greece, the Styx, and other catabothra, or lost rivers—emptying into subterranean abysses, suggested to the ancients streams that girdled the whole under world. So our mining shafts sunk time out of mind are a prophecy and an assurance of copper bonanzas for explorers in the future so vast as will make us utterly forget whatever has been discovered. All hail such a ressurrection [sic] of the copper age. The longer it has been lost the more welcome will it be when found again.



William Francis Allen, A.M.
(1830–1889)

Expert in Roman history, voluminous author, and editor of the classics; professor of ancient languages and history (later history and Latin) at the University of Wisconsin; sixth president of the Wisconsin Academy, 1888–89

DEPARTMENT

OF SOCIAL AND POLITICAL SCIENCE

UNITED STATES SOVEREIGNTY—WHENCE DERIVED, AND WHERE VESTED

BY W. F. ALLEN, A. M.,

Professor of History and Latin in the University of Wisconsin

The late war brought to an end the long and fierce controversy as to the nature of the Federal Union. What argument had not been able to decide, was decided by arms; and the United States are recognized as a Nation, possessed of sovereignty. With the determination of this controversy, however, another question has come into prominence, as to the origin of this sovereignty. Before the war it was commonly held that the act which severed the colonies from the mother country had as its effect the creation of thirteen independent and sovereign States; and that it was not until the formation of the Federal Constitution that sovereignty was conferred upon the central government. This doctrine, however, of the original sovereignty of the States, has been thought to afford some foundation for the doctrine of Secession. Some of the most ardent advocates, therefore, of the national and sovereign character of our Union, have, since the war, brought into great prominence the theory that the Nation was not created by the States, but the States by the Nation; that the States were never, in any true sense of the term, sovereign, but that the act of independence created at once a sovereign Nation. This view has been most fully elaborated in a series of articles in the first volume (1865) of the *Nation*, by Hon. Geo. P. Marsh, United States minister to Italy; it is presented also by Professor Pomeroy in his "Introduction to Constitutional Law." In this work the authority of Hamilton, Jay, Marshall, Story and Webster is claimed for this theory. I do not think, however, that Marshall and Webster can fairly be cited as its adherents. Mr. Pomeroy has given no citations in support of his view, and on the other hand both these jurists have expressed themselves unequivocally in favor of the original sovereignty of the States. Webster says, of the Confederation: "it was a league, and nothing but a league."[*] Chief Justice Marshall's language is: "it has been said, that they [the States under the Confederation] were sovereign, were completely independent, and were connected with each other only by a league. This is true."[†]

Admitting, therefore, that the one theory has in its behalf the authority of Jay, Hamilton, Story and Kent, the other has the equally high authority of Marshall, Madison and Webster. We may, therefore, where authorities disagree, proceed to examine the arguments with perfect freedom from bias. The question is eminently an historical one—that is, a question of facts, not of theory. Sovereignty being the supreme power to command, it is simply a question of fact what organization was found in possession of this power, when it ceased to be exercised by Great Britain.

It requires no argument to show that before the Revolution the colonies were absolutely dependent upon Great Britain; whatever powers of government they severally possessed was in virtue purely of sufferance or explicit grant, on the part of the mother country. It is equally clear that the colonies were connected with one another by no organic bond. There was no government of the united colonies; each colony had its own government; and if sometimes, for the convenience of administration, two or more colonies were united under the same royal governor, this was simply an administrative union—one official managing two independent governments at a time, not a single government resulting from the fusion or union of two individual ones. There were thirteen organized communities, standing in a condition of coequal dependence upon the government of Great Britain. This tie of dependence was severed by the Declaration of Independence, July 4, 1776, sustained, as this act was, by armed force.

Two points fall here under consideration: first, the power which severed the tie; second, the logical effects of the act of severance.

First, the power that performed the act of severance was the Continental Congress. But by what authority, and in virtue of what delegation of power did the Continental Congress act? Was the Congress the organ of the several States, or of the "people at large" (to use Mr. Marsh's expression)?[‡] To answer this question, which rests at the bottom of the argument, we must trace briefly the history of this Congress.

[*] Speech on "The Constitution not a Compact," Works, iii. 454.

[†] Ogden vs. Gibbons, 9 Wheaton, 187.

[‡] The Nation, No. 23.

In the year 1764, upon motion of James Otis, the General Court of Massachusetts passed a resolution proposing to the other colonies to form a union for the purpose of resisting the acts of the British government. This proposition was accepted, first by Virginia, then by the other colonies. The Congress met the next year (1765), and shortly afterward, as a result of the spirit thus manifested, the Stamp Act was repealed. The Second Continental Congress met in 1774, called in a precisely similar manner. In both cases the members of the Congress were elected by the several colonies, and in both cases it was only a portion of the colonies—nine the first time, twelve the second—that were represented. Now so long as Georgia staid [sic] away, it is clear that not "the people at large of the United States," but only the people of twelve colonies, were engaged in formal acts of resistance. In the assembly thus composed of delegates from the several colonies, the colonies voted *as such*; no measure was adopted by a majority of votes, as would have been the case if they had been considered to represent the people at large; a majority of the *colonies* must always decide. It was by colonies that the Declaration of Independence was passed, and in this document the several colonies are declared to be "free and independent States."

Let us pause a moment upon this word "State," which thus makes its appearance in our political vocabulary. The great convenience of having a different term to denote the units which compose our federal government from that which designates the federal government itself, has established, in American constitutional law, a fundamental difference in the meaning of the respective terms. By *State* we understand a political organization inferior to the *Nation*. But this distinction is peculiar to American public law. The two terms are originally identical in meaning, or rather in application; being applied indifferently to the same object, but from different points of view. A State is, in public law, a Nation, regarded from the point of view of its organization; a Nation is a State, regarded from the point of view of its individuality. We must not, therefore, suppose that when the colonies, in 1876, declared themselves to be free and independent States, they attributed to the word State the same inferiority which we now associate with the word. They understood by it, a sovereign political organization. That they selected this term, rather than Nation, is no doubt partly due to its expressing more distinctly the idea of organization; partly, I am ready to admit, to the feeling that *Nation* was a larger term, and that a higher organization, which should embrace all these individuals in one whole, was destined to result. Nay, we meet the term Nation very early, as applied to the united body.

That the Congress considered itself as acting as the organ of the colonies or States, and not of the people at large, appears manifest from the language habitually used. On the tenth of May, 1776 Congress resolved to "recommend" to the "respective assemblies and conventions of the United Colonies," to form permanent governments. August 21, of the same year, it made use of the expression: "All persons not members of, nor owing allegiance to any of the United States of America,"—showing that allegiance was regarded as due to the several States. Its constant title for itself was "the United States in Congress assembled"—a term which plainly recognizes that the United States, as an organized body, has no existence except in the Congress, which Congress, as we have seen, acted purely as the organ of the several States.

I pass now to the nature and effect of the act of severance. This act was in the first place purely negative in its intrinsic character. It simply put an end to a certain previously existing relation—that by which the colonies individually depended upon the British sovereignty. The relations of the several colonies to one another could not be affected by it. If before the act they formed a united, organized body, this united body, in virtue of the act of independence, succeeded to the sovereignty surrendered by the mother country; if they were individual and disconnected before, they remained so after the act, and each individual passed into the full enjoyment of sovereignty.

Now I have shown first, that before the revolution the colonies had no organic connection with one another, but only with the mother country; second, that the union which they formed for purposes of resistance professed to be nothing but a voluntary, incomplete and temporary association, with only limited and temporary aims, possessing none of the essentials of a permanent government, capable, it is true, of developing into a complete sovereignty, but in all its acts and words appearing as not itself an organic body, but the representative of certain organic bodies. "The United States in Congress assembled," made no claim to individual or independent existence, but acted avowedly as a mere intermediary or instrument of joint action for organisms which did possess individual existence. And this practical independence accrued to the several colonies simply from the fact that, upon the severance of the tie which connected them severally to the mother country, each was left standing legally alone; and, standing alone, having no legal superior, but possessing a complete and adequate organization of its own, each colony passed into the undisputed enjoyment of sovereignty.

Neither before nor after the commencement of the revolution, therefore, did there exist any united organic body which could supersede the several colonies, and assert a claim to the lapsed sovereignty of Great Britain. And if this is true for the period of inchoate nationality which intervened between the first acts of resistance and the practical establishment of independence, still more is it true for the ensuing period of the Confederation. It needs no argument to show that the States were at this time recognized as fully and exclusively sovereign; its Articles explicitly provide "that each state retains its sovereignty and power which is not by this Confederation expressly delegated to the United States in Congress assembled." All that can be said in opposition to this view is that this was a "palpable usurpation,"* set on foot during this "embryonic or inchoate period"†; and their arguments plainly imply that they understand the Articles of Confederation to represent a different phase of national life from the Declaration of Independence, and as requiring therefore to be construed from a different point of view; they were adopted by Congress sixteen months later than the other act, (Nov. 15, 1777.) and in this period of time, it is hinted, the "flow of enthusiasm," under which the united act of independence had been accomplished, "receded," and selfish and local prejudices took its place. Now, if the Articles of Confederation were really drawn up a year and a half after the Declaration of Independence, this reasoning would have much weight. But the date here given is only that of the *adoption* of the articles by Congress. They were reported to Congress July 12, 1776, just a week after the Declaration—the preliminary steps, indeed, were taken in June, before the passage of the act of independence. It is therefore perfectly legitimate to interpret the act of independence in the light of the government which was established after it. The two acts were to all intents and purposes parts of one and the same act. In the very act of declaring their independence, the States formed themselves into a Federal Union; and in this Union the several States were explicitly declared to be independent and sovereign; from which it necessarily follows that the Union thus formed, was, in Webster's words, "a league and nothing but a league."

It will be seen that the whole controversy turns upon the period between the suspension of the royal authority and the establishment of the confederation. While the royal authority continued to be rec-

* Pomeroy, p. 48.

† Mr. Marsh, in the Nation, No. 1.

ognized, sovereignty of course belonged to Great Britain; after the establishment of the Confederation, it as manifestly belonged to the several States. Was there an interval during which it was possessed by the United Colonies? Mr. Marsh says:* "it was not for a moment imagined that the sovereignty was in the interim lodged anywhere except in the whole people of the United Colonies." But he brings no facts to prove this assertion.

At the beginning of this discussion it was remarked that the question was essentially an historical one, and must find its decision in historical facts—that is, in the series of events by which the sovereignty was transferred from Great Britain to the United States; and I think I have shown that, as a matter of fact, this transfer was not made at one stroke, but that the sovereignty was actually possessed for a while by the several States, before it was transferred by a deliberate act to the nation. There remain, however, some theoretical objections to this view, which it will be necessary to consider.

Mr. Pomeroy states these theoretical objections in the following strong terms: "Grant that in the beginning the several states were, in any true sense independent sovereignties, and I see no escape from the extreme positions reached by Mr. Calhoun."† No arguments are presented in support of this startling assertion, except the doctrine that among the attributes of sovereignty, "the one which underlies all others, and is, in fact, necessarily implied in the very conception of separate nationality, is that of supreme continued self-existence. This inherent right can only be destroyed by overwhelming opposing force; it cannot be permanently parted with by any constitution, treaty, league, or bargain, which shall forever completely resign or essentially limit their sovereignty, and restrain the people from asserting it." There is no attempt made to prove this doctrine; it rests simply upon Mr. Pomeroy's assertion, backed by references to the works of half a dozen European publicsts [sic]. According to this doctrine Texas was never annexed; if the United States had conquered her, and forced her into the Union, her status would have been a legal one; but as she came in voluntarily, surrendering her sovereignty and individual existence, the act was null and void. According to this doctrine the act of union by which, in 1706, England and Scotland surrendered their individual sovereignty, and united into the new sovereignty of Great Britain, was an impossible act; and Scotland might now, if she chose,

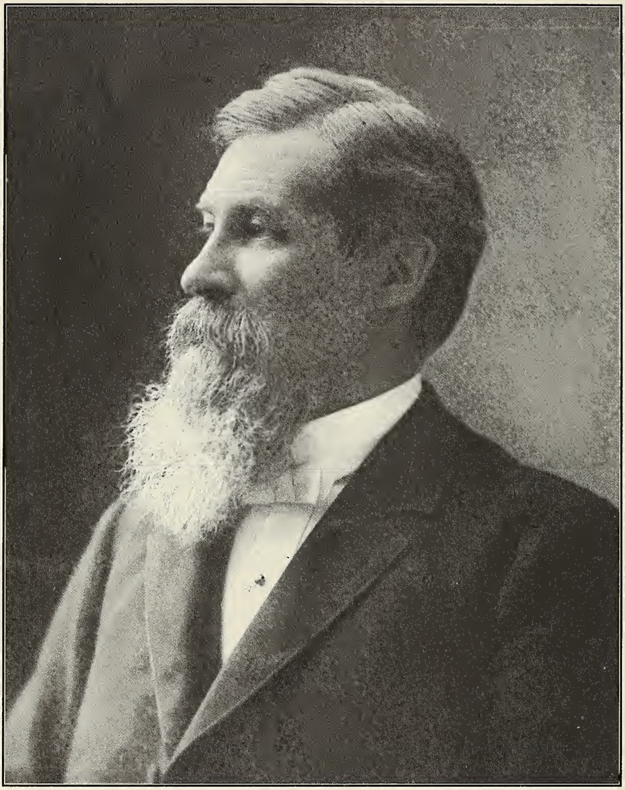
* The Nation. No. 21.

† p. 39.

re-establish her Parliament at Edinburgh, and crown a Presbyterian King at Scone. Again; on this theory, what are we to do with Rhode Island and North Carolina in the interval between the establishment of the Federal Government, and their accession to it? They were certainly not members of the new Union; which made no claim to extend its power over them. The Confederation of which they had been members, no longer existed. There is but one answer to this question. They were independent, sovereign States, as independent and as sovereign as Costa Rica, or San Marino, or the Free City of Hamburg.

In arguing for the original sovereignty of the States, I would not be understood to advocate the modern doctrine of State Rights. I hold with Marshall, Webster and Story, with Mr. Marsh and Mr. Pomeroy, that the United States form a nation, and possess full powors [sic] of sovereignty. But I hold that this sovereignty was formally and voluntarily conferred upon them by the States in the act of forming the Federal Constitution. The doctrine advanced by Mr. Pomeroy* as to the relation of the States to the United States, which is essentially that of Mr. Austin, I fully accept. "The people of the United States, as a nation, is the ultimate source of all power, both that conferred upon the General Government, that conferred upon each State as a separate political society, and that retained by themselves." Only, by "ultimate source," I do not understand historical filiation, but legal authority, under the constitution; the States—meaning by that the people of the several States—formed themselves, by this act, into "the People of the United States;" and this sovereign people, as organized in States, exercises its sovereign powers by the two-fold instrumentality of the National Government and the States' Governments, distributing these powers between these two instrumentalities as seems most expedient. Thus the States are as much sovereign as the nation; but in truth neither is sovereign, but each is an organization for the exercise of a certain definite portion of the powers of government. The sovereignty is not divided between States and Nation, because sovereignty is indivisible and absolute; but the functions of government, in which consists the exercise of the powers of sovereignty, can be divided, and are divided between these two organizations.

* Page 23



Courtesy The State Historical Society of Wisconsin Whi(x3)33074

Thomas Chrowder Chamberlin, Ph.D., Sc.D., LL.D.
(1843–1928)

Wisconsin State Geologist; professor of geology at Beloit College; charter member and fifth president of the Wisconsin Academy, 1885–87; president of the University of Wisconsin, 1887–92; professor at the University of Chicago

DEPARTMENT

OF THE MATHEMATICAL AND PHYSICAL SCIENCES

ON THE EXTENT AND SIGNIFICANCE OF THE WISCONSIN KETTLE MORAINE

BY T. C. CHAMBERLIN, A.M.,

State Geologist, and Professor of Geology in Beloit College[1]

At the meeting of the Academy, three years since, I took the liberty of occupying the attention of the members by the presentation of some observations and conclusions in reference to a peculiar series of drift hills and ridges in eastern Wisconsin, known as the Kettle range, and the views then advanced afterwards found a place in my report on the geology of eastern Wisconsin.[2] Similar observations were subsequently made by Professor Roland D. Irving, of the Wisconsin survey, and his conclusions are in perfect agreement with my own.[3]

In neither case, however, was any attempt made to show the full extent of the formation outside of the districts reported upon, or to point out its theoretical significance, the chapters being intended only as contributions to local geology, made under somewhat severe limitations as to space.

It is not now possible to map, or even safely conjecture, the complete extent and limitations of the formation; but it is the purpose of this article to add such trustworthy observations as have since been made, and to gather such evidence as may justify a provisional mapping of the range, where it has not been actually traced. A portion of the paper will, therefore, relate to well ascertained facts, while other portions will be in various degrees hypothetical. If care is taken to distinguish between these portions, no harm can arise from their association; while the provisional

[1]I have taken advantage of the interval between the date of reading and the printing to introduce new matter. T.C.C.

[2]Geology of Wis., Vol. II, 1877 (revised edition 1878), pp. 205–215.

[3]Geology of Wis., Vol. II, 1877 (revised edition 1878), pp. 608–635.

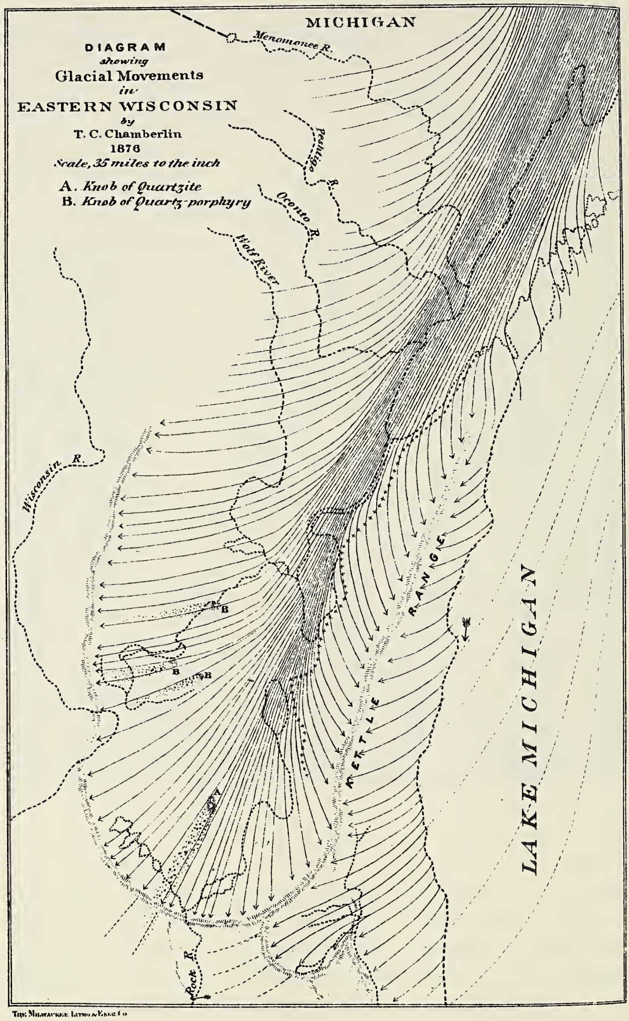


DIAGRAM
showing
Glacial Movements
in
EASTERN WISCONSIN
by
T. C. Chamberlin
1876
Scale, 35 miles to the inch
A. Knob of Quartzite
B. Knob of Quartz-porphyry
MICHIGAN
Menomonee R.
Peshtigo R.
Oconto R.
Wolf River
Wisconsin R.
KETTLE RANGE
LAKE MICHIGAN
Rock R.
The Milwaukee Litho & Engr Co

mapping will, it is hoped, prove of service in both stimulating and guiding further investigation. The extent of the range is likely to prove too great for the immediate time and means of a single observer; while the broad and irregular, and sometimes obscure, character of the belt is such that it is likely to be overlooked, as a continuous range, as experience has shown, unless attention be called to it, or the observer be keenly alive to distinctions in drift topography. It is believed, therefore, that the presentation of some things that are only probably, not certain, will not be without value.

It will be advisable to consider first, somewhat critically, the character of the formation. The following description, which is based upon careful observation, relates more specifically to the moraine in Wisconsin, where it is usually well developed, and may require some modification in its application to the range where sub-aqueous deposits overlap or encroach upon it, and in other special situations.

Surface Features.—The superficial aspect of the formation is that of an irregular, intricate series of drift ridges and hills of rapidly, but often very gracefully, undulating contour, consisting of rounded domes, conical peaks, winding and, occasionally, geniculated ridges, short, sharp spurs, mounds, knolls and hummocks, promiscuously arranged, accompanied by corresponding depressions that are even more striking in character. These depressions, which, to casual observation, constitute the most peculiar and obtrusive feature of the range, and give rise to its descriptive name in Wisconsin, are variously known as "Potash kettles," "Pot holes," "Pots and kettles," "Sinks," etc. Those that have most arrested popular attention are circular in outline and symmetrical in form, not unlike the homely utensils that have given them names. But it is important to observe that the most of these depressions are not so symmetrical as to merit the application of these terms. Occasionally, they approach the form of a funnel, or of an inverted bell, while the shallow ones are mere saucer-like hollows, and others are rudely oval, oblong, elliptical, or are extended into trough-like, or even winding hollows, while irregular departures from all these forms are most common. In depth, these cavities vary from the merest indentation of the surface to bowls sixty feet or more deep, while in the irregular forms the descent is not unfrequently one hundred feet or more. The slope of the sides varies greatly, but in the deeper ones it very often reaches an angle of 30° or 35° with the horizon, or, in other words, is about as steep as the material will lie. In horizontal dimensions, those that are popularly recognized as "kettles" seldom exceed 500 feet in diameter, but, structurally considered, they cannot be limited to this dimension, and it may be difficult to assign definite limits to them. One of the peculiarities of the range is the large number of small lakes, without inlet or outlet, that dot its course. Some of these are mere ponds of water at the bottom of typical kettles, and, from this, they graduate by imperceptible degrees into lakes of two or three miles in diameter. These are simply kettles on a large scale.

Next to the depressions themselves, the most striking feature of this singular formation is their counterpart in the form of rounded hills and hillocks that may, not inaptly, be styled inverted kettles. These give to the surface an irregularity sometimes fittingly designated "knobby drift." The trough-like, winding hollows have their correlatives in sharp serpentine ridges. The combined effect of these elevations and depressions is to give to the surface an entirely distinctive character.

These features may be regarded, however, as subordinate elements of the main range, since these hillocks and hollows are variously distributed over its surface. They are usually most abundant upon the more abrupt face of the range, but occur, in greater or less degree, on all sides of it, and in various situations. Not unfrequently, they occur distributed over comparatively level areas, adjacent to the range. Sometimes the kettles prevail in the valleys, the adjacent ridges being free from them; and, again, the reverse is the case, or they are promiscuously distributed over both. These facts are important in considering the question of their origin.

The range itself is of composite character, being made up of a series of rudely parallel ridges, that unite, interlock, separate, appear and disappear in an eccentric and intricate manner. Several of these subordinate ridges are often clearly discernible. It is usually between the component ridges, and occupying depressions, evidently caused by their divergence, that most of the larger lakes associated with the range are found. Ridges, running across the trend of the range, as well as traverse spurs extending out from it, are not uncommon features. The component ridges are themselves exceedingly irregular in height and breadth, being often much broken and interrupted. The united effect of all the foregoing features is to give to the formation a strikingly irregular and complicated aspect.

This peculiar topography, however, finds a miniature representative in the terminal moraines of certain Alpine glaciers. Most of the glaciers of Switzerland, at present, terminate in narrow valleys, on very steep slopes, and leave their debris in the form of lateral ridges, or a torrentially washed valley deposit. A portion of them, however, in their recently advanced state, descended into comparatively open valleys of gentle decline, and left typical, terminal moraines, *formed from the ground moraines of the glaciers*, and only slightly obscured by the medial and lateral morainic products, which have little or no representative in the Quaternary formations. The Rhone glacier has left three such ridges, separated by a few rods interval, that are strikingly similar in topographical eccentricities to the formation under discussion, save in their diminutive size. The two outer ones have been modified by the action of the elements, and covered by grass and shrubs, while the inner one remains still largely bare, and, as they have been cut across by the outflowing glacial streams, they are exceedingly instructive as to glacial action under these circumstances. The inner one graduates in an interesting way into the widespread ground moraine, which occupies the interval between it and the retreating glacier, where not swept by floods, and which presents a different surface contour, illustrative of Till topography. The two Grindelwald glaciers have left similar moraines; those of the upper one, being the more massive, and being driven closer together, present an almost perfect analogy to the Kettle ranges. The Glacier du Bois, the terminal portion of the Mer de Glace, the Argentière, and, less obviously, the Findelen, and others, so far as their situation favored, have developed similar moraines, and indicate that this is the usual method of deposit under these conditions. Reference is here made *only* to the terminal deposit of the *ground moraine*, eliminating, as it is quite possible to do, for the most part, the material borne on the surface of the glacier.

The Material of the Formation. — This topic, which is one of primary importance in determining the origin of the deposit, readily divides itself into three subordinate ones, all of which need discriminative attention; (1) the *form* of the constituents, (2) their *arrangement* as deposited, and (3) their *source*.

(1) Premising that the Kames, and those deposits which have been associated with them in the literature of the subject, are described as composed mainly of sand and gravel, it is to be remarked, in distinction, that *all* the four forms of material common to drift, viz.: clay, sand, gravel, and boulders, enter largely into the constitution of the Kettle range, in its typical development. Of these, gravel is the most conspicuous element, *exposed to observation*. This qualification is an important one in forming an adequate conception of the true structure of the formation. It is to be noticed that the belt, at many points, exhibits two distinct formations. The uppermost—*but not occupying the heights of the range*—consists almost wholly of sand and gravel, and lies, like an irregular, undulating

sheet, over portions of the true original deposit. This superficial formation is confined mainly to the slopes and flanks of the range, and to depressed areas between its constituent ridges; though, when the whole belt is low, it often spreads extensively over it, so as sometimes to be quite deceptive. But, where the range is developed in force, this superficial deposit is so limited and interrupted, as to be quite insignificant, and not at all misleading; and, at some points, where it is more widely developed, excavations reveal unequivocally its relationship to the subjacent accumulations. In such cases, the lower formation shows a more uneven surface than the upper one, indicating that the effect of the latter is to mask the irregular contour of the lower and main formation. Notwithstanding this, the upper sands and gravels are often undulatory, and even strongly billowy, and the bowls and basins in it commonly have more than usual symmetry. A not uncommon arrangement of this stratum is found in an undulating margin on the flank of a ridge of the main formation, from which it stretches away into a sand flat or a gravel plain.

Setting aside this, which is manifestly a secondary formation, it is still true that gravel forms a large constituent of the formation. Some of the minor knolls and ridges are almost wholly composed of sand and gravel, the elements of which are usually very irregular in size, frequently including many boulders. But, notwithstanding these qualifications, *the great core of the range*, as shown by the deeper excavations, and by the prominent hills and ridges, that have not been masked by superficial modifications, *consists of a confused commingling of clay, sand, gravel, and boulders, of the most pronounced type.* There is every gradation of material, from boulders several feet in diameter, down to the finest rock flour. The erratics present all degrees of angularity, from those that are scarcely abraded at all, to thoroughly rounded boulders. The cobble stones are spherically rounded, rather than flat, as is common with beach gravel, where the attrition is produced largely by sliding, rather than rolling.

Stratification. — As indicated above, the heart of the range is essentially unstratified. There is, however, much stratified material intimately associated with it, a part of which, if my discriminations are correct, was formed simultaneously with the production of the unstratified portion, and the rest is due to subsequent modification. The local overlying beds, previously mentioned, are obviously stratified, the bedding lines being often inclined, rather than horizontal, and frequently discordant, undulatory or irregular.

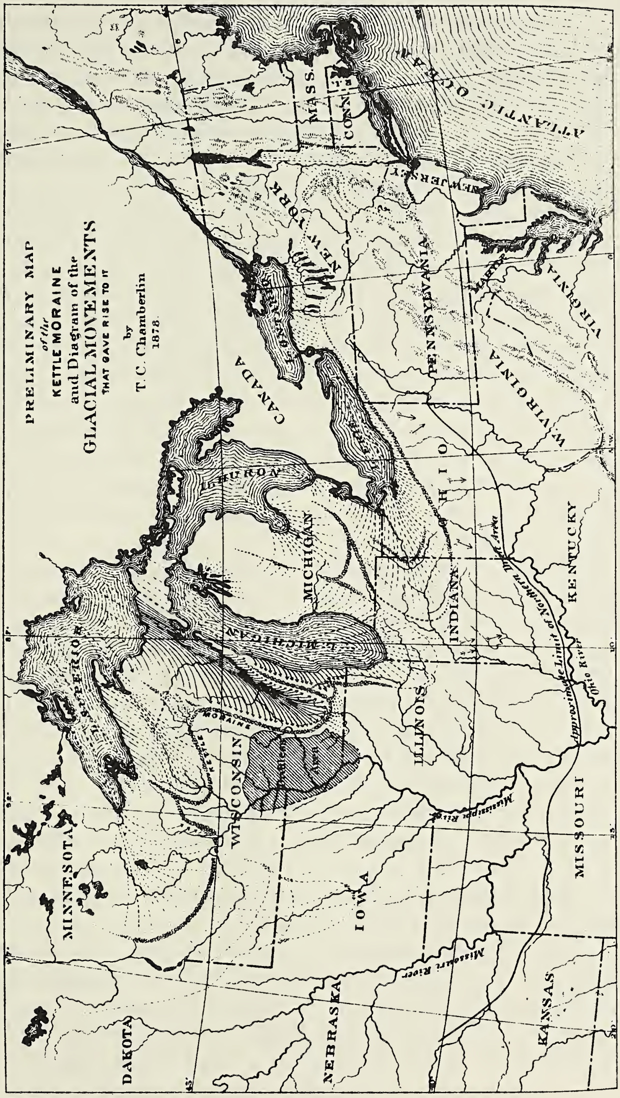
The Source of the Material. — This, so far as the range in Wisconsin is concerned, admits of the most unequivocal demonstration.

The large amount of coarse rock present renders identification easy, and the average abrasion that has been suffered indicates, measurably, the relative distance that has been traveled. The range winds over the rock formations in a peculiar manner, so as to furnish fine opportunities for decisive investigation. Of the many details collected, there is room here for a single illustrative case only. The Green Bay loop of the range surrounds on all sides, save the north, several scattered knobs of quartzite, porphyry and granite, that protrude through the prevailing limestones and sandstones of the region. These make their several contributions to the material of the range, *but only to a limited section of it, and that invariably in the direction of glacial striation.* Any given segment of the range shows a notable proportion of material derived from formation adjacent to it, in the direction of striation; and a less proportion, generally speaking, from the succeeding formations that lie beyond it, backward along the line of glacial movement for three hundred miles or more. It is undeniable, that *the agency, which produced the range, gathered its material all along its course for at least three hundred miles to the northward, and its largest accumulations were in the immediate vicinity of the deposit.* For this reason, as the range is traced along its course, its material is found to change, both lithologically and physically, corresponding to the formation from which it was derived.

These facts find ample parallel in the moraines of Switzerland. The marginal portion of the great moraine of the ancient expanded glaciers, on the flanks of the Juras, is composed, very largely, of boulder clay, derived from the limestones that lie in its vicinity, while the quantity of material derived from the more distant formations of the Alps is quite subordinate. Of the more recently formed moraines, those derived from the Bois, Viesch, Rhone, Aar, and other glaciers, which pass over granitic rocks, consist quite largely of sand, gravel, and boulders, clay being subordinate, while those glaciers of the Zermatt region, that pass mainly over schistose rocks, and the Grindelwald glaciers, that, in the lower part of their course, traverse limestone, give rise to a decided amount of clay. The moraines, previously referred to as miniature kettle ridges, are composed of commingled unstratified debris, in the main, but there are instances of assorted and stratified material. The inner moraine of the upper Grindelwald glacier presents much fine assorted gravel and coarse sand, heaped up, very curiously, into peaks and ridges, in various attitudes on the summit and sides of the moraine.

Relations to Drift Movements. — This is manifestly of most vital consideration. The course of drift movement may be determined, (1) by the grooving of the rock surface, (2) by the direction in which the material has been transported, (3) by the abrasion which rock prominence have suffered, (4) by the trend of elongated domes of polished rock, and, (5) less decisively, by the arrangement of the deposited material and the resulting topography. Recourse has been had to all these means of determination, in that portion of the range that has been carefully investigated, and their individual testimony is entirely harmonious, and their combined force is overwhelming. Exceptional opportunity for positive determination is afforded by the protruding knobs of Archæan rocks before alluded to, from which trains of erratics stretch away in definite lines, continuous with the striation on the parent knobs, and parallel to that of the region, as well as concordant with the general system. The united import of all observations, in eastern Wisconsin, testifies to the following remarkable movements, which may be taken as typical, and which are here given, because they have been determined with much care. Between Lake Michigan and the adjacent Kettle range, the direction was obliquely up the slope, as now situated, southwestward, towards the range. On the opposite side, between the Green Bay valley and the range, the course was, after surmounting the cliff bordering the valley, obliquely down the slope, southeastward, toward the range. In the Green Bay trough, the ice stream moved up the valley to its watershed, and then descended divergingly the Rock River valley. Between the Green Bay valley and the Kettle belt on the west, the course was up the slope, westward, or southwestward, according to position. These movements, which are imperfectly shown on the diagram, exhibit a remarkable divergence from the main channel toward the margin of the striated area, marked by the Kettle range.

Much of the data relating to the movements, outside of Wisconsin, has been derived from a study of publications relating to the geology of the several states, to whose authors I am indebted, but who should not be held responsible for the special collocation presented in the accompanying diagram, which, in some of its details, may prudently be held as somewhat tentative, until more rigorously verified. But the grand features of these movements, which may be confidently accepted, are very striking, and are very singularly related to the great basins of the lake region. The three main channels were the troughs of the great lakes, Superior, Michigan, and the couplet, Erie and Ontario, while between these lay three subordinate ones in the basins of the great bays, Saginaw, Green and Keweenaw.



The Milwaukee Litho & Engrav'g

The divergence of the striations from the main channels toward the range, in the case of the Green Bay valley, and, so far as the evidence goes, in other troughs, was an unexpected result, developed by combining individual observations; but, when the method of wasting and disappearance of a glacier is studiously considered, appears not only intelligible, but a necessary result, and one which finds partial illustration among existing glaciers.

Topographical Relations and Distribution. — The topographical relations of the formation are an essential consideration, but may be best apprehended in connection with its geographical extension, which now claims our attention. If we start with the northern extremity of the long known Potash Kettle Range, in Wisconsin, we find ourselves about midway between the southern extremity of Green Bay and Lake Michigan, and on an eastward sloping, rocky incline. The base of the range is here less than 200 feet above Lake Michigan, and is flanked on either side by the lacustrine red clays of the region; and seems, in some measure, to be obscured by them. From this point, it stretches away in a general south-southwestward direction, for about 135 miles, ascending gradually, and obliquely, the rocky slope, until it rests directly on its crest.

When within about twenty miles of the Illinois line, *it divides*, one portion passing southward into that state, and the other, which we will follow, curves to the westward, and crosses the Rock river valley. A profile of the rock surface across this valley, beneath the range, would show a downward curve of more than 300 feet. The range should not, perhaps, be regarded as sagging more than half that amount, however, in crossing the valley, as the canon-like channel of the pre-glacial river, seems to have been filled without much affecting the surface contour of the drift. But the fact of undulation to conform to an irregular surface, produced by erosion, and not by flexure of the strata, is a point to be noted, as it is a serious obstacle in the way of any explanation that is only applicable on the supposition that the formation was in a horizontal position when formed, as the view that it was produced by beach action, or the stranding of icebergs.

After crossing Rock river, the range curves gradually to the northward, passing over the watershed between the Rock and Wisconsin rivers, "descends abruptly 200 feet into the low ground of the valley of the Wisconsin,"[1] crosses the great bend of the river, sweeping directly over the quartzite ranges, according to Prof. Irving, with a vertical undulation of

[1] Prof. Irving, Geol. of Wis., Vol. II, 1877, page 616.

over 700 feet, after which it gradually ascends the watershed between the Mississippi and St. Lawrence drainage systems, until its base reaches an estimated elevation of 700 to 800 feet above Lake Michigan. From thence it has been traced across the headwaters of the Wisconsin river, by Mr. A. Clark, under my direction.[1]

Within the Chippewa valley, it has been observed by Prof. F. H. King, of the Wisconsin Survey, and I have observed it in the vicinity of the Wisconsin Central railroad. This region is covered by an immense forest, mainly unsettled and untraversed, even by foot paths, so that geological exploration is difficult and expensive, and, as no industrial importance attaches to it, and the rock below is deeply concealed by it, I have not deemed it sufficiently important to trace the belt continuously to justify the large expenditure of time and means requisite, especially as I entertain no serious doubts as to its continuity and general position. The observations made, indicate that it descends obliquely the eastern slope of the Chippewa valley, and crosses the river below the great bend (T 32, R. 6 and 7), near which the Flambeau, Jump, and several smaller streams gather themselves together, in a manner very similar to that of the branches of the Rock and Upper Wisconsin rivers, just above the point where they are crossed by the range. From this point the belt appears to curve rapidly to the northward, forming the western watershed of the Chippewa. It is joined in eastern Burnett county by a portion of the range coming up from the southwest, the two uniting to form a common range, analogous to that of eastern Wisconsin. The conjoint range thus formed, extends along the watershed of the Chippewa and Nemakagon rivers, to the vicinity of Long and Nemakagon lakes, on the watershed of Lake Superior. This part is given mainly on the authority of Mr. D. A. Caneday, who visited a portion of the formation with me, and whose discrimination can, I think, be trusted. Mr. E. T. Sweet, of the Wisconsin Survey, describes[2] a kettle range as lying along the axis of the

[1] To the eastward of the range, as thus traced, Col. Whittlesey describes (Smithsonian Contributions, 1866) a similar formation in Oconto County. I have observed the same at several points. Mr. E. E. Breed informs me that it occurs on the watershed between the Wolf and Oconto rivers, but it has not yet been traced through the wilderness, to any connection with the main range, and it is uncertain whether it is so connected or constitutes a later formation, as such later moraines have been observed at other points.

[2] Manuscript report on Douglas and Bayfield counties, to form a part of Vol. III, Geol. of Wis.

Bayfield peninsula, but it has not been ascertained that this is connected with the belt under consideration.

Returning to the junction of the two ranges in eastern Burnett county, I have traced the belt thence southwestward through Polk and St. Croix counties to St. Croix lake, on the boundary of the state. The lower portion of this has also been studied by Prof. L. C. Wooster, of the Wisconsin Survey. The southeastern range of the belt may be conveniently seen on the North Wisconsin railroad, near Deer Park, and on the Chicago, St. Paul & Minneapolis line, to the west of the station Turner, but only in moderate force.

If a good surface map of Minnesota be consulted, it will be seen that there lies along the watershed, between the Upper Mississippi and the conjoint valleys of the Minnesota and Red rivers, a remarkable curving belt of small lakes. Along this line, lies a chain of drift hills, known in its northwestern extension as the Leaf hills. In the Sixth Annual Report of the Geological Survey of Minnesota, received just as this article is going to the printer, Prof. N. H. Winchell, speaking of the great moraines of the northwest, says: "There are two such that cross Minnesota, the older being the Coteau and the younger, the Leaf hills. Corresponding to the latter, the Kettle Range in Wisconsin seems a parallel phenomenon."[1] I have seen this belt, west of Minneapolis, and concur in Prof. Winchell's opinion. I have also observed, hastily, what I regard as portions of it—dissevered by the river channels—on the peninsula formed by the bend of the Mississippi and the Minnesota, south of St. Paul, and on the similar peninsula between the Mississippi and Lake St. Croix; and this seems to be the line of connection between the Wisconsin and Minnesota ranges. It appears to me, therefore, well nigh certain, that the Leaf hills of Minnesota are not only analogous to the Wisconsin Kettle range, but are portions of the same linear formation.

The multitude of small lakes, found in Wisconsin, lie almost exclusively either along the Kettle belt itself, or in the area within, or north of it. The surface outside has a much more perfect system of drainage, and is almost entirely free from lakelets. The Kettle range constitutes the margin of the lake district. But in Minnesota, south of the Leaf hills, there is an extensive lake region stretching southward in a broad tongue, nearly to the center of Iowa, though the lakes are

[1] Sixth Annual Rept. Geol. & Nat. Hist. Sur. Minn., p. 106. The R. R. profiles crossing this belt furnish valuable data. See Ann. Rept. for 1872, pp. 53 and 57, and Sixth Ann. Rept., pp. 47 and 156.

not very numerous in the latter state. The question naturally arises, whether this lake district is likewise bordered by similar drift accumulations, and this question, though not essential to the present discussion, has much interest in connection with it. In respect to this, I can only give some detached observations and quotations. As already stated, accumulations of this character occur south of St. Paul. Still further to the southward, in the town of Aurora, Steel county, there is a moderate exhibition of gravelly boulder-bearing hillocks and ridges, accompanied by shallow basins and irregular marshes, much after the manner of the formation in question. From the descriptions of Prof. Harrington,[1] these features appear to characterize the county somewhat widely, especially in the southern part. Near Albert Lea, in the adjoining county, on the south, and only a few miles from the Iowa line, there is a more prominent development of similar features, the ridges having a southwestward trend. Dr. C. A. White, in the Geology of Iowa, describes a terrace in the northern part of the state, which, in its eastern extension, "becomes broken up into a well marked strip of 'knobby country.' Here it consists of elevated knobs and short ridges, wholly composed of drift, and usually containing more than an average proportion of gravel and boulders. Interspersed among these knobs and ridges, are many of the peat marshes of the region."[2] One knob he estimates as rising 300 feet above the stream at its base. This area lies in the line of the preceding localities, and near the Minnesota border. Between the "knobby country" and the Algoma branch of the C., M. & St. P. R. R., and stretching southwestward from the latter, there is a broad belt of low mounds and ridges, some of which show the structure and composition common to the Kettle moraine, while others present externally only a pebble clay, similar to that which characterizes the level country to the west of it. The whole presents the appearance of a low range modified by lacustrine deposits.

Near the center of the state, Dr. White describes a second range under the name of "Mineral Ridge,"[3] as consisting, "to a considerable extent, of a collection of slightly raised ridges and knolls, sometimes interspersed with small, shallow ponds, the whole having an elevation, probably, nowhere exceeding 50 feet above the general surface, but, being in an open prairie region, it attracts attention at a considerable distance." Both of these ridges, Dr. White classes as probable moraines.

[1] Geol. and Nat. Hist. Sur. Minn., Ann. Rept. 1875, pp. 108 *et seq.*

[2] Geol. of Iowa, 1870, p. 99.

[3] Loc. cit.

This Mineral ridge lies south of the lake district, and may be regarded as forming its margin in that direction. On the western border, Dr. White describes "knobby drift," in Dickinson county, which, however, is "without perceptible order or system of arrangement."[1] To the northwest from this, we soon encounter the morainic accumulations of the "Coteac de Prairie,"[2] and the "Cobble Knolls" and "Antelope Hills."

These observations do not indicate a continuous, well defined range, but seem rather to point to a half-buried moraine, that only here and there, along its course, protrudes conspicuously, and this is the impression gained from an inspection of the formation. It is to be noted, as supporting this view, that, at least so far as the eastern side is concerned, this supposed moraine is flanked on the *exterior* by level plains, of smooth surface, often underlaid by sand and gravel, that seemingly owe their origin to broad rivers or lakes that fringed the border of the glacier, in its advanced state, when it probably discharged its waters over the moraine at numerous points, rather than at one, or a few, selected points, as would more likely be the case during its retreat, when accumulations of water could gather along its foot, within the moraine, and large areas be discharged at some single favorable point. But on the inner side of the moraine, the surface, although nearly level, in its general aspect, undulates in minor swells and sags, and the drainage is imperfect. The substratum, instead of being gravel, sand, or laminated clay, is generally a pebble or boulder clay. *Outside* of the moraine, the existing surface contour was formed in the presence, and, to some extent, under the modifying influence, of a fairly established drainage system. But on the *interior*, the drainage system has not, even yet, become fully established, much less impressed itself upon the surface configuration, except in the vicinity of the main rivers.

The terrace-like ridge mentioned by Dr. White, and some of the lines of hills described by Prof. Winchell in Minnesota, as running in a similar direction, may be perhaps regarded as minor morainic lines, stretching across the glacial pathway and marking oscillations in its retreat, analogous to some quite clearly made out in Wisconsin.[3]

[1] Geol. of Iowa, Vol. II, p. 221.

[2] See note of Prof. Mather, Nat. Hist. Sur. 1st Dist., N.Y., p. 193. See also 2d Annual Report Geol. and Nat. His. Sur. Minnesota, by N. H. Winchell, pp. 193 to 195; also *loc cit., ante.*

[3] Geol. of Wis., Col. II, 1876, p. 215 *et seq.*

This southern morainic loop is, of course, presumed to be older than the Kettle range, and is here discussed because of the interesting way in which it is associated with the latter formation, and the suggestions it may contribute to the final solution of the main problem, to which the special one under discussion is only a tributary, viz.: the definite history of the Quatenary formations.

Returning to the branching of the range in southeastern Wisconsin, we find the left arm, or that nearest Lake Michigan, striking southward into Illinois. If we lay before us Prof. Worthen's geological map of that state, and attentively observe its topographical features and its drainage systems, it will be observed that nearly all the lakelets, the greater part of the marshes, and most of the region of abnormal drainage may be included in a curving line, rudely concentric with the shore of Lake Michigan, starting near the center of McHenry county, on the Wisconsin line, and ending in Vermillion county, on the Indiana border. It may also be observed, on a similar inspection of Indiana, that nearly all the lake district lies north of the Wabash.

In Wisconsin, as already stated, we have found this area bordered by the Kettle range, which is itself notably lake-bearing. The range continues to sustain this relationship in Illinois, so far as I know it to be directly continuous. It exhibits a progressive broadening, and flattening, as it enters upon the level county that encompasses the head of Lake Michigan. The pebble clay deposit—not coarse boulder clay—that characterizes the flat country, and which, to the north, has been separated from the range by a belt of coarse boulder clay, here approaches, and appears, to some extent, to overlap the range, and to be one cause of its less conspicuous character. From what I have seen of the region south of Lake Michigan, and from all I can find in geological reports relating to the region, I gather that the range, so far as it escaped the destructive action of the floods issuing from the Lake Michigan basin, both while occupied by ice, and subsequently, is, to a large extent, buried beneath later deposits, or so modified as to be inconspicuous. Whatever the correct interpretation, it remains a fact beyond question, that the belt becomes very obscure, compared with its development to the northward. Dr. E. Andrews says: "As we trace it southward, the material becomes finer, and the hills lower, until they shade off imperceptibly into the drift clay, of the Illinois prairies."[1] The members of the geological corps of Illinois did not recognize it distinctively, in the sense in which it is now considered, but Dr. Ban-

[1]On Western Boulder Drift, Am. Jour. Sci., Sept. 1869, p. 176.

nister, in his report on Lake county, says: "In the western part of the county, near the Fox river, we find the ridges, in some places, to be largely composed of rolled limestone boulders. The same character has been observed further south along the same stream and remarked upon in the chapter on Cook county."[1] In respect to McHenry county he says: "In the vicinity of the Fox river, the same kind of gravel ridges are met with as those which have been described as occurring in the western part of Lake county."[2] This lies in the belt identified by me, from personal observation, as belonging to the Kettle range.

Concerning the district farther south, he says: "Boulders of granite, quartzite, greenstone, and various other rocks are abundant in various localities on the surface of the ground, and are frequently met with in excavations for wells, etc., and large deposits of rolled boulders, chiefly of limestone from the underlying Niagara beds, similar to those already described in the report on Cook county, occur in the drift deposits of the adjoining portions of Kane and Du Page counties."[3] Concerning the topography, the same writer says: "Along some of the principal streams, and especially the Fox river in Kane county, the country is more roughly broken, and can, in some parts, even be called hilly, although the more abrupt elevations seldom exceed eighty or one hundred feet above their immediate base."[4] This broken country, if we may judge from what is true of the rough country along the same river to the north of this, is not due so much to the drainage erosion of the river as to the original deposition of the drift. The same features are said to continue into Kendall county, next south, which brings us to the vicinity of the ancient outlet of Lake Michigan, where, of course, the moraine is locally swept away. Still farther south, in Livingston county, Mr. H. C. Freeman mentions a ridge running southeasterly from a point in La Salle county, to near Chatsworth, a distance of about forty miles. "This is gravelly and sandy, giving it a distinctive character as compared with the adjacent prairie."[5] This is quite too meager to base an identification upon, but I have thought it worthy of quotation here. At Odell, which lies near this ridge, the drift is said to be 350 feet deep.[6]

[1] Geol. Sur. of Ill., Vol.I V, p. 130.

[2] Loc. cit., p. 131.

[3] Geol. Surv. of Ill., Part IV, p.113.

[4] Geol. Surv. of Ill., Part IV, p. 113.

[5] Geol. Surv. of Ill.,Vol. IV, p. 227.

[6] Geol. Surv.of Ill., Vol. VI, p. 237.

On the railroad line from Chicago to Kankakee, there is no recognizable indication of the formation under consideration. Southwestward from Kankakee, on the line to La Fayette, Ind., there are a few mounds and ridges that bear a somewhat morainic aspect, but they are isolated in a generally level tract of lacustrine, rather than glacial, topography. They are, perhaps, remnants of a formation that has been largely eroded or buried. Near Fowler, in Benton county, Indiana, there is a belt of low mounds and ridges, accompanied by shallow depressions, that quite closely resemble the Kettle range in its more modified phases. Boulders appear upon the surface, and, in the more immediate vicinity of the village, are large and numerous. This is probably a portion of the "stream of boulders two miles wide," which Mr. F. H. Bradley mentions as extending through the eastern part of Iroquois county, Illinois, and the central part of Benton county, Indiana,[1] and which he attributes to floating ice. He does not, however, mention the associated topography or underlying drift formation. South of this low range, the country again becomes level, or gently undulating, as far as the Wabash.

The Indiana geologists have not yet critically examined the heavy drift region in the northern part of the state, through which the moraine might be supposed to pass, but in such preliminary inspection as has been made, they have not recognized any prominent moraine-like accumulation. The superficial expression of the region is quite monotonous, and presents to view deposits of sand, gravel, lacustrine or pebble clays, but more rarely the coarse boulder clay or mixed material, that I regard as the unmodified ground moraine. The modifying agencies which produced this phase of the deposits, would be antagonistic to ridge-like morainic accumulations, and their presence, in sharp outline, is not to be expected. In the vicinity of Ligonier, in Noble county, there is a feeble, but somewhat characteristic development of some of the features of the formation. So also, in the vicinity of Rome and La Grange to the northeast. Between La Port and Otis there is a kindred, though somewhat peculiar formation, but I am in doubt as to its true character.

On entering Michigan, we find the formation more unequivocally developed. Just north of Sturgis, which is near the southern line of the state, the formation appears in marked development. It does not attain a great altitude, but presents the peculiar strongly undulating and hummocky contour, and the coarse, mingled material, character-

[1] Geol. Surv. of Ill., Vol. VI, p. 236.

istic of the deposit. It may be seen to advantage on the line of the Grand Rapids & Indiana R. R. To the northeast in the vicinity of Albion, it may be seen from Springport on the north, to Condit on the south. It is here broad and flat, and superficially composed of gravel, for the greater part, but some of the deeper excavations reveal the characteristic coarser material. On the Michigan Central R. R., the formation may be observed between Jackson and Dexter, the most prominent portion being between the stations Francisco and Chelsea. It is not very prominent on the immediate line of the road, which was doubtless selected to avoid it, but in the vicinity it rises into prominent hills and ridges. Some of these, on the north, are conspicuous objects at considerable distances. Still farther to the northeast, my friend, Dr. D. F. Boughton, whose identifications I have elsewhere verified, informs me that the range is well developed in Oakland county, and is finely exhibited near the line of the Flint & Pere Marquette R. R., between Plymouth and Holly. Still farther to the northeast, it may be seen at great convenience and advantage, along the Detroit & Milwaukee R. R. from Birmingham, below Pontiac, to Holly. On the flanks, its features are subdued, the hills and ridges being rather low, with more or less level surface between them, and the superficial sands and gravels are prevalent; but from Waterford to beyond Clarkston, the range has a fine, though irregular development. The hills rise with characteristic contours, to an estimated altitude of 200 feet or more above the surface of the beautiful lakelets embosomed at their base. The deep cuts near the latter station, amply exhibit the coarse, commingled material, characteristic of the core of the range.

Putting the foregoing observations together, they seem to establish beyond reasonable doubt the existence of a broad, massive belt stretching northeastward on the highland between the Saginaw and Erie basins.

If we return again to the southwestern part of the state, we are informed by Dr. Boughton that we shall find a similar accumulation at, and in the vicinity of, Kalamazoo. To the north-northeast, in Barry county, the Thorn Apple river cuts across this range between Sheridan and Middleville. This belt here, though broad, presents a more prominent and ridge-like aspect, with better defined limits than elsewhere observed in Michigan. To the north of this, opposite Saginaw bay, there occurs, near Farwell, broken, rough country and abundant coarse drift, that probably belongs to the belt in question, but my opportunity for observation was unsatisfactory. Beyond this point, I have no definite information, but I deem it highly probable that the moraine will be found extending some distance farther, on the highlands of the Peninsula.

The lake survey charts show that Grand Traverse bay has the remarkable depth of over 600 feet. This great depth, together with its linear character, and the form and arrangement of the associated inlets and lakes, has suggested that it may have been the channel of a separate minor glacier, analogous to that of Green Bay on the opposite side of the great lake, but I have no direct evidence that such was the fact.

In the reports of the geological survey of Ohio, a formation of nearly, or quite, identical characteristics is carefully described by the several writers whose districts embraced it. In the second volume,[1] Dr. Newberry gives, under the name of "Kames," an excellent summary of its leading features. These harmonize very nearly with those of the Kettle belt. The main points of difference are the less conspicuous character and massiveness of the Ohio range, and the greater prevalence of assorted and stratified material; in other words, its features are the same that the Kettle range presents in its more subdued aspects, especially where it is formed in a comparatively smooth country, and is flanked by pebble clays, with level surface, instead of coarse boulder clay, with ridged, or mammillary, contour. I cannot turn aside, here, to define, with sufficient circumspection, the distinction between these clays, further than to indicate my belief that the former are sub-aqueous, and the latter sub-aerial, or, if you please, sub-glacial, deposits.[2]

Where I have seen the Ohio formation, it presents almost precisely the characteristics that are exhibited by the Kettle range in northern Illinois, where it is similarly related to plane topography and pebble clays, and it is also very similar to the same formation opposite Green Bay, where it is bordered on both sides by red lacustrine clays of later date. Dr. Newberry quite clearly recognizes the parallelism, but perhaps not the identity, of the formations.[3] Col. C. Whittlesey, in his

[1] Pages 41–47. See also "Surface Geology of Northwestern Ohio," Proc. Am. Assoc. Ad. Sci. 1872, by Prof. N. H. Winchell, under heads of St.Johns and Wabash Ridges.

[2] I have mapped these formations separately in eastern Wisconsin. See Atlas accompanying Vol. II, Geol. of Wis. 1877, Plate III, Map of Quaternary formations. See also, p. 225 of the volume.

[3] Geol. Surv. of Ohio, Vol. II, pp. 4, 5, and 453. Dr. Newberry's views as to the origin of the Ohio "Kame" belt are at variance with those here presented.

article on the "Fresh Water Glacial Drift of the Northwestern States,"[1] classes the formations together as identical in character, though he does not seem to have considered them members of a continuous formation, and could not well do so with the prevalent view, which he somewhat emphasizes, that it is peculiarly a *summit* formation. It very often does occupy the summit of a rock terrane, and it sometimes *forms* a watershed by its own massiveness, but it likewise occupies slopes and crosses valleys, as shown in detail in the Wisconsin report. Prof. Andrews of the Ohio survey, in a personal communication, adds his conviction that the Ohio and Wisconsin deposits are parallel formations. It would seem, then, that the only question relates to the *continuity* of the belts. Unfortunately there intervenes the Wabash valley, the ancient drainage channel of the Erie basin. Absolute continuity undoubtedly does not exist. If my views are correct, this was the great—not exclusive—channel of discharge of the glacial floods, at the very time the moraine was being formed, where it could be formed, and, for that reason, the debris was swept away or leveled. In addition to this, the region has been subjected to the vicissitudes of erosion, of a reversal of drainage systems, and of lacustrine and fluviatile accumulation. It is to be presumed, therefore, that a portion of the range, where once formed, has been lost, leveled, or buried. Some remnant indications of the range, on the upper slopes, might, however, rationally be presumed to exist. But, awaiting a critical examination of the region, we must confess a want of direct evidence. The belt stretches entirely across Ohio and enters Indiana, but has not been traced farther.

In the line of indirect testimony, however, some facts may be noticed. Prof. N. H. Winchell describes in the Ohio reports[2] six ridges running parallel to Lake Erie, and Mr. G. K. Gilbert has described that portion of these which lie in the more immediate Maumee valley.[3] Two of the inner ones are conceded to be lake beaches. The two outer ones are members of the "Kame," or Kettle belt, according to Dr. Newberry.[4] The one next within, the St. Mary's ridge, Prof. Newberry distinguishes, apparently, with justness, from both the other classes. Mr. Gilbert gives a clear and discriminating description of this, and expresses the conviction that it is "the superficial represen-

[1] Smithsonian Contributions, 1866.

[2] See also Proc. Am. Assoc. Ad. Sci., 1872.

[3] Geol. Sur. Ohio, Vol. II, pp. 56 and 57.

[4] Geol. Surv. Ohio, Vol. I, pp. 537 *et seq.*

tation of a terminal glacial moraine, that rests directly on the rock bed and is covered by a heavy sheet of Erie clay, a subsequent aqueous and iceberg deposit."[1] The views of Professors Newberry and Winchell, while they each differ somewhat, agree with this in the only point essential to the present discussion, viz: *that this ridge represents the margin of the glacier at the time it was formed.* This shows the glacier to have been a tongue or lobe of ice, differentiated from the supposed continental glacier, and having its axis coincident with the Maumee valley, and, withal, capable of forming a morainic accumulation on both sides. The St. Mary's ridge crosses the Maumee-Wabash valley—the glacial trough—and, recurving upon itself, bears away to the northeast, approximately parallel to the Kettle belt already described in southeastern Michigan. This wing of the St. Mary's ridge bears the same relation to the Kettle belt bordering the Erie basin on the Michigan side, that the opposite wing does to the "Kame" belt on the south side. The force of this relationship is not easily escaped.

If my views are correct, that this Michigan belt was formed along the right hand margin of the Erie glacier (conjointly with the Saginaw glacier), just as the "Kame" belt was formed on the left hand margin, then its composition should give evidence of the fact. In the case of the Green Bay glacier, I have shown that the lines of striation and transportation diverge from the main axis toward the margin,[2] and, so far as the paths of other glaciers lie within Wisconsin, the observations made upon them, imply the same method of movement, and this habit finds partial exemplification among the glaciers of the Alps — partial, because their contracted valleys and steep slopes afford little opportunity to deploy in this fashion. If this manner of movement holds true with the Erie glacier, material from its trough will be found to have been transported westward and northwestward toward the moraine. Thirteen years ago, in an article in the American Journal of Science, entitled, "Some Indications of a Northward Transportation of Drift Material in the Lower Peninsular of Michigan,"[3] Professor Alexander Winchell called attention, with much detail and precision, to a large mass of evidence, which finds, for the first time, so far as I am aware, satisfactory explanation in the view now presented, and, in return, has the force of confirmatory evidence. It appears that immense, and often but slightly eroded masses of Corniferous limestone,

[1] Loc. cit.

[2] Geol. of Wis., Vol. II, pp. 199 *et seq.*

[3] Am. Jour. of Sci.,Vol. XL, Nov., 1865.

have been borne in the direction indicated, and scattered over the areas of the Hamilton group, the Marshall sandstone, and the Subcarboniferous limestone; that similar blocks of Hamilton rock have been deposited over the two last named formations and even beyond; that the Marshall sandstone has likewise been borne on to the Carboniferous limestone, and that this transportation has been from lower to higher levels, as the strata now lie, and are presumed to have lain, since the basin is one of excavation and not of flexure. These phenomena, in all their details, are precisely what we should expect from the action of a glacier advancing through the Erie valley, and moving in a manner analogous to that of the Green Bay glacier. That a glacier moved through this valley has been abundantly shown by the Ohio geologists. The only labor of this article is to show that it was an individualized stream, forming the Ohio "Kame" belt on one side, and the Michigan on the other, simultaneously, and that they are collateral members of a common moraine.

Eastward from Ohio, there has been, so far as I am aware, no definite attempt to trace out the extent of the belt. In western New York, Prof. Hall mentions, as one of the three general aspects of the superficial deposits, a surface "broken into irregular hills or ridges, with deep bowl-shaped depressions, or long valleys, which often communicate in more extensive ones, or are enclosed on all sides by drift,"[1] but he does not definitely locate the formation, or indicate whether it assumes the form of a belt, or otherwise. In central New York, Prof. Vanuxem says: "There is another class of deposits, well defined as to position, but irregular as to composition, which are worthy of note. They occur in the north and south valleys, which are on the south of the Mohawk river, or the great level." "The whole of these deposits have a common character. They are in short hills, quite high for their base and are usually in considerable numbers." "They consist of gravel, stones, of stones also of greater size, sand and earth."[2] These, he says, greatly resemble the "deluvial elevations" noticed in the survey of Massachusetts,[3] the description of which is perfectly applicable to the formation under consideration. Furthermore, Prof. F. H. King, of the Wisconsin survey, has examined the same deposits in the vicinity of Ithaca, and recognizes their identity in kind. Neither of these observers, however, discern a definite belt, although Prof. Vanuxem destroys the force of his apparent limitation of the formation

[1] Nat. Hist. Surv. 4th Dist., Geol., Pt. IV, pp. 320, 321.

[2] Nat. Hist. Surv. N.Y., 3d Dist., p. 218.

[3] Geol. of Mass., E. Hitchcock, 1833, p. 144.

to the valleys, by stating that there are numerous points where it has formed over the hill sides, and by associating in mention with it accumulations on the "heights, apparently in no regular order."[1] As these are deep, canon-like valleys, they would probably modify in some degree, the comparatively thin margin of the glacier, giving it a somewhat digitate outline, and the greatest accumulations would take place near the extremities of the tongues, in the valleys, so far as drainage permitted; while the connecting chains would form retreating lines, and be less conspicuous, and might, therefore, escape observation not definitely turned to the subject. This, at least, is suggested by some observations of my own in similar situations. Such valley accumulations, however, do occur at the extremities of linear glacial lakes that are unconnected with a definite belt, as in the case of Green Lake, Wisconsin.[2]

On the line of the Erie R. R., along the small tributary of the Delaware river that is followed up, westward, from Deposit, I have observed winding Osar-like ridges, parallel to the valley, and Kame-like hills upon the slope, up to the watershed of the Delaware and Susquehanna; likewise in the valley of the latter, at and near the village of Susquehanna, but I have no knowledge of their intimate structure, extent or relations.

In the southeastern district of New York, Prof. Mather recognizes the distinctive aspect of this class of accumulations.[3] He cites several instances of its occurrence on the east side of the Hudson, leaving the impression that they are local features. But on Long Island, it forms "an elevated ridge, called by some 'Green Mountains,' and by others, the 'Backbone' of the island.[4]

This he describes in detail and maps, showing that it branches at the east, one chain extending along the southern peninsula to Montauk Point, and the other, along the northern to its extremity, and, theoretically, to the islands beyond.

Professors Cook and Smock have recently examined this, and have shown its connection with a similar moraine, that stretches across the northern part of New Jersey, from Perth Amboy to the Delaware river, below Belvidere.[5] The descriptions of this range tally quite perfectly with that of the Kettle moraine. This range, however, lies on the mar-

[1] Loc. cit., p. 219.

[2] Nat. Hist. Surv. N.Y. 1st Dist., Pt. IV, p. 212.

[3] Geol. of Wis., 1877, Vol. II, p. 138.

[4] Loc. cit., p. 161.

[5] Ann. Rept. of State Geologist, N.J., 1877, pp. 9 *et seq.*

gin of the area of northern drift, while the western one is medial in position, and at some points is quite distant from the margin. It will be observed, nevertheless, that this distance is greatest, in general, at the west, and that in Ohio it becomes very greatly reduced, so that the fact of coincidence on the Atlantic coast, presents no reason for supposing the ranges to be distinct. But, whether distinct or not, is a matter to be settled by observation, and it is to be hoped that it will not long remain undecided for want of it. The extension of the New Jersey moraine westward has not, so far as I can learn, yet been traced, but the survey of Pennsylvania, in progress, will, doubtless, soon leave nothing to be desired, so far as that State is involved.

To the eastward, Mr. Warren Upham has recently been engaged in studying its probable continuation in southeastern Massachusetts. In a personal communication he writes: "A very clear line of terminal moraine extends along the chain of the Elizabeth islands southeast of Buzzard's Bay; thence it bends to the northeast and north as far as to North Sandwich, when *it turns at a right angle* to the east, and extends through Barnstable and other towns to Orleans, running along the east and west portion of Cape Cod, and terminating at its east shore." "This terminal moraine, like the 'Kettle moraine', is not at the outmost limit reached by the ice-sheet; for hills, in series nearly parallel to the moraine already described, and similarly composed of glacial drift with many boulders, occur on Martha's Vineyard and Nantucket islands, corresponding, perhaps, to the terminal moraine which forms the 'backbone' of Long Island. * * The moraine of the Elizabeth islands and Cape Cod has a length of about 65 miles." It may be suggested that the range along the Elizabeth islands may correspond to the northern branch of the Long Island moraine described by Prof. Mather, and that, as Mr. Upham suggests, that of Martha's Vineyard and Nantucket corresponds to the southern.

Dr. E. Hitchcock refers to these accumulations in his report on the geology of Massachusetts,[1] and classes with them "diluvial elevations and depressions," occurring at other points in that and adjoining States. It would appear, from the geological reports of the Eastern States that analogous, though not certainly identical formations, occur locally, more frequently than in the interior, and this, from the mountainous nature of the country, is not strange; but no continuous massive range seems to have been discerned, except the southern one already described.

[1] Geol. of Mass., 1883, pp. 144 *et seq.*

In the interior, so far as yet ascertained, the drift limit is not marked by any such persistent ridge-like accumulation, but gradually dies away or is buried by later deposits, so that the precise limit of glacial advance is not easily determined. The only approach to an exception to this, known to me, is the case of the Kettle moraine in Central Wisconsin, where it lies near the border of the driftless area. Elsewhere around that area, the drift thins out very gradually, so as to render the mapping of its margin a work of close inspection; and, as the region presents no evidence of subsequent submersion, or any other special modifying agency, except the usual meteorological forces, this would seem to represent approximately the original form of deposit.

It is evident from the foregoing sketch that much observation remains to be made before the complete geography of this formation is determined. The conjectural lines on the map are only theoretical suggestions, preliminary to observation.

Summary. — It may be helpful at this point to summarize, and bring into close juxtaposition, in thought, the leading characteristics of this remarkable formation.

1. Its linear extent is very great, whatever its final limits may be found to be.

2. It has a width of from one to thirty miles.

3. Its average vertical thickness can only be very roughly estimated, but may, very prudently, be placed at 200 or 300 feet.

4. Its surface configuration is peculiarly irregular, and denotes an extraordinary origin.

5. It is a complex range, the component ridges being often arranged in rude parallelism.

6. A distinction is usually to be observed between the superficial and lateral portions of the deposit on the one hand, and the central, underlying one on the other, the former being chiefly sand and gravel, the latter complex commingled debris.

7. The superficial sands and gravels are usually stratified in various attitudes, but the core of the range is mainly unstratified.

8. The irregularities of the range are most conspicuous where the superficial sands and gravels are least abundant.

9. The material was derived, in part, conspicuously so, from the vicinity of the range, and, in part, from the formations lying backward along the line of drift movement for at least 300 miles.

10. A portion of the material is spherically rounded, a part is scratched and polished, and some is little affected, though sometimes soft or friable, the latter being usually from adjacent formations.

11. The range is tortuous in its course, but sustains a remarkable and significant relationship to the great lake basins.

12. It undulates over the face of the country, varying at least 800 feet in its vertical oscillations.

13. It does not sustain any uniform relation to present, or what are presumed to have been, preglacial drainage systems in their details. In some portions, it occupies water-partings; in others, lies on slopes; and in still others, stretches across valleys.

14. It crosses, in its course, all the indurated formations, from the Laurentian to the Coal measures, but exhibits no specific relation to their strike or dip.

15. It sustains a definite and most important relationship to the lines of general drift movement.

16. The range is frequently flanked on its southern, or outer edge, by level areas of sand and gravel, of greater or less extent. These also occur between the component ridges of the belt, and on the inner flank, but less frequently.

17. The surface contour of the adjacent region within, or north of, the belt, usually, though not invariably, has a less perfect drainage system, and exhibits less noticeably the effects of superficial modification, than the outer side.

Origin. — Waiving, for the present, some further generalizations, it is thought that the foregoing phenomena present a *specific combination* which points unequivocally to a morainic origin. To the writer, familiar with the multitudinous details, that cannot here find a place, and having studied recent moraines with special reference to this formation, they have a force little less than demonstrative. The range is confidently regarded as a moraine formed at the margin of a group of glaciers—which may be regarded as a single lobate one—and marking a definite stage of their history. A more vivid and graphic view of the outline and movements of these glaciers, than can be given in words, may be obtained from the accompanying map, from which it will appear that through each of the great lake troughs there poured an ice stream, attended by minor currents through the lesser channels.

Its Medial Position. — It has already been remarked that, in the interior, this moraine does not mark the extreme limit of glacial advance. Numerous striations, and other evidence of glaciation, occur on the south side of it. A line has been drawn on the map intended to indicate the approximate limit of northern drift, based on several authorities.[1] How

[1] Tesley, Newberry, Cox, and assistants, Worthen, Swallow, and Mudge.

nearly this shows the limit of actual glacial progress, in distinction from other means of transportation, is not, I think, as yet definitely ascertained, but the general fact of progress, to a considerable distance beyond the Kettle moraine, is sufficiently established. The moraine was, therefore, formed *after the retreat of the glacier had commenced, and marks a certain stage of its subsequent history.*

Glacial Movements before the Formation of the Moraine. — It becomes an interesting question to ascertain whether the glacial movements were the same before the formation of the moraine, as afterwards. Fortunately, in southern Wisconsin, we have very definite and specific evidence bearing on this question. In the towns of Portland and Waterloo, which lie within the area of the Green Bay glacier, and from twenty-five to thirty miles distant from the moraine, there are several domes of quartzite that rise through the horizontal sandstones and limestones, which occupy the surrounding region. These domes are glacially abraded and grooved in a direction S. 30° W., and trains of quartzite boulders stretch away in that direction to the moraine, and, mingling with it, pass onward to an equal distance beyond. At the same time there is abundant evidence from the material of the drift, from the surface contour and from striation, recently observed by Mr. I. M. Buell, that the westerly movement of the Lake Michigan glacier, near the Illinois line, extended to the west side of Rock River, and that the line of junction of the two glaciers was on the west side of that stream. It appears then, that in this region, the movements were in the same general direction before and after the formation of the moraine, but that there were changes in the details, and that the relative size and position of the glaciers were somewhat different, the Green Bay glacier being relatively smaller in the earlier epoch. Testimony of similar general import, but less specific, may be gleamed [sic] from the reports of the other states involved.

Method of Formation. — If, then, the glacial movements were the same, in general, before and after the formation of the moraine, and yet the minor movements and relative size of the glaciers somewhat different, how was the moraine formed? A halt in the retreat of the glaciers, by which their confluent margin should remain stationary for a period, would doubtless cause an unusual accumulation of debris, but this would fail to account for the varying width or irregularities of the moraine. The structure of the range seems to indicate an alternating retreat and advance of the ice mass. During the former, debris was thrust out at the foot of the melting mass, which, when the glacier advanced, was plowed up into immense ridges. If this process be repeated several times parallel ranges will be accounted for, and the irregularities incident to such advance and retreat will explain the complexity of the range. Where the later advances were equal to the earlier ones, the accumulation of drift material would be forced into a single massive ridge. Where any advance failed to equal a former one, an interval between the accumulations of the two would result, giving rise to a depression whose form would depend upon the relations of the two accumulations, but would in general be more or less trough-like in character. Where tongues of ice were thrust into the accumulated material an irregular or broken outline would be the result. If masses of the ice became incorporated in the drift, as has been suggested, their melting would give rise to depressions, constituting one form of the kettles that characterize the range. The suggestion just made, with reference to the irregular advance of the ice mass, accounts for other forms, and, at the same time, for the irregular hills, mounds, and hillocks. Certain of the kettles may be due to underdrainage, through the action of strong underground streams that occasionally flow, as full brooklets, from its base. The drainage of the glacier, while it was advancing and pushing the debris before it, was probably quite general and promiscuous *over* the moraine, and this would give rise to the stratified sands or gravels, and other evidences of the action of water, among which may perhaps, be reckoned some of the minor mounds, ridges and depressions. The changing attitudes, which the debris would be likely to assume, as it was forced along, would, perhaps, give peculiar force to torrential effects.

The gaps in the range, attended by plains, or long streams of gravel and sand, appear to represent the more considerable points of discharge of the glacial floods. When the surface about the margin of the glacier permitted the accumulation of water, the moraine would doubtless be much modified by it and present a subdued aspect.

The Alpine moraines, above referred to, are regarded as miniature exemplifications of the process by which the Kettle moraine was formed.

But, in addition to the structure of the range, the change in the relative position of the Green Bay and Lake Michigan glaciers, already alluded to, affords evidence of an exceedingly interesting character, which has a significance much beyond what can be here indicated. It appears that the junction between the Green Bay and Lake Michigan glaciers at the last observable stage, preceding the formation of the Kettle moraine, was about twenty-five miles farther west, than at the time of the latter's formation, or in other words, there is an abrubt easterly shift of the line of junction. It appears, also, that the width of the ante-morainic Green Bay glacier, measured just south of the Kettle moraine, was only half that of the post-morainic glacier, north of it, measured at a distance just far enough to escape the terminal curvature. An inspection of the outline of the Green Bay glacier shows that this eastward shift of the junction of the two glaciers was not due simply to encroachment on the Lake Michigan stream, nor to a common movement of both in that direction, for the opposite margin of the Green Bay glacier lay close upon the borders of the driftless region, demonstrating that there was no eastward swaying on that side. Indeed, the indenture of the outline of the driftless area strongly suggests actual encroachment on that side also, and this view is not without independent support.

In harmony with these phenomena are the fiords of the Green Bay peninsula, which indicate that the Green Bay ice stream overflowed into the basin of Lake Michigan. These facts, taken altogether, seem to warrant the belief that both glaciers retreated sufficiently far to the northward, and within their respective basins, to allow time and opportunity for the change in the relative size and position of the two ice streams, and that, under slightly changed conditions that favored the Green Bay glacier, they advanced to the position of the Kettle moraine, and, after a series of oscillations, retreated permanently. This view seems also to be demanded by certain details in the distribution of the drift material that are otherwise enigmatical, but whose discussion would too much extend this article.

Significance. — As forty-five years have passed since Dr. Hitchcock called attention to some of the phenomena under consideration, or, at least, to some distinctly related to it, and yet, the matter has received so little consideration, that our present knowledge is limited to such a degree, that I lay myself liable to the charge of undue temerity in attempting to correlate the observations, I may be pardoned in attempting to indicate, briefly, something of the significance and importance the foregoing conclusions, if sustained, have in relation to the Quaternary history of the region involved. The moraine constitutes *a definite historical datum line*, in the midst of the glacial epoch, and becomes a basis of reference and correlation for adjacent formations. It is an historical rampart, outlining the great dynamic agency of the period, at an important stage of its activity, and separating the formations on either hand by a chronological barrier. It is manifest that the true Boulder Clay, or ground moraine, south of the belt, must have been formed earlier than that north of it, and that the two portions are not at all synchronous. In sedimentary formations synchronism is found in horizontal strata, but in glacial deposits it is to be sought in linear belts, concentric with the margin of the glacier. This fact finds illustration, and emphasis, in the demarcation introduced by this singular corrugation of the wide-spread glacial sheet. It is difficult to limit the value of such a determinate line, in the midst of the complex drift formations, if fully established, and should similar belts be found to mark other stages of glaciation, there would be opened a definite line of investigation that promises much assistance in unraveling the gnarled skein of Quaternary history.

While it does not follow, necessarily, that all formations overlaying the true glacial clay, south of the Kettle moraine, are older than those occupying similar relations to the newer Till, north of it, it is clear, that similarity of stratigraphical sequence is not, by any means, sufficient ground for assuming chronological equivalence. It is evident, that all endeavors at correlation between the superficial deposits, on the opposite sides of the moraine, should be attempted with much circumspection.

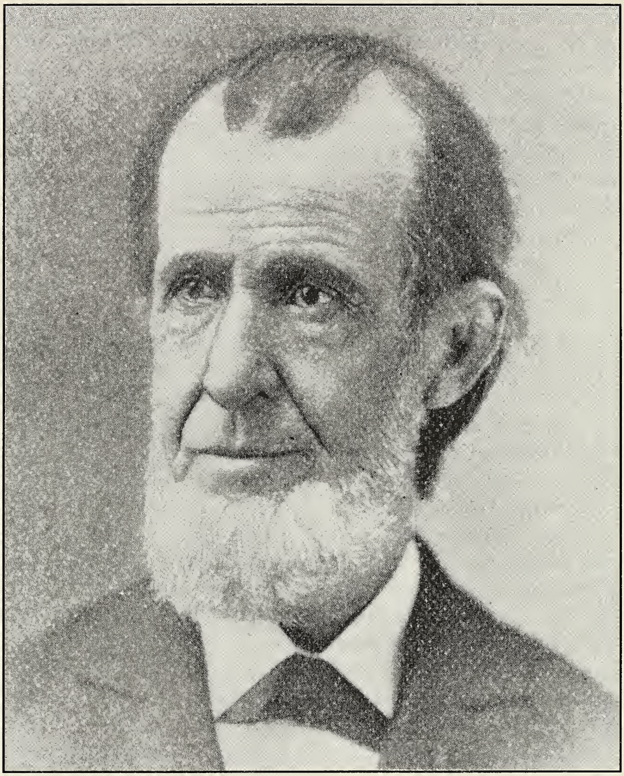
These suggestions have especial application to the discussion of the vegetal deposits, so frequently found in the later Quaternary formations. By many writers, the various deposits of this kind, in the Mississippi basin, have been, very naturally, in the present state of our knowledge, grouped together without reference to the necessary discriminations above indicated, and, as a result, beds of diverse age are referred to a common stratum. A general discussion of these deposits is not sufficiently germane to our subject to be fittingly introduced here, but it is appropriate to point out the fact that some of the vegetal strata sustain such a relation to the Kettle moraine, that they must be widely separated from others, in the date of their accumulation and burial. Some of these organic strata lie at the immediate foot of the moraine, beneath fluviatile and lacustrine deposits that, I am confident, began to be accumulated during the accumulation of the moraine, and through the agency of glacial floods; while it is even more certain, that other vegetal deposits accumulated much subsequently, as those found in the red clays of Wisconsin, which are lacustrine deposits of the great lakes formed after the recession of the glacier. It would be too much to assume that all plant remains, found south of the moraine, antedate its formation, but it is safe to affirm that, with only phenomenal exceptions, e.g., such as escaped glacial abrasion, all north of it are more recent.

The bearing of these definite determinations of the glacial outlines and movements upon the question of the origin of the remarkable driftless area of Wisconsin, Minnesota, Iowa and Illinois (see map) was early perceived, and it was clearly foreseen that this line of investigation promised a *demonstrative* solution of the problem. The driftless area manifestly owes its origin to the divergence of the glaciers through the Lake Superior channel, on the one hand, and that of Green Bay and Lake Michigan, on the other, and to the obstacle presented by the highlands of northern Wisconsin and Michigan. This obstacle the glacier surmounted, and passed some distance down the southern slope, but apparently not in sufficient thickness to overcome the melting and wasting to which it was subjected, and so it terminated midway the slope. But the deep, massive ice currents of the great channels pushed far on to the south, converging toward each other; and, if they did not actually unite, at least commingled their debris south of the driftless area.[1] An instance closely similar to this, considered from a dynamical point of view, may be seen, at the present termination of the Viesch glacier, and illustrations of the general principles involved in the explanation may be seen in connection with several other Alpine glaciers.

If the evidence adduced to show that the Kettle moraine was due to an advance of the glaciers be trustworthy, then, to the extent of that advance, whether much or little, the moraine marks a secondary period of glaciation, with an interval of deglaciation between it and the epoch of extreme advance. Its great extent indicates that whatever agency caused the advance was very wide spread, if not continental in its influence. The moraine, therefore, may be worthy of study in its bearings upon the interesting question of glacial and interglacial periods.

It will also furnish definite data bearing upon the somewhat mooted question of the origin of the Great Lakes, as well as other questions involving both perglacial [sic] and postglacial topography.

[1] Compare N. H. Winchell in An. Rep., Geol. of Minn., 1876, and R. D. Irving, Geol. of Wis., Vol. II, 1877, whose views are closely analogous to the above and each to the other but are not strictly identical. See, also, J. D. Dana, Am. Jour. Sci., April 1878.



Philo Romayne Hoy, M.D.
(1816–1892)

Physician, surgeon, and scientist; collector of plants, fossils, and relics of aboriginal life; charter member and second president of the Wisconsin Academy, 1876–78

THE LARGER WILD ANIMALS THAT HAVE BECOME EXTINCT IN WISCONSIN

(Read at the Racine meeting)

BY DR. P. R. HOY

A record of the date and order in which native animals become extinct within the bounds of any country is of present interest, and in the future may be perused with redoubled satisfaction.

Fifty years ago the territory now included in the state of Wisconsin was nearly in its primitive condition. Then many of the larger wild animals were abundant. Now all has changed; the ax and plow, gun and dog, railway and telegraph, have completely metamorphosed the face of nature. Not a few of the large quadrupeds and birds have been exterminated or have hid themselves away in the wilderness of northern Wisconsin.

There was a time, away back in the dim past, when the mastodon, ox, elephant, tapir, peccary, and musk-ox roamed over the ancient prairies of Wisconsin, but now only their bones, from time to time, are exhumed and thus exposed to the wondering gaze of the ignorant many and the trained eye of the wiser few. We shall at this time, however, confine our attention to the historic period.

The antelope, *Antilocarpa Americana*, now found only on the western plains, did, two hundred years ago, inhabit Wisconsin as far east as Lake Michigan. In October, 1679, Father Hennepin, with La Salle and party, in four canoes, coasted along the western shore of Lake Michigan. In Hennepin's narrative he says: "The oldest of them" [the Indians] "came to us the next morning, with their calumets of peace, and brought some *wild goats*." This was at or near Milwaukee. "Being in sore distress, we saw upon the coast a great many ravens and eagles, from whence we conjectured there was some prey, and having landed on that spot we found above the half of a fat wild goat which the wolves had strangled. This provision was very acceptable to us, and the rudest of our men could not but praise the Divine Providence which took so particular care of them." This was, undoubtedly, near Racine. "On the 16th" [October 16, 1679] "we met with abundance of game; a savage we had with us killed several stags and *wild goats*, and our men a great many turkey, very fat and big." This last point was between Kenosha and Racine. Hennepin's goats were without doubt antelopes. Father Joliet, a little earlier, mentions that "on the Wisconsin there are plenty of turkey cocks, parrots, quails, wild oxen, stags and wild goats." All species of the deer family were called stags by the early travelers. Schoolcraft mentions antelopes as occurring in the Northwestern Territory, and as late as 1850. Antelopes were not uncommon in southern Minnesota, only forty miles west of the Mississippi river. It is evident, then, that antelopes have retired quite leisurely.

When the last buffalo, *Bos. Americana*, crossed the Mississippi is not precisely known. Governor Dodge told me that buffalo were killed on the Wisconsin side of the St. Croix river the next year after the close of the Blackhawk war, which would be 1833. So Wisconsin had the last buffaloes east of the Mississippi river.

The Woodland Caribon, *Rangifer Caribou*, were probably never numerous within the limits of the state. A few, however, were seen near La Point in 1840; none since.

Elk, *Cervus Canadensis*, were on Hay river in 1863, and I have but little doubt that a few still linger with us. The next to follow the buffalo, antelope and reindeer.

Moose, *Alce Americanus*, continue to inhabit the northern part of the state, where they still range in spite of persecution. A fine cow moose was shot near the line of the Wisconsin Central Railway in December, 1877.

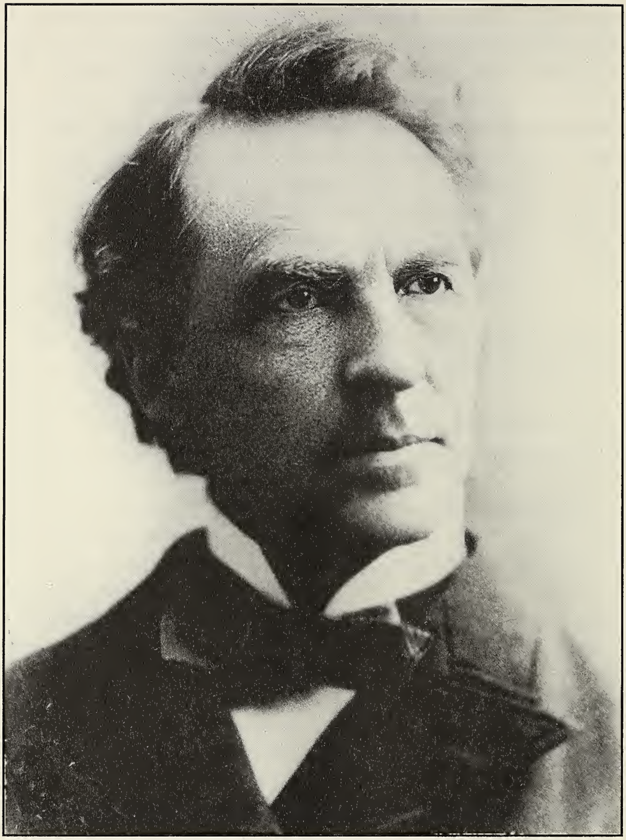
A few panthers, *Felis Concolor*, are yet with us; a straggler is occasionally seen. Benjamin Bones of Racine shot one on the head-waters of Black river, December, 1863.

Wolverines, *Gulo luscus*, are occasionally taken in the timber; one was taken in La Crosse County in 1870.

Of beaver, *Castor Canadensis*, a few still continue to inhabit some of the small lakes situated in Lincoln and adjacent counties.

The badger, *Taxidea Americana*, is now nearly extinct in Wisconsin. In a few years the only badger found in the state will be the one on the coat of arms.

The opossum, *Didelphis Virginiana*, were not uncommon in Racine and Walworth counties as late as 1848. They have been caught as far north as Waukesha, and one near Madison in 1872, since which time I have not heard of any being taken. I am told that a few are still found in Grant county. They will soon be exterminated, no doubt. The last wild turkeys, *Meleagris Gallopavo*, in the eastern part of the state, was [sic] in the fall of 1846, at which time a few were discovered near Racine. They were hunted with such vigor that the entire number were shot, "The last of the Mohicans." I am told, by Dr. E. B. Wolcott, that turkeys were abundant in Wisconsin previous to the hard winter of 1842–3, when snow was yet two feet deep in March, with a firm crust, so that the turkeys could not get to the ground; they hence became so poor and weak that they could not fly and so were an easy prey for the wolves, wildcats, foxes and minks. The Doctor further stated that he saw but one single turkey the next winter, and none since. One was shot in Grant county in the fall of 1872. Possibly there are a few yet to be found in this large southwestern county; if not, then wild turkeys are exterminated in the state of Wisconsin.



Courtesy The State Historical Society of Wisconsin WHi(x3)1759

John Wesley Hoyt, M.D., LL.D.
(1831–1912)

Professor of chemistry and natural history at Antioch College; secretary of the Wisconsin State Agricultural Society; editor of the *Wisconsin Farmer*; charter member and first president of the Wisconsin Academy, 1870–75; governor of the Wyoming Territory and first president of the University of Wyoming

SOME PERSONAL RECOLLECTIONS OF ABRAHAM LINCOLN

BY JOHN WESLEY HOYT

My deep interest in Mr. Lincoln came, first, of his manifestations of opposition to any further extension of slavery over the territories of the United States—an opposition in which I believe I shared as sincerely as any American; for, while a student and medical professor in Cincinnati, in the early fifties of the last century, I had ofttimes looked across the Ohio River to the shadows of the Kentucky side, and now and then, by sympathy, felt the smart of a driver's lash on Freedom's shore; there, too, had earnest part in forming the great political party solemnly sworn to resist extension of the damning curse of human bondage, and thence had gone out, as one of Freedom's advocates on more than a hundred 'stumps,' in Ohio, Indiana, Illinois, and Wisconsin.

Meanwhile, I had, with profound interest, so watched the masterly discussions of Mr. Lincoln with Douglas, in northern Illinois, and so marked him for his destiny, that, in the winter of 1858–9, being then in command of agricultural affairs in Wisconsin, I went down to Chicago to congratulate him and, if possible, secure him for delivery of the annual address at the next state fair, to be held at Milwaukee in September, 1859.

We spent half the night together, in his chamber, reviewing the past and outlining a possible, even probable future—an evening so deeply interesting that, after fifty years, the discussions and incidents are still almost fresh enough for recital in detail. Even then the dark clouds of a coming conflict hovered near enough to make one anxious; but in the minds of both, even civil war, with carnage widespread and fearful, seemed not so dreadful as a further extension of human slavery over half a continent by consent of possessors whose immediate ancestors had themselves been freed from British oppression, not half so terrible, at great cost of blood and treasure. There was yet hope that the resolute champions of the curse would stay their demands, but the prospect was sadly faint, for even then the need of preparing for the worst was painfully felt.

I need hardly say that my conviction of the greatness of Mr. Lincoln, already gained by a reading of his discussions of the all-engrossing questions of the time, was yet further deepened by that night's experience and study of the homely, robust statesman before me, and that, with a glad heart I bore away, at midnight, his promise to be with us, in Milwaukee, at the appointed time.

When, at the moment of departure, he was asked to let me know the time of his leaving Chicago, so that I could meet him on his arrival in Milwaukee, he merely said, with his characteristic simplicity: "Oh, don't trouble yourself on my account; I'll be at the Newhall in good time, all right." And so he was, some eight months later.

But it so happened that his actual arrival was at midnight, and that the room intended to be reserved for him had, by the blunder of a clerk, been given to a man and his wife who were already in bed and asleep. There was no remaining vacant room in the house, and the clerk, having been stoutly arraigned by the landlord, was in distress of mind; seeing which, Mr. Lincoln, with a smiling countenance and comforting words, said: "Oh, my dear sir, don't be unhappy on my account. I see there is vacant space enough right here, at the end of the counter. Just bring a cot and clothes-rack, with sheet for a screen, and I'll sleep like a top." The thing was done, and the distinguished guest, after a cheerful and hearty "Goodnight, gentlemen," handsomely retired.

Of course I was prompt to fulfill my promise to come down in good time to breakfast with him, but he was a little tardy, so that when, having heard a little stir behind the screen, I ventured to tap gently on the frame, word came out at once, "Come in!" But, on passing 'round, I found him not only half dressed, but shaving himself, and so encumbered that, instead of moving his chair for a greeting of his visitor, having recognized my voice, he turned his head squarely back and saw me, with his lathered face inverted and considerably broadened by a smile. Of course I was quick to retire and wait.

The breakfast disposed of, we were soon on our way to the Fair grounds, for Mr. Lincoln said he wanted to see what sort of farmers, gardeners, and mechanics the Badgers made.

The address was to be at 11:00, and meanwhile we made ourselves very busy, going the rounds of all the departments. It soon became apparent that, notwithstanding his modest disclaimer of knowing much of practical affairs beside wood-chopping and rail-splitting, he did know much of many things in country life; that he was in fact capable of critical judgment of horses, cattle, sheep, and other domestic animals, as well as of most products of the soil.

The address was listened to by many thousands, some say thirty thousand, not a few of whom had made special efforts and sacrifices that they might see and hear the man who, from the depths of poverty and laborious service in wood and field, had risen to a foremost place in the legal profession and in statesmanship. Perhaps no address more practical, useful, and entertaining was ever delivered on any such occasion. It dealt with the necessary relation between education and labor, as well as with the economy of thorough work in farming especially, and was so enlivened by humorous hits that it was at once highly entertaining and of enduring value. It was in fact so admirable, and so deepened my conviction of his eminent fitness for leadership, that then and there I began to speak of him as the man for the next President of the United States—fit for a superior service in statesmanship at any time, but pre-eminently fit for such a crisis as then seemed surely very near—in due time I went to Chicago, to help nominate him, and thereafter gave myself to platform service in many of the Northern states, and to the end of the campaign.

How nobly, now grandly he transcended the highest expectations of his most sanguine admirers is too well known for historic proof. No greater demand for a national guide and guardian was ever made, or more nobly and wonderfully met in any part of the world. It is certain that, for measure of endowment and balance of powers, the supreme founder and father of the Republic alone can be compared with Lincoln, its preserver and the emancipator of millions of a downtrodden and most wretched race.

Intellectually, Mr. Lincoln was remarkable for the habit of close and critical attention to whatever engaged his thought; for such power of discrimination and comparison as made him clear-headed; such power of logical analysis as made him quick to detect a flaw and expose a fallacy, on which account his opponent in debate ofttimes found himself floundering ere he knew he was on the wrong side, and painfully subject to such withering sarcasm, if he deserved it, as Mr. Lincoln knew so well how to use; remarkable also for such readiness to discover the relations of things as made him far-sighted and hence either courageous, even bold and daring, or prudent, as the occasion might justify or demand.

On the side of the sensibilities I was happy to find, after a further acquaintance, that I had myself underrated him. His rugged, stalwart frame was at first suggestive of a probable sternness of spirit and manner. But, as I came nearer, I was charmed by the delicacy, even tenderness, and all-abounding sympathy of a great and beautiful soul—qualities that made him a lover of the beautiful in nature; that prompted him, on entering the great round rent at the Wisconsin State Fair, with its magnificent display of fruits and flowers, to take off his hat, for a salute, with a grace that won the hearts of all who were present, saying: "How beautiful! Eden transferred!;" that made him too glad for utterance when he signed the immortal Emancipation Proclamation and saw the shackles fall from millions of his fellow-men, and again when, after one of the most fearful conflicts in human history, he knew the Republic saved and foresaw a Union grander and more glorious than had been dreamed of in all the past, a thing of destiny; qualities, too, that made him so impressionable by others, so sensitive in soul, that he almost never failed to judge rightly the men with whom he had to do, and enabled him to draw into the service of his country so great a galaxy of men of genius, devotion, and heroic virtue.

Morally, Mr. Lincoln was nothing less than an embodiment of virtue, truth, and justice. Those who knew him best believed him incapable of wilful wrong. He so loved truth that he was ever in earnest search of it, and anxious to make it known; and it was the cherishing of a profound love of justice, and his exalted aims and aspirations that made him every ready, even glad, to do and die for his country.

As for the will, he was resolution itself—never halting or hesitating in his course. Because he felt himself right, and knew the right must win, there was fixedness of purpose. He never just hoped for a final victory; he saw it coming, and though deeply sad over the dreadful fate of so many martyrs, yet, after all, whenever the future of the Republic was referred to, his noble face was illumined. It was this high assurance of a determined soul that made it easy for him to say to me, one dark morning, when I had gone to the White House, with anxious sympathy, because great armies of Confederate troops had boldly crowded into Pennsylvania and were threatening both Harrisburg and Philadelphia, "Never mind, Dr. Hoyt, you may be sure we'll trot them out of there very soon and make them glad to get home again."

It was this fixedness of purpose and his unfailing confidence that enabled him to preserve his calmness, so that he was rarely disturbed in spirit and never really agitated. His face and voice and daily life were ever giving expression to an unwavering trust in God.

And thus it is that we are amply justified in pronouncing Abraham Lincoln one of the very noblest and grandest of men in all human history.

Washington, D.C.

Part Two:
Current Articles

John A. Cross

Dairying in an urban environment: The Milwaukee metropolitan area

Abstract *Urban expansion in the greater Milwaukee area has displaced dairy farming. Southeast Wisconsin now accounts for only three percent of the state's milk production. The spatial pattern of decline in dairy production in southeastern Wisconsin between 1989 and 1994 is examined at the civil town level, considering farm entry and exit. Farm relocation from the region is also explored, and the stress experienced by the region's farmers is surveyed.*

Urban expansion in the greater Milwaukee metropolitan area has significantly altered the pattern of dairy farming in the southeastern Wisconsin agricultural reporting district, whose boundaries roughly coincide with the Census Bureau-defined Milwaukee, Racine, and Kenosha metropolitan areas. Early this century Waukesha County was considered one of the state's leading milk producers, having more pure blood dairy cows than any other similar area in the nation (Whitbeck 1921). Half a century ago 50 percent of Milwaukee County was in agricultural production, with 440 dairy farms in operation (Durand 1962). Durand (1962, 1963) has described in detail the steep decline of dairying in Milwaukee County in the two decades following the outbreak of World War II. By the beginning of the 1960s approximately 50 dairy farms remained in Milwaukee County and dairying had retreated in Waukesha and Ozaukee Counties. The zone of agricultural demise that Durand described is now overwhelming the surrounding counties. Four dairy herds remain in Milwaukee County, and only two are on commercial farms. One of the other two herds is at the Milwaukee County Zoo Heritage Farm, while the second is at the Wisconsin State Fair Park. These herds are but small reminders of dairying in a county that once had been "near the top of the leading dairy counties of the nation" (Durand 1962).

This paper explores the spatial pattern of decline in dairy production in the metropolitan counties of southeastern Wisconsin. By spring 1994 the region had only 925 herds (Table 1), with a total of 63,100 cows counted the previous year (Wisconsin Agricultural Statistics Service 1994a). Twenty years earlier Milwaukee County already had dropped to 14 dairy herds, but southeastern Wisconsin still had 2,050 herds, with a total of 89,400 cows (Wisconsin Statistical Reporting Service 1975). The entire region lost 41.3 percent of its herds over the past decade, with a decline of 23.7 percent between 1989 and 1994.

The decline in number of milk cows in southeastern Wisconsin has only slightly trailed the shrinkage in number of dairy farm herds. While the region lost 21.1 percent of its milk cows since 1983, most of the loss was in the past half decade, inasmuch as the number of cows within the area fell by only 2,700 between 1983 and 1988. Between 1988 and 1993 the region lost 9,300 dairy cows, a loss of 18.4 percent, and milk production decreased by 14.2 percent (Wisconsin Agriculture Reporting Service, 1984; Wisconsin Agricultural Statistics Service 1989, 1994a).

Spatial Patterns of Decline

Over the past half decade, at the county level the greatest proportional declines in dairying in southeastern Wisconsin occurred in Waukesha and Kenosha Counties, both of which lost more than one quarter of their herds (Table 1). Wisconsin Department of Agriculture lists of dairy herds that have undergone the Brucellosis Ring Test (required for commercial milk sales) reveal changes in dairy operations at the civil town (Table 2) and section level (see Cross 1994a). The entry and exit behavior of dairy farmers at the civil town level provides a clearer picture of the expanding ring of dairy abandonment, a ring corresponding to the perimetropolitan bow wave that Hart (1991) has so eloquently described. Dairy farming, of all types of agriculture, is among the most vulnerable to urban development, because of a variety of conflicts that arise with non-farm neighbors (Hirschl and Long 1993). Such conflicts include vandalism and trespassing, complaints about farm odors and farm equipment moving over suburban roads, and inevitable increases in taxes and land use controls.

Only four towns in the southeast Wiscon-

Table 1. Decline in number of dairy herds in southeast Wisconsin

	Dairy Farms			Dairy Herds		
County	*Number in 1940*	*Number in 1990*	*% decline 1940–1990*	*Number in 1984*	*Number in 1994*	*% change 1984–1994*
Kenosha	1,166	98	91.6	131	75	-42.7
Milwaukee	992	4	99.6	3	4	+33.3
Ozaukee	1,361	157	88.5	214	122	-43.0
Racine	1,650	106	93.6	146	88	-39.7
Walworth	2,287	270	88.2	359	219	-39.0
Washington	2,452	384	84.3	511	310	-39.3
Waukesha	2,711	155	94.3	213	107	-49.8
WISCONSIN	167,407	33,805	79.8	43,508	28,641	-34.2

Data sources: U.S. Census of Agriculture, 1947 (number of farms reporting milk cows in 1940), Wisconsin Agriculture Reporting Service 1984; Wisconsin Agricultural Statistics Service 1994 (number of herds in late March or early April of each year tested for Brucellosis—required for milk sales).

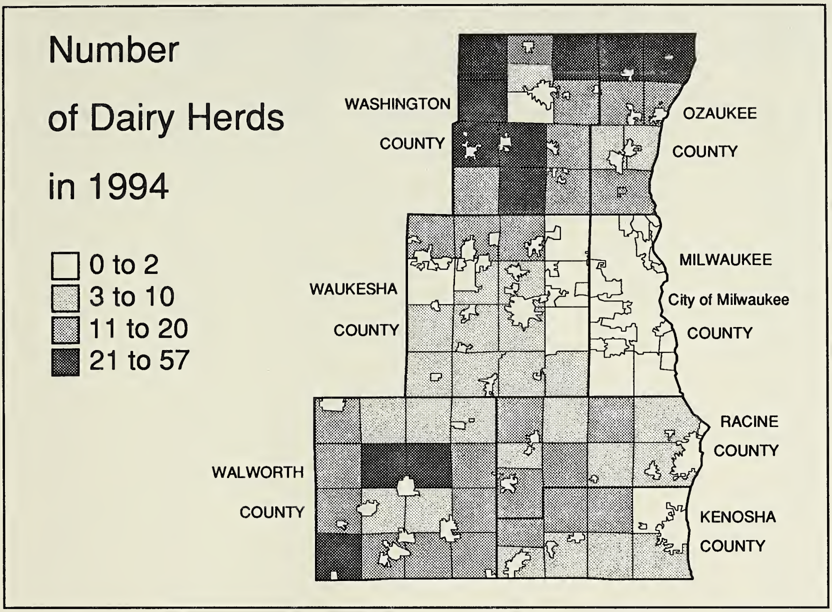


Fig. 1. Number of dairy herds is greatest in towns most distant from Milwaukee. Data source: See Table 2.

sin agricultural reporting district had as many as one dairy herd per square mile by early 1994 (Figure 1). One of these was in northern Ozaukee County, and the other three were in western Washington County. Closer to Milwaukee County, three towns within eastern Waukesha County (Brookfield, Menomonee Falls, and New Berlin) had two or fewer herds. Brookfield had none. None of the towns along Lake Michigan south of Milwaukee to the Illinois state line had more than five herds. The greatest proportional decreases in dairy herds since 1989 were in a swath of towns extending from Menomonee Falls in northeast Waukesha County southwest to Mukwonago in Waukesha County and three towns in northern Walworth County. All lost at least ten percent of their herds annually since 1989 (Figure 2). Because many of these towns already had relatively few surviving dairy farms, the greatest numerical losses were in towns that were farther from Milwaukee (Figure 3). For example, four towns north and west of the Menomonee Falls-Pewaukee areas all lost more than six herds. Four towns in northern Ozaukee and Washington Counties and several towns within Walworth County had similar losses.

Entry and Exit Activity

One measure of the declining viability of dairying is the ratio of new dairy operators to farmers leaving. The number of farmers quitting dairying outnumbered the number

Table 2. Farmers entering and exiting dairy operations by civil town between 1989 and 1994

County/ Town	*Dairy Herds 1989*	*Dairy Herds 1994*	*Net Change 1989–94*	*Farmers Entering Dairying*	*Farmers Exiting Dairying*	*Farmers Moving in Town*
Kenosha						
Brighton	25	20	-5	1	6	0
Bristol	8	4	-4	2	6	0
Paris	20	18	-2	1	3	0
Pleasant Prairie	5	4	-1	0	1	0
Randall	11	5	-6	1	7	0
Salem	5	4	-1	1	2	0
Somers	4	2	-2	1	3	0
Wheatland	25	18	-7	2	9	0
Milwaukee						
Franklin	1	1	0	0	0	0
Granville	0	0	0	0	0	0
Greenfield	0	0	0	0	0	0
Lake	0	0	0	0	0	0
Milwaukee	0	1	+1	1	0	0
Oak Creek	2	1	-1	0	1	0
Wauwatosa	1	1	0	0	0	0
Ozaukee						
Belgium	40	34	-6	3	9	1
Cedarburg	12	9	-3	1	4	0
Fredonia	42	29	-13	1	14	0
Grafton	6	4	-2	0	2	0
Mequon	14	11	-3	1	4	0
Port Washington	23	16	-7	1	8	0
Saukville	22	19	-3	1	4	0
Racine						
Burlington	18	13	-5	0	5	0
Caledonia	3	3	0	0	0	0
Dover	17	15	-2	3	5	0
Mt. Pleasant	4	4	0	0	0	0
Norway	14	10	-4	0	4	0
Raymond	21	15	-6	1	7	0
Rochester	7	4	-3	0	3	0
Waterford	21	16	-5	1	6	0
Yorkville	9	8	-1	0	1	0
Walworth						
Bloomfield	14	13	-1	5	6	0
Darien	19	15	-4	1	5	0
Delavan	10	9	-1	1	2	0
East Troy	9	4	-5	0	5	0
Geneva	13	10	-3	0	3	0
Lafayette	25	21	-4	4	8	1
La Grange	13	6	-7	2	9	0
Linn	11	13	+2	4	2	0
Lyons	17	15	-2	3	5	0
Richmond	14	13	-1	3	4	0
Sharon	37	28	-9	4	13	1

County/ Town	Dairy Herds 1989	Dairy Herds 1994	Net Change 1989-94	Farmers Entering Dairying	Farmers Exiting Dairying	Farmers Moving in Town
Spring Prairie	23	16	-7	6	13	1
Sugar Creek	22	21	-1	3	4	0
Troy	14	5	-9	1	10	1
Walworth	14	11	-3	0	3	0
Whitewater	21	19	-2	7	9	2
Washington						
Addison	68	57	-11	5	16	0
Barton	11	9	-2	0	2	0
Erin	17	11	-6	2	8	0
Farmington	32	30	-2	8	10	0
Germantown	19	13	-6	1	7	0
Hartford	47	38	-9	6	15	0
Jackson	26	20	-6	3	9	0
Kewaskum	24	17	-7	2	9	0
Polk	41	34	-7	5	12	0
Richfield	31	23	-8	2	10	0
Trenton	29	20	-9	2	11	0
Wayne	45	37	-8	3	11	0
West Bend	5	1	-4	0	4	0
Waukesha						
Brookfield	0	0	0	0	0	0
Delafield	10	9	-1	1	2	0
Eagle	14	9	-5	2	7	0
Genesee	7	4	-3	2	5	0
Lisbon	22	16	-6	0	6	1
Menomonee Falls	2	1	-1	0	1	0
Merton	21	15	-6	0	6	0
Mukwonago	11	5	-6	0	6	0
Muskego	11	6	-5	0	5	0
New Berlin	2	2	0	0	0	0
Oconomowoc	25	15	-10	1	11	0
Ottawa	12	9	-3	0	3	0
Pewaukee	6	3	-3	0	3	0
Summit	3	1	-2	0	2	0
Vernon	10	9	-1	1	2	0
Waukesha	6	3	-3	1	4	0

Data sources: Computer tapes listing dairy farms having had the Brucellosis Ring Test (required of all commercial dairy herds), which provided the dairy farmers' names, mailing addresses, grade and farm location (by county, civil town, and section). These tapes, produced in early April 1989, early April 1990, early April 1991, late March 1992, late March 1993, and April 4, 1994 (the last four dates coordinated with the published statistics of the Wisconsin Agricultural Statistics Service) were obtained from the Wisconsin Department of Agriculture, Trade, and Consumer Protection, Madison.

NOTE: Farmers who had ceased operations within any given civil town between any two consecutive years were considered to have exited. Farmers who had begun operations within any given civil town between any two consecutive years were considered to have entered. Because many farmers moved their operations during a year, these figures will overestimate the actual number of farmers who have abandoned dairy operations entirely, regardless of location. Farmers moving within a town had moved their operations within the same civil town to a noncontiguous section, thus a distance of at least one mile, and are listed separately, but not included within the totals of farmers entering and exiting dairying.

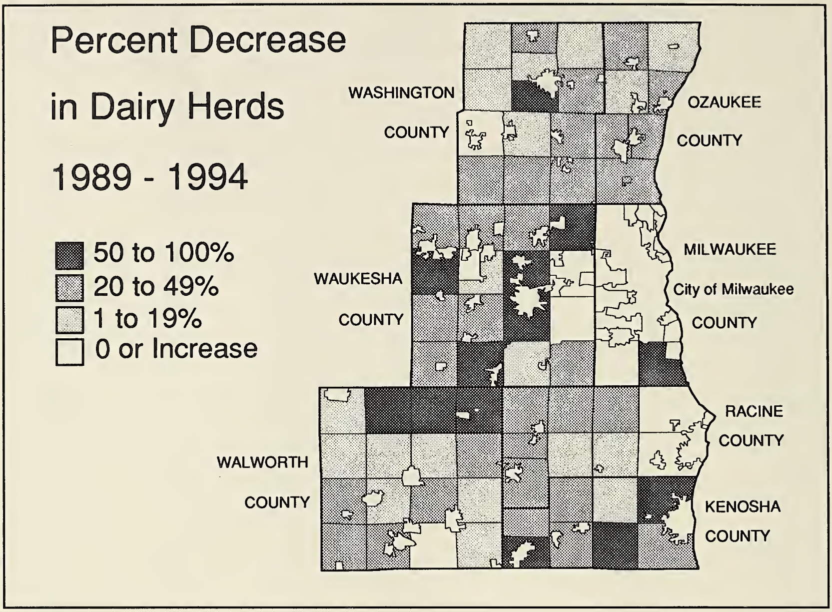


Fig. 2. Percentage decrease in dairy herds is typically greatest in towns experiencing urban expansion, as in Waukesha County. Data source: See Table 2.

of farmers entering in the metropolitan counties of southeastern Wisconsin (excluding Walworth County) by a ratio of 4.2 to 1.0, far surpassing the overall statewide ratio of 2.0 to 1.0. Although dairying is still viewed as viable within some towns, such as Farmington in northeastern Washington County, where eight new operators replaced ten who ceased operations between 1989 and 1994, only a few other towns have ratios close to the state average. These towns are around the northern and western perimeter of the southeast Wisconsin agricultural reporting district. Many towns have no entering dairy farmers, and former dairy farms are becoming the sites of shopping centers and residential subdivisions.

Farmers exiting dairying in southeastern Wisconsin are not necessarily leaving agriculture. Over half of the land area in five of the region's seven counties is still classified as "land in farms" (Table 3), and 63.1 percent of Racine County is considered agricultural. Conversely, farmland now comprises less than ten percent of Milwaukee County, but the 130 remaining farmers received average earnings of $1,727 per acre in 1992, a figure far higher than the statewide average of $318 (calculated from Wisconsin Agricultural Statistics Service 1994b). Wisconsin farmers as a whole rely on dairying to produce over half of their cash receipts, but farmers in several metropolitan counties have concentrated upon other agricultural

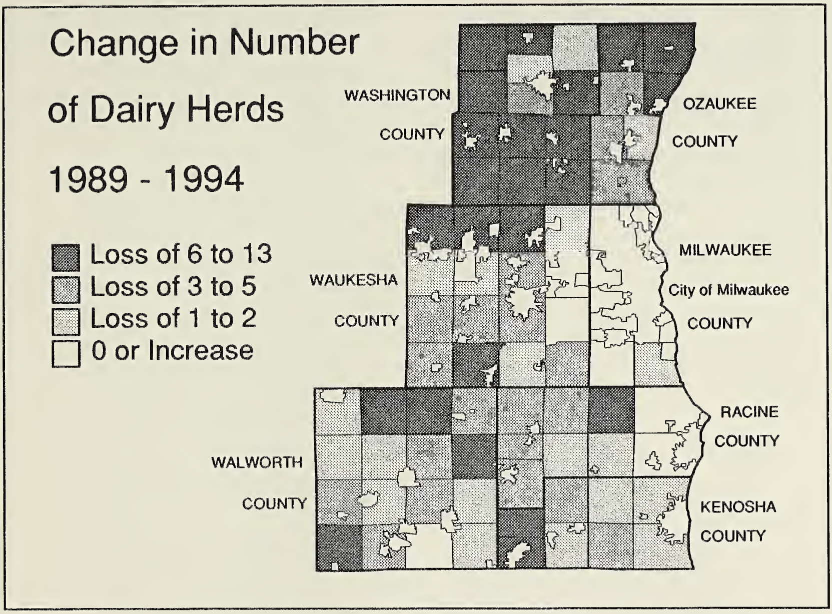


Fig. 3. Largest losses in number of dairy herds often occur in towns with the largest number of herds. Data source: See Table 2.

Table 3. Agricultural production in southeastern Wisconsin

County	*Number of all farms (1993)*	*Land in farms (acres) (1993)*	*% Area in farms (1993)*	*% Farms in dairying (1993)*	*% Earnings from dairying (1992)*	*Total cash receipts per acre (1992)*
Kenosha	550	99,000	56.9	14.5	33.7	$300.02
Milwaukee	130	14,000	9.2	3.1	0.7	$1,727.36
Ozaukee	530	87,000	58.2	24.9	53.1	$400.07
Racine	780	136,000	63.1	11.9	16.5	$515.40
Walworth	1,050	247,000	69.2	21.5	37.9	$333.77
Washington	1,070	159,000	58.0	31.4	57.0	$455.30
Waukesha	890	138,000	38.8	13.4	37.0	$319.38

Data source: Wisconsin Agricultural Statistics Service 1993a and 1994b activities. Milwaukee County leads the state in its cash receipts for "other crops," a category that includes greenhouse and nursery crops together with fruit and miscellaneous specialty crops. Racine County is the state's second largest producer of eggs and poultry (Wisconsin Agricultural Statistics Service 1993). Moreover, as Hart (1991) notes in his discussion of the bow-wave process, "[s]ome . . . keep their land and continue to farm it less intensively." The low cash receipts per acre for Kenosha and Waukesha Counties, where only one in seven farmers have dairy herds, lend credence to such arguments.

Emigration of Dairy Farmers

Some farmers remain in dairying by fleeing the advance of urbanization. Undoubtedly, some dairy farmers may have moved to locations in northwestern Illinois, eastern Iowa or southern Minnesota, although the available data does not permit those movements to be traced. Statistics do show that between 1989 and 1994 fifty-two southeastern Wisconsin dairy farmers moved their operations to other locations in the state. Some of these moves were local: thirteen were to another town within the same county, eight others were to non-contiguous sections within the same town, and two were to another county within southeastern Wisconsin. However, 29 dairy farmers moved from southeast Wisconsin to other areas of the state (Figure 4). For example, dairy farmers moved from Racine County to Lafayette, Sauk, Buffalo, Manitowoc, and Sheboygan Counties. Waukesha County lost dairy farmers to Dodge, Jefferson, Waupaca, Green, and Richland Counties.

Neighbors or kin sometimes move in unison. Clark County received three incoming operators from a small area of far western Kenosha and adjacent Walworth Counties. Two farmers living six miles apart in Washington County relocated to towns in eastern Taylor County. Eight of the 29 farmers relocating from southeastern Wisconsin moved more than 100 miles.

Stresses of Urbanization

Stresses of urbanization are clearly recognized by dairy farmers in southeastern Wisconsin (Table 4). Although survey respondents (Cross 1994b) in southeastern Wisconsin did not differ significantly from dairy farmers elsewhere in the state in their evaluation of a variety of potential problems facing them—including wholesale milk prices, hay and feed prices and shortages, labor availability, farm debt and interest rates, various climatic hazards, and government regulations—their evaluations of property taxes and local urban expansion were significantly different statistically. Indeed, half of the surveyed dairy farmers in southeastern Wisconsin (55 percent, excluding Walworth County) ranked "local urban expansion" as a "major problem," compared with just 6.1 percent of dairy farmers elsewhere in the state. Nevertheless, only 13.2 percent of the farmers in this region wish to sell their farms, compared with 26.8 percent of the farmers elsewhere in the state, a statistical difference significant at the 0.10 level.

Ties to the land are strong, with dairy farms in southeastern Wisconsin more likely to have been owned by a family member since the 1800s than in any other region of the state. Twenty-four percent of the dairy farmers surveyed by the author in the region indicate that their family had operated their farm since the last century, compared with 14 percent elsewhere in Wisconsin. Southeastern Wisconsin dairy farmers were less likely to submit bids to participate in the

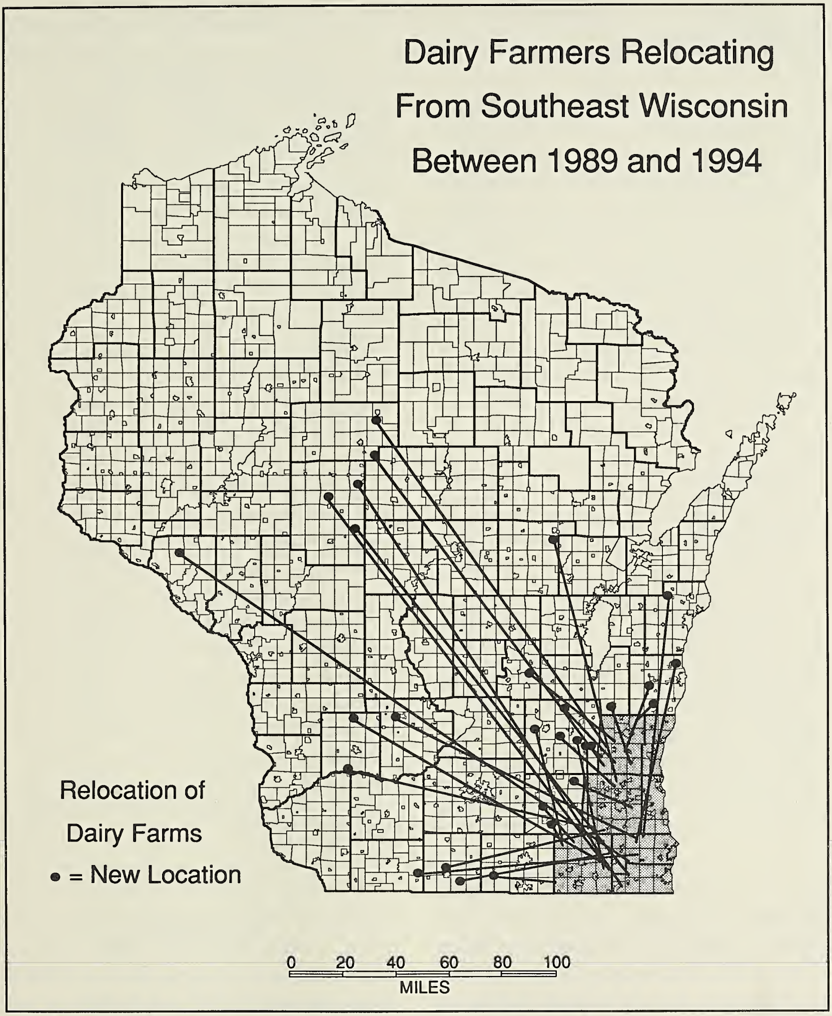


Fig. 4. Twenty-nine dairy farmers moved their herds from southeastern Wisconsin to other parts of the state between 1989 and 1994. Data source: See Table 2.

Table 4. Perception of problems facing dairy farmers: southeast Wisconsin versus other Wisconsin farmers

	Percent of farmers ranking item as:			
Factor considered:	*Major Problem*	*Somewhat a Problem*	*Minor Problem*	*Not a Problem*
Milk support prices				
Southeast Wisconsin	26.3	50.0	13.2	10.5
Other Wisconsin Farmers	52.4	29.6	11.3	6.8
Prices of Hay and Feed				
Southeast Wisconsin	24.3	32.4	27.0	16.2
Other Wisconsin Farmers	19.8	36.5	27.0	16.7
Shortages of Hay and Feed				
Southeast Wisconsin	23.7	18.4	31.6	26.3
Other Wisconsin Farmers	21.7	31.0	27.8	19.6
Shortage of Farm Labor				
Southeast Wisconsin	23.7	36.8	21.1	18.4
Other Wisconsin Farmers	21.9	27.2	26.9	24.0
Excessive Debt				
Southeast Wisconsin	21.1	42.1	15.8	21.1
Other Wisconsin Farmers	30.8	33.4	18.9	16.8
Flood Possibilities				
Southeast Wisconsin	7.9	23.7	28.9	39.5
Other Wisconsin Farmers	3.7	13.9	34.9	47.5
Government Regulations				
Southeast Wisconsin	34.2	39.5	15.8	10.5
Other Wisconsin Farmers	45.5	37.4	12.1	5.0
Property Taxes				
Southeast Wisconsin	73.7	15.8	0.0	10.5
Other Wisconsin Farmers	68.1	24.5	4.7	2.6
Local Urban Expansion				
Southeast Wisconsin	50.0	15.8	23.7	10.5
Other Wisconsin Farmers	6.1	16.1	20.6	57.3

Data source: Survey of Wisconsin dairy farmers conducted spring 1993. See Cross 1994b.

Dairy Termination Program in 1986 than elsewhere in the state, although their bid acceptance rates exceeded the state average (Cross 1989). On the other hand, southeastern Wisconsin dairy farmers are slightly less likely (36.8 versus 42.7 percent, not statistically significant) to "expect that a son, a daughter, or another relative will operate their dairy farm after [they] retire."

Agricultural land sales prices in southeast Wisconsin are the highest in the state, averaging $1,929 per acre if the land remained in agriculture and $3,679 if the land was diverted to other uses. These 1992 figures were actual decreases from 1991 values (Wisconsin Agricultural Statistics Service 1994b). Prices averaged $3,539 and $3,348 per acre for land remaining in agriculture in Milwaukee and Waukesha Counties. Such high land prices burden farmers with high taxes, make farm expansion prohibitively expensive, and provide strong incentives for farmers wishing to sell. In contrast, agricultural land sales averaged less than $1,000 per acre in 54 of

Wisconsin's 72 counties and below $750 in 38 of the state's counties.

The median acreage owned by southeastern Wisconsin dairy farmers responding to the 1993 survey was 130 acres, contrasting with a statewide median of 180 acres. (Actual median farm size was 255 acres, because many farmers rented additional acreage.) Furthermore, land fragmentation is a problem. In no other region of Wisconsin did a smaller proportion (13 percent) of dairy farmers report that their "farm fields were located all together," not even separated by a road. One third of the southeastern Wisconsin dairy farmers, the highest proportion in the state, reported that their fields were separated by at least two miles.

The average dairy farmer in southeastern Wisconsin grows over 95 percent of the hay and feed grains fed to his herd, the highest average among the state's nine agricultural reporting districts. Nearly three-quarters of the dairy farmers in this area report that they normally grow all of the feedstuffs for their cows. Unlike their counterparts in other urbanizing areas, whose dairy farms survive by importing large quantities of feed, the southeastern Wisconsin dairy farmer relies upon production from his increasingly expensive farmlands. Nevertheless, average herd size in southeastern Wisconsin exceeds that of all the state's other agricultural districts.

Conclusions

Three broad dairying zones can be identified in southeastern Wisconsin: (1) a zone in which dairying has ceased to be important, with only a few solitary holdouts who have resisted the pressures to sell-out; (2) a zone of rapid decline, in which large numbers of farmers are abandoning dairying at rates considerably in excess of average rates statewide; and (3) a peripheral zone in which dairying remains important. Although the impacts of urban expansion upon dairying may be most conspicuous in the greater Milwaukee metropolitan area, fingers of decline have spread towards other areas of Wisconsin, including a zone extending west to Madison and north along the Fox River Valley, particularly between Fond du Lac and Green Bay. What we have seen surrounding Milwaukee is not unique. The same process has been documented around Chicago (Berry 1979), but it is radically different from the process in southern California (Gilbert and Akor 1988), which has resulted in highly capitalized corporate dairy farms that took away Wisconsin's number one rank as a milk producing state during August 1993. Wisconsin remains a state of family farms, but dairy farmers are rapidly leaving the southeastern metropolitan area of the state.

Acknowledgments

I wish to thank two anonymous reviewers for their valuable comments upon an earlier version of this manuscript. Funding for the survey that provided data for part of this paper was provided by the University of Wisconsin Oshkosh Faculty Development Research Board.

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Eric E. Jorgensen and Lyle E. Nauman

Small mammal distribution associated with commercial cranberry production

Abstract *We documented the distribution of small mammals in association with commercial cranberry production in south-central Wisconsin. Small mammals were captured with snap traps, in and adjacent to cranberry beds. Fewer small mammals were present in cranberry beds compared to habitat directly adjacent them ($\underline{P}$ < 0.0214, 2 df). This may have been due to cultural influences, structural diversity, or predation. A range extension for the arctic shrew* (Sorex arcticus) *was documented.*

Commercial cranberries are extensively cultivated in Wisconsin. Cultivation is typified by intensive management of discrete crop producing complexes within a wetland matrix (U.S. Army Corps of Engineers 1991). Cranberry growing is unique, compared to other agricultural practices, because it is practiced in modified wetlands. Only one study has investigated small mammals in this unique setting. IEP (1990) studied three cranberry production facilities. They used snap traps but only had five captures (three meadow voles [*Microtus pennsylvanicus*], and one each of white-footed mouse [*Peromyscus leucopus*] and meadow jumping mouse [*Zapus hudsonius*], with about 1% trap success.

Small mammal distributions in association with agricultural practices have seldom been the subject of research. This research documented the distribution and diversity of mammals near commercial cranberry beds.

Description of the Study Areas

Five commercial cranberry production facilities in Wood County (Township of Babcock Sec. 32, T22N, R4E; Township of Vesper Sec. 13, T22N, R4E; Township of City Point Sec. 19, T21N, R2E), Juneau County (Township of Shennington

Sec. 17, T18N, R2E), and Portage County (Township of Dancy Sec. 17, T25N, R7E) were studied in south-central Wisconsin. Different wetland habitat types were associated with these facilities including shallow open water communities, sedge (*Carex* spp.) meadows, and sphagnum (*Sphagnum* spp.) bogs. All of the commercial cranberry wetlands studied in this research were classified as palustrine (Cowardin et al. 1979).

Trapping was conducted in commercial cranberry beds and adjacent wetlands. Adjacent wetlands were composed of sedge meadows and mats, sphagnum communities, wet meadows, and lowland forest. A detailed description of the study areas is found in Jorgensen (1992).

Methods

Each of the five facilities was sampled over two periods of two nights each from May through August, 1991. Each day, 100 snap traps baited with peanut butter were placed in 25 identical clusters of four traps consisting of two Museum Special and two Victor mouse traps (Call 1986). Clusters were located using a stratified random sampling method. Stratification was in three distance classes, relative to the cranberry bed matrix: clusters were placed in the cranberry beds, within 50 m of the cranberry beds and greater than 100 m from the cranberry bed matrix. The response variable was the number of small mammals caught per cluster per night. Data were analyzed with a Friedman Test because of non-normality and heteroscedasticity (unequal variances). Facilities were blocks and distance classes were treatments. There were 40 cluster nights in the 50 m treatment and 30 cluster nights in each of the other treatments per facility. Because each cluster night was a sample and not an experimental unit, this imbalance only affected the results to the extent that experimental error was increased, biasing our results toward nonsignificance. Means of ranked data within blocks were separated by the Tukey-Kramer method (Sokal and Rohlf 1981) for unequal sample sizes when treatment effects were observed.

Results

Eight species were trapped, and each facility's (block) small mammal assemblage appeared unique (Table 1). Species level comparisons were not made because sample sizes were too small to detect differences.

Table 1. Small mammals snap-trapped in and adjacent to commercial cranberry production beds in south-central Wisconsin during 500 trap cluster nights, 1991

Species	*Wood County no. 1*	*Wood County no. 2*	*Wood County no. 3*	*Juneau County no. 1*	*Portage County no. 1*
Microtus pennsylvanicus	22	31	1	9	6
Zapus hudsonius	3	5	–	2	3
Peromyscus leucopus	4	–	–	1	4
Peromyscus maniculatus	–	10	–	–	–
Blarina brevicauda	–	–	–	7	1
Sorex arcticus	–	–	1	5	–
Sorex cinereus	1	–	2	1	–
Eutamias striatus	–	–	–	–	1

Table 2. Catches of small mammals snap-trapped in and adjacent to commercial cranberry beds in south-central Wisconsin, 1991

Distance Class	*Cluster Nights N*	*Average Catch (Catches/cluster night)[a]*	*Std. Error*
Cranberry Beds	150	0.06	0.092
< 50 m	200	0.27	0.213
> 100 m	150	0.22	0.242

[a]Mean separation ($\alpha = 0.05$, Tukey-Kramer test) on ranks indicates that the number of small mammals captured was unique at each distance class.

The meadow vole (*M. pennsylvanicus*) was the most frequently caught and observed small mammal. At Wood County no. 2 the prairie deer mice (*P. maniculatus*) were of the subspecies *P. m. bairdii*. Small mammal populations were nonrandomly distributed with respect to distance class ($\underline{P} = 0.0214$, Friedman's Test, 2 df). Subsequent mean separation ($\alpha = 0.05$) indicated that the number of small mammals caught at each distance class was distinct, with the fewest animals captured in the cranberry beds (0.06 catches/cluster night) and the most captured (0.27 catches/cluster night) within 50 m of the beds (Table 2). The mean separation test was exceptionally powerful because of consistent results in the ranked data across treatments, though large differences in the unranked data were observable only with respect to the cranberry beds themselves (Table 2).

Catches within the beds totaled six *M. pennsylvanicus*, three *P. maniculatus*, and two masked shrews (*Sorex cinereus*). We consider the number of captures too few to allow accurate analyses of diversity.

Arctic shrews (*S. arcticus*) were caught at Juneau County no. 1 (Township of Shennington, Sec. 17, T18N, R2E) and Wood County no. 3 (Township of City Point, Sec. 19, T21N, R2E). These records are outside of the previously documented range for the arctic shrew in Wisconsin (Jackson 1961; C. A. Long, pers. comm.), and two specimens have been placed in the mammal collection of the Museum of Natural History at the University of Wisconsin–Stevens Point (catalogue numbers 7100 and 7101).

Discussion

Small mammals were present in greater numbers ($\underline{P} = 0.0214$) in the semi-natural habitat outside of the cranberry beds compared to the beds themselves (Table 2). We call these areas semi-natural because although they are not directly modified to cranberry beds, their close proximity probably affects plant distribution (Jorgensen 1992; Jorgensen and Nauman 1994) and bird distribution (Jorgensen and Nauman 1993).

There were three factors that could contribute to the distribution of small mammals we measured. The first factor was the continual disturbance that is present in the beds. Disturbance included various human intrusions and pesticide applications. The second factor may have been a relative lack of cover (Wrigley et al. 1979; Reich 1981). There appeared to be less vertical cover in the beds, which were maintained as monocultures, than in the adjacent habitat. Harriers (*Circus cyaneus*) hunt over the beds. A lack of cover might have contributed to increased predation, or otherwise caused a lack of suitable habitat. The third factor might have been a lack of diversity in both vegetative structure and plant species within the beds. The vegetation is essentially monotypic, and the insect populations, when they were not being controlled, were probably monotypic also and present in low numbers. Interspecific competition has also been implicated as a factor affecting small mammal distribution (Buckner 1966) in wetlands. This study was not designed to detect this type of interaction.

Acknowledgments

We thank the Wisconsin State Cranberry Growers Association and the Natural Resources Foundation of Wisconsin, Inc. for funding this research. Thanks to Dr. Charles Long for verifying identification of the small mammals.

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Ken Parejko and Douglas Wikum

The effect of manure management on phosophorus and suspended solids in the Lake Tainter, Wisconsin, watershed

Abstract *Phosphorus, suspended solids, and conductivity were measured during the spring of 1993 at five sites in the Lake Tainter (Dunn County, Wisconsin) watershed upstream and downstream from fields spread with turkey litter. Three sites were spread with litter during the winter, and two sites were spread in the spring after the ground was thawed. There was no significant difference in most sites in the phosphorus, suspended solids, and conductivity upstream versus downstream. Increased solids were detected downstream from two sites during spring-spreading and spring tillage. Phosphorus concentration showed a highly significant relationship to suspended solids but was inversely related to conductivity.*

Human effects on aquatic ecosystems stem primarily from point-source and nonpoint-source effluents. Point sources such as industries and municipal wastewater facilities are regulated through the permitting process. Nonpoint inputs are more difficult to regulate or control. Yet in 75% of the nation's lakes, measureable improvement in water quality will only come with control of nonpoint-source impacts (Committee on Restoration et al. 1992.)

Tainter Lake, in Dunn County, Wisconsin, is an impoundment of the Red Cedar and Hay Rivers, with a large, predominately agricultural watershed of over one million acres. This lake is experiencing significant cultural eutrophication, primarily due to phosphorus inputs that contribute to nuisance algal blooms and consequent undesireable effects. With relatively large watersheds and a high potential for nutrient loading in comparison to natural lakes, reservoirs such as Tainter Lake are considered especially susceptible to cultural eutrophication (Baxter 1977; Thornton 1984). Schreiber (1992) estimated that at least 90% of the phosphorus entering Tainter Lake is nonpoint source in origin. More than half of the total annual phosphorus loading into Tainter Lake arises during spring snowmelt runoff (U.S. Geological Survey 1990). Spring snowmelt also contributes more than half the total suspended solids loading into the lake.

Runoff from agricultural sources is suspected as the major source of phosphorus loading into the Tainter Lake watershed (Mechelke et al. 1992). Phosphorus enters the watershed from barnyard runoff, decaying vegetation, and runoff of commercial and manure fertilizers. Although considerable interannual variation may occur due to the amount of precipitation, the variation in frost depth, and the timing of manure application relative to snow and rain events, nutrient runoff studies indicate that total phosphorus runoff is significantly affected by several factors: the amount of phosphorus applied as fertilizer (Coote et al. 1979), the presence or absence of vegetated buffers between the field and the waterway (Thompson et al. 1979), soil texture and type, slope (Magette 1988), and winter-spreading versus spring-spreading manures (Khaleel et al. 1980.) Though there is little information on actual nutrient inputs into streams from individual fields, studies of intercepted runoff from experimental plots suggest that manure applied to frozen ground may have much more runoff potential than manure spread on thawed ground and incorporated in a timely manner (Converse et al. 1975; Klausner et al. 1976; Minshall et al. 1970; Mueller et al. 1984; Young and Mutchler 1976.)

Best management agricultural practices, based on these experimental studies, call for soil testing for phosphorus and limiting application to necessary amounts; applying manures in the spring after thaw and incorporating them as soon as possible; and restricting application of manures to fields with minimal slopes (Magette 1988). For example, the spreading of turkey litter from large turkey farms in the Tainter Lake watershed falls under Wisconsin Pollutant Discharge Elimination System (WPDES) permits that use these best management practices as guidelines for spreading. In a recently granted permit for one large turkey farm, farmers who purchase turkey litter from Jerome Foods of Barron, Wisconsin, are prohibited from winter-spreading that litter in several townships in the Tainter Lake watershed.

This study had two purposes. The first was to test the ability to detect phosphorus and erosional sediment inputs into waterways from individual fields that have been winter-spread and spring-spread with turkey litter. The second was to test for significant differences in phosphorus and sediment inputs into the rivers, comparing the two manure management strategies.

Study Sites and Methods

With the cooperation of Jerome Foods, Barron, Wisconsin, two fields adjacent to streams within the watershed that were spring-spread with turkey litter (sites A and B) and three fields that had been winter-spread (sites C, D and E) were selected (Fig. 1). Turkey litter applied at spring-spread sites was incorporated within three days of spreading. Sites are characterized as to runoff potential in Table 1. Sampling locations were established just upstream and just downstream from the field sites. Sampling began on March 13 and ended on May 6, 1993. During snowmelt runoff and for

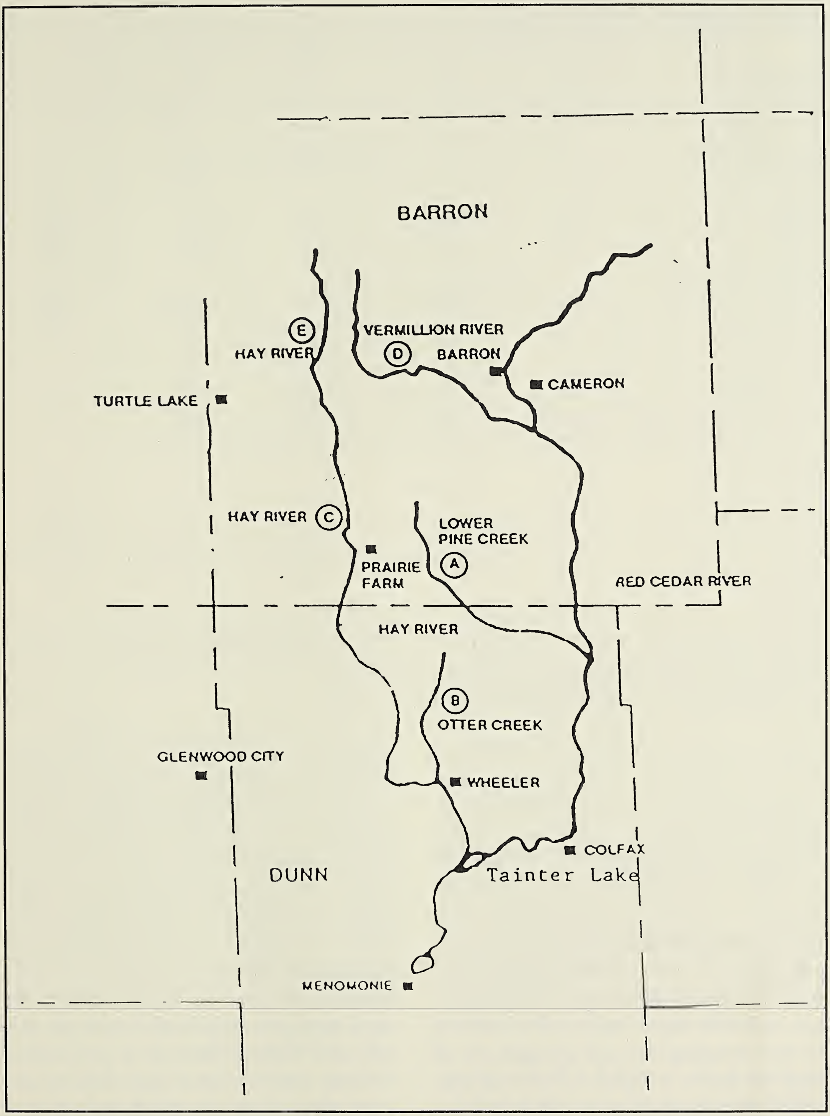

Fig. 1. Sampling sites for manure management study

Table 1. Study site characterization

Parameter	Site A	Site B	Site C	Site D	Site E
Total hectares	18.2	10.1	8.9	2.4	4.0
Metric tons turkey litter applied	211	61	55	44	73
Kg phosphorus applied	4590	1330	1190	950	1580
Kg phosphorus applied per hectare	252	132	134	396	395
Date of application	4/21/93	4/20/93	2/24/93	11/5/92	12/2/92
Average slope	2%	< 2%	2%	2%	4-6%
Soil type[a]	1	2	3	3	4
Streambank, ft[b]	1000	900	1400	2400	800
Vegetated buffer, % of streambank	100%	100%	100%	100%	100%
Vegetated buffer, average width (m)	5 m	5 m	8 m	8 m	12 m
Crop, fall 1992	Corn	Soybeans	Corn	Hay	Corn
Tillage, fall 1993	none	Chisel plow	none	none	none
Phosphorus Runoff Potential[c]	84	4.0	23	64	94

[a]Soil types: I = Urne Silt Loam; 2 = Plainfield Sandy Loam and Brems Sandy Loam; 3 = Antigo Silt Loam; 4 = Otterholt Silt Loam.
[b]Streambank = approximate footage of streambank along the field.
[c]for Phosphorus Runoff Potential calculation, see text, pp. 95–96.

about one week bracketing the spreading and incorporation of litter at spring-spread sites, sampling was done on an approximately daily basis. At other times sampling was done approximately two to three times per week. For technical reasons, we were unable to coordinate sampling dates with precipitation events. Precipitation amounts at Cedar Falls Dam on the Red Cedar River, supplied by the Wisconsin State Climatologist, and snow depth (measured at each site on each sampling date and averaged over all sites) are shown in Figure 2. Dates are converted to consecutive numerals: March 1 = 1 and May 6 = 67.

At each upstream or downstream location for each site, samples were taken as a single grab, about six feet from the stream bank and just beneath the water's surface. Aliquots (100 ml) were acidified, refrigerated up to 28 days, and analyzed for total phosphorus by the Colfax Commercial Testing Lab, Colfax, Wisconsin. Phosphorus concentrations are means of duplicate analyses. The limit of detection was 0.04 mg/liter total phosphorus. Suspended solids were determined from a one liter sample taken in the same manner as the phosphorus sample. Solids were filtered through a preweighed Gelman type A/E membrane, dried to constant weight and reweighed, according to Standard Methods (APHA 1985). In-lab measurement of conductivity (umhos/cm) was performed using a YSI model 33 con-

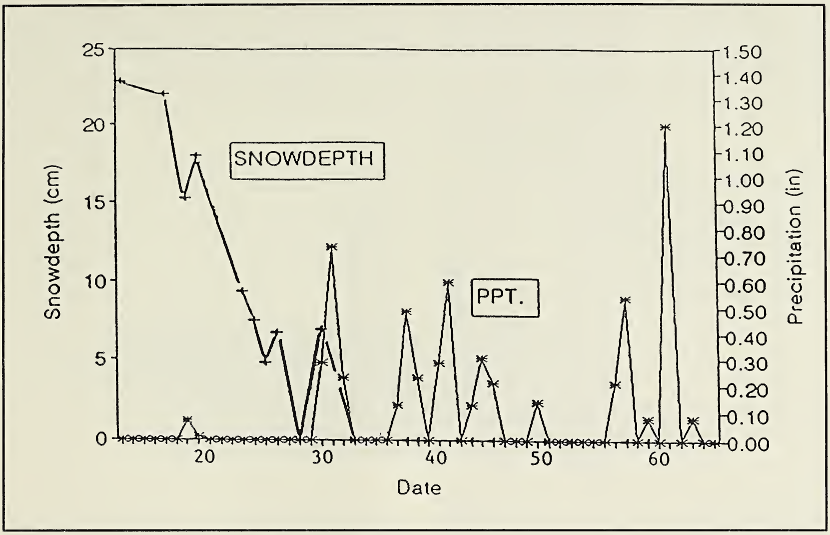

Fig. 2. Snowdepth (cm) and precipitation (in.) vs date

ductivity meter on samples refrigerated at 4°C. All conductivity values were standardized to 25°C.

Staff gages were installed in the rivers at downstream sampling locations before the study. Discharge at staff gages was measured on four to seven dates during the study with use of a Marsh McBurney Model 201 flowmeter. Stream cross-section was determined by measuring stream depth at 1 m intervals. Flow was measured at 0.6 x depth at midpoint of the 1 m intervals, and total discharge summed over the entire stream cross-section. A gage versus discharge curve was developed by plotting log gage depth versus. log discharge (Chow 1964). Discharges for dates on which flows were not measured were interpolated from the gage/discharge curve. For sites B, C, D, and E there were several dates when staff gages had been uprooted by ice or high water and not yet replaced. For those dates, flags on the streambank were used to measure stream height. For a few dates, it was necessary to interpolate river depths from data from other sites. Stream discharges are shown in Figure 3.

To compare sites in their potential for phosphorus loading, we created a Phosphorus Runoff Potential (PRP). This parameter for sample sites was calculated as follows:

PRP = kilograms phosphorus applied x application date factor x slope factor x streambank factor x vegetative buffer factor x crop factor x tillage factor, where

Application date factor = 1 for manure applied under snow, 0.5 for manure applied on top of snow, and 0.25 for spring-spread manure (see Thompson et al. 1979);

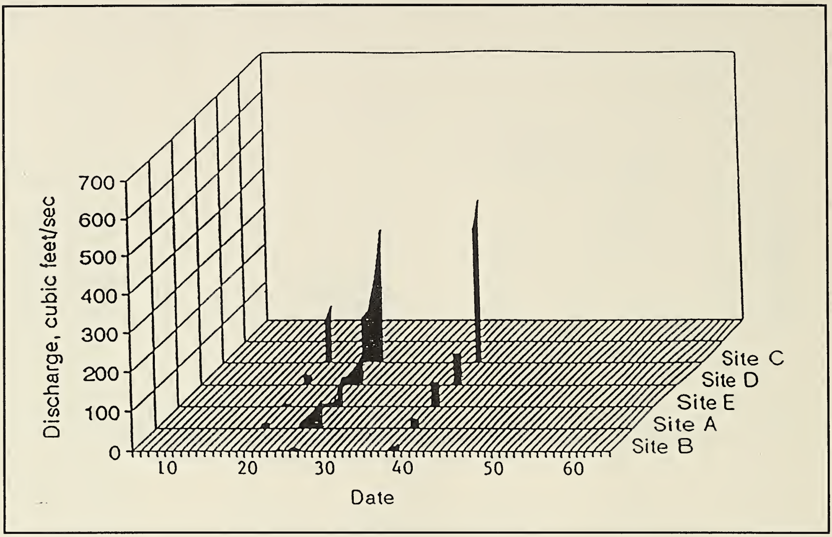

Fig. 3. Stream discharge vs date

Slope factor = 0.25 for slope < 2%, 0.5 for slope 2%, 0.75 for slope 2–4%, 1 for slope 4–6%;

Soil factor, all = 1 for soils encountered in this study;

Streambank factor = number of feet of streambank/2400;

Vegetative buffer factor is an estimate, interpolated from Thompson et al. 1979, of the percent of phosphorus reaching the streambank with various widths of vegetative buffers. For 5 meters, buffer = 35%, for 8 m = 27%, for 12 m = 18%;

Crop factor estimates runoff potential from different crops onto which manure is applied (Thompson et al. 1979). For corn or soybeans, = 1; for non-alfalfa hay = 0.5;

Tillage factor estimates the effect of tillage on runoff (from Mueller et al. 1984). For no tillage = 1; for chisel plow = 0.5.

For example, for site A, PRP = 4590 x 0.25 x 0.5 x 1 x 0.42 x 0.35 x 1 x 1 = 84.

The Phosphorus Runoff Potential should not be viewed as a quantitative estimate of the amount of phosphorus potentially entering the stream. It is instead a numerical method of comparing the study sites A through E. Sites with higher PRPs would be expected to have more nutrient runoff potential than sites with lower PRPs. Mean PRP for spring-spread sites is 44; for winter-spread sites it is 69. These can be considered approximately equivalent.

Most-probable-number fecal coliform analyses were done in the UW–Stout microbiology lab on stream samples taken on one date during snowmelt runoff and one date during spring-spread runoff, for all sites. To estimate what portion of total phosphorus was attached to particulates, on several dates total phosphorus analyses were done on samples of unfiltered stream water and on filtrates of the same sample that had passed through a Gelman A/E 1 micron cutoff membrane.

Statistical analyses were done with Minitab release 7.1. Data were checked for normality by correlating n scores with raw data. Correlations routinely fell below critical values due to a few very high values (phosphorus, suspended solids) or low values (conductivity) during runoff events. Log transformation of data gave very high n score correlations, indicating normality. Thus, we normalized data using log transformation.

Results

Data for suspended solids, conductivity, phosphorus, and flow discharge are shown in Appendices 1–4. In general, we found no obvious water quality patterns as a result of runoff from winter-spread versus spring-spread fields. Using paired t-tests, sites A through E were tested for a significant difference in suspended solids at upstream versus downstream locations. Over all 22 sampling dates, suspended solids were significantly higher downstream than upstream only at site B ($p < .01$) and higher downstream at both sites B and E for dates corresponding to spring-spreading (April 20–May 6). For all other dates and sites, there was no significant difference ($p > .10$) in suspended solids upstream versus downstream of each field.

Conductivity was lower downstream than upstream at site B ($p <. 001$) and higher downstream than upstream at site E ($.01 < p < .05$), over all dates. For dates corresponding to snowmelt runoff (March 26–April 17), site B showed lower conductivity downstream than upstream ($.02 < p < .05$), and site E showed higher conductivity downstream than upstream ($.05 < p < .10$). For dates corresponding to spring-spreading, only site B showed a significant difference in conductivity, with downstream sites lower than upstream ($p < .01$).

Phosphorus concentrations at all sites except site E were not significantly different between downstream and upstream sampling locations for all dates, whether winter-spread dates or spring-spread dates. Site E had significantly lower phosphorus downstream than upstream ($.02 < p < .05$), for snowmelt runoff dates only.

Separate single-factor regressions relating log-transformed phosphorus concentrations, conductivity and levels of suspended solids for each site/sampling location (five sites x two sampling locations per site) indicated a significant ($p < .01$) positive relationship between phosphorus concentration and suspended solids for all ten site locations. Phosphorus was significantly negatively related to conductivity for site A only ($p < .01$.) Conductivity was significantly negatively related to suspended solids at all sites except site D, downstream data (all $p < .10$).

When all sites were regressed together, phosphorus was significantly positively correlated with suspended solids ($p < .001$) and negatively correlated with conductivity ($p < .001$.) Conductivity was negatively related to suspended solids ($p < .001$.)

Table 2 shows the results from two sites, on two dates, of phosphorus analyses on filtered and unfiltered samples. Total soluble phosphorus in these samples accounted for 44–100% of the total phosphorus in the sample.

Fecal coliform analysis of stream samples taken on March 31 (during snowmelt runoff) resulted in all ten samples having 100 or more bacteria per ml, with site D, upstream, showing highest coliform levels (14,000/ml) and site B showing lowest

Table 2. Phosphorus analyses of filtrates of selected samples

Date	*Sampling Location*	*Total P mg/l*	*Filtrate P mg/l*	*Filtrate P/ Total P*
3/25	Site A, upstream	0.28	0.26	0.93
	A, downstream	0.27	0.27	1.00
	C, upstream	0.44	0.21	0.48
	C, downstream	0.55	0.32	0.58
3/27	Site A, upstream	.87	0.38	0.44
	A, downstream	0.86	0.36	0.42
	C, upstream	1.30	0.85	0.65
	C, downstream	1.18	0.83	0.70

coliform (100 and 200 per ml, downstream and upstream.) Coliform estimates on samples taken on April 27 (spring-spread) resulted in site A, upstream, having 100 bacteria/ml; all other sites had less than 100/ml.

Discussion

Highest stream discharges coincided with the period of most rapid snow melt, with peak discharges occurring around March 26 (see Figs. 2 and 3). A second discharge peak occurred on April 8, at a time of relatively heavy rains. A heavy rainfall on April 30, however, did not result in significant increases in stream discharge. Snow depth and frost depths for the 1992-93 winter were below normal compared to averages for the past 20 years, as was precipitation for March (pers. comm., Wisconsin State Climatologist). Precipitation for April and May were above normal. Total runoff potential for the spring of 1993, which is directly related to snow depth and precipitation and inversely related to frost depth, should therefore be considered about normal compared to the past 20 years.

A single sample of surface water runoff, taken in a part of the field containing turkey litter at site C during snowmelt, was measured for total phosphorus as 32 mg/l (data not shown). However, these very high nutrient levels on-site do not translate into statistically detectable solids or phosphorus inputs from individual fields during spring snowmelt runoff. Snowmelt is a period of very high discharge and relatively high phosphorus concentrations and levels of suspended solids. These high levels within the streams result from the cumulative contributions of many fields, barnyards, and forests within the watershed. The incremental load from an individual field appears to represent too small an input, under these conditions, to be detectable. Fields used in this study had phosphorus and sediment runoff ameliorated by relatively gentle slopes, sandy soils, and the presence of vegetative buffers. It is possible that under conditions of more potential runoff, such as fields with higher slope, more clay, and no buffers, or during years of abnormally high runoff, increments from individual fields may be detectable.

During spring-spreading of litter, and during spring tillage, sediment inputs were detected at two of the sites. At this time, while fields were being tilled, streams had low discharge and low sediment loads. Under these conditions, it was possible to detect sediment loading from some of the fields.

Conductivity (dissolved ions) was generally not significantly different upstream from downstream. One site (site B) showed lower conductivity downstream than upstream, and one site (site E) showed higher conductivity downstream than upstream, during snowmelt runoff.

Janzen et al. (1974) measured nutrient concentrations in small streams in South Carolina, adjacent to fields spread with dairy manure. They noted somewhat higher phosphorus concentrations in the streams directly adjacent to but not 50–600 meters downstream from the fields. In our study, it was generally not possible to detect phosphorus inputs from individual fields. At site E and site C during snowmelt runoff, phosphorus concentrations were significantly lower downstream than upstream.

In addition to nutrient input into streams, animal manure has the potential to degrade water quality from the input of coliform bacteria. Robbins et al. (1971) noted a significant increase in the numbers of coliforms in water adjacent to fields spread with animal manure. Janzen et al. (1974) found similar results. Although we were not able to detect significant increments of bacteria from individual fields, our results indicate that bacteria from the manure are in fact making their way into the streams. This was especially notable during snowmelt runoff. Numbers of coliform dropped below limits of detection after snowmelt runoff, when suspended solids and phosphorus concentrations also declined.

Phosphorus entered the study streams in both the soluble and insoluble forms. An average of 65% of measured phosphorus remained in the filtrate as soluble phosphorus for two dates, shown in Table 2. The portion of phosphorus as soluble phosphorus appears, from these results, to vary from site to site and date to date. The significant positive regression between phosphorus and suspended solids for all sites over all dates suggests that in general increased erosional input into streams will increase the input of phosphorus. Conductivity is determined by the concentration of total cations and anions in the stream, which may show a different mobility in the soil, compared to phosphorus itself (Rodhe 1949). Previous studies have also demonstrated a negative relationship between phosphorus and conductivity (Mueller et al. 1984).

Although this study was not able to pinpoint phosphorus loading from particular fields into nearby streams, levels of this nutrient and of erosional sediments within the streams were seen to increase drastically during snowmelt runoff. The incremental loading of nutrients from various sources into the nation's waterways provides an input into lakes and reservoirs that causes a significant impact on water quality. Monitoring streams during snowmelt runoff and during low-flow, background loading both for total phosphorus and total dissolved phosphorus has the potential to provide information useful in improving nutrient management. In addition, monitoring phosphorus concentrations in streams during snowmelt can help identify those subwatersheds that contribute the most phosphorus to particular lakes or reservoirs.

Appendix 1. Suspended solids, mg/l at upstream (u) and downstream (d) sampling sites

Date	*A,u*	*A,d*	*B,u*	*B,d*	*C,u*	*C,d*	*D,u*	*D,d*	*E,u*	*E,d*
6			3.2	5.1		3.1	3.4			
13			6.9	6.6	3.8	3.8	5.5	4.2	5.3	4.2
17			2.7	5.1	2.1	3.1	4.1	4.6	4.7	5.2
19	1.4	1.4	1.5	2.6	1.9	1.4	4.4	2.7	1.9	2.4
20	0.9	0.9	1.8	3	1.6	2.2	3.1	3.2	3.3	3.6
24	3.8	7.8	25.8	26.3	6.7	4.1	4	3.5	5.8	4.8
25	11	10.9	16.7	16	8.6	11.1	4.2	6.5	6.2	5
26	24.9	16.8	70.7	74.4	60.6	41.4	9.6	9.2	36.6	12
27	13.4	11.2	42.2	34.6	55	45.5	95	44.5	24.8	25.4
29	6.9	6.4	14.4	18.9	26.4	27.4	19.2	24.6	12.6	14
31	4.7	5	8.6	6.1	11.4	11.6	10.4	10.7	6.8	8.1
34	4.4	4.3	3.7	5.9	7.8	7.7	5.2	5.6	5.1	5.2
39	3.9	9.1	14.2	8.3	26.3	29.9	12.4	13.9	13.3	14.8
40	3.8	5.3	6.5	5.8	15	16.6	7.5	7.1	8.5	8.6
44	1.7	1.8			9.3	9.9				
45	1.7	1.7	3.3	9.1	7.7	7.5	11.5	10.8	5.5	6.3
48	1.9	1.5	4.5	5.4	6.7	6.8	4.6	4.6	5.1	6.2
53	3.1	3.1	3	9.2	5.1	5.8	5.7	5.3	7.6	9.2
55	1	0.8	2.4	4.7	5.8	7.3	4.4	4.6	5.7	7.1
58	2.3	1.8	10.9	11.1	4.4	4.6	4	4.9	4.9	6.9
60	1.3	3.6	3.7	7.5	7.8	11	4.7	4.7	6.7	8.3
62	1.9	2.7	4.5	4.5	6.1	7	5.3	4.9	5.3	5.4
67	3	4.2	4	6.6	15.8	17.8	9.4	8.5	22.8	28.8

For dates, 1 = March 1; 32 = April 1; 62 = May 1.

Appendix 2. Conductivity, umhos/cm², at 25°C at upstream (u) and downstream (d) sampling sites

Date	*A,u*	*A,d*	*B,u*	*B,d*	*C,u*	*C,d*	*D,u*	*D,d*	*E,u*	*E,d*
17			277	269	237	202	205	196	221	224
19	344	371	261	258	234	234	213	221	234	237
20	363	376	261	252	229	229	202	212	228	231
24	338	335	224	224	142	142	198	194	215	213
25	300	300	218	212	245	272	207	205	224	224
26	205	198	174	164	229	220	202	196	210	223
27	130	130	174	177	172	175	144	174	152	155
29	101	99	125	126	114	114	150	164	114	11
31	194	191	207	202	137	133	166	167	144	145
34	270	272	224	224	160	161	153	153	153	158
39	224	235	190	175	139	126	123	131	155	153
40	204	204	201	190	156	149	115	120		
45	237	237	142	128	160	160	114	114	139	139
48	256	261	234	221	167	174	142	142	141	142
53	299	297	239	235	191	191	158	160	174	174
55	307	307	245	237	207	205	163	166	212	220
58	300	300	213	205	221	221	169	172	218	220
60	272	269	237	221	205	209	172	169	207	207
62	299	288	251	237	219	223	167	163	220	216
67	269	283	251	234	172	177	175	174	136	142

For dates, 1 = March 1; 32 = April 1; 62 = May 1.

Appendix 3. Phosphorous,mg/l at upstream (u) and downstream (d) sampling sites

Date	*A,u*	*A,d*	*B,u*	*B,d*	*C,u*	*C,d*	*D,u*	*D,d*	*E,u*	*E,d*
13			0.100	0.090	0.080	0.110	0.130	0.060	0.090	0.130
17			0.210	0.130	<.04	<.04	0.120	0.090	0.050	0.040
19	<.04	0.040	0.040	<.04	<.04	<.04	0.070	0.050	0.050	0.050
20	0.040	<.04	0.060	0.120	<.04	<.04	0.040	0.050	0.040	0.040
24	0.200	0.300	0.200	0.200	0.200	0.200	0.200	0.090	0.120	0.090
25	0.280	0.270	0.130	0.120	0.440	0.550	0.190	0.190	0.220	0.210
26	0.630	0.580	0.260	0.250	1.190	0.790	0.300	0.300	0.480	0.460
27	0.870	0.860	0.490	0.290	1.300	1.180	0.730	0.620	0.750	0.720
29	0.260	0.290	0.080	0.170	0.850	0.770	0.540	0.570	0.420	0.420
31	0.140	0.140	<.04	<.04	0.370	0.370	0.400	0.410	0.170	0.160
34	<.04	<.04	<.04	<.04	0.130	0.110	0.250	0.240	<.04	<.04
39	0.130	0.120	<.04	<.04	0.330	0.270	0.250	0.240	0.220	0.190
40	0.130	0.130	<.04	<.04	0.280	0.270	0.190	0.190	0.130	0.130
44	<.04	<.04			0.130	0.150				
45	<.04	<.04	<.04	<.04	0.140	0.120	0.140	0.140	<.04	<.04
48	<.04	<.04	<.04	<.04	0.110	0.130	0.140	0.180	<.04	<.04
53	<.04	<.04	<.04	<.04	<.04	<.04	<.04	0.110	0.150	<.04
55	<.04	<.04	<.04	<.04	0.120	0.100	<.04	0.120	0.120	0.100
58	<.04	<.04	<.04	<.04	<.04	<.04	<.04	<.04	<.04	<.04
60	<.04	<.04	<.04	<.04	<.04	<.04	<.04	<.04	0.130	0.140
62	<.04	<.04	<.04	<.04	0.110	0.120	0.110	0.100	0.120	0.130
67	<.04	0.100	<.04	<.04	0.130	0.210	0.220	0.370	0.190	0.160

For dates, 1 = March 1; 32 = April 1; 62 = May 1.

Appendix 4. Manure management study, spring 1993, water discharge, ft^3/sec

Date	Site A	Site B	Site C	Site D	Site E
6	*	0.1	140	32	12
13	*	0.1	160	32	13
17	*	0.2	190	35	15
19	11	0.1	110	27	4.6
20	14	0.1	140	23	4.6
24	12	3.0	120	20	5.1
25	29	0.6	140	22	6.0
26	41	8.0	220	42	11
27	72	1.7	350	79	74
29	44	2.8	600	140	81
31	27	1.1	430	110	65
34	13	0.1	140	81	62
39	25	1.1	350	79	60
40	24	18	430	79	60
45	10	13	110	54	46
48	5.9	6.9	89	46	37
53	7.6	6.0	54	30	24
55	3.4	7.0	51	28	20
58	5.5	15	43	28	19
60	6.4	7.0	54	30	21
62	5.5	5.2	48	32	21
67	5.5	6.0	74	19	41

For dates, 1 = March 1; 32 = April 1; 62 = May 1.

Acknowledgments

The authors wish to acknowledge the University of Wisconsin–Stout Alumni Foundation for a significant portion of funding of this study. Additional funds were provided by the Dunn County Land Conservation Department through a Lake Improvement Planning Grant. We gratefully acknowledge the cooperation and technical assistance provided by Jerome Foods, Inc., Barron, Wisconsin, and the West Central Office of the Wisconsin Department of Natural Resources. Ed Ramsaroop competently and enthusiastically performed field sampling. We thank George Nelson, UW–Stout Biology Department, for fecal coliform analyses. Bill James, Eau Galle Limnological Laboratory, Spring Valley, Wisconsin, and Mike Nelms, Jerome Foods, made helpful comments on this manuscript.

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The effect of picnic beetles (Glischrochilus quadrisignatus) *on European corn borer* (Ostrinia nubilalis) *larval mortality*

Abstract *A study was conducted to ascertain the effects of the picnic beetle* (Glischrochilus quadrisignatus [Coleoptera: Nitidulidae]) *on European corn borer* (Ostrinia nubilalis [Lepidoptera: Pyralidae]) *larval mortality. The experiment consisted of two treatments: corn plants with a European corn borer larva only and corn plants with a European corn borer larva and picnic beetles. Significantly more corn borer larvae survived in the control than in the treatment receiving picnic beetles. Picnic beetles caused a 17.5% increase in corn borer mortality.*

The picnic beetle (*Glischrochilus quadrisignatus* [Say]), which is distributed throughout the northern United States (Luckman 1963), is associated with a variety of foods including plant sap, fungi, fruits, and vegetables and is often found in the corn agroecosystem (Luckman 1963; Foott and Timmins 1971). As McCoy and Brindley noted (1961), the introduction of the European corn borer *(Ostrinia nubilalis* [Hübner]) to the Midwest provided the picnic beetle with an additional food source in the form of injured corn plants and European core borer (hereinafter ECB) frass. The picnic beetle is primarily saprophagous and feeds on a variety of fermenting and decomposing plant material. However, on the basis of early reports by Everly (1938) and Barber and Dicke (1944) that picnic beetles may be ECB predators, McCoy and Brindley (1961) investigated the possible reductive effects picnic beetles have on ECB populations. They reported that during the period of peak beetle populations, the number of dead ECBs and empty tunnels increased. McCoy and Brindley also reported that picnic beetles do not actively prey on ECB larvae in the confines of an ECB tunnel. Rather, it appeared that the activity of picnic beetles may cause accidental injury to the ECB larvae, which the beetles subsequently fed on. Empty tunnels are a result of picnic beetle movement irritating ECB larvae so as to drive them from their tunnels (McCoy and Brindley 1961). When Carlson and Chiang (1973) assessed the role of sucrose sprays on concentrating predatory insects against the ECB, they found a negative correlation between the number of beetles per plant and number of ECBs per tunnel. They concluded that picnic beetles reduce ECB populations after the larvae have entered the stalk. The literature supports the idea that picnic beetles can have a deleterious effect on ECB populations; however, the evidence has been circumstantial, and no rigorous study has been conducted to confirm these effects. The purpose of this study was to evaluate the effects picnic beetles have on a known population of ECBs.

Methods and Materials

This experiment was conducted at the University of Wisconsin Arlington Agricultural Research Station in Columbia County during the summer of 1994. The experiment was a completely randomized design with two treatments and six replicates. Each plot consisted of ten corn plants. The Kansas pipette tip procedure (Higgins, described by Bode and Calvin 1990) was used to introduce one-fourth instar ECB larvae into the stalks of the corn plants on 26 August 1994. A single larva was placed in the third internode above the brace roots. The larvae used in this study were reared from eggs bought from Dekalb Genetics. When the treatments were applied, the corn (Pioneer 3751) was in approximately the R3 milk stage of development, the kernels had yellowed, and the silks were brown and dry (Ritchie et al. 1982). To facilitate entry of the 1 ml pipette tip (Fisher Scientific, Reference Tip) into the corn stalk, a 20 d common framing nail was driven through a block of wood and used as a hole punch. The nail was forced into the stalk to a depth of 2 cm, making it easier to insert the pipette tips. All plants were punched, and the stalks were given 15 minutes for the flow of plant sap to diminish before the pipette tips containing ECB larvae were inserted. This delay was necessary since it was known from prior experience that pipettes inserted immediately after the stalk was punched resulted in high ECB mortality: the larvae drowned in plant sap collecting in the pipette tip. The larvae were brought to the field in pipette tips. The wide end of the pipette was plugged with clay, and the tip was plugged with cotton to prevent the ECB larvae from escaping. The cotton was removed from the pipette tip when it was time to insert the ECB larvae into the corn plants. The larvae were allowed three days to burrow into the stalks. On 29 August one-half of the stalks were infested with three picnic beetles per plant via pipette tips. The picnic beetles used in this study were collected in banana-baited Lindgren funnels at the Arlington Agricultural Research Station. Forty-eight hours after the picnic beetles were introduced into the corn plants, the stalks were split open and the condition of the ECB larvae was recorded. The percent of ECB larvae alive, dead, or missing was calculated for each treatment, and a chi-square analysis was used to analyze the data.

Results and Discussion

A significant difference was found between corn plants containing an ECB larva only and corn plants containing both an ECB larva and picnic beetles ($X^2 = 15.715$, P <

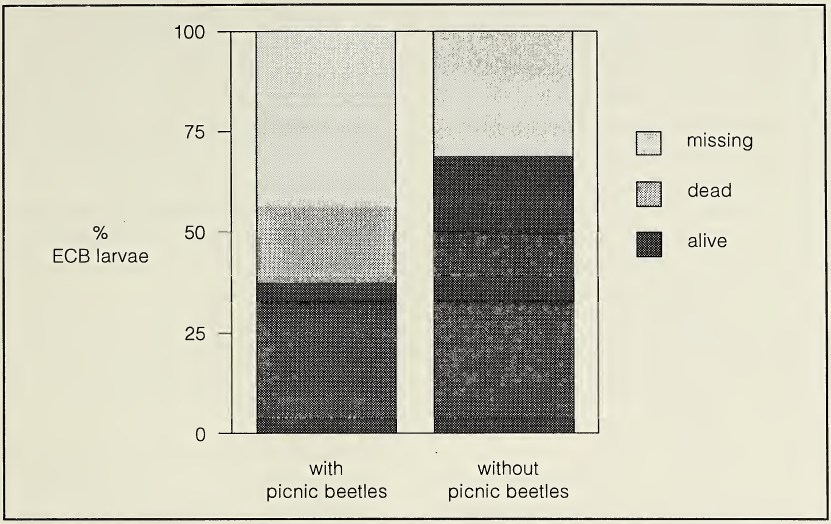

Fig. 1. Percent of European corn borer larvae missing, dead, and alive in cavities containing European corn borer larvae and picnic beetles and in cavities containing European corn borer larvae only.

0.001). Of the plants infested with picnic beetles, 61.4% of the ECB larvae were either dead (17.5%) or missing (43.9%); by comparison, plants in the control group contained no dead larvae and 33.3% missing larvae (Fig. 1). Significantly more ECB larvae (66.7%) survived in the control than in the treatment receiving picnic beetles (38.6%). These data quantify the direct effects picnic beetles can have on ECB mortality and confirm the earlier suspicions of McCoy and Brindley (1961) and Carlson and Chiang (1973). It appears that the death of 17.5% of the larvae in this experiment probably resulted from mechanical injury of larvae by picnic beetles. The inability to observe events within the plant, however, makes it impossible to know whether nitidulids are actually preying on ECB larvae or injuring them via accidental mechanical damage. Although on two occasions picnic beetles feeding on ECB larvae were observed in the field, it is possible that the larvae were injured or weakened prior to picnic beetle feeding. Generally, picnic beetles appear to be disinterested in ECB larvae when the two are placed together in petri dishes.

Picnic beetles have been shown to reduce ECB populations after the larvae have entered the stalk. However, this reductive effect may be more pronounced during the first generation than the second generation. Picnic beetles are attracted to and feed on corn pollen, and second generation ECBs lay eggs on corn plants that have tasseled and are near the pollen-shedding stage. Once pollination begins, picnic beetles may concentrate more heavily where pollen collects than where ECB larvae and frass collect, which reduces opportunities for contact with second generation ECB larvae and reduces their value as a predator.

Although picnic beetles have a reductive effect on ECB populations, this positive result should be weighed against the possible deleterious effects picnic beetles may have on the corn system itself. Picnic beetles have been implicated in the transmission of the corn fungal pathogens *Fusarium* spp. (Windels, Windels, and Kommedahl 1976) and *Gibberella zea* (Attwater and Busch 1983). The plant injuries (i.e., ECB cavities and ECB ear damage) that attract picnic beetles are excellent entrance points for plant pathogens. The spread of stalk and ear rots may be exacerbated by movement of picnic beetles from plant to plant.

Moreover, picnic beetles themselves may be considered corn pests if their numbers become heavy. Picnic beetles are considered secondary invaders of injured or over-ripe fruits and vegetables, and a buildup of picnic beetles may occur anywhere a plant has been damaged. In the case of silking corn ears, Luckman (1963) found picnic beetles to be primary invaders, possibly attracted to pollen fermenting in the silks. A large picnic beetle population in sweet corn may warrant control measures where contamination of processed corn with insect body parts occurs.

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ISSN 0084-0505