TRANSACTIONS

of the Wisconsin Academy of Sciences, Arts and Letters

Volume 87 • 1999

TRANSACTIONS

of the Wisconsin Academy of Sciences, Arts and Letters

Volume 87 • 1999

Editor William J. Urbrock
Department of Religious Studies
University of Wisconsin Oshkosh
Oshkosh, Wisconsin 54901

Managing Editor Patricia Allen Duyfhuizen
Department of English
University of Wisconsin Eau Claire
Eau Claire, Wisconsin 54702-4004

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. Please prepare figures with reduction in mind.

ISSN 0084-0505

For information on membership in the Academy,
call (608) 263-1692.

Contents

TRANSACTIONS
Volume 87 • 1999

From the Editor

You know you're from Wisconsin if . . .

. . . you define summer as three months of bad sledding.

. . . you have experienced frostbite and sunburn on the same weekend.

. . . you have more miles on your snowblower than your car.

. . . your Fourth of July picnic was moved indoors due to frost.

. . . you define swimming season as Labor Day weekend.

. . . you design Halloween costumes to fit over snowsuits.

. . . you decided to have a picnic this summer because it fell on a weekend.

Sound familiar? While this group of one-liners was forwarded to me by a friend in Texas, Wisconsinites are used to sharing similar sentiments with each other about Wisconsin weather, especially its frequent long hard winters. Let's face it: the weather in Wisconsin is a source of endless fascination (and, at times, frustration) to residents and visitors alike.

There are, of course, many positive sides to the Wisconsin weather story. From my own weather experiences over just this past year I can bring to mind scintillating star shows in the unobstructed winter skies above Door County; a frost-swathed mid-March morning in Oshkosh when every tree and bush sparkled and tinkled like a swaying crystal chandelier in the dawning sunlight; balmy evenings in late spring and early summer when the scent of lilacs graced my walks around our neighborhood; a cool, drizzly day that turned a hike along the Wisconsin River at the Dells into a sort of walk through an Impressionist painting; hot, hot days in mid-July that called out a profusion of wildflowers, especially the roadside chicory and fields of Queen-Anne's-lace, purple knotweed (a.k.a. knapweed or star thistle), and coneflowers; sunny days at the Cedarburg Bog in Saukville and at the Whitefish Dunes State Park along Lake Michigan; and a picture-postcard summer day at the beginning of August when white clouds flung carelessly across a deep blue sky seemed to gently chide the carefully patterned green and gold farm fields of southwestern Wisconsin between Platteville and Madison. *You know you're from Wisconsin if . . . you've ever enjoyed days like these.*

I was reminded of what a special place Wisconsin is by the fourteen school teachers from twelve other states (from as nearby as Illinois and Michigan and as far away as Hawaii, North Carolina, and Massachusetts) who spent a month studying with me on the University of Wisconsin Oshkosh campus from mid-June to mid-July. While they enjoyed engaging in intellectual pursuits during our National Endowment for the Humanities seminar, they literally reveled in our trips together around some of the eastern parts of the state. Their visits to beautiful Crescent Beach at Algoma; Summer Fest in Milwaukee; an evening pops concert at Buttermilk Park in Fond du Lac; State Street, the Wisconsin State Capitol, and the University of Wisconsin campus in Madison; the International Crane Foundation, with its marvelous restored prairie, in Baraboo; and various places around Green Lake, the Fox Cities, and Oshkosh, invariably resulted in praises for the people, places, flora and fauna, geology, and—yes!—even the weather of Wisconsin. *You know you've visited Wisconsin if . . . you have memories to treasure like these.*

This issue of *Transactions* features articles we have grouped into two sections, each of which showcases Wisconsin and its natural and human environments.

The three featured contributions to the opening section of *Transactions* pay tribute to one of Wisconsin's (and the nation's) pioneer conservationists, Aldo Leopold. Many have observed 1999 as a sort of Leopold Year, marking as it does the fiftieth anniversary of the publication of Leopold's classic, *A Sand County Almanac.* The Wisconsin Academy has joined wholeheartedly in the commemoration. The Academy's 129th Annual Conference at Stevens Point in April featured a day-long plenary session on "Aldo Leopold and Conservation on Private Lands." In October the Academy sponsored a national conference in Madison dedicated to "Building on Leopold's Legacy: Conservation for a New Century." Honorary co-chairs for this conference were Nina Leopold Bradley of the Aldo Leopold Foundation and Gaylord Nelson, former U.S. Senator and now counselor for the Wilderness Society, which Leopold helped found in 1935. An entire issue of our sister publication, *The Wisconsin Academy Review,* also was devoted to Leopold and his legacy.

The three articles on Leopold are revised versions of lectures originally presented as part of an extended Aldo Leopold Lecture Series sponsored by the University of Wisconsin Arboretum in Madison last year. Andrew Hipp deserves special thanks for his efforts in helping make these lectures available to *Transactions.* We are especially delighted that Nina Leopold Bradley consented to let us include her homage to her father, including her reminiscences of life at the now famous Leopold family "Shack." Also of great interest are the contributions of J. Baird Callicott and Susan Flader. The former presents an incisive analysis of the important speech Leopold delivered at the dedication of the Wisconsin Arboretum and Wildlife Refuge and the extensively revised version he subsequently published in *Parks and Recreation* magazine. The latter offers us valuable insights into the meanings and implications of environmental citizenship, as suggested by Leopold's work and writings. *You know you're from Wisconsin (certainly in spirit!) if . . . you share some way in the wilderness vision of Aldo Leopold.*

In the second section of articles, Ellen Argyros takes a fresh look from an ecofeminist perspective at *Come and Get It,* a novel by one of Wisconsin's most celebrated writers, Edna Ferber. Other articles in this section concentrate on

Wisconsin's natural resources. Craig Annen and Jonathan Lyon present a study of the Curtis Prairie restoration project at the University of Wisconsin Arboretum, while Thomas Eddy documents the vascular flora of Mitchell Glen in Green Lake County. Terry Balding takes readers to another part of Wisconsin with his study of red-shouldered hawk detections along the lower Chippewa River. Waterways of Wisconsin and its neighbors provide the focus for the other three studies presented in this section: Ed Avery's research on brown trout in Emmons Creek in central Wisconsin; the analyses by Joan Jass and Jeanette Glenn of museum specimens of a freshwater bivalve mollusk abundant throughout Wisconsin; and Jeffrey Ripp's historical review of the evolution of the Great Lakes Fisheries Commission.

I hope all readers of this issue of *Transactions* will find the contents both challenging and enlightening. Dare we forecast a "warm and sunny" reading experience? Ah, but as my son will remind me when next he ventures a mid-winter visit from Atlanta to Oshkosh:

You know you're from Wisconsin if . . .

. . . *the snow on your roof in September weighs more than you do.*

. . . *you've taken your kids trick-or-treating in a blizzard.*

. . . *driving is better in the winter because the potholes get filled with snow.*

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.

Nina Leopold Bradley

A Sense of Place

Today I speak to you of my own experience, my own deep attachment to a particular place. This attachment happened over time, with my family, on a sand farm along the Wisconsin River—land that was neither grand nor dramatic, but mundane, humbled, and degraded. It seems to have happened by slow accrual, like the growth of a coral reef. I dwell in this place and am finally a part of this place.

Recently I came across a splendid little book by Deborah Tall, who inspired me with the following statement: "How does land evoke our love? Surely not just driving through *scenery* or *landscape,* treating nature as a prop."

This makes me think of a quip in *The New Yorker* not long ago, recording two secretaries in conversation after their drive-through vacations. It went something like this:

> "But you get so tired with nothing but scenery all the time."
> "Yes, but you get even more tired and bored without any scenery."
> "Well, I guess. But I like it better when there's mostly landscape and not so much scenery."
> "Well, I guess. But then most of the scenery was gone when we were there. There were just mountains and things."

It seems all too often we hurry through "scenery," without any attempt to engage the land. This may be the price we pay for our mobility and rootlessness.

On our sand farm along the Wisconsin River I was able to get inside the scenery and the landscape. I became a living part of a living place. As we worked with family, friends, and neighbors to restore health to the abused land, we were experiencing the slow sensitizing of people to land. We learned how to look, how to dwell, and how to think about land. This was *sick land* but *rich country* for the growth of perception.

No one knew better than my father, Aldo Leopold, the joy of wild, unspoiled land. His love of wilderness was passionate and enduring. He had spent immense energy in protecting wilderness and trying to understand its dramatic complexity. He realized that wilderness was important in part so that we might retain the capacity to compare unspoiled land with lands more intensively altered by human economic activity. My father's rationale for wilderness protection was not just recreational or scenic, but scientific, biological, political, economic, and deeply aesthetic. He wrote, ". . . the raw wilderness gives definition and meaning to the human enterprise . . . the ability to see the cultural value of wilderness boils down, in the last analysis, to a question of intellectual humility."

In the 1930s Aldo visited the Rio Gavilan in northern Mexico. This river still ran clear between mossy, tree-lined banks. Fires burned periodically without any apparent damage, and deer thrived in the midst of their natural predators, wolves and mountain lions. "It is here," Leopold reflected years later, "I first realized . . . that all my life I had seen only sick land . . . here was a biota still in perfect aboriginal health." In *Song of the Gavilan* he wrote:

> This song of the waters is audible to every ear, but there is other music in these hills, by no means audible to all. To hear even a few notes of it you must first live here for a long time, and you must know the speech of hills and rivers. Then on a still night, when the campfire is low and the Pleiades have climbed over rimrocks, sit quietly and listen for a wolf to howl, and think hard of everything you have seen and tried to understand. Then you may hear it—a vast pulsing harmony—its score inscribed on a thousand hills, its notes the lives and deaths of plants and animals, its rhythms spanning the second and the centuries.

Here, the vital new idea for my father was the concept of biotic health. In this essay Aldo grasped the idea of the land community and the need for a deeper understanding of the functioning of land as an interrelated, indivisible whole. Through his intellectual struggle to better understand the system as a whole, there evolved within him a continuing love and respect for land—a deepening spirituality. He would now inspire others along the same route.

The ecological integrity of the Gavilan was put into perspective when my father visited the slick, clean forests of Germany in 1935—spruce trees in straight lines, the forest floor devoid of vegetation. Litter piled up on the forest floor as a dry, sterile blanket which smothered all natural undergrowth, even moss.

Leopold came to realize that what was lacking in the German forests was *wildness*—not wilderness per se—but a lack of *biodiversity*. He wrote of Germany,

> The forest landscape is deprived of a certain exuberance which arises from a rich variety of plants fighting with each other for a place in the sun. It is almost as if the geological clock had been set back to those dim ages when there were only pines and ferns. I never realized before that the *melodies* of nature are music only when played against the undertones of evolutionary history. In the German forest one now hears only a dismal fugue!

My father's experience in the German landscape deepened his appreciation of ecological integrity—his conviction of a relationship between ecological diversity and the stability of the land organism.

And so it was an extraordinary event when Aldo Leopold purchased his Wisconsin farm. Here, the frontier story had come full circle from *wilderness* to *farm land* to *waste*. Here was the perfect metaphor for "sick land."

In *A Sand County Almanac* he wrote, "My own farm was selected for its lack of goodness and its lack of highway; indeed my whole neighborhood lies in a backwash of the River Progress."

Gross understatement! The sandy soils, outwash from the glacier, had produced one or two crops of corn—perhaps a crop of buckwheat or rye before the soils were exhausted. Any timber had been cut. The corned out fields were coming up in sand burrs and quack grass. Sand burrs in our socks were effective reminders.

There was little left to support a farm family. The previous owner had finally given up and moved to California, the farm house having burned to the ground. The only remaining structure was an old chicken coop, waist deep in chicken and cow manure.

What could be more of a challenge for a bunch of teenagers than repairing the chicken coop. Weekend after weekend, the Leopold family worked to make the chicken coop more habitable—cleaning out manure, constructing a fireplace, attaching a bunk house, a new roof, drilling a small sandpoint well, and many other items contributing to comfort.

The "Shack" became a family enterprise to which each member contributed: cutting and splitting wood, building bird houses for martins, screech owls, and bluebirds.

In my father's quiet way we finally were led to understand his direction: what *did* this land look like before white man took it away from the Indians. Reconstruction of the native landscape became our aim. We now realize this was one of the earliest attempts at ecological restoration.

From April to October scarcely a weekend went by that someone did not plant or transplant something—butterfly weed, tamarack, wahoo and oak, penstemon and puccoon. Spring vacation became the principal planting season. Each year we planted some 3,000 native pines on the land. We planted them with shovels so sharp they sang and hummed in our wrists as they sliced the earth. We planted a mosaic of conifers, hardwoods, and prairie to restore health and beauty to the community.

In winter we banded resident birds. We recorded daily, weekly, seasonal events on the land—tracks of animals in the snow, arrival of migratory geese, courtship of woodcock, etc. Here in reality Father's statement rang true—"Keeping records enhances the pleasure of the search, and the chance of finding order and meaning in these events."

It was our mother whose enthusiasm sustained the project. Mother worked as hard as anyone, planting, weeding, whatever the enterprise. She was "chief sawyer" as the gang cut good oak to cook our grub and warm our Shack.

With Mother's Spanish background she taught us Spanish songs, and each evening the guitar concert filled the old shack until weariness forced us to our bunks.

In years of drought, our struggling plantings did not survive. We learned that "sun, wind and rain" and the thrust of life would truly determine the outcome of all our investment in the place.

Here in the sand counties, Aldo Leopold initiated a *different relationship* with the land, at once more personal and more universal. From his own direct participation in the restoration of the land he was to come to a deeper appreciation of the ecological, ethical, and aesthetic understanding of land. He gained a new sense of belonging to something greater than himself, a continuity with all life through time. At the same time he was finding new dimensions to his sense of place—so, too, did his family members, colleagues in this venture.

What happened involved the senses, the memory, the history of family. It came from working on the land in all weathers, suffering from catastrophes, enjoying its mornings or evenings or hot noons, valuing it for the very investment of labor and feelings.

By his own actions my father instilled in his children a love and respect for the land community and its ecological functioning.

I now read with new perspective my father's statement: "There are two things that interest me—the relationship of people to each other and the relationship of people to land."

Family weekends at our sand county farm turned out to be a place where my father put these two concepts into practice—the relationship of our family members to each other and their relationship to this piece of land. These two interests became more a way of life than simply interests. New values were developing somewhere within us.

At the Shack, we all became participants in the drama of the land's inner workings. In the very process of restoration—of planting, of successes and failures, of animals and birds responding to changes—we grew increasingly to appreciate and admire the *interconnectedness* of living systems.

As we transformed the land, it transformed us. This must be how a *sense of place* is nurtured. My father once wrote that restoration can be a ritual of self renewal. And so it was. As we worked together, there came love and respect for each other and for the land community.

One of the principal achievements of *A Sand County Almanac* is the recasting of our notion of natural beauty, away from the conventionally "scenic" to the more subtle sense that comes with ecological and evolutionary awareness.

Through my father, my family, and this experience I have learned to love this land. This place has taught me how to look and how to live, and so at last to sing its poetry.

Nina Leopold Bradley *lives on the Leopold Memorial Reserve and is a director of the Aldo Leopold Foundation. She is a plant ecologist presently working on prairie restoration and continuing the study of phenology started by her father in the 1930s.* ***Address:*** *Aldo Leopold Foundation, Inc., E12919 Levee Road, Baraboo, WI 53913.*

J. Baird Callicott

"The Arboretum and the University": The Speech and The Essay

The dedication ceremony of the University of Wisconsin Arboretum and Wildlife Refuge occurred on June 17, 1934. Aldo Leopold had joined the faculty the previous year as the nation's first professor of game management, and had been involved, as such, in the conception and design of the Arboretum (Meine 1988). He was among those who spoke on this occasion.

According to William R. Jordan III (personal communication), long a member of the Arboretum staff and founding editor of *Restoration and Management Notes,* in his speech Leopold was the first person to clearly articulate the concept of ecological restoration and provide a rationale for it. Once more, Leopold earns the metonyms of pioneer and prophet that so frequently accompany his name. Apparently, he is the seminal figure in ecological restoration as he is in ecosystem-management forestry, conservation biology, and environmental ethics.

Here is the key passage: "Our idea in a nutshell is to reconstruct, primarily for the use of the University, a sample of original Wisconsin—a sample of what Dane County looked like when our ancestors first arrived here during the 1840s." Before this central and summary statement, Leopold characterized what most arboretums were about as "a collection of trees" of one sort or another, some organized taxonomically, others—those that were "more advanced"—organized "ecologically" as "natural associations." The restoration project at the University of Wisconsin Arboretum was then unique and (perhaps now as well as then) represented the most advanced concept of what an arboretum might be.

Leopold followed this clear articulation of ecological restoration with a lyrical description of "what our state was like before we took it away from the Indians" and how different the Lake-Wingra environs were then from what his audience beheld in 1934. His description was organized hydrologically. He first described the "oak-openings" on the uplands; next the tamarack forest on the Wingra marsh, "undergrown with sphagnum moss and orchids"; then the "wild rice bed" on the lakeshore; and finally the lake itself, once a haven for waterfowl, but by 1934 spoiled as a habitat for its erstwhile avifauna and native fishes by, in all probability, the introduction of carp. This could all be ascertained from the "embalmed" pollen grains preserved in the marsh peat, he noted.

Next Leopold turned to the question "why dig up these ecological graves?" And answered that the ecological changes befalling the area, while the concomitants of the laudable utilitarian conversion of aboriginal Wisconsin to fair farms and productive forests, portended disutilities for the future: "the erosion of topsoil which followed too much wheat and too many cattle"; fires which "burned up the peat beds in our drained marshes"; exotic insect pests, such as white-pine blister rust and white-oak June-beetles "from the four corners of the earth"—all will at a minimum "reduce our standard of living" and may even "threaten the actual physical existence of . . . the present social structure." To us Leopold may seem to have been not only a prophet, but, more particularly, a Jeremiah, predicting a plague of locusts and thistles, a prophesy that has not come true—not yet anyway. The little island of ecological healing represented by the Arboretum notwithstanding, the ecological changes Leopold reviews and laments have, if anything, accelerated by many orders of magnitude since 1934. Yet here we are today enjoying, for the moment at least, an unprecedented standard of living and a social structure that remains more or less intact. But remember, this was 1934. Dust Bowl. Depression. Bolshevism entrenched in Russia. Fascism gathering force in Germany. The future did not look at all either certain or bright.

Just as he had reduced the concept of ecological restoration to a "nutshell," so he reduced the rationale for it to a nutshell at the end of his remarks. He said: "This, in a nutshell, is the function of the Arboretum: a reconstructed sample of old Wisconsin to serve as a bench mark, a starting point, in the long and laborious job of building a permanent and mutually beneficial relationship between civilized men and a civilized landscape."

There are two distinct lobes of meat in this nutshell. Examine the latter first: "a mutually beneficial relationship between civilized men and a civilized landscape." This is one of several formulations that Leopold struck to crystallize his novel philosophy of conservation.

At the turn of the century two philosophies of conservation had taken shape (Hays 1959, Fox 1981). The more venerable, going back to Ralph Waldo Emerson and Henry David Thoreau, came to be called "preservation." Its most forceful and influential champion was John Muir. Its standard or norm and its sanctum sanctorum was wilderness, "in contrast with those areas where man and his own works dominate the landscape . . . an area where the earth and its community of life are untrammeled by man, where man is a visitor who does not remain"—to quote the eventual Wilderness Act of 1964 (Anonymous 1998: 121). The other philosophy—call it conservation proper—was summed up, at the turn of the century, as the "wise use" of "natural resources." Its most forceful and influential champion was Gifford Pinchot, the first Chief of the United States Department of Agriculture Forest Service, by which Leopold was first employed. Pinchot's (1947: 325–26) conservation motto was straightforwardly utilitarian and anthropocentric: "the greatest good of the greatest number [of people, it went without saying] for the longest time."

Leopold and another maverick ranger, Arthur Carhart, had first proposed a system of wilderness preserves under the auspices of the Service on the national forests (Meine 1988). Thus we tend to think of Leopold as having begun his career in forestry firmly in the Pinchot camp. Then, gradually he became enlightened by his study of ecology and his experience on the ground in the arid Southwest, especially in regard to range management (Leopold 1924). The interconnection among "natural resources," Leopold slowly but steadily came to realize, frustrates their separate utilitarian exploitation and management for maximum sustained yield. Ultimately, therefore, he left the ecologically unenlightened Pinchot conservationist camp and came over to the Muir preservationist camp. His resignation from the Forest Service in 1928 formalized and finalized this conversion.

But that's not the correct interpretation of what happened. Leopold's push for wilderness preservation in the mid-1920s was expressed in terms of Pinchovian wise use, not Muirian Transcendentalism (Leopold 1925). The principal use of wilderness was recreation, which of course for Leopold mainly meant big game hunting. And for some regions of the country—too rugged to log, too remote to graze, too arid or too nutrient-poor to plow—wilderness recreation was their highest use. Leopold did reject species-by-species, commodity-oriented resource management, but not in the context of his wilderness advocacy. In any case, by the time he had become a university professor he had evolved a new paradigm of conservation that lay between the Pinchovian and Muirian extremes. Leopold's new idea of conservation was a human harmony with nature, as he expressed it with characteristic grace and simplicity in the *Almanac* (Leopold 1949). Not hands-off Muirian nature preservation. Not efficient Pinchovian resource exploitation. Not a compromise between the two: islands of wilderness—the bigger and more numerous the better—surrounded by intensively, albeit efficiently, exploited but ecologically degraded tree plantations, grain plantations, cattle pasture and feedlots, suburban and urban sprawl. Rather a mutually beneficial relation between people and land; a symbiosis; a mixture of beauty and utility *in the same place* (Leopold 1939, 1991*a,* 1999*a*).

Now examine the other lobe of meat in the nutshell rationale for ecological restoration, the function of the Arboretum. It will be a reconstructed sample of old Wisconsin, to serve as a bench mark, a starting point, in the long and laborious job of building a permanent and mutually beneficial relationship between civilized men and a civilized landscape. After having come to his novel philosophy of conservation, incidentally, Leopold was justifying wilderness preservation in exactly the same terms. "A science of land health," he wrote, "needs, first of all, a base datum of normality, a picture of how healthy land maintains itself as an organism. . . . The most perfect norm is wilderness" (Leopold 1941: 3). Less perfect, perhaps, but just as important is an ecologically restored landscape. Doubtless there is intrinsic value in a reconstructed sample of old Wisconsin as there is in a big Western wilderness preserve. In Leopold's rapturous description of the presettlement environs of Lake Wingra, there is a palpable nostalgia and affection. But that is not the only rationale for the Arboretum restoration project, nor is it the rationale that Leopold explicitly states. Rather, if we are to forge our own symbiosis with the land upon which we now live, we need a bench mark of land health. We found the land in a state of good health. We have ecologically transformed it and thereby compromised its health. We cannot and will not everywhere try to take it back to what it was, try to restore it to a previous state. "Americans shall look forward not backward," Leopold says expressly. Americans are civilized and their landscape shall be civilized. But can it not also be healthy? Can there not also be a mutually beneficial relationship between civilized men and a civilized landscape? At the conclusion of this article I return to Leopold's concept of land health and, more particularly, its ecological and ethical foundations.

Implicit in the possibility of a future symbiosis between civilized European-Americans and the civilized landscape upon which it is erected is the conviction that the previous tenants of the Upper Midwest had established their own mutually beneficial relationship with the place that would later be called Wisconsin. If *they* could do it, maybe *we* could do it. In *The Story of My Boyhood and Youth,* John Muir (1913: 32) exclaims "Oh that glorious Wisconsin wilderness!" To the contrary, Leopold knew that Wisconsin was not in a wilderness condition in 1849 when Muir first beheld it, for Leopold acknowledges that "we took it away from the Indians." Moreover, though not mentioned in Leopold's talk, present at the dedication, dressed in full ceremonial regalia, and giving a speech of his own, was a Winnebago Chief, Yellow Thunder, a living reminder that old Wisconsin was not a place where, until the 1840s, man was a visitor who did not remain (Meine 1988).

Four months later, Leopold's address at the dedication ceremony of the University of Wisconsin Arboretum and Wildlife Refuge was published in the October issue of *Parks and Recreation.* Or was it? Leopold had so thoroughly revised the text of his speech that only a few phrases remained from the original to indicate that the published essay had evolved from it—and in so short a period of time, given manuscript preparation, typesetting, proofreading, and the other time-consuming steps from the pencil, with which Leopold composed, to the printing press. One memorable fragment stands out: In the speech Leopold wrote: "This task [preserving an environment fit to support citizens] is of a complexity far beyond what I can here take time to explain. I will ask you to accept my word that it is a long and difficult job. To perform it, a University must have, for the daily use of its faculty and students, a living exhibit of what Wisconsin was, what it is, and what it expects to become." In the essay we read, "If civilization consists of coöperation with plants, animals, soil, and men, then a university which attempts to define that coöperation must have, for the use of its faculty and students, places that show what the land was, what it is, and what it ought to be." Hard on the heels of this remark is a disparaging mention of what an arboretum normally is, "a 'collection' of imported trees," which also echoes the speech. Finally, in the next and last paragraph of the essay, the whole of which is shorter than the speech, Leopold condensed his invidious comparison of the present ecological condition with that prevailing in the past, emphasizing the corrosive combination of wetland draining and burning. But his eye to the past remains, in the essay as in the speech, in service of his eye on the future. "At what stage in the retrogression from forest to meadow is the marsh of greatest use to the animal community? How is that desirable stage to be attained and maintained? What is the role of drainage? These questions are of national importance. They determine the future habitability of the earth, materially and spiritually. . . . The scientist does not know the answer—he has been too busy inventing machines. The time has come for science to busy itself with the earth itself. The first step is to reconstruct a sample of what we had to start with. That, in a nutshell, is the Arboretum."

So here is a mystery: Why didn't Leopold just mail the text of his speech to *Parks and Recreation* for publication? Why did he so thoroughly rework it? Adding to the mystery is the fact that the essay purports to be the text of a speech. In it he writes "This Arboretum . . . " as if he were actually standing in it as he spoke. A line or two afterward he writes "I am here to say . . ." a locution more appropriate to a speech than to an essay. Most unambiguously misleading he writes "Take the grass marsh here under our view . . . ." Let me hasten to say that I do not accuse Leopold of dishonesty. Rather, it is a most revealing example of his artistry. By way of comparison, I am convinced that "Thinking Like a Mountain," *Sand County*'s second most famous and oft-quoted essay, is fictional. Neither Susan Flader (1974) nor Curt Meine (1988), Leopold's biographers, could find a record of such a signal event as it purportedly recalls in Leopold's correspondence or journals. "Thinking Like a Mountain" was written in response to a criticism by Albert Hochbaum, who was reading and critiquing drafts of the book that was to become the *Almanac* (Ribbens 1987). Hochbaum had complained that Leopold came off as elitist and superior and reminded him that he had once been as ecologically blind as those he criticized (Ribbens 1987). In support of that observation Hochbaum pointed out that Leopold had had a hand in the extirpation of wolves from the Southwestern game fields (Ribbens 1987). Leopold might enable his readers more to identify with the author, Hochbaum suggested, if the author found his lessons in his own mistakes (Ribbens 1987). Leopold responded with "Thinking Like a Mountain," an environmental transmogrification, as it seems to me, of the story of Saint Paul's conversion on the road to Damascus. The old she-wolf, silently asks, in effect, why persecutest thou me?, with that bewitching green fire in her dying eyes. That in all probability the event did not actually happen does not in the least diminish the truth of the essay. It fits like the keystone in one of the twentieth century's greatest works of literature and one of the greatest works of literary natural history of all time.

So part of the solution to our present mystery is the author's need to transform his text from an oral to a written work of art. The speech is far less aggressive. At one point in the speech Leopold almost apologetically issues a disclaimer. "Now this is not a tirade against careless farming, lumbering, or transportation," he says to his audience that might well include farmers, lumbermen, teamsters, and engineers. But in the essay he openly admits to being "indignant about something." The artist also seems to have felt a need to scale up from the municipal, regional, and state level to the continental and even global level for a national publication; hence the Wisconsin landscape is less the central subject, than an example used to illustrate the more general plight of land and the current human maladaptation to the earth.

The most startling change Leopold made in transforming the Arboretum speech into the Arboretum essay is not in voice or in adaptation to audience, but in substance. He added a philosophical, one might even say, eco-metaphysical theme that is completely absent in the speech—and he put it at the very beginning. Leopold wished his national readership to imagine that this is how he opened his address to the company assembled at the dedication of the University of Wisconsin Arboretum and Wild Life Refuge:

> For twenty centuries and longer, all civilized thought has rested upon one basic premise: that it is the destiny of man to exploit and enslave the earth.
>
> The biblical injunction to "go forth and multiply" is but one of many dogmas which imply this attitude of philosophical imperialism.
>
> During the past few decades, however, a new science called ecology has been unobtrusively spreading a film of doubt over this heretofore unchallenged "world view." Ecology tells us that no animal—not even man—can be regarded as independent of his environment. Plants, animals, men, and soil are a community of interdependent parts, an organism. No organism can survive the decadence of a member. Mr. Babbitt is no more a separate entity than is his left arm, or a single cell of his biceps. Neither are those aggregations of men and earth which we call Madison, or Wisconsin, or America. It may flatter our ego to be called the sons of man, but it would be nearer the truth to call ourselves the brothers of our fields and forests.
>
> The incredible engines wherewith we now hasten our world-conquest have, of course, not heard of these ecological quibblings; neither perhaps have the incredible engineers. These engines are double-edged swords. They can be used for ecological coöperation. They are being used for ecological destruction on a scale almost geological in magnitude. . . .

Pretty strong stuff. And bold. The only mention of ecology in the Arboretum speech is adjectival, first used to characterize the way the more "advanced institutions arrange their tree collection," viz., as "ecological groupings," and then to characterize the Arboretum project as digging up "ecological graves." In the Arboretum essay ecology is characterized as more than just a new science. It is a new world view pregnant with ethical import.

But what ecology? Evidently the ecology of Frederic Clements, the dean of that emerging new science in the early twentieth century, who boldly represented plant formations as superorganisms. The Clementsian paradigm in ecology cast doubt not just on the Judeo-Christian view of nature as created for man's use, it also cast doubt on the prevailing mechanistic world view of classical physics, which informed engineering. The Judeo-Christian dogma that it is man's God-given right to have dominion over and subdue the earth and "the mechanistic conception of the earth" in Newtonian physics combined to create the "iron-heel" mentality that Leopold twice goes on to condemn in the Arboretum essay. A decade earlier (in an essay that he never got around to publishing in his lifetime, but that was finally published more than fifty years after it was written), Leopold (1979) had more fully contrasted the organismic ecological world view with the biblical and mechanical world views, allied in their "anthropomorphism" as he called it.

Now back to the theme with which I began: Leopold's articulation of the nature of and a rationale for ecological restoration in his Arboretum speech. Supplementing the speech with the essay it is evident that the prophet and pioneer of ecological restoration was informed by the Clementsian paradigm in ecology, with one major and crucial difference, as I shall explain directly.

According to Clements (1905, 1916), each region of the world, which he called a "biome," had a characteristic plant "formation" that he called the "climax" because it was determined by the climate—which he supposed to be stable and unchanging. Climate consists of two principal gradients, moisture and temperature. In North America, for example, the moisture gradient runs, low to high, from the Sierra rain shadow eastward to the Atlantic; in the dry Southwest, a formation dominated by saguaro cactus is the climax; a little farther east the climax is short-grass steppe; still farther east, it's long-grass prairie; from the Mississippi valley on eastward, it's forests. Similarly the temperature gradient determines forest types from southern oak-hickory hardwoods to northern spruce-fir softwoods. Elevation complicates this picture, and it does demonstrably in the Southwest where Leopold first worked. Going upslope is like going north, and, in the U.S., like going east: the micro-climate is cooler and wetter at higher elevations.

In any case, from time to time the climax formation in a biome experiences catastrophic external disturbances—volcanic eruption, wild fire, flood, wind storm. There follows a series of plant formations until the climax formation is reestablished. Clements called this process "succession."

Moreover, he viewed this process as a kind of organismic development, an ontogeny. It was the climax "sere" (successional stage) that he believed to be a highly integrated superorganism. Ecology is the study of its anatomy, physiology, and metabolism.

Clements' study area was the Nebraska prairie just at the time it was being settled by European-American agriculturists. To him they represented an alien and external disturbance that not only destroyed the climax formation but that also disrupted and forestalled the process of succession back to climax.

It is just here, I think, that Leopold parts company with Clements. Human beings too, in Leopold's view, are members of ecological superorganisms. Sinclair Lewis's Babbitt, no less than Yellow Thunder, is but one cell of the superorganism in which he lives, moves, and has his being. Human beings and human ecological impacts are not metaphysically set apart from nature, as our biblical Western philosophical traditions often interpret them to be. Nor is *Homo sapiens* a physically alien species, invading Earth from another planet. Hence the ecological effects of human activities are not by definition sullying. Just like the activities of other species, human activities can be ecologically benign as well as malignant, functional as well as dysfunctional, harmonious as well as disruptive. Our "engines . . . can be used for ecological coöperation," Leopold writes, even though at present "they are being used for ecological destruction on a scale that is almost geological in magnitude."

Ecological restoration, as we have come to know it, I submit, rests, implicitly, on the orthodox Clementsian paradigm in ecology, not the Leopoldian alternative (Jordan et al. 1987). The putatively "objective" norm for conventional ecological restoration is the humanly undisturbed climax formation for a given biome. Supposedly, that was the condition it was in just prior to human "settlement" by the "white man," i.e., by *Homo sapiens* of European descent and cultural habits. Granted, the Indians were here already, but they were too few and their cultures were too primitive to have much ecological effect. Or so restorationist orthodoxy would have us think. In addition to destroying the climax and disrupting the process of succession, the white man brought with him a range of "exotic" species; that is, species that had evolved, naturally or artificially, elsewhere. Some of these—for example, wheat, cattle and sheep—were his domesticated cultivars. Others—such as carp and Johnson grass—were neither domesticated, that is, artificially selected, nor cultivated, but were, nevertheless, deliberately introduced. Still others—such as the Norway rat—were inadvertently introduced. Hence, in addition to "pre-settlement" ecological conditions, native species also became a norm for ecological restoration and exotic species a target for eradication.

Contemporary biogeography, ecology, and anthropology have rendered these straightforward norms for ecological restoration problematic (Pickett and Ostfeld 1995):

- The climate has not been stable during the Holocene; hence forests, grasslands, and deserts have slowly wandered around (Davis 1986).
- Local disturbance has been frequent, and not exceptional, and once a patch within a biome has been disturbed, succession does not follow a lock-step order through a series of intermediate formations back to the original climax (Pickett and White 1985).
- Further, the reductive "individualistic" paradigm in ecology, first advocated by Henry Gleason (1926), has eclipsed Clementsian holism; plant formations are not now regarded as highly integrated superorganisms, or even as typological biotic communities that come and go as units, but as stochastic aggregates of species populations that are adapted to similar climatic and edaphic gradients (Simberloff 1980).
- Because species are constantly dispersing to new areas and disappearing from their former haunts, mixing and matching, hit or miss, catch as catch can, the sharp distinction between native and exotic species is blurred (Peretti 1998).
- And, lastly, the impact of *Homo sapiens* has been significant and ubiquitous throughout the Holocene. Geographers and anthropologists now estimate the indigenous population of the Western Hemisphere on the eve of European discovery to be ten to twenty times as great as the geographers and anthropologists contemporary with Clements estimated it to be (Denevan 1992). In 1492 the biomes of North and South America were as much an artifact as those in Europe at the same time—just a different kind of artifact. The oak openings which Leopold eulogizes were created and maintained by Indian-set fires, as John Curtis (1959)—he of the Arboretum's Curtis Prairie—notes in his wonderful book, *The Vegetation of Wisconsin.* In 1492 the only sizable land mass in a "pristine" condition was Antarctica. Then, one of the largest cities in the world, Kahokia, lay only some 600 kilometers and change east of the area in which Clements did his research at the turn of the last century, and only some 500 kilometers south of Lake Wingra (Doolittle 1992). Between the European "discovery" of America and "settlement" Old World diseases reduced the Indian population by ninety or ninty-five per cent—a demographic debacle of unprecedented proportions (Denevan 1992). So it was easy for twentieth-century ecologists to ignore the impact of the indigenes of the Western Hemisphere, as Clements did. But to their credit Leopold and Curtis did not, at least not in Wisconsin.

As a target for restoration, the condition of a given patch when the white man first laid eyes on it is therefore but a snapshot in the ever-changing, ubiquitously human-impacted biogeography of an area. Ecological restoration may learn to live with that, in which case it might be compared to architectural and automotive restoration. Some people have a quaint fondness for structures built in an architectural style at some arbitrarily selected particular time in the past—the Victorian era, for example—and are willing to spend considerable time and energy restoring them. Other people have a quaint fondness for particular old cars—1957 Chevrolets, for example—and are willing to spend considerable time and energy restoring them. Likewise, we environmentalists have a quaint fondness for "pre-settlement" oak savannas and long-grass prairies and are willing to spend considerable time and effort restoring them. I think that Aldo Leopold would confess to being something of an ecological antiquarian himself—without apology. Just as some people buy an old Victorian house and restore it to its former condition as a hobby, Leopold bought an old worn-out farm and attempted to restore the land to its condition prior to its being farmed. (The analogy is not perfect, but it's close enough.)

Such a concession, however, would rob ecological restoration of its moral high ground. We environmentalists believe that the time and energy of ecological restorationists should be subsidized by the general public—in the case of the Arboretum restoration project, through the agency of the University—because it is both the right and the necessary thing to do. Ecological restoration is more than a matter of personal taste, we feel, it is also a matter of impersonal environmental ethics. But why? Leopold may not be as scientifically up-to-date as we are now, nearly sixty-five years later. Even prophets do not always see unerringly into the future, especially into the twists and turns of a science so fickle as ecology. But he is unfailingly wise.

Remember, his rationale for ecological restoration is not stated in terms of the superior value of the previous ecological condition over the present one because the former is "pristine" or "virgin" and the latter is anthropogenic, as Thoreau and Muir before him had done. As noted, contrary to Clements as well as to Muir, he viewed human beings—Lewis's Babbitt as well as Yellow Thunder—as a part of nature. His own antiquarian affections aside, the objective value of the past ecological condition is as a point of reference, a bench mark, for a once and future condition of what Leopold (1991*a*, 1991*b*, 1999*a*, 1999*b*) elsewhere called "land health." Ecological restoration, *sensu stricto*, the restoration of a past ecological condition, is a point of reference for a more general program that we might call ecological *rehabilitation* (Callicott et al. 1999). What was good and right about the Wisconsin that the Indians lived in, took their living from, and actively managed? It was neither pristine nor virgin; the Indians were members of the same species, *Homo sapiens*, as their European-American successors; they lived on the land; and not without significant ecological impact. The difference was that under the aegis of the Indians, old Wisconsin was ecologically functional. Prior to European settlement, the Wisconsin biota recruited, retained, and recycled nutrients from the parent materials. It stabilized the top soil that it had built up. It percolated and modulated the flow of surface waters. It was composed of a diverse assemblage of plants, which provided habitat for a diverse community of animals, related in tangled food webs, woven of lengthy food chains, topped off by long-lived, large-bodied carnivores (Leopold 1991*a*, 1991*b*, 1999*a*, 1999*b*). What Leopold envisioned, indeed what he conceived the task of conservation to be, is the creation of a similar ecological condition in the future, but one that would necessarily involve different species of plants and animals than that which the Indians had adapted to their economy—just as it would involve a different stock of *Homo sapiens.* He characterized it as a civilized landscape for civilized men. The bench mark, the reference point would be the ecological status quo ante as it was when we took it away from the Indians. And the Arboretum was to restore that condition for that purpose. In a nutshell, the principal objective reason for undertaking ecological *restoration* at the Arboretum and elsewhere, from Leopold's point of view, was its service of the more general, more important, and more difficult goal of ecological *rehabilitation* everywhere.

Appendix A: The Speech[1]

What Is the University of Wisconsin Arboretum, Wild Life Refuge, and Forest Experiment Preserve?

What Is an Arboretum? An arboretum is ordinarily a place where the serious-minded citizen can learn, by looking at them, the difference between a white and a black spruce, or see in person a Russian olive, a tamarisk, or an Arizona cypress. That is, it is a collection of trees.

Sometimes an arboretum also serves as an outdoor library of horticultural varieties, i.e., a place where one can compare all the apples, all the lilacs, all the roses.

Some advanced institutions arrange their tree-collection as natural associations, rather than as taxonomic groups. They present, for example, a sample of the Douglas fir forest of the Northwest, showing the hemlocks, larches, and balsams which grow in association with Douglas fir, and also the ferns, salmonberries, yews, and shrubs which grow under it, and if possible the mosses and herbs which grow under the shrubs. Such exhibits are called "ecological groupings" and represent "advanced thought" in arboretum management.

The Wisconsin Arboretum. We want to have all these things, but they by no means represent the main idea which we are trying to express here. It is something new and different. Perhaps we should not call the place an arboretum at all. Whether our idea is a worthy one, I will have to leave you to judge.

Our idea, in a nutshell, is to reconstruct, primarily for the use of the University, a sample of original Wisconsin—a sample of what Dane County looked like when our ancestors arrived here during the 1840s.

Obviously, it will take 50 years to do this thing. Obviously, too, it will be done for research rather than for amusement, and for use by the University, rather than for use by the town.

What I want to try and picture today is why it is important to the future welfare of our state to know what it was like before we took it away from the Indians.

Rebuilding the Wisconsin Landscape. First let me convince you that if you were set down, blindfolded, in Nakoma in 1840, you would not only fail to recognize the place, but you might fail to realize you were in Wisconsin at all.

This hill on which we stand was then an "oak-opening." Our grandparents describe, sometimes with rapture, the beauty of these open orchard-like stands of oaks, interspersed with copses of shrubs, and the profusion of prairie grasses, and flowers which grew between. But just what shrubs, grasses, and flowers were they? We don't know. Why did they remain open, instead of growing up to solid woods? Probably fire, but we're not sure. What oaks? Largely burr-oak, but we are not sure. We do know this, that the bluegrass which now covers half of our

[1]Given by Aldo Leopold at the dedication of the University of Wisconsin Arboretum on June 17, 1934. Printed by permission of the Aldo Leopold Foundation.

county was not present—it came with the white man—while the native grasses which then grew here are now rare or even possibly extinct. The pheasants and possibly even the quail which now inhabit Nakoma were absent; instead the oak-openings were populated with sharptailed grouse, then appropriately called "burr-oak grouse," and now found only a hundred miles to the north. The wild turkey apparently did not occur. The copses contained the ordinary partridge or ruffed grouse. There were elk and deer—elk horns have been pulled out of our local marshes, and of deer we have ample records.

The Wingra Marsh, which we boast of as largely "unspoiled," we would not have recognized in 1840. Those waving meadows of grass, rushes, and dogwood were then largely a tamarack forest, undergrown with sphagnum moss and orchids. We know this because tamarack logs were encountered in draining the golf course. The tamarack forest has been gradually converted into grassland by repeated burning, cutting, grazing, and mowing—a process still plainly visible in any of the tamarack relicts of the eastern half of the county.

The deep layers of peat which comprise this marsh are merely the closely packed remains of sphagnum plants which could not decay because of the acid water in which they were "pickled" through innumerable generations. Professor Fassett of the Botany Department takes his students there to exhume samples of this peat from various depths, and in these samples he finds embalmed the very pollen grains which fell or were blown into the marsh from the plants then growing in and around it. So perfectly are these pollens preserved that their shape and structure tell the kinds of plants which grew, while the relative abundance of the various kinds tells which plants were then most common. The bog is, in short, a vast historical library telling the story of the arboretum back to the Glacial Epoch, 10,000 years ago. Its volumes are still largely untranslated, but it is easy to see why they constitute a valuable educational and scientific asset.

Lake Wingra itself wears so different an aspect that the early settler would not know it now. Much of the shore was then a wild rice bed. The water level fluctuated more, but averaged higher. It was full of waterfowl, whereas now the ducks show almost an aversion to it. Presumably the introduction of carp contributed heavily to these changes, but we do not know.

Why Study Original Wisconsin? Granted, then, that we have radically changed the aspect of land, what of it? It's still good to look at—why worry? Why try to discover the exact processes by which the Wisconsin of 1840 became the Wisconsin of 1930? Americans shall look forward, not backward, so why dig up these ecological graves?

Because we are just beginning to realize that along with the intentional and necessary changes in the soil and its flora and fauna, we have also induced unintentional and unnecessary changes which threaten to undermine the future capacity of the soil to support our civilization.

In some places these changes will merely reduce our standard of living—physical, in the sense of a healthy agriculture; spiritual, in the sense of needless spoliation of natural beauty. In other places, these changes threaten the actual physical existence of even the present social structure. In some cases, the damage is temporary, in others permanent.

For example, the erosion of topsoil which followed too much wheat and too many cattle is carrying the best parts of southwestern Wisconsin to the Gulf of

Mexico. It will take time, geological time, to repair this loss.

The fires which followed lumbering have probably cut by half, for at least a generation or two, the capacity of northern Wisconsin to support a self-sustaining population. Everybody knows this, but few know that the same fires have burned up many of the peat beds in our drained marshes, and thus threaten to turn land once too wet into a future sand-dune. Three marshes in Dane County have been burning all summer. When some old rattletrap of a building catches fire we all rush to the rescue, but when the compound interest of 10,000 years of plants catches fire, our officials sit by with folded hands while the average citizen's depth of understanding is reflected by the observation that he dislikes the smell of peat smoke.

The new insects which modern transportation continuously imports from the four corners of the earth are a standing threat to future agriculture. Our white pine—the very backbone of our original economic structure—now threatens to go down before the blister rust, an imported disease. In the offing stands the threat of June-beetles (white grubs) making it imperative to cut down all the white oaks in our pastures. Granted we could shade our cows under tin roofs—who would want to live in a Wisconsin of oakless pastures?

Now this is not a tirade against careless farming, lumbering, or transportation. It is rather an admission that the tools wherewith we are building our civilization are so powerful, and their use has such complex and unexpected consequences, that we are tearing down about as fast as we are building up. It is an admission that science does not yet know enough, or is not yet sufficiently listened to, to anticipate and prevent this process of wreckage which attends our supposedly advancing footsteps.

Research. The business of a University has heretofore been conceived to be the preparation of citizens to cope with their environment. The University must now take on the additional function of preserving an environment fit to support citizens. This task is of a complexity far beyond what I can here take time to explain. I will ask you to accept my word for the fact that it is a long and difficult job. To perform it, a University must have, for the daily use of its faculty and students, a living exhibit of what Wisconsin was, what it is, and what it expects to become. Examples of what it is lie on every hand. What it expects to become may be exemplified on public forests, refuges, farms, and parks. What it was is to be exemplified on the Arboretum, and I hope on numerous areas created for the purpose.

This, in a nutshell, is the function of the Arboretum: a reconstructed sample of old Wisconsin, to serve as a bench mark, a starting point, in the long and laborious job of building a permanent and mutually beneficial relationship between civilized men and a civilized landscape.

Appendix B: The Essay[2]

The Arboretum and the University (1934)

For twenty centuries and longer, all civilized thought has rested upon one basic premise: that it is the destiny of man to exploit and enslave the earth.

The biblical injunction to "go forth and multiply" is merely one of many dogmas which imply this attitude of philosophical imperialism.

During the past few decades, however, a new science called ecology has been unobtrusively spreading a film of doubt over this heretofore unchallenged "world view." Ecology tells us that no animal—not even man—can be regarded as independent of his environment. Plants, animals, men, and soil are a community of interdependent parts, an organism. No organism can survive the decadence of a member. Mr. Babbitt is no more a separate entity than is his left arm, or a single cell of his biceps. Neither are those aggregations of men and earth which we call Madison, or Wisconsin, or America. It may flatter our ego to be called the sons of man, but it would be nearer the truth to call ourselves the brothers of our fields and forests.

The incredible engines wherewith we now hasten our world-conquest have, of course, not heard of these ecological quibblings; neither, perhaps, have the incredible engineers. These engines are double-edged swords. They can be used for ecological coöperation. They are being used for ecological destruction on a scale almost geological in magnitude. In Wisconsin, for example, the northern half of the state has been rendered partially uninhabitable for the next two generations by man-made fire, while the southwestern quarter has been deteriorated for the next century by man-made erosion. In central Wisconsin a single fire in 1930 burned the soil off the better part of two counties.

It can be stated as a sober fact that the iron-heel attitude has already reduced by half the ability of Wisconsin to support a coöperative community of men, animals, and plants during the next century. Moreover, it has saddled us with a repair bill, the magnitude of which we are just beginning to appreciate.

If some foreign invader attempted such loot, the whole nation would resist to the last man and the last dollar. But as long as we loot ourselves, we charge the indignity to "rugged individualism," and try to forget it. But we cannot quite. There is a feeble minority called conservationists, who are indignant about something. They are just beginning to realize that their task involved the reorganization of society, rather than the passage of some fish and game laws.

---

[2]From Susan L. Flader and J. Baird Callicott, *The River of the Mother of God and Other Essays by Aldo Leopold.* Madison: The University of Wisconsin Press. Copyright 1991. Reprinted by permission of the University of Wisconsin Press and the Aldo Leopold Foundation. The essay first appeared in *Parks and Recreation,* Vol. 18, No. 2, October 1934.

What has all this to do with the Arboretum? Simply this: If civilization consists of coöperation with plants, animals, soil, and men, then a university which attempts to define that coöperation must have, for the use of its faculty and students, places which show what the land was, what it is, and what it ought to be. This Arboretum may be regarded as a place where, in the course of time, we will build up an exhibit of what was, as well as an exhibit of what ought to be. It is with this dim vision of its future destiny that we have dedicated the greater part of the Arboretum to a reconstruction of original Wisconsin, rather than to a "collection" of imported trees.

The iron-heel mentality is, of course, indifferent to what Wisconsin was. This is exactly the reason why the University cannot be. I am here to say that the invention of a harmonious relationship between men and land is a more exacting task than the invention of machines, and that its accomplishment is impossible without a visual knowledge of the land's history. Take the grass marsh here under our view: From the recession of the glacier until the days of the fur trade, it was a tamarack bog—stems and stumps are still imbedded there. In its successive layers of peat are embalmed both the pollens which record the vegetation of the bog and the surrounding countryside, and also the bones of its animals. During some drouth, man-caused fires burned off the tamarack, which gave place first to grass and brush, and then, under continual burning and grazing, to straight grass. This is the history and status of a thousand other marshes. What will happen if the decomposed surface peat is all burned off? At what stage of the retrogression from forest to meadow is the marsh of greatest use to the animal community? How is that desirable stage to be attained and maintained? What is the role of drainage? These questions are of national importance. They determine the future habitability of the earth, materially and spiritually. They are just as important as whether to join the League of Nations—it is only our iron-heel inheritance which makes the comparison ludicrous. The scientist does not know the answer—he has been too busy inventing machines. The time has come for science to busy itself with the earth itself. The first step is to reconstruct a sample of what we had to start with. That, in a nutshell, is the Arboretum.

Literature Cited

Anonymous. 1998. The Wilderness Act of 1964. Pp. 120–30 *in* J.B. Callicott and M.P. Nelson, eds. *The great new wilderness debate.* University of Georgia Press, Athens.

Callicott, J.B., L.B. Crowder, and K. Mumford. 1999. Current normative concepts in conservation. *Conservation Biology* 13:22–35.

Clements, F.E. 1905. *Research methods in ecology.* University of Nebraska Press, Lincoln.

Clements, F.E. 1916. Plant succession: an analysis of the development of vegetation. Publication No. 242. Carnegie Institution, Washington, D.C.

Curtis, J.T. 1959. *The vegetation of Wisconsin.* University of Wisconsin Press, Madison.

Davis, M.B. 1986. Climatic instability, time lags, and community disequilibrium. Pp. 269–84 *in* J. Daimond and T.J. Case, eds. *Community Ecology.* Harper and Row, New York.

Denevan, W.M. 1992. The pristine myth: the landscape of the Americas in 1492. *Annals of the Association of American Geographers* 82: 369–85.

Doolittle, W.E. 1992. Agriculture in North America on the eve of contact: a reassessment. *Annals of the Association of American Geographers* 82: 386–401.

Flader, S.L. 1974. *Thinking like a mountain: Aldo Leopold and the evolution of an ecological attitude toward deer, wolves, and forests.* University of Missouri Press, Columbia.

Fox, S. 1981. *John Muir and his legacy: the american conservation movement.* Little, Brown and Company, Boston.

Gleason, H.A. 1926. The individualistic concept of the plant association. *Bulletin of the Torrey Botanical Club* 53:1–20.

Jordan, W.R., III, M.E. Gilpin, J.D. Aber, eds. 1987. *Restoration ecology: a synthetic approach to ecological research.* Cambridge University Press, Cambridge, MA.

Leopold, A. 1924. Grass, brush, timber, and fire in southern Arizona. *Journal of Forestry* 22(6):1–10.

Leopold, A. 1925. Wilderness as a form of land use. *Journal of Land and Public Utility Economics* 1:398–404.

Leopold, A. 1939. The farmer as a conservationist. *American Forests* 45:294–99, 316, 323.

Leopold, A. 1941. Wilderness as a land laboratory. *Living Wilderness* 6(July):3.

Leopold A. 1949. *A sand county almanac, and sketches here and there.* Oxford University Press, New York.

Leopold, A. 1979. Some fundamentals of conservation in the southwest. *Environmental Ethics* 1:131–41.

Leopold, A. 1991*a*. Conservation: in whole or in part? Pp. 310–19 *in* S.L. Flader and J.B. Callicott, eds. *The River of the Mother of God and Other Essays.* University of Wisconsin Press, Madison.

Leopold, A. 1991*b*. Land pathology. Pp. 212–17 *in* S.L. Flader and J.B. Callicott, eds. *The river of the Mother of God and other essays.* University of Wisconsin Press, Madison.

Leopold, A. 1999*a*. The land health concept and conservation. Pp. 218–26 *in* J.B. Callicott and E.T. Freyfogle, eds. *For the health of the land: previously unpublished essays and other writings.* Island Press, Washington, D.C.

Leopold, A. 1999*b*. Biotic land use. Pp. 198–206 *in* J.B. Callicott and E.T. Freyfogle, eds. *For the health of the land: previously unpublished essays and other writings.* Island Press, Washington, D.C.

Meine, C. 1988. *Aldo Leopold: his life and work.* University of Wisconsin Press, Madison.

Muir, J. 1913. *The story of my boyhood and youth.* Houghton Mifflin, Boston.

Peretti, J. 1998. Nativism and nature: rethinking biological invasion. *Environmental Values* 7:181–92.

Pickett, S.T.A., and R.S. Ostfeld. 1995. The shifting paradigm in ecology. Pp. 261–78 *in* R.L. Knight and S.F. Bates, eds. *A new century for natural resource management.* Island Press, Washington, D.C.

Pickett, S.T.A., and P.S. White. 1985. *The ecology of natural disturbance and patch dynamics.* Academic Press, New York.

Pinchot, G. 1947. *Breaking new ground.* Harcourt, Brace, New York.

Ribbens, D. 1987. The making of *A Sand County Almanac.* Pp. 91–109 *in* J.B. Callicott, ed. *Companion to* A Sand County Almanac. University of Wisconsin Press, Madison.

Simberloff, D. 1980. A succession of paradigms in ecology: essentialism to materialism and probabilism. *Synthese* 43: 3–39.

J. Baird Callicott *is professor of philosophy and religion studies at the University of North Texas. He is editor or author of many works by or about Aldo Leopold including* The River of the Mother of God and Other Essays by Aldo Leopold *(with Susan L. Flader),* For the Health of the Land: Previously Unpublished Essays and Other Writings by Aldo Leopold *(with Eric T. Freyfogle),* Companion to A Sand County Almanac: Interpretive and Critical Essays, In Defense of the Land Ethic: Essays in Environmental Philosophy, *and* Beyond the Land Ethic: More Essays in Environmental Philosophy. ***Address:*** *Department of Philosophy, University of North Texas, P.O. Box 310920, Denton, TX 76203-0920.* ***Email:*** *callicott@unt.edu*

Susan Flader

Aldo Leopold and Environmental Citizenship

In the outpouring of books and articles in recent years on the meaning of citizenship, many of them lamenting the weakening of civic bonds in America, there has been scant attention to the role of citizenship with respect to the environment.[1] Even among environmentalists, who realize that citizen action has been a hallmark of the "new environmental movement" from the time of the first Earth Day (1970), there is little appreciation of the extent to which our citizenry has played a vital role in the shaping of American environmental policy ever since the origins of the nation.[2]

As we seek the historical roots of our quest for environmental quality and the means for sustaining it, it is worth pondering the roles and responsibilities of citizens and the relationship between the citizenry and the state—in short, how American democracy works. In this exploration, we may seek insights from Aldo Leopold, who was profoundly conscious of the American democratic tradition within which he was working and who thought hard throughout his career about the meanings and implications of environmental citizenship.

We have had in the United States a tradition of a limited or weak state. It may not seem that way today when people complain of a bloated federal bureaucracy, but relative to the strong central states in the democracies of Western Europe and certainly to authoritarian regimes, our government is decidedly limited and our citizens have always had a healthy skepticism about most everything that government tries to do. In this weak state we have traditionally had rather low legal expectations of our citizens. Citizens are expected to obey the law and pay taxes; even voting is optional. Yet we have had in America a concomitantly vibrant tradition of voluntary citizen action.

The foremost interpreter of the era of the American Revolution, Gordon Wood, has termed the phenomenon of revolutionary citizen action "the people out of doors."[3] He was likely not thinking environmentally, but rather portraying "people out of doors" as citizens acting voluntarily outside of the formal channels of government to shape the kind of community they wanted. When we look back at the controversies of the era, however, we see citizens acting often on environmental issues. Local groups organized, with some success, to prevent new dams from blocking the passage of salmon upstream, for example, seeking to protect their community's customary right to fish against interference by new industrial mills.[4]

When we think of the origins of the nation, we tend to think of citizens struggling for liberty, for the right of the individual to pursue his own self-interest. This is a concept of American history that became cemented in our imaginations especially during the Cold War, when we were fighting the menace of international Communism and trying to picture America as everything that the Soviet Union was not. Yet, historians returning to the original documents of the revolutionary era several decades ago began to see in them some ideas that were at first startling, because they were so at odds with the usual interpretation. What they found were people who thought of themselves as citizens of a republic in which the greatest virtue was civic consciousness, a willingness to subordinate one's own self-interest to the good of the community. "Civic virtue," they called it, or "civic republicanism," referring to the participatory civic values of a republic like that of ancient Athens.[5] We tend to celebrate America as a country grounded in individual rights, like the freedoms of speech and of the press and of assembly enshrined in the first article of the Bill of Rights. But a case can be made that these rights pertain to communities as well as to individuals; they protect the opportunity for ordinary citizens to organize and communicate with each other outside of the formal channels of government to shape the environment of their communities or the policies of their governments.[6]

The complex of republican values so pervasive in revolutionary America was largely overwhelmed, scholars are agreed, by democratic egalitarianism, liberal individualism, and capitalist development in the early nineteenth century, ushering in the liberal democratic state we celebrate today. But the tradition of civic organizing has persisted in American history. It has not been mandated by law; it has been voluntary. The tendency of Americans to form voluntary groups—"associations," Alexis de Tocqueville called them[7]—could be used to sustain traditional community values; it could also be used to protect economic self-interest. This tradition of citizen action, especially in its "civic republican" strain, is the tradition out of which much of our American conservation movement grew. But it may also be the tradition from which several strands of what we may think of today as anti-environmentalism emerged—groups devoted to "wise use," property rights, and county supremacy.[8] Citizens organize for a variety of purposes.

It must be noted that not everyone regards voluntary citizen action as key to the shaping of society or environmental policy. Many would argue that ours is a *representative* democracy and that the shaping and administration of policy is the responsibility of elected representatives and executive agencies. Indeed, much of the administrative capacity of the modern American state was developed in the Progressive Era at the turn of the twentieth century, in large part in response to environmental concerns. The U.S. Forest Service, in which Aldo Leopold began his career, has been regarded by scholars as the quintessential example of a progressive agency.[9] Gifford Pinchot, the first chief of the Forest Service, sought to place technically trained experts—professional foresters like Leopold—in government and let them establish specific policies and manage the resources. This was a model of governance that elevated the values of order, efficiency, and control—values that may be quite incompatible with democratic participation. Pinchot once said, "The first duty of the human race is to control the earth it lives upon," and I think Leopold himself once may have believed that.[10] From the perspective of a later day, however, we may note that the progressive model, in elevating the virtues of professionalism and technical expertise, tended to crowd out the citizenry and also their elected representatives, the politicians.

Inasmuch as Aldo Leopold began his career as a professional in the employ of the modern administrative state and is today regarded as something of a prophet of the new environmental consciousness, which elevates the responsibilities of citizenship, we may look to him for insights into the meanings of environmental citizenship—into the role of citizens in the modern state, the tension between the rights of individuals and the claims of the community, and the tension also between professional resource managers and citizen activists. We look first at what Leopold had to say about citizenship in *A Sand County Almanac*, the slender volume of nature sketches and philosophical essays that represents the distillation of his mature thought, and then explore the evolution of his thinking during the course of his career.

As we page through *A Sand County Almanac*, we meet our first citizen in the very first essay, "January Thaw":

> The mouse is a sober citizen who knows that grass grows in order that mice may store it as underground haystacks, and that snow falls in order that mice may build subways from stack to stack: supply, demand, and transport all neatly organized.[11]

The mouse is what kind of citizen?—an ordinary citizen who goes about his own business and pursues his own interests. We have many such in our communities.

Skipping perhaps a few citizens, we come to "Pines Above the Snow": "Each species of pine," Leopold tells us, "has its own constitution, which prescribes a term of office for needles appropriate to its way of life." He continues with his analogy between human constitutions and the regimen of various pine trees, the white pine retaining its needles for a year and a half, red and jackpines for two and a half years. "Incoming needles take office in June, and outgoing needles write farewell addresses in October."[12] These pines are going about their own business, but they are also meeting the legal requirements of citizenship, acting according to their constitutions, even taking office in a perfunctory way.

Next we meet the thick-billed parrots of Chihuahua, who "wheel and spiral, loudly debating with each other the question . . . whether this new day which creeps slowly over the canyons is bluer and golder than its predecessors, or less so."[13] They are debating the criteria of the good life, which in Aristotelian thought is an activity of citizenship more fundamental even than that of developing legal constitutions. The vote being a draw, Leopold observes, they head to the high mesas for breakfast.

In "Clandeboye," the great prairie marsh of Manitoba, we find the grebe, a species of ancient evolutionary lineage impelled, Leopold believes, by "pride of continuity."

His is the call that dominates and unifies the marshland chorus: "Perhaps, by some immemorial authority, he wields the baton for the whole biota."[14] Here is the grebe as ethical citizen, as a leader directing the chorus of the marsh for the longterm betterment of the whole community.

Not until the more philosophical essays in the last section of the book do we meet *human* citizens. In "Conservation Esthetic" Leopold discusses the various components of the recreational process, beginning with the most basic motivation of trophy seeking, common to hunters with both shotgun and field glass as well as to most conservationists and even professionals. He goes on to discuss other more highly evolved components of the recreational process, such as a feeling of isolation in nature or the perception of natural processes, and then reaches what to him is the ultimate component, a sense of husbandry. This component, he tells us, "is unknown to the outdoorsman who works for conservation with his vote rather than with his hands. It is realized only when some art of management is applied to land by some person of perception."[15] So, to Leopold, husbandry is the highest form of citizenship: actually working with one's hands, participating actively to build or maintain the land community.

Leopold expresses his concept of environmental citizenship most memorably in "The Land Ethic":

> In short, a land ethic changes the role of Homo sapiens from conqueror of the land-community to plain member and citizen of it. It implies respect for his fellow-members, and also respect for the community as such.[16]

Here Leopold offers us a concept of citizenship in a community larger even than humankind; we are plain member and citizen of a community that embraces the land and all the plants and animals that are a part of it. The usual formula for conservation, "Obey the law, vote right, join some organizations, and practice what conservation is profitable on your own land; the government will do the rest," he tells us is too easy. "It defines no right and wrong, assigns no obligation."[17] Leopold's formula implies personal responsibility to participate actively as an ordinary citizen in maintaining or restoring the health of the biotic community.

This review of *A Sand County Almanac* suggests that Leopold's mature concept of environmental citizenship, with its emphasis on obligation to the community, is similar in some respects to the concept of civic virtue in the republican ideology of the American Revolution, though he conceives the community much more broadly. But one would not necessarily expect to find these ideas early in his career, when he was working for the U. S. Forest Service, modeled on a different conception of the relationship between citizens and the state.

Aldo Leopold throughout his career was a consummate professional, extremely efficiency-oriented during his years in the Forest Service and fascinated by the intricacies of administrative procedures and standards.[18] And yet we get a sense from one of his earliest publications that he was not wholly satisfied with the Forest Service model of governmental administration. Shortly after he had become supervisor of the Carson National Forest in New Mexico at age 25, he was stricken with an illness that nearly led to his death and required more than a year of recuperation. During this time he addressed a letter "to the forest officers of the Carson" reflecting on their responsibilities. The problem that concerned him was how to measure success in forest administration. Was success simply a matter of efficiently following prescribed policies and procedures, or was there something else? "My measure," Leopold wrote, "is *the effect on the forest.*" Even at the start of his career he was concerned about the *ends* of administration, what was happening to the land, not only the procedures, or *means.*[19]

It was a preoccupation he would continue to pursue into the early 1920s, when he was chief of operations in charge of roads, trails, fire control, personnel, and finance on twenty million acres of national forests in the Southwest. In order to improve the efficiency of administration while focussing attention on "the effect on the forest," he developed an intricate system of tally sheets for a new system of forest inspection that would enable foresters to diagnose local problems and monitor the effectiveness of management solutions. Leopold regarded this elaborate system of inspection as one of his points of greatest pride during his career in the Southwest. And indeed, his lifelong fascination with tracking the dynamics of change and the efficacy of management for the total biotic system, begun during his inspection forays in the Southwest, would lead him in our own day to be acknowledged as the exemplar of the new philosophy of ecosystem management recently adopted by the Forest Service and other land management agencies.[20]

Clearly, Leopold was enlarging the responsibilities of professional foresters by extending the boundaries of the community of concern to include the entire biota—soils, waters, plants, and animals—as well as trees and the economic interests of the people who used them. But there was scant room for ordinary citizens in Leopold's model of forest administration. Though he recognized the difficulty of determining the *objectives* of management—a problem that bedevils ecosystem management today—he concluded that these decisions should be made by "only the highest authority."[21] Yet the essay in which he dealt most directly with what he called "standards of conservation" tails off in mid-sentence and remained unpublished, suggesting that Leopold may have realized he was caught in an unresolved problem of authority: who decides the objectives and on what basis? A kind of 'super-inspector' would crop up in his writing from time to time over the years, but I am not sure he was ever really comfortable with this type of authority.[22]

Despite Leopold's commitment to professional expertise in forest administration, he saw roles for citizens in related endeavors. Indeed, when his illness prevented him from resuming his post as a forest supervisor, he began developing a new line of activity—game management—in the Forest Service, and in conjunction with this he traveled all across Arizona and New Mexico organizing game protective associations—citizen conservation organizations—in local communities and statewide. These associations of sportsmen, ranchers, and townspeople would work for non-political game wardens, predator control, and refuges. They were grassroots citizen-action groups in a long-standing American tradition.

Leopold addressed the subject of citizenship in a number of lectures early in his career, including one on "Home Gardens and Citizenship" to students at the University of New Mexico in 1917, just after the American entry into World War I. A home garden, he said, was one mark of a useful citizen. Nobility is won by soiling your hands with useful labor, by building something. Leopold was always one for building something. If your job doesn't allow enough play for creativity, he told the students, you can be creative by working the ground, whereupon he went into a soliloquy about how to raise spectacular tomatoes in your Albuquerque backyard. In a world threatened with food shortage, what right have we to hold idle some of the best agricultural lands in our back yards? he asked. Better to turn them into gardens and learn to be good citizens.[23]

A year later he spoke to the women's club on "The Civic Life of Albuquerque." Having left the Forest Service to become secretary of the Albuquerque Chamber of Commerce, Leopold was now asking "What has the 20th-century American city contributed to human progress?" His answer was public spirit. He defined it as "year-round patriotism in action; . . . intelligent unselfishness in practice." He tried to trace the idea historically, contrasting Confucius, whom he saw as more interested in personal virtues and family ties than in obligations to others, with Socrates, who knew that citizens had a moral obligation to support and improve their government. But then he lost the thread, explaining that "it would require a better scholar than I am to even attempt to trace the idea of public spirit through the era of individualism and the political revolutions of the 18th and 19th centuries."[24]

From this we realize that the concept of civic virtue, the republican ideology of the American Revolution, had been lost to consciousness by 1918. Leopold was assuming a revolutionary America dedicated to individualism; he had lost the thread of public spirit, though he sensed it must have been there somewhere. And in fact historians would not rediscover it until the late 1960s, twenty years after his death. But he went on to define the "modern idea"—modern as of 1918—of public spirit: "It means that a democratic community and its citizens have certain reciprocal rights and obligations." Not only rights, but obligations as well. "The man who cheerfully and habitually tries to meet this responsibility," he says, "we call public-spirited."

Leopold went on to offer a critical assessment of the public spirit of Albuquerque, confiding his dream that his own Chamber of Commerce might serve as the "common center" to organize the "democratic welter" of professional societies, women's groups, religious, political, labor, and other voluntary associations of citizens toward accomplishment of common goals for the betterment of Albuquerque. But he also admitted to some frustration—businessmen unwilling to welcome representation in the chamber by labor and craft organizations, for example.

After little more than a year, Leopold left the Chamber of Commerce to rejoin the Forest Service. A few years later, still feeling the effects of his experience in the chamber, he delivered a scathing "Criticism of the Booster Spirit" to an Albuquerque civic society in which he excoriated "the philosophy of boost." Boost was premised on growth by unearned increment, rather than investment in basic resources, especially the soil, he charged. In his quest for fundamental improvement in the resource base, he began looking to enforced responsibility of landowners. In "Pioneers and Gullies," for example, he described numerous valleys of the Southwest torn out by erosion, and he predicted, for the first time in print, that one day proper land use would be a responsibility of citizens: "The day will come when the ownership of land will carry with it the obligation to so use and protect it with respect to erosion that it is not a menace to other landowners and the public."[25]

Leopold left the Southwest in 1924 to accept a job in Madison, Wisconsin, as director of the Forest Products Laboratory. Though the laboratory's focus on industrial products after the tree was cut proved ultimately frustrating for one so committed to the growing forest and he would leave after only four years, he did manage to extract from the experience a lesson for citizens. In an article, "The Home Builder Conserves," he admonished people, before they castigated the "wasteful lumberman," to think about how their own arbitrary demands as consumers and home builders cause waste. The thinking citizen has power not only in his vote but in his daily thoughts and actions, and especially in his habits as a buyer and user of wood. "Good citizenship is the only effective patriotism," he concluded, "and patriotism requires less and less of making the eagle scream, but more and more of making him think." This theme of the responsibility of the citizen as intelligent consumer is one Leopold would return to from time to time, most notably during World War II in "Land Use and Democracy."[26]

Shortly after his move to Wisconsin, Leopold became involved with the state chapter of the Izaak Walton League of America, which was the most vibrant citizen conservation organization in the 1920s. He worked with the league to promote a non-partisan conservation commission and a forestry policy for Wisconsin. Still hewing to his professional orientation as a forester, however, he warned members to eschew the tendency to actually *write* policy: "It is a pretty safe rule to remember that while groups of men can insist on and criticize plans, only individuals can create them."[27] Leopold himself was a professional writer of policies, as he demonstrated both in the Forest Service and after he left in 1928 to conduct game surveys and recommend conservation policies in the midwestern states, when he drafted an "American Game Policy" adopted by the American Game Conference in 1930, and when he helped write a "Twenty-Five Year Conservation Plan" for his home state of Iowa in 1931.

Leopold was tremendously impressed by the citizen commitment to conservation in Iowa and genuinely proud of the plan for integration of all aspects of conservation—parks, forests, wildlife, fish, water quality, soil conservation—that the team of nationally recognized experts wrote. Iowa was clearly a leader among the states in conservation thought and practice in these years. But buried in Leopold's correspondence are intimations of foreboding. He warned his colleagues in Iowa that they needed to make a special effort to educate the public about what was in the plan, lest people buy into it without personally engaging with it. He was concerned especially about the protection-minded women so active in the parks movement who might become upset if they were suddenly to discover that the plan aimed to produce game to shoot. "There is grave danger," he said, "that the conservationists will blow it up before they even understand what it is."[28]

In 1933, shortly after he accepted a newly created chair of game management at the University of Wisconsin, Leopold proposed to the dean of agriculture the development of a conservation plan for Wisconsin farms similar to the Iowa plan. The purpose, as in Iowa, would be to get all the government agencies working together to encourage farmers and other landowners to care for their lands in a more conservative way—or, as he put it, to "integrate economic with esthetic land use." But the means would differ. In Iowa the plan was produced by imported experts who did not participate in its execution, an arrangement that clearly left Leopold uneasy, whereas in Wisconsin he proposed to "evolve" a plan "rather than to *write* one out-of-hand."[29]

Leopold's emphasis on evolving a plan from the grassroots was prophetic—not only of the emerging emphasis on public involvement in resource planning in our own day but of the situation in Iowa at the time. By 1935 the Iowa conservation plan disintegrated, at least in Leopold's view. After Iowa merged all relevant agencies into a single department, as recommended in the twenty-five–year plan, the new Iowa Conservation Commission bypassed the man whom to Leopold was the obvious director, and most of Leopold's friends in fish and game resigned or were fired. The issue apparently had to do with the Iowa commission's insistence on an immediate showing of quick results by government through public works rather than, as Leopold and his colleagues preferred, a long-term emphasis on building a new conservation consciousness in the citizenry, especially among landowners.[30]

In the wake of the Iowa debacle, Leopold commented to a friend that the only state conservation effort to survive was in Michigan, "strangely enough, by a process of internal disharmony. I am tempted to draw the conclusion that complete unanimity within a state [such as in Iowa] is a symptom of approaching dissolution."[31] In other correspondence and articles in the 1930s he addressed the problem of factions within the conservation community, especially the shotgunners versus the field glass hunters, arguing for tolerance, a capacity for self criticism, and an institutional structure within which factions could argue out their conflicts. "It is a question of applying the democratic process to conservation," he concluded.[32]

Leopold's thoughts on democracy and conservation were further stimulated by travel in Germany in 1935, where he observed an elaborate system of law, public administration, ethics, and customs that was "incredibly complete and internally harmonious." Though he could observe no real distinction between the government, acting hierarchically from the top down, and popular acceptance from below, he recognized that the German system, with its strong central governmental authority, was "manifestly a surrender of individualism to the community."[33] While he could admire it in Germany (before he understood the connection with the Nazi movement), he knew that it wouldn't work in America.

Leopold addressed the tension between the claims of the community and the rights of the individual in America in a number of essays in the 1930s in which he dealt with the role of government. How can we get conservation? he often asked. And his answer: we can legislate it, we can buy it, or we can build it. Government's initial efforts at conservation had been through laws prohibiting hunting, fishing, or cutting, a first step but inadequate. The second step, augmented by the open money bags of the New Deal, was to buy land for conservation, but that could be carried only "as far as the tax-string on our leg will reach." The solution had to be found on private land.[34]

By the time he wrote "Land Pathology" under the menacing clouds of the dust bowl in 1935, he saw only two possible forces that could effect change in private land use. One was the development of institutional mechanisms for protecting the public interest in private land—a quest he had been on for over a decade, especially after his new chair of game management was lodged in the University of Wisconsin's famed Department of Agricultural Economics with its institutional bent. The other was his new preoccupation with "the revival of land esthetics in rural culture." Out of these forces he hoped might eventually emerge what he was even then beginning to term a "land ethic."[35] After his friend Jay "Ding" Darling cautioned him that his search for institutional controls could lead to socialization of property,[36] Leopold seemed increasingly to emphasize development of a personal sense of obligation to the land community, a sense of husbandry.

During these years of the depression Leopold experimented with a form of citizen organization he hoped would encourage a sense of husbandry. With farmers, sportsmen, and his own wildlife students he established a series of cooperative ventures intended to apply conservation to land and improve habitat for game. One of them, the Coon Valley Erosion Project near LaCrosse, Wisconsin, involved cooperation of local landowners with government agencies in a pathbreaking demonstration of erosion control and integrated land use on a watershed scale. But others functioned entirely outside the formal channels of government, including the Riley Cooperative and the Faville Grove Area within an easy drive of Madison. Leopold described these experiments in community conservation as *vertical* rather than horizontal planning, focusing a battery of minds simultaneously on one spot. "It may take a long time to cover the country spot by spot," he admitted, "but that is preferable to a smear."[37]

As war clouds darkened the horizon and called into question his earlier admiration for Germany's tightly regimented system of resource administration, Leopold lectured to his wildlife ecology students about "Ecology and Politics," presenting the case for an evolutionary mandate for individualism. Individual deviations from societal norms in land management, like individual evolutionary variations, he suggested, might enable certain individuals to survive catastrophe even when most members of a species were eliminated.[38] This was an individualism not of economic self-interest but of creative experimentation, in the sense of solutions generated from the bottom up by individual citizens or communities rather than mandated by government on all alike. It was in this spirit that Leopold looked to the evolution of a land ethic.

American entry into World War II further defined the issue: "We must prove that democracy can use its land decently," Leopold argued in a seminal essay, "Land Use and Democracy." Here he called for conservation from the bottom up instead of from the top down. It had to begin with "that combination of solicitude, foresight, and skill which we call husbandry," practiced by landowners on their own land. But nonlandowning citizens had responsibilities in their roles as consumers as well. They could refuse to buy "exploitation milk" from cows pastured on steep slopes and insist on "honest boards" from properly managed forests. There was an indispensable role for government as "tester of fact vs. fiction" or guardian of standards, Leopold acknowledged, but farmers could scrutinize their own practices through courageous use of their self-governing Soil Conservation Districts, and there were opportunities also for self-scrutiny by industrial or citizen groups.[39] More than half a century later, the Forest Stewardship Council's independent third-party certification of forest products and other examples of the movement for green production and consumption standards would attest to the validity of Leopold's visionary argument.

Aldo Leopold's ideas about the roles of government and citizens in the shaping of environmental policy were tested in the last decade of his life as never before by his involvement in the traumatic deer debates of the 1940s in Wisconsin. After being nearly hunted to extirpation in the early decades of the century, the state's deer herd had increased to such an extent that by the early 1940s it needed to be reduced for the good of both deer and forest, and Leopold sought to work with the Conservation Department to build a case for an "any-deer" season, for killing does as well as bucks. But the call for reduction stirred disbelief and resentment among both hunters and the general public, to whom conservation of deer was a good thing. In response, the Conservation Commission organized a Citizens' Deer Committee, appointing Aldo Leopold as chairman.[40]

Leopold's committee had a cross-section of citizens, mostly from northern Wisconsin, most of them distrustful of the policy he was urging on the department. For the first meeting he prepared maps and charts to provide an historical review of deer irruptions nationwide. But he was upstaged by another member of the committee, Joyce Larkin, editor of the *Vilas County News Review.* She didn't think there were too many deer, and she arrived at the meeting armed with a printed booklet of history and local opinion about the deer situation in Vilas County. We don't know how Leopold reacted to Larkin that day, but we do know that he decided to take the committee and several newspaper reporters on a three-day tour of deer yards, to let them discuss what they were actually seeing on the ground. Joyce Larkin, among others, was impressed. She went back to Vilas, got the county board to accept Leopold's challenge to bring clashing interests together to look at the problems locally, and came to a subsequent meeting of the committee with a new report in favor of an any-deer season.[41]

However successful Leopold proved at changing attitudes among the members of his Citizens' Deer Committee by letting them argue out their views with respect to conditions in particular locales, the deer problem proved too widespread and public attitudes too entrenched for him to make much headway in the state as a whole. A new newspaper, *Save Wisconsin's Deer,* ridiculed and castigated him in virtually every issue and offered fuel to those who opposed his reasoning. Yet he never gave up on his effort to educate the citizenry, individually and collectively. It is likely that the unremitting stress of dealing with the deer issue in the public arena during the 1940s helped send Leopold to an early grave. But he had been appointed to a six-year term on the Wisconsin Conservation Commission, and he believed it was his responsibility as a citizen to serve.[42]

During those years he took solace in the exercise of another type of citizenship that he had advocated since the days of his backyard garden in Albuquerque: he practiced husbandry as plain member and citizen of the land community at the sand farm his family called "the shack." He expressed this form of citizenship—citizenship as creative individualism—perhaps most poignantly in his essay, "Axe-in-Hand," which includes a definition of a conservationist that could as easily be read as his definition of a citizen:

> I have read many definitions of what is a conservationist [citizen], and written not a few myself, but I suspect that the best one is written not with a pen, but with an axe. It is a matter of what a man thinks about while chopping, or while deciding what to chop. A conservationist [citizen] is one who is humbly aware that with each stroke he is writing his signature on the face of his land. Signatures of course differ, whether written with axe or pen, and this is as it should be.[43]

Endnotes

[1]See *A Nation of Spectators: How Civic Disengagement Weakens America and What We Can Do About It* (Final Report of the National Commission on Civic Renewal, 1998); and Robert D. Putnam, "Bowling Alone: America's

Declining Social Capital," *Journal of Democracy* 6:1 (January 1995), 65–78. Much of the recent attention to citizenship in the United States has been stimulated by scholarly writing concerning the forging of civil society in new democracies around the world, especially since the fall of the Iron Curtain. See, for example, Andrew Arato, "Interpreting 1989," *Social Research* 60:3 (Fall 1993), 609–46; Michael Bernhard, "Civil Society after the First Transition: Dilemmas of Post-Communist Democratization in Poland and Beyond," *Communist and Post-Communist Studies* 29 (1996): 309-30; Shu-Yun Ma, "The Chinese Discourse on Civil Society," *The China Quarterly* 137 (1994); James Bohman, "Complexity, Pluralism, and the Constitutional State: On Habermas's *Faktizitat und Geltung*," *Law & Society Review*, 28:4 (1994), 897–930; and Nancy Fraser, "Rethinking the Public Sphere: A Contribution to the Critique of Actually Existing Democracy," in *Justice Interruptus: Critical Reflections on the "Postsocialist" Condition* (New York: Routledge, 1997), 69–98.

[2]Susan L. Flader, "Citizenry and the State in the Shaping of Environmental Policy," *Environmental Review* 3:1 (January 1998), 8–24.

[3]Gordon S. Wood, *The Creation of the American Republic, 1776–1787* (New York: W.W. Norton and Co., 1972), 319–28.

[4]See, for example, Gary Kulik, "Dams, Fish, and Farmers: Defence of Public Rights in Eighteenth-Century Rhode Island," in *The Countryside in the Age of Capitalist Transformation*, ed. Steven Hahn and Jonathan Prude (Chapel Hill: University of North Carolina Press, 1985), 25–50.

[5]See Robert E. Shalhope, "Republicanism and Early American Historiography," *William and Mary Quarterly* 39 (1982):334–56; Joyce Appleby, ed., "Special Issue: Republicanism in the History and Historiography of the United States," *American Quarterly* 37 (1985); Gordon S. Wood, *The Radicalism of the American Revolution* (New York: Alfred A. Knopf, 1992).

[6]See Jack N. Rakove, "Parchment Barriers and the Politics of Rights," in *A Culture of Rights: The Bill of Rights in Philosophy, Politics, and Law—1791 and 1991*, ed. Michael J. Lacey and Knud Haakonssen (Cambridge: Cambridge University Press, 1992), 103; and William A. Galston, "Practical Philosophy and the Bill of Rights: Perspectives on Some Contemporary Issues," ibid., 234.

[7]Alexis de Tocqueville, *Democracy in America*, ed. Phillips Bradley (New York: Vintage, 1945), I:ch. 12, II:ch. 5.

[8]See Philip D. Brick and R. McGreggor Cawley, eds., *A Wolf in the Garden: The Land Rights Movement and the New Environmental Debate* (Lanham, Md.: Rowman and Littlefield, 1996).

[9]See Stephen Skowronek, *Building a New American State: The Expansion of National Administrative Capacities, 1877–1920* (New York: Cambridge University Press, 1982); and Samuel P. Hays, *Conservation and the Gospel of Efficiency: The Progressive Conservation Movement, 1890–1920* (Cambridge: Harvard University Press, 1950).

[10]Gifford Pinchot, *The Fight for Conservation* (Garden City, NY, 1910), IV:6. Compare Leopold: "It is no prediction, but merely an assertion that the idea of controlled environment contains colors and brushes wherewith society may some day paint a new and possibly a better picture of itself;" in "The Conservation Ethic," *Journal of Forestry* 31:6 (October 1933), 634–43.

[11]Aldo Leopold, *A Sand County Almanac and Sketches Here and There* (New York: Oxford University Press, 1949), 4.

[12]Ibid., 87.

[13]Ibid., 138.

[14]Ibid., 161.

[15]Ibid., 166–67, 175.

[16]Ibid., 204.

[17]Ibid., 207–8.

[18]For details of Leopold's biography see Curt Meine, *Aldo Leopold: His Life and Work* (Madison: University of Wisconsin Press, 1988), and Susan L. Flader, *Thinking Like a Mountain: Aldo Leopold and the Evolution of an Ecological Attitude toward Deer, Wolves, and Forests* (1974; Madison: University of Wisconsin Press, 1994).

[19]"To the Forest Officers of the Carson," *The Carson Pine Cone* (July 1913), reprinted in *The River of the Mother of God and Other Essays by Aldo Leopold*, ed. Susan L. Flader and J. Baird Callicott (Madison: University of Wisconsin Press, 1991), 41–46 [hereafter cited as *River*].

[20]See Susan Flader, "Aldo Leopold and the Evolution of Ecosystem Management," in *Sustainable Ecological Systems: Implementing an Ecological Approach to Land Management*, ed. W. Wallace Covington and Leonard F. DeBano (USDA Forest Service General Technical Report RM-247, 1994), 15–19.

[21]"Standards of Conservation" (handwritten ms., c. 1922), General Files—Aldo Leopold, Series 9/25/10-6, Box 16, University of Wisconsin Division of Archives [hereafter cited as LP 6B6 (Leopold Papers, Series 6, Box 16)], reprinted in *River*, 82–85.

[22]See, for example, "Conservation Economics," *Journal of Forestry* 32:5 (May 1934), 537–44, reprinted in *River*, 201. For discussion of the problem of authority as related to the relationship between professionals and citizens see Terry L. Cooper, "Citizenship and Professionalism in Public Administration," *Public Administration Review* 44 (March 1984), 143-149; and J. Douglas Wellman and Terence J. Tipple, "Public Forestry and Direct Democracy," *The Environmental Professional* 12 (1990), 77–86.

[23]"Home Gardens and Citizenship," 23 April 1917, 7pp. tps., LP 8B8.

[24]"The Civic Life of Albuquerque," 27 September 1918, 9pp tps., LP 8B8.

[25]"A Criticism of the Booster Spirit," 6 November 1923, 10pp tps speech to Ten Dons, LP 6B16, reprinted in *River*, 98–105; "Pioneers and Gullies," *Sunset Magazine* 52:5 (May 1924), 15–16 and 91–95, reprinted in *River*, 106–13. Leopold's language on the obligation of landowners was similar to that in a speech he had written in December 1922 for the New Mexico Association for Science, "Erosion as a Menace to the Social and Economic Future of the Southwest." The speech was published many years later in *Journal of Forestry* 44:9 (Sept 1946), 627–33.

[26]"The Homebuilder Conserves," *American Forests and Forest Life* 34:413 (May 1928), 276–78 and 297, reprinted in *River*, 143–47; "Land-Use and Democracy," *Audubon Magazine* 44:5 (Sept-Oct 1942), 259–65, reprinted in *River*, 295–300.

[27]"Izaac Walton League and Its Relation to Forestry in Wisconsin," [n.d., c. 1925], 10pp tps, LP 6B16.

[28]Leopold to Claude V. Campbell, 15 October 1932, LP 3B5, and associated correspondence. See also Jacob L. Crane, Jr., and George Wheeler Olcott, *Report on the Iowa Twenty-five Year Conservation Plan* (Des Moines: Meredith, 1933).

[29]"A Conservation Plan for Wisconsin Farms," 23 October 1933, 6pp tps., LP 6B16.

[30]See Leopold to William Schuenke, 10 July 1935; I.T. Bode to Leopold, n.d. [c. July 1935]; and Leopold to I.T. Bode, 19 July 1935, all in LP 3B5. See also Rebecca Conard, *Places of Quiet Beauty: Parks, Preserves, and Environmentalism* (Iowa City: University of Iowa Press, 1997), 120–36.

[31]Leopold to P.S. Lovejoy, 18 July 1935, P.S. Lovejoy Papers, Michigan Historical Commission Archives, Lansing, RG63-12 B12F6.

[32]"A House Divided," *Wisconsin Sportsman* (October 1940), 5. See also "Game and Wild Life Conservation," *The Condor* 34:2 (Mar-Apr

1932), 103–06, reprinted in *River*, 164-68. For recent examples of local democratic participation in decisionmaking see Daniel Kemnis, *Community and the Politics of Place* (Norman: University of Oklahoma Press, 1991); and Mark Sagoff, "The View from Quincy Library: Civic Engagement in Environmental Problem-Solving" (Working Paper #16, The National Commission on Civic Renewal).

[33]"Notes on Game Administration in Germany," *American Wildlife* 25:6 (Nov–Dec 1936), 85, 92–93.

[34]See, for example, "The Conservation Ethic," *Journal of Forestry* 31:6 (Oct 1933), 634–43 [*River*, 181–92]; "Conservation Economics," *Journal of Forestry* 32:5 (May 1934), 537–44 [*River*, 193–202]; "Conservation in the World of Tomorrow," lecture notes 29 March 1937, 5pp tps, LP 6B14; and "The Farmer as a Conservationist," *American Forests* 45:6 (June 1939), 294–99, 316, 323 [*River*, 255–65].

[35]"Land Pathology," 15 April 1935, 8pp tps, LP 6B16, reprinted in *River*, 212–17.

[36]J.N. Darling to Leopold, 20 November 1935, LP 6B16.

[37]"Farmer-Sportsman Set-ups in the North Central Region," *Proceedings North American Wildlife Conference*, February 3–7, 1936 (Senate Committee Print, 74th Cong., 2d sess., 1936), 279–85. See also "Coon Valley: An Adventure in Cooperative Conservation," *American Forests* 41:5 (May 1935), 205-208 [*River*, 218–23]; "Helping Ourselves" (with Reuben Paulson), *Field and Stream* 39:4 (August 1934), 32–33, 56 [*River*, 203–08]; and "History of the Riley Game Cooperative, 1931–1939," *Journal of Wildlife Management* 4:3 (July 1940), 291–302. For recent examples of the burgeoning movement in community conservation, see the special issue of the *Journal of Forestry* 96:3 (March 1998) on community forestry.

[38]"Ecology and Politics," WLE 118 Introductory Lecture, n.d. [c. 1941], 7pp tps, lp 6B16 [*River*, 281-89].

[39]"Land-Use and Democracy," *Audubon Magazine* 44:5 (Sept–Oct 1942), 259–65 [*River*, 295–300].

[40]See Flader, *Thinking Like a Mountain*, 168–260.

[41]Ibid., 183–93.

[42]Ibid., 194.

[43]*A Sand County Almanac*, 68.

Susan Flader is professor of American western and environmental history at the University of Missouri-Columbia and has written or edited six books and numerous articles, including Thinking Like a Mountain *(a biographical study of Aldo Leopold) and* The River of the Mother of God *(essays by Aldo Leopold, edited with Baird Callicott). She has served as president of the American Society for Environmnental History and the Missouri Parks Association and as a director of the National Audubon Society, the American Forestry Association, and the Forest History Society.* ***Address:*** *Department of History, University of Missouri-Columbia, 101 Read Hall, Columbia, MO 65211.* ***Email:*** *fladers@missouri.edu*

Craig Annen and Jonathan Lyon

Relationships between Herbaceous Vegetation and Environmental Factors along a Restored Prairie-Oak Opening Ecotone

Abstract *We studied a potential ecotone between a wet-mesic prairie and an oak opening in a restored landscape in southern Wisconsin. We described the relationships between herbaceous vegetation and soil variables along the prairie-oak opening transition using twenty-five 1-m^2 plots located on five 75-m transects. We identified a total of 46 herbaceous species and analyzed eight environmental variables: seven soil variables and photosynthetically active radiation (PAR). We observed distinct soil gradients along the ecotone: soil organic matter, total N, pH, P, Mg, and Ca levels all exhibited significant reductions when moving along the ecotone from prairie to oak opening. PAR was weakly correlated with vegetation patterns. Using cluster analysis and ordination techniques, we identified few distinct herbaceous community types along the transition, except for a unique assemblage dominated by reed canary grass* (Phalaris arundinacea *L.*). *Our canonical correspondence analysis (CCA) results indicated strong correlations between herbaceous vegetation and soil N, pH, Ca, and Mg gradients. Herbaceous species richness and Shannon-Wiener diversity increased moving from the prairie into the oak opening. Overall, our results indicated that (1) distinct soil gradients exist at the site, (2) soil gradients are correlated with herbaceous vegetation patterns in the restored area, and (3) while* P. arundinacea *has a strong influence on the composition of vegetation at the site, non-*Phalaris*–dominated plots exhibited continuous rather than discrete ecotonal properties. The potential importance of soil variables and soil gradients should be considered when studying the characteristics of ecotones in restored habitats.*

Ecotones are transition zones between two or more distinct community types. The role of ecotones (and ecoclines) in describing and explaining spatial and temporal vegetation patterns has received renewed attention in recent years (Naiman and Décamps 1990, Holland et al. 1991, Hansen and di Castri 1992, Gosz 1993, Risser 1995), although interest in the structure and ecological impact of ecotones is by no means new (Clements 1905, Leopold 1933, Weaver and Albertson 1956). Recent ecotone research has been focused on biodiversity (Pulliam 1988, Hansen and Urban 1992, Leach and Givnish 1996), nutrient and material flows between communities (Johnston 1993, McClaran and McPherson 1995), ecotones in landscapes (Boren et al. 1997, Dyer and Baird 1997, Sagers and Lyon 1997), and regulation and response to large-scale climatic change (Nielson 1993, Rusek 1993). Despite the renewed interest in ecotones, characterization of vegetation in and across ecotones remains problematic (Auerbach and Shmida 1993, Jarvis 1995, Stohlgren et al. 1997).

Rates of spatial change in vegetation are scale-dependent, and ecotones can be characterized over a wide range of spatial scales (di Castri 1993, Gosz 1991, Crumley 1993). Assigning boundary classifications can be difficult at larger scales because of the tendency of small-scale differences to average out at larger levels of observation (Allen and Hoekstra 1992). Ecotone studies at the population level encompass the spatial distribution of individuals in a small habitat and facilitates analysis at smaller scales (Fahrig and Merriam 1985, Gosz 1993). In both large and small scale ecotonal landscapes, specific environmental variables can strongly influence the distribution and abundance of vegetation and be correlated with the spatial distribution of ecotones (Gosz and Sharpe 1989, Risser 1990, van der Maarel 1990, Neilson 1993). Grassland and prairie vegetation, in particular, have been shown to be sensitive to changes in soil nutrient status and balance (Wedin and Tilman 1996), and soil gradients have been shown to have a strong influence on the composition of prairie and savanna vegetation (Curtis 1959, Anderson 1968, Jastrow 1987, Zak et al. 1990, Leach 1994).

We studied a suspected ecotone between a restored prairie community and a remnant oak opening. The study was conducted in the Curtis Prairie, a prairie restoration project at the University of Wisconsin-Madison Arboretum. The restoration effort at the Curtis Prairie has been studied from a variety of perspectives, including land use history (Blewett and Cottam 1984), fire (Anderson 1972, Peet et al. 1975), vegetation dynamics (Cottam and Wilson 1966, Blewett 1981), and organic matter incorporation into soils (Nielsen and Hole 1963). However, no studies have assessed potential linkages between underlying soil gradients and composition of vegetation along the restored prairie-oak opening ecotone. Our overall objective was to determine how herbaceous vegetation was distributed in the ecotonal region and if vegetation patterns were correlated with soil variables and/or photosynthetically active radiation (PAR). Specifically, we wanted to determine:

(1) if and how the environmental variables changed across the prairie-oak opening boundary;

(2) if the boundary between the two vegetation zones was discrete or continuous;

(3) if any of the environmental variables were correlated with vegetation composition;

(4) if a plant diversity gradient existed between the adjacent vegetation zones.

Study Site

The 0.45-ha study site was located in the northwestern portion of the Curtis Prairie, a prairie restoration project within the University of Wisconsin-Madison Arboretum. Presettlement vegetation in the area consisted of an oak opening intermixed with patches of tallgrass prairie (Curtis 1959, Sachse 1965, Cottam and Wilson 1966, Blewitt and Cottam 1984). The area was settled and converted into farmland in the 1850s. By the 1920s, the agricultural fields were abandoned, and the area was used as a horse pasture. In 1932 the Arboretum acquired the land, and in 1935 the prairie restoration project at Curtis Prairie was initiated. By 1948 the first prescribed burning was conducted (Curtis and Partch 1948). Current management of the Curtis Prairie includes a two-year cycle of prescribed burning; two-thirds of the prairie are burned one year, and the remaining third is burned the next (Anderson 1972). Occasional brushing and mowing also have been used as management tools. A detailed history of the site is provided by Blewitt and Cottam (1984).

Methods

Herbaceous Vegetation Sampling

Five 75-m transects were established at intervals of 15 m running parallel across the prairie-oak opening border. The transects started at a small drainage channel running southwest to northeast across the site (a topographical low point). Position 1 was in the prairie while position 5 was in the oak opening. All transects were set up at an azimuth of 310°. Sampling plots were located at 15 m intervals along the transect. Herbaceous vegetation was sampled using 1-m^2 quadrat constructed from PVC pipe. Vegetation samples were taken at each 15 m interval along each of the five transects for a total of 25 plots. The quadrat shape and size are appropriate for this type of vegetation (Brummer et al. 1994).

Herbaceous vegetation within each plot was clipped at the base of the plant (plant-soil interface) and separated according to species. Nomenclature follows Gleason and Cronquist (1991). The species samples were then dried by placing them in a drying oven at 65°C for 48 hours or until a constant weight was obtained. Dry weight biomass was determined for each species (g m^{-2}) (Appendix A). Photosynthetically active radiation (PAR) was measured on each plot using a Li-Cor LI-192SA Quantum Sensor (Lincoln, NE). Paired light measurements were taken in full sunlight adjacent to the study area, above the herbaceous canopy (approximately 1.3 m) as a measure of light interception by oak opening burr oaks (*Quercus macrocarpa* Michx.), and at approximately 8 cm above the ground surface beneath the herbaceous canopy.

Soils

A composite soil sample was taken from each plot to a depth of approximately 10 cm from three arbitrary locations within each plot. Leaf litter was removed from the sample area prior to soil collection. Soil samples were stored in plastic bags and kept refrigerated until analysis. Soils were analyzed at the University of Wisconsin-Madison's Soil Testing, Plant Analysis and Feed and Forage Analysis Laboratory in Madison, WI. Soils were analyzed for pH, organic matter, total N, available P, and exchangeable K, Ca, and Mg.

Soil pH was measured using a glass electrode pH meter in a 1:1 w/v aqueous solution following the methods of Corey and Tanner (1961). Calcium was measured as lime ($CaOH_2$) using a glass electrode Ca meter in a 1:1 w/v aqueous solution. Available phosphorous was measured after the methods of Bray and Kurtz (1945). Available potassium was measured according to the methods outlined in Wilde et al. (1979). Percent organic matter (OM) was determined following the methods of Schulte (1980). Total nitrogen was measured using the semi-micro Kjeldahl procedure (Bremner and Mulvaney 1982)

Vegetation Analysis

Classification of herbaceous vegetation was conducted using Cluster Analysis performed by program PC-ORD (McCune and Mefford 1995). To evaluate the variation in herbaceous vegetation and environmental variables along the transects, analysis of variance tests were performed using the general linear model (GLM) procedure in Minitab 8.2 (Minitab 1991). Mean separations across transect position groups were conducted using Fisher's test at $P < 0.05$. Species density was defined at the total number of species found in a sample plot and was used as an estimate for species richness (Magurran 1988). Species diversity was determined using the Shannon-Wiener diversity index, H' = $-\sum$ pi ln pi, where pi is the proportion of importance value of the ith species. These values were based on dry-weight biomass.

To evaluate relationships between vegetation and environmental variables, we performed multivariate analyses, namely detrended correspondence analysis (DCA) and canonical correspondence analysis (CCA) ordinations on herbaceous species-environmental variable matrices. We conducted the ordinations using the programs PC-ORD (McCune and Mefford 1995) and CANOCO 3.10 (ter Braak 1990). Herbaceous species biomass was used in the plant matrix as an indicator of plant abundance. Plant dry weight biomass was used in all the ordination and classification methods described. The DCA procedure used segment detrending, nonlinear rescaling of axes, and rare species downweighting (Hill and Gauch 1980). The CCA procedure involved linear combination of variables for site scores, no transformation of species abundance matrices, and the use of a Monte Carlo permutation to test the significance of the first axis eigenvalue (ter Braak 1990). In all CCA ordinations performed, the Monte Carlo test indicated that the eigenvalues for the first axis were significant ($P < 0.05$). Given the influence of noisy environmental data on CCA (McCune 1997), CCA was used and interpreted in the limited context of describing plant community variation with respect to the limited set of measured environmental variables in the study. Soil and environmental variables were transformed, when necessary, to meet the assumptions of normality. Significance is reported at the alpha = 0.05 level, unless otherwise noted in the text.

Results

A total of 46 herbaceous species were found on the study plots (Appendix A). Standing crop, dry weight biomass on the plots ranged from 69 to 2117 g m^{-2} (mean = 533 g m^{-2}). A distinct biomass gradient was also observed along the prairie-oak opening transition; mean plot biomass was 642 g m^{-2}, 1046 g m^{-2}, 437 g m^{-2}, 307 g m^{-2}, and 231 g m^{-2}, at transect positions 1, 2, 3, 4, and 5, respectively. Herbaceous species density on plots ranged from 2 to 11 species (mean = 5.9). Note that the species density totals do not include a limited number of spring ephemeral species. A summary of the overall fidelity of the herbaceous species encountered in the study indicated that the majority of the species sampled were uncommon; cumulative totals of species fidelity show that

64.6% of the species were found on three or fewer plots, 29.1% were found on from four to eight plots, and the remaining 6.3% were found on nine or more plots.

Soil Chemical Gradients

Table 1 provides a comparison of the means, standard deviations, and ranges of the environmental variables in the study. The relatively wide ranges of environmental variables depicted in Table 1 indicate the existence of soil heterogeneity at the site. Table 2 summarizes the correlations between environmental variables in the study. Moving from prairie towards the oak opening, seven of the eight environmental variables under examination were found to be negatively and significantly correlated with distance along the transects: pH (r = -0.81), organic matter (r = -0.73), N (r = -0.75), P (r = -0.63), Ca (r = -0.82), Mg (r = -0.88), and PAR above the herbaceous canopy (r = -0.53) (Figure 1). Table 2 shows that K was not significantly correlated with distance or any of the environmental variables measured. Furthermore, PAR above the herbaceous canopy was weakly correlated with all other environmental variables, and PAR beneath the herbaceous canopy exhibited even weaker correlations (Table 2). Table 2 also shows that many of the soil nutrient variables were strongly correlated.

Table 1. Means, standard deviations, and ranges (minimum and maximum) of environmental variables along a prairie-oak opening ecotone in the Curtis Prairie.

Variable[a]	*Mean*	*Standard Deviation*	*Range*
pH	6.6	0.7	5.3 - 7.5
Organic matter	5.3	1.2	2.6 - 7.1
N	0.23	0.06	0.11 - 0.34
P	24.6	6.8	13.0 - 35.5
K	0.34	0.07	0.23 - 0.48
Ca	5.5	1.7	2.8 - 7.7
Mg	4.0	1.4	1.9 - 6.2
PAR	76.1	34.5	8.6 - 97.6

[a]Variables shown are in the following units: organic matter (OM) %; Total N %; available P (P) mg/l; exhangeable K (K) cmol+kg^{-1}; exhangeable Ca (Ca) cmol+kg^{-1}; exhangeable Mg (Mg) cmol+kg^{-1}; photosynthetically active radiation (PAR) µmol s^{-1}m^{-2}.

Table 2. Pearson correlation coefficients between variables measured in the study.

Variable[a]	*D*	*pH*	*OM*	*N*	*P*	*K*	*Ca*	*Mg*	*PAR over*	*PAR under*
Distance (D)	-	-.81	-.73	-.75	-.63	.06	-.83	-.88	-.53	-.14
pH		-	.54	.68	.41	.10	.87	.89	.49	.20
OM			-	.92	.80	.19	.76	.76	.43	.14
Total N				-	.74	-.02	.46	.43	.40	.17
P					-	.08	.28	.67	.20	-.05
K						-	-.03	.01	.13	.11
Ca							-	.94	.46	.13
Mg								-	.43	.07

[a]Variables shown are in the following units: distance (D) m; organic matter (OM) %; Total N %; available P (P) mg/l; exhangeable K (K) cmol+kg^{-1}; exhangeable Ca (Ca) cmol+kg^{-1}; exhangeable Mg (Mg) cmol+kg^{-1}; photosynthetically active radiation (PAR) µmol s^{-1}m^{-2}.

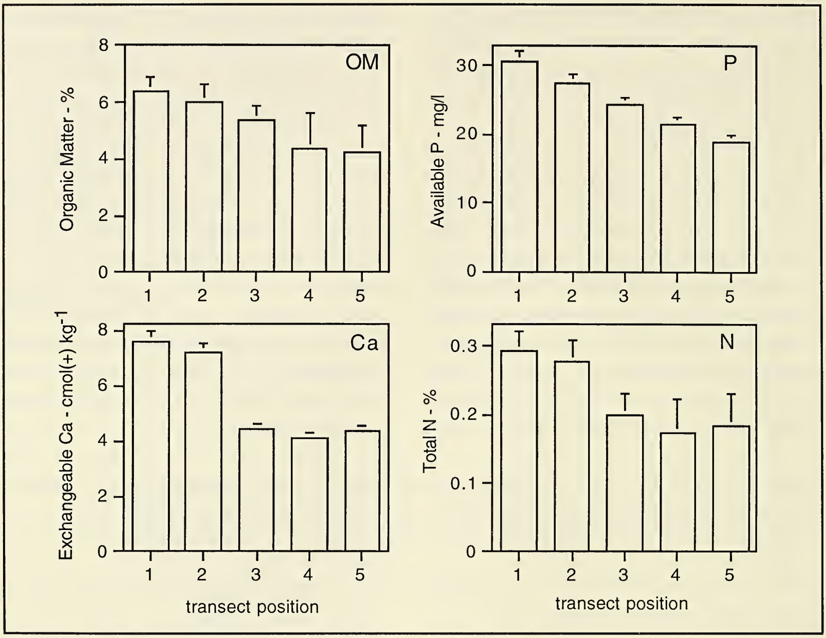


Figure 1. Graphs show relationships between transect position and soil nutrient levels. Transect position 1 corresponds to prairie and 5 corresponds to oak opening in the Curtis Prairie. Bars represent one standard deviation.

Figure 1 is a composite graph of transect position plotted versus measured soil levels of total N, available P, exchangeable Ca, and percent OM. Significant reductions in soil N (P < o.001), Ca (P < 0.001), P (P = 0.030), and OM (P = 0.002) were noted moving from prairie (position 1) to oak opening (position 5). The Mg results (not shown) were highly similar to the Ca results. These results indicate strong underlying soil gradients on the study site moving across the prairie restoration-oak opening transition zone.

Vegetation along the Transition

Cluster analysis identified six weak clusters in the dataset. However, only a single distinct herbaceous assemblage was found in the study area. Reed canary grass (*Phalaris arundinacea* L.) dominated the plant assemblages found in transect positions 1 and 2 along the ecotone. The DCA ordination results (not shown) also indicated this pattern. Figure 2 shows that positions 1 and 2 had significantly lower DCA mean scores than positions 3 to 5 (P < 0.001). No significant differences in mean DCA scores were found between positions 3, 4, and 5. However, the standard deviation was highest for position 3. This latter result indicates the vegetation at position 3 (between the prairie restoration and oak opening) shows a high rate of species change at that location. The five remain-

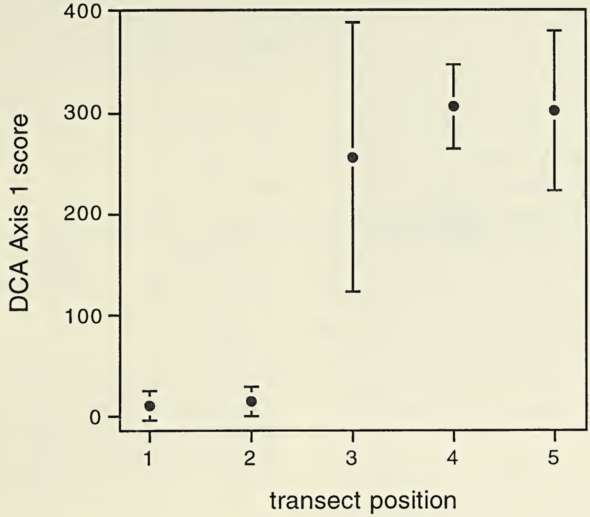


Figure 2. A plot of DCA axis 1 scores (±1 SD) versus plot position along the five study transects.

ing non-Phalaris–dominated clusters were located in plots spread out along the three remaining transect positions. No clear patterns of prairie versus oak opening vegetation were found.

Vegetation-Environmental Relationships

Ordinations were used to detect relationships between vegetation and measured environmental variables. Both DCA and CCA were run, but because the two ordinations produced similar results, only the CCA results are presented in detail. Figure 3 is a summary CCA ordination showing plot ordination on a biplot for the 25 vegetation plots with eight environmental variables. The first three axes of the CCA ordination explained 35.2% of the variation in the species matrix. The three vectors shown in Figure 3 correspond to the environmental variables showing strong correlations with the first CCA axis, namely Ca ($r = -0.88$), N ($r = -0.72$), and pH ($r = -0.71$). Mg also exhibited a strong correlation ($r = -0.78$) as did OM ($r = -0.58$); however, a vector for Mg wasn't included in Figure 3 because Mg results were similar to those of Ca. The results in Figure 3 parallel the results presented in Table 2. The CCA correlations also closely paralleled the correlations between environmental variables and the DCA ordination axes. While CCA may be sensitive to noise in environmental data (McCune 1997), the results provide corroboration of the soil gradient analysis and the DCA results.

The distribution of plots in Figure 3 also shows a separation of the plots dominated by *Phalaris*, with all *Phalaris*-dominated plots located exclusively on the left side of the ordination. No clear segregation of plots

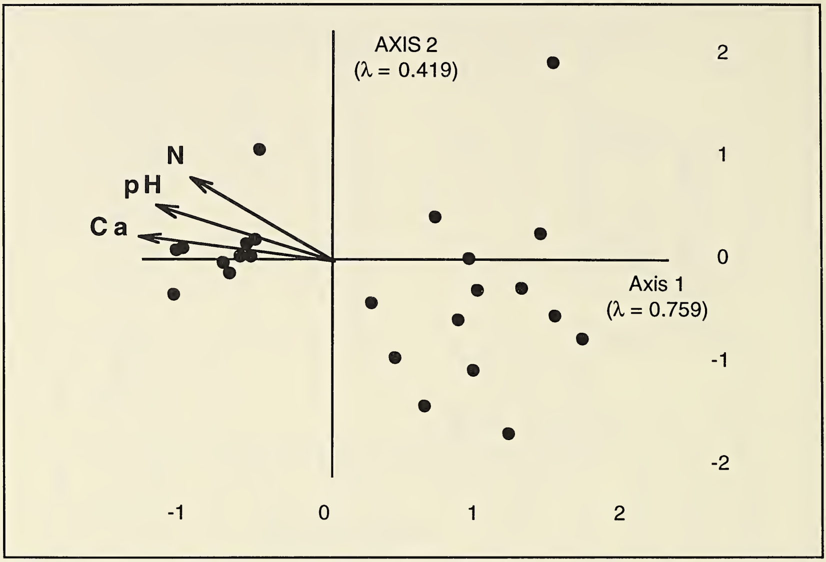


Figure 3. A CCA ordination biplot of 25 plots and 9 environmental variables. The environmental variables with the strongest correlation with the vegetation matrix are shown in the biplot.

was observed on the right half of the CCA biplot, indicating more of a continuous distribution than discrete gradation of herbaceous assemblages in the non-*Phalaris*–dominated plots.

Diversity Gradients

In addition to soil chemical gradients, a herbaceous plant diversity gradient also was found along the prairie-oak opening transition. Plant diversity was calculated for each transect position using both species richness (S) and the Shannon-Weiner Diversity Index (H'). The results in Table 3 show that both species richness and Shannon-Weiner diversity were positively correlated with distance along the transition zone; as prairie graded into oak opening, species richness and diversity increased. Diversity estimates were strongly correlated with Ca (r = -0.90), N (r = -0.84), OM (r = -0.72), and pH (r = -0.67). Interestingly, no significant relationships were found between any of the PAR measurements and species diversity measures.

There was a strong negative correlation between *Phalaris* and species richness (r = -0.75) and diversity (r = -0.78) along the ecotone transition. While the cause-effect relationship between *Phalaris* and plant diversity is beyond the scope of this study, the results suggest that *Phalaris* dominance reduces diversity.

Discussion

The term ecotone was first used by Clements (1905) to describe the "tension zone" between plant communities where the major

Table 3. Correlations between Shannon-Weiner diversity (H'), species density (S), and distance and environmental variables. Values represent Pearson's correlation coefficients (r).

Variable[a]	*S*	*H'*
Distance (D)	.60	.73
pH	-.44	-.67
OM	-.66	-.72
N	-.74	-.84
P	-.82	-.53
K	.12	.13
Ca	-.62	-.90
Mg	-.67	-.80
PAR	-.25	-.46

[a]Variables shown are in the following units: distance (D) m; organic matter (OM) %; Total N %; available P (P) mg/l; exhangeable K (K) cmol+kg^{-1}; exhangeable Ca (Ca) cmol+kg^{-1}; exhangeable Mg (Mg) cmol+kg^{-1}; photosynthetically active radiation (PAR) µmol s^{-1}m^{-2}.

dominant species in adjacent communities overlapped in their distribution. In recent years, the term ecotone has been used interchangeably with the terms "transition zone" and 'landscape boundary' (van der Maarel 1990; Shugart 1990; Holland et al. 1991; Hansen and di Castri 1992). The presence of ecotones and their manifestation are influenced by a host of factors, including edaphic conditions, geomorphology, disturbance, and climate (Risser 1990, van der Maarel 1990, Gosz 1993).

The results of our study indicate distinct ecotonal characteristics in both vegetation and soil variables in the Curtis Prairie. The herbaceous layer exhibited sharp ecotonal boundaries only at the transition between *Phalaris*-dominated communities and prairie-oak opening vegetation. Cluster analysis and CCA ordinations showed little distinct separation between plots on non-*Phalaris*–dominated plots; herbaceous vegetation assemblages were more continuous than discrete across the prairie-oak opening transition. Our results also indicate that there were both soil chemical and diversity gradients along the prairie-oak opening ecotone in the study area. Organic matter, pH, P, Ca, Mg, and total N decreased along the gradient from prairie to oak opening; plant diversity increased from prairie to oak opening. Given the importance of total N and available P to plant nutrition, the role and influence of OM in prairie soil development, and the impacts of Ca and Mg on plant distribution in calcareous and dolomitic soils, our results highlight the importance of soil gradients along the prairie oak opening transition in this study. However, the presence of *Phalaris* at the site may have had a strong influence on altering pre-*Phalaris*–invasion vegetation and soil patterns.

Integrating vegetation analyses with environmental and physiographic variables can provide a more robust basis for classification and characterization than vegetation analyses alone (Rowe 1984, Hix 1988, Palmer 1993). The soil gradient analysis and CCA results indicate that herbaceous species were influenced by soil gradients across the ecotonal landscape. The correlations between the soil variables and herbaceous species diversity indicate that plant diversity may also be influenced by soil chemical gradients. In the oak opening portion of the ecotone, lower nutrient availability may promote greater diversity compared to that of the prairie.

Ecotones may provide pathways for the invasion of exotic plants that can disrupt community dynamics (Risser 1990, Planty-Tabacchi et al. 1996). An important factor influencing the observed diversity patterns in our results was that *Phalaris* had a negative impact on herbaceous species diversity on the study site. *Phalaris* was a dominant species on the wetter soils on the prairie side of the ecotone but was not found in the oak opening or the prairie-oak opening interface. *Phalaris* is an exotic species that grows in dense clumps, outcompetes local flora, and is highly resistant to flooding (Apfelbaum and Sams 1987, Chonchou and Fustec 1988). Seasonal flooding has occurred and continues to occur near and around an overflow ditch within the study area. *Phalaris arundinacea* was most dominant near the overflow ditch, and it follows that the ditch is quite possibly the vector by which seeds of *P. arundinacea* first entered the area.

Current management techniques (i.e., fire and selective brushing) may have influenced the ecotone under study. In addition, light (PAR) may have a long-term impact on the vegetation composition at the site depending on phenology, available wavelengths of light, and variation in herbaceous canopy composition. While the influence of these variables requires more investigation, the results of the present study clearly demonstrate the potential influence of soil factors on the composition and distribution of herbaceous vegetation. We suggest that soil variables and gradients should be considered when studying characteristics of ecotones in restored habitats.

Acknowledgments

We would like to thank the Dr. Mark Leach and the University of Wisconsin-Madison Arboretum for access to the Curtis Prairie site. Kevin Hollender and Melissa Slabich provided a great deal of field assistance in collecting data and in the preliminary analysis of that data. We would also like to thank Dr. Robert Bohanan and an anonymous reviewer for reviewing preliminary drafts of the manuscript. This manuscript is submitted through Edgewood College's Environmental Studies Program.

Appendix A. A summary of all herbaceous species identified in the vegetation sampling.

Species	Total Biomass - g
Agrostis alba L.	21.3
Allium cernuum Roth.	11.7
Andropogon geradii Vitm.	798.5
Arctium minus Bernh.	1.0
Asclepias syriaca L.	0.5
Aster ericoides L.	3.8
Aster laevis L.	5.6
Aster lanceolatus Willd.	9.8
Aster novae-angliae L.	148.9
Aster oolentangiensis Riddell	1.9
Aster pilosus Willd.	21.0
Baptisia leucantha T.&G.	47.9
Blephilia ciliata (L.) Raf.	1.1
Brachelytrum sp.	52.2
Bromus inermis Leyss.	18.2
Carex sp.	17.9
Cirsium discolor (Muhl.) Spreng.	3.3
Cornus racemosa Lam.	182.9
Euphorbia corollata L.	2.1
Galium triflorum Michx.	0.4
Helianthus grosseserratus Martens	602.4
Hypericum perforatum L.	14.7
Lactuca canadensis L.	36.0
Lespedeza capitata Michx.	100.3
Liatris aspera (L.) Willd.	14.0
Lycopus americanus Muhl.	4.2
Monarda fistulosa L.	658.0
Oenothera biennis L.	33.3
Pastinaca sativa L.	26.3
Pedicularis canadensis L.	2.2
Phalaris arundinacea L.	142.6
Poa compressa L.	21.8
Poa pratensis L.	52.2
Polygonum pensylvanicum L.	85.2
Pycanthemum virginianum (L.) Durand & Jackson	6.4
Rosa sp.	3.3
Rubus occidentalis L.	10.4
Rudbeckia hirta L.	0.3
Silphinium terebinthinaceum Jacq.	42.1
Solidago altissima L.	732.7
Solidago gigantea Ait.	14.3
Solidago nemoralis Ait.	856.8
Solidago ulmifolia Muhl.	0.2
Sorghastrum nutans L.	504.8
Toxicodendron radicans (L.) Ktze.	0.6
Unknown	2.4
Viola pedata L.	0.1
Vitis riparia Michx.	0.0

Literature Cited

Allen, T.F.H., and T.W. Hoekstra. 1992. *Toward a unified ecology.* Columbia University Press, New York. 384 pp.

Anderson, M.R. 1968. Vegetational changes on the Greene Prairie in relation to soil characteristics. M.S. Thesis, University of Wisconsin-Madison.

Anderson, R.C. 1972. *The use of fire as a management tool on the Curtis Prairie.* University of Wisconsin Press, Madison.

Apfelbaum, S.I., and C.E. Sams. 1987. Ecology and control of reed canary grass. *Natural Areas Journal* 7:69–74.

Auerbach, M., and A. Shmida. 1993. Vegetation change along an altitudinal gradient on Mt Hermon, Israel—no evidence for discrete communities. *Journal of Ecology* 81:25–33.

Blewett, T.J. 1981. An ordination study of plant species ecology in the Arboretum prairies. Ph.D. Thesis, University of Wisconsin-Madison.

Blewett, T.J., and G. Cottam. 1984. History of the University of Wisconsin Arboretum Prairies. *Transactions of the Wisconsin Academy of Sciences, Arts & Letters* 72:130–44.

Boren, J.C., D.M. Engle, M.S. Gregory, R.E. Masters, T.G. Bidwell, and V.A. Mast. 1997. Landscape structure and change in a hardwood forest-tallgrass prairie ecotone. *Journal of Range Management* 50:244–49.

Bray, R.H., and L.T. Kurtz. 1945. Determination of total, organic and available forms of phosphorous in soil. *Soil Science* 59:39–45.

Bremner, J.M., and C.S. Mulvaney. 1982. Nitrogen — Total. Pp. 595–624 *in* A.L. Page, R.H. Miller, and D.R. Keeney, eds. *Methods of soil analysis: Part 2 – microbiological and biochemical properties.* Soil Science Society of America Inc and American Society of Agronomy. Madison, WI.

Brummer, J.E., J.T. Nichols, R.K. Engel, and K.M. Eskridge. 1994. Efficiency of different quadrat sizes and shapes for sampling standing crop. *Journal of Range Management* 47:84–89.

Chonchou, O., and E. Fustec. 1988. Influence of hydrological fluctuations on the growth and nutrient dynamics of *Phalaris arundinacea* L. in a riparian environment. *Plant and Soil* 112:53–60.

Clements, F.E. 1905. *Research methods in ecology.* University Publishing Company, Lincoln, NE.

Corey, R.B., and C.B. Tanner. 1961. *Soil Science Society of America Proceedings* 25:326–27.

Cottam, G., and H.C. Wilson. 1966. Community dynamics on an artificial prairie. *Ecology* 47:88–96.

Crumley, C.L. 1993. Analyzing historic ecotonal shifts. *Ecological Applications* 3:377–84.

Curtis, J.T. 1959. *The vegetation of Wisconsin: an ordination of plant communities.* University of Wisconsin Press, Madison. 657 pp.

Curtis, J.T., and M.L. Partch. 1948. Effect of fire on the competition between blue grass and certain prairie plants. *The American Midland Naturalist* 39:437–43.

di Castri, F., A.J. Hansen, and M.M. Holland, eds. 1993. A new look at ecotones; emerging international projects on landscape boundaries. *Biology International*, Special Issue 17.

Dyer, J.M., and P.R. Baird. 1997. Remnant forest stands at a prairie ecotone site: presettlement history and comparison with other maple-basswood stands. *Physical Geography* 18:146–59.

Fahrig, L., and G. Merriam. 1985. Habitat patch connectivity and population survival. *Ecology* 66:1762–68.

Gleason, H.A., and A. Cronquist. 1991. *Manual of the vascular plants of northeastern United States and Adjacent Canada.* New York Botanical Garden, NY. 910 pp.

Gosz, J.R. 1991. Fundamental ecological characteristics of landscape boundaries. Pp. 8–30 *in* M.M. Holland, R.J. Naiman, and P.G. Risser, eds. *Role of landscape boundaries in the management and restoration of* *changing environments.* Chapman and Hall, New York.

Gosz, J.R. 1992. Ecological functions in biome transition zones: translating local responses to broad-scale dynamics. Pp. 55–75 *in* A.J. Hansen and F. di Castri, eds. *Landscape Boundaries: Consequences for biotic diversity and Landscape Flows. Ecological Studies 92.* Springer-Verlag, New York.

Gosz, J.R. 1993. Ecotone hierarchies. *Ecological Applications* 3:369–76.

Gosz, J.R., and P.J.H. Sharpe. 1989. Broad-scale concepts for interactions of climate topography and biota at biome transitions. *Landscape Ecology* 3:229–43.

Hansen, A.J., and D.L. Urban, eds. 1992. Epilogue: biodiversity and ecological flows across ecotones. Pp. 423–38 *in* A.J. Hansen and F. di Castri, eds. *Landscape Boundaries: Consequences for Biotic Diversity and Ecological Flows. Ecological Studies 92.* Springer Verlag, New York.

Hansen, A.J., and F. di Castri, eds. 1992. *Landscape boundaries: consequences for biotic diversity and landscape flows. Ecological Studies 92.* Springer Verlag, New York.

Hill, M.O., and H.G. Gauch. 1980. Detrended correspondence analysis, an improved ordination technique. *Vegetatio* 42:47–58.

Hix, D.M. 1988. Multifactor classification and analysis of upland hardwood forest ecosystems of the Kickapoo River watershed, southwestern Wisconsin. *Canadian Journal of Forest Research* 18:1405–15.

Holland, M.M., P.G Risser, and R.J. Naiman, eds. 1991. *Ecotones.* Chapman and Hall, New York, NY.

Jarvis, P.G. 1995. Scaling processes and problems. *Plant, Cell Environment* 18:1079–89.

Jastrow, J.D. 1987. Changes in soil aggregation associated with tallgrass prairie restoration. *American Journal of Botany* 74:1656–64.

Johnston, C.A. 1993. Material fluxes across wetland ecotones in northern landscapes. *Ecological Applications* 3:424–40.

Leach, M.K. 1994. Savanna plant species distributions along gradients of sun-shade and soils. Pp. 223–27 *in* J.S. Fralish, R.C. Anderson, J.E. Ebinger, and R. Szafoni, eds. *Proceedings of the North American Conference on Barrens and Savannas.* U.S. Environmental Protection Agency, Great Lakes National Program Office, Chicago, IL.

Leach, M.K., and T.J. Givnish. 1996. Ecological determinants of species loss in remnant prairies. *Science* 273:1555–58.

Leopold, A. 1933. *Game Management.* Charles Scribner's Sons, New York.

Magurran, A.E. 1988. *Ecological Diversity and Its Measurement.* Princeton University Press, Princeton, NJ.

McClaran, M.P., and G.R. McPherson. 1995. Can soil organic carbon isotopes be used to describe grass-tree dynamics within a savanna and at the savanna-grassland ecotone? *Journal of Vegetation Science* 6:857–62

McCune, B. 1997. Influence of noisy environmental data on canonical correspondence analysis. *Ecology* 78:2617–23.

McCune, B., and M.J. Mefford. 1995. *PC-ORD.* Multivariate analysis of ecological data, version 2.0. MjM Software Design, Gleneden Beach, Oregon, USA.

Minitab. 1991. *Minitab reference manual.* Release 8.2. Minitab Inc. Data Tech Industries, Valley Forge, PA.

Naiman, R.J., and H. Décamps, eds. 1990. *The ecology and management of aquatic-terrestrial ecotones.* United Nations Education, Scientific and Cultural Organization, Paris.

Nielsen, G.A., and F.D. Hole. 1963. A study of the natural process of incorporation of organic matter into soil in the University of Wisconsin Arboretum. *Transactions of the Wisconsin Academy of Sciences, Arts & Letters* 52:213–27.

Nielson, R.P. 1993. Transient ecotone response to climatic change: some conceptual and modeling approaches. *Ecological Applications* 3:385–95.

Palmer, M.W. 1993. Putting things in even better order: the advantages of canonical correspondence analysis. *Ecology* 74:2215–30.

Peet, M., R. Anderson, and M.S. Adams. 1975. Effects of fire on big bluestem production. *The American Midland Naturalist* 94:15–26.

Planty-Tabacchi, A.M., E. Tabacchi, R.J. Naiman, C. Deferrari, and H. Decamps. 1996. Invisibility of species-rich communities in riparian zones. *Conservation Biology* 10:598–607.

Pulliam, H.R. 1988. Sources, sinks, and population regulation. *American Naturalist* 132:652–61.

Risser, P.G. 1990. The ecological importance of land-water ecotones. Pp. 7–21 *in* R.J. Naiman and H. Décamps, eds. *The Ecology and Management of Aquatic-Terrestrial Ecotones.* United Nations Education, Scientific and Cultural Organization, Paris, France.

Risser, P.G. 1995. The status of the science examining ecotones. *BioScience* 45:318–25.

Rowe, J.S. 1984. Forestland classification: limitations of the use of vegetation. Pp. 132–47 *in* J.G. Bockheim, ed. *Proceedings of a symposium on forest land classification: experience, problems, perspectives.* University of Wisconsin, Madison.

Rusek, J. 1993. Air-pollution-mediated changes in alpine ecosystems and ecotones. *Ecological Applications* 3:409–16.

Sachse, N.D. 1965. *A thousand ages.* University of Madison Press, Madison. 149 pp.

Sagers, C.L., and J. Lyon. 1997. Gradient analysis in a riparian landscape: contrasts among forest layers. *Forests Ecology and Management* 96:13–26.

Schulte, E.E. 1980. Recommended soil organic matter tests. Pp. 28-30 *in* W.C. Dahnke, ed. *Recommended chemical soil test procedures for the north-central region.* North Central Regional Research Publication No. 221. North Dakota State University, Fargo.

Stohlgren, T.J., G.W. Chong, M.A. Kalkhan, and L.D. Schell. 1997. Multiscale sampling of plant diversity: effects of minimum mapping unit size. *Ecological Applications* 7:1064–74.

ter Braak, C.J.F. 1990. CANOCO — a fortran program for canonical community ordination. Microcomputer Power, Ithaca, New York.

van der Maarel, E. 1990. Ecotones and ecoclines are different. *Journal of Vegetation Science* 1:135–38.,

Weaver, J.E., and F.W. Albertson. 1956. *Grasslands of the Great Plains: Their nature and use.* Johnson, Lincoln, NE.

Wedin, D., and D. Tilman. 1996. Influence of nitrogen loading and species composition on the carbon balance of grasslands. *Science* 274:1130–32.

Wilde, S.A., R.B. Corey, J.G. Lyer, and G.K. Voight. 1979. *Soil and plant analysis for tree cultures.* Oxford and IBH Publishing Company, Bombay and New Delhi.

Zak, D.R., D.F. Grigal, S. Gleeson, and D. Tilman. 1990. Carbon and nitrogen cycling during old-field succession: constraints on plant and microbial biomass. *Biogeochemistry* 11:111–29.

Jonathan Lyon *is assistant director of Community Conservation in Gays Mills, Wisconsin. He is a plant ecologist with interests in community structure and plant-soil relationships.* ***Address:*** *Community Conservation, RD1 Box 96, Gays Mills, WI 53711.* ***E-mail:*** *ccc@mwt.net*

Craig Annen *received his B.S. degree from Edgewood College in 1998.* ***Address:*** *Natural Sciences Department, Edgewood College, 855 Woodrow Street, Madison, WI 53711.*

Ellen Argyros

"Pulp Fiction": Edna Ferber's *Come and Get It* and Ecofeminism

Edna Ferber's novel *Come and Get It* is pulp fiction not so much because of its dealings with sensational subjects or its being printed on low-quality paper as because it is about the making of pulp, the logging industry in Wisconsin in the early half of the twentieth century, the empire-making of Barney Glasgow. Granted, the book does contain some melodramatic elements: the lust of a sugar daddy for a sweet young thing, the sudden *deus ex machina* when that sugar daddy dies in a boating accident, the social-climbing tendencies of that opportunistic young woman once the wealthy Barney Glasgow dies and she can marry his son, heir to his fortune. Still, *Come and Get It* is of interest not because of its melodrama but because what it reveals about the status of women and the status of the environment in Wisconsin around the turn of the century right up until before World War II. It is also is an impressive testimony to the "Wisconsin character," as Ferber defines it. In her novel, Ferber rewards those who are unpretentious, work hard, save their money yet do not become seduced by the trappings of material success into becoming what they are not. She is also extremely aware of the way in which Midwesterners define themselves—sometimes defensively—against standards set in the east.

Given the recent interest in such local environmental issues as what to do about the high concentration of PCBs in the Fox River and in such national gender-political issues as the sexual predation of our own president upon young women like Monica Lewinsky, it would appear to be a timely moment in which to examine the kinds of connections Ferber makes in her novel between the treatment of the environment and the treatment of women.

After giving an overview of Ferber's life, I will provide a brief plot synopsis for those unfamiliar with this relatively obscure novel, address what kind of a feminist she is, and then go on to argue that it is tempting to read Ferber as a kind of proto-ecofeminist in some parts of *Come and Get It,* even though her primary sympathies are not so much with those who share her gender or ideological stance towards the environment as with those who share her values about the salubrious and ethical benefits of hard work.

Edna Ferber's Life

Edna Ferber is described by her biographer, Julie Goldsmith Gilbert (Ferber's great-niece), as a "massive little woman" who may have been physically tiny—she was only 5'2"—but was extremely strong-willed. The Ferber in Gilbert's biography could be fiercely protective of those she loved, while unsparingly savage towards those for whom she felt contempt; there's a kind of masculine swagger in Edna Ferber, according to Gilbert's presentation. Ferber had a great deal of respect for the common worker, enjoyed being in the position of the sharply observant onlooker, gave lavish meals, was given to fits of outrage, had difficulty trusting others, and always wanted to be the one who rejected first. Gilbert writes that Ferber's

> life was antiseptic—absolutely no excesses were allowed. She was a Middle Western maiden lady who took care of her mother, her family, and her typewriter. She recycled herself with every book, and each seemed a testament more to her own health and vigor than to inspiration. With themes like Seattle, Oklahoma, Alaska, New England, the West, Texas—she had no time or penchant for personal probing. There was too much to do. Her ego was as mammoth as her scope, and no man, vice, crisis, or illness was going to deter her. An obsessive in the most productive sense, a spinster in the most resolved sense, a plain woman who kept herself in silk purses, and an angry daughter who determinedly made her mother's life roses. . .one would assume that her bill of mental health was immaculate. A presumption. Her complete devotion to her mother Julia bordered on the incestuous. Her hatred of her sister Fannie was at times close to being pathological. Her need and ability to 'play God' was despotism at its worst. There were chinks in her armor. Many. (Gilbert, 13)

Edna Ferber was born on August 15, 1885, in Kalamazoo, Michigan, of Jewish parents. According to Gilbert, Edna's mother had wanted a boy, whom she would have named Edward. Instead, she had a second girl, and she named her Edna. Edna's father, Jacob, was a Hungarian; her mother, Julia, was born in Milwaukee. Her father was the owner of a general merchandise store, first in Iowa, then in Appleton (on College Avenue). Her older sister, Fanny, and Edna had frictive relations for much of their lives, perhaps because Fanny was the more beautiful of the two, but there may have been other reasons as well.

At 17, Ferber graduated from the Ryan High School in Appleton. For her graduating essay she wrote an account of the life of the women workers in a local mill. The local editor of the *Appleton Daily Crescent* saw it, recognized that it was good reporting, and gave her a job in 1903 as a local reporter at $3.00 a week—a huge salary for a young woman in a small town. She then was graduated from the Appleton paper to Milwaukee, where she was also a reporter. While she was earning a living as a reporter, she wrote *Dawn O'Hara*, her first novel. It sold well. While it was in the press and selling during 1911 and 1912, Ferber began publishing the story of Emma McChesney, a travelling saleswoman. The character appealed to the public, and Ferber's success began to grow. In 1913, the stories were collected under the title *Roast Beef Medium,* and that book also sold well. This was followed by *Buttered Side Down,* another collection of short stories, and more novels, *Fanny Herself* (1917), *Cheerful by Request* (1918), *The Girls* (1922), *Show Boat* (1926), *Giant* (1952), *Ice Palace* (1958), and others. She was a prolific writer, with a total of twelve novels—including *So Big,* for which she won a Pulitzer Prize in 1924—twelve short story collections, two autobiographies, nine plays. Twenty five of her properties sold to the films, although "only" ten of her works were actually made into motion pictures. She never married, and she died in 1968 at the age of 83.

Come and Get It : Plot Synopsis

Come and Get It was published in 1935, just before World War II struck in Europe and Asia and at a time of labor strikes in the United States. *Porgy and Bess* was opening in New York at this time; the following year *Gone with the Wind* was a best-seller, and Charlie Chaplin's *Modern Times* was released.

In *Come and Get It,* Edna Ferber chronicles the rags to riches tale of the handsome Barney Glasgow, who marries the boss's homely daughter in order to consolidate his wealth and become one of the leading lumber barons in the state; after Barney's death about two thirds through the novel, she goes on to describe his son's inheritance and augmentation of the Glasgow fortune.

Barney Glasgow is orphaned at the age of 14 and taken under the wing of Swan Bostrum. The young Barney proves a quick study in how to fell a tree and how to make himself indispensable to his boss. He discovers the various illicit but technically legal ways of acquiring land with lumber on it. Through clever bits of legal fraud, Barney wins his way into his boss' heart and business. He secures his career when he opportunistically marries the boss's "thin-lipped, hook-nosed, bony" daughter, Emma Louise, who is several years older than the dashing Barney. Barney is not attracted to his wife, nor does he like his calculating son Bernard, although he is fond of his daughter Evelyn. Evelyn, following in her father's footsteps, is in the process of marrying a person she does not love simply because he is the son of another lumber baron, and because she feels that this is what she is expected to do. The marriage is even more of a travesty because she really loves and is loved by a handsome Italian worker, whose love she sacrifices in order to maintain her social standing. Prior to his marriage to Emma Louise, Barney and Swan both had been attracted to a pretty young prostitute, Lotta Morgan. Barney loves her, but Swan does the right thing and marries her. Lotta remains married to Swan for ten years and then, after giving birth to a little girl Karie, dies.

Then the plot skips ahead 35 years, and we meet Karie's daughter, Lotta Lindbeck (Lotta II). At age 18, Lotta II is now a "ravishing beauty." Barney never actually forces himself sexually upon her, but he is infatuated with her, showers her with gifts, and regards her as his possession. He wishes to marry her and feels that with all the millions he has, it's a shame that he remains married to a homely woman whom he does not love. He is therefore incensed to discover Lotta and his son Bernie kissing at a party and to learn of Bernie's intention to marry her. The two men fight and nearly kill one another. Barney threatens to disown his son, whom his wife hides. Then, when everyone in the family but the son Bernie decide to go out on a boat, the boat explodes. Bernie becomes heir to the Glasgow fortune and marries Lotta.

The rest of the novel follows the career of Lotta Glasgow, who is shunned by the wealthy women of Butte des Morts; in frustration she becomes an expatriate, travelling in Europe and repudiating the life she once lived in Butte des Morts. But her grandfather Swan, the moral authority in the novel, returns to Iron Ridge to resume his humble life among the pine trees. Lotta's mother Karie, although she stays with her daughter and helps her care for her grandchildren, remains as down to earth, unpretentious, and seemingly uncorrupted by wealth as she ever was. Lotta, of course, becomes a complete social-climber and snob, flaunting her newfound wealth. Against her will, her European-born children become intrigued by their American origins. When their father loses millions during the Great Depression and has a nervous collapse, his wife reluctantly returns home with their grown children—who are excited about the paper mills but who also want to travel across America and learn about their native land.

The novel ends with Lotta and Karie and the grandchildren helping to celebrate Swan's 85th birthday up in his tiny cabin up north. The old man can still heft an axe, and he cuts down a 100 year old pine tree while his daughter Karie yells "Come and get it!" to the gaping crowd.

Public Reception of the Novel and Brief Critical Evaluation

The public's initial response to *Come and Get It* was anger. Specifically, Ferber's treatment of Polish-American workers was perceived as pejorative, discriminatory. Gilbert defends Ferber: "Ferber, always true to authentic ethnicity, had used the term 'dumb Polack girls' in the context of the story. No doubt, in her research of the territory, she had heard it mentioned. To Polish-Americans, it was unmentionable" (Gilbert 329). Gilbert even received a letter of protest from a congressman. Others complained that Ferber had conducted her research for the novel in a way that violated the etiquette of the time. Gilbert writes:

> When she went to Wisconsin to do research for *Come and Get It*, she enlisted the help of an executive of a large paper mill in Neenah . . . . The executive gave her all she needed to know. What he didn't know was that he unwittingly gave her himself to use as the main character in her book . . . . What stung him was not so much her portrayal of him, but the fact that she never, after their long sessions together, even wrote him a thank-you note. And, as is often the case in tight-knit societies, everyone knew about her rude conduct. The whole town tsked. (330)

In my opinion, *Come and Get It* is not Ferber's best work. The characters seem a bit two-dimensional: the dashing robber baron, the dowager wife, the blond bombshell. The plot plods along somewhat tediously until Barney's lust for the young Lotta develops; then it suddenly erupts into melodrama, only to have Barney's family (with the exception of his heir, Bernard) die in a rather improbable plot contrivance.

Ferber herself recognized that this was not a perfect novel. In her autobiography *A Peculiar Treasure,* she writes about how "in the writing of the novel Come and Get It, [sic] I was guilty of. . . [a] . . . stupid blunder. I killed Barney Glasgow in the middle of that book because he was dominating the story. The book gave a gasp right there, and the murder was doubled." (223)[1] Ferber further confesses that "Plot is something that doesn't interest me. Character I find absorbing. My novels usually are character-strong and plot-weak. I'd be sorry to have it the other way round" (224). There is, of course, a rather transparent and somewhat defensive false dilemma implicit her assumption that a writer will inevitably make mistakes in one area, either in developing characters or in developing plotlines.

Ecofemism Defined

Its failings notwithstanding, when I first read this novel and in subsequent readings of it, I was struck by the sorts of connections Ferber invites us to make between Barney's ravaging of the land—with no intentions of replenishing the lumber supply once it has been depleted—and his desire to ravage his best friend's granddaughter, again, with little thought about what the consequences of this action would be on his friendship with Swan, on his relationship with his children, or on his relationships with the people of his community. Vaguely remembering that ecofeminists also draw connections between the treatment of the land and the treatment of women, I did some research into ecofeminism and then re-read the novel through the lens provided by that ideological perspective.

Ecofeminism, I found, is a relatively recently coined term used to link the domination of both land and women without regard for the feelings or desires of the women or for the future productiveness of the land. Literary ecofeminists explore the manifold ways in which the exploitative treatment of women reflects a similarly exploitative and opportunistic treatment of the environment. Marie Mies and Vandana Shiva in *Ecofeminism* describe the origins of ecofeminism, "which grew out of various social movements of the late 1970s and early 1980s . . . The meltdown at Three Mile Island prompted large numbers of women in the USA to come together in the first ecofeminist conference—'Women and Life on Earth: A Conference on Eco-Feminism [*sic*] in the Eighties'—in March 1980, at Amherst. At this conference the connections between feminism, militarization, healing and ecology were explored" (Mies and Shiva 13-14).

Gretchen Legler discusses what an ecofeminist literary criticism might look like: "Ecofeminist literary criticism is a hybrid criticism . . . that gives literary and cultural critics a special lens through which they can investigate the ways nature is represented in literature and the ways representations of nature are linked with representations of gender, race, class, and sexuality" (quoted in Warren 227). According to Legler, "many canonical authors still place nature 'out there' as an 'other.' Many canonical authors refine and entrench the notion of nature as a sacred place where only solitary, single, and chaste men go to cleanse their spirits and be one with God" (quoted in Warren 229). Legler suggests that "critiquing canonical works through an ecofeminist lens might include investigating the ways in which gender, race, and class are represented in and inform the writings of these 'fathers' of American nature writing"; she goes on to suggest that ecofeminists might well study the texts of such contemporary women writers as Annie Dillard, Gretel Ehrlich, Linda Hasselstrom, Sue Hubbell, Alice Walker, Leslie Silko, Diane Ackerman, and others in order to study how their "postmodern pastoral" is a vision "informed by ecological and feminist theories, and . . . that images human/nature relationships as 'conversations' between knowing subjects" (quoted in Warren 229).

Putting it bluntly, Legler suggests that ecofeminists today might take one of two tacks: bashing the likes of Melville and Hawthorne as perpetuators of a colonialist approach to nature or marveling at the subversive strategies of Silko and Dillard. Her assumption seems to be that the nineteenth-century male writers will inevitably "get it wrong" in their representation of nature as a feminine category to be transcended, while the late twentieth-century female writers will "get it right." My approach is to ignore these polarized positions and stake out a third possibility in examining the work of a woman writer for whom gender alone is not, as we have seen, an easy means of identification with others—for whom a hard work ethic was a more important means of identification—in order to see where she fits into the vast gulf between Melville and Dillard, in order to investigate how her novel might be read as a precursor to ecofeminist paradigms.

An Ecofeminist Reading of *Come and Get It*

Let us return to Ferber's novel. That Barney Glasgow has a nakedly exploitative relationship to the land and to women is evident in the very title of the novel *Come and Get It,* the title of which may be read as a double entendre, conflating the desires for (lumberjack) food, (cheap) land, and (extramarital) sex. In fact, at one point, Katie warns the lovely Lotta to be suspicious about the extent of Mr. Glasgow's attentions to her. Her exact words to Lotta—"A girl looks the way you do men just think they can come along and help themselves" (177)—underscore this connection between appetite for food and appetite for sex. Barney's lust to wring profit from the land and his lust to consummate his relationship with the lovely granddaughter of his best friend are clearly equated: he feels he is entitled to both, and his sense of self-restraint towards Lotta is slowly weakening at the point when he is suddenly killed off in the narrative.

Moreover, although his son recognizes the importance of replanting new trees for future generations to harvest, Barney—in his infinite stubbornness and shortsightedness—refuses to do so. Then again, he also lacks the vision to see that his son's plans of inventing paper cups and paper towels for bathrooms are viable economic ventures. So Ferber suggests that Barney's tense and competitive relationship with his son prevents him from perceiving where his future economic success lies. Barney's son Bernie, though not well-developed as a character, represents a kind of progress over his father in the sense that he is more rational, more far-sighted, more genuinely devoted to his wife, and also—interestingly—slightly more androgynous. Bernie never needs to desire a mistress because he is married to the most desirable woman he knows, nor is he a Lydgate character freighted with a gorgeous but insipid wife who cannot understand his ambitions. It is as if Ferber grudgingly rewards him for being more restrained and far-seeing than his father, even though she is not as compelled by him as a character.

In addition to these larger plot contours which indicate Ferber's making a connection between Barney's unbridled desire to harvest as many trees as possible and to possess Lotta, there are at least four identifiable passages from the text which become illuminated by an ecofeminist reading. In these passages, Ferber covers a gamut of attitudes towards women and the environment. Women like the horse-faced Emma Louise are identified as stifling agents of civilization; their association is with smothering domestic interiors which drive Barney to seek the freedom of the almost masculine northern woods. At the same time, insofar as beautiful young women like Lotta are represented as vulnerable, consumable commodities, they are identified with those elements of nature which are, to Barney's way of thinking, "tailor-made" for raping: that is, the forests of pine trees which furnish Barney with lumber. Women also furnish Barney with cheap labor for his rag-paper mills, and they satisfy male appetites—while suppressing their own—in two ways: by feeding the lumberjacks, as Barney's mother does, and by offering men like Barney fantasies of sexual availability and a renewal of youthful vigor, as Lotta does.

Consider the first passage, which occurs relatively early in the novel:

> If the thick, rich routine of the well-ordered household and the feminine possessiveness of Emma Louise and Evelyn threatened to smother [Barney] completely, he escaped to the northern woods whence he had come, and in that pine-laden atmosphere found healing. (12)

Here, manipulative women like Emma Louise are identified as stifling agents of civilization, threatening to smother Barney, virtually forcing him into the healing arms of his mistress, the great outdoors. This theme of Barney's need to escape is developed in the novel: whenever Barney feels oppressed by Emma Louise within the domestic sphere of his home in Butte des Morts, he retreats up north to Iron Ridge, a small camp devoid of the comforts of home but also mercifully devoid of the entrapments and social restrictions imposed by the likes of Emma Louise. Barney feels he can be himself, be authentic, eat simple lumberjack fare, and be bawdy while he is in Iron Ridge. Barney's retreats to Iron Ridge prefigure and foreshadow his illicit desire to make Lotte Lindberg his mistress.

In the second passage, Barney surveys the "Polish and Bohemian" women working in the rag-paper mill:

> Barney had always hated the rag-paper mill over at Grand Chute . . . The rag mill made the finest grade of writing paper obtainable—much superior in texture and quality to the wood-pulp paper manufactured in this Butte des Morts mill. Barney almost never visited it, and only from necessity. He hated the rags piled mountain high; he loathed the rag sorting room with its cloud of dust and lint whirling up from the sorting bins over which the girls bent. They wore pieces of gauze tied across their faces, futilely, to shield mouths and noses. They coughed, and their complexion was a curious clay gray. Polish and Bohemian, most of them, they lived the other side of the tracks or over on the Flats. . . Though the odors of the wood-pulp mill were none too ambrosial Barney did not find them offensive. Of the rag mill he said, "It stinks." He seemed to find something peculiarly obnoxious in the smell of the acids that reduced old rags to the least common denominator of white pulp. Even the magic of the process by which a pair of tattered overalls might be transformed into a fragrant love-missive, or an old shirt or pair of ragged muslin drawers might, Cinderella-like, emerge as a delicately tinted invitation to a ball, did not interest Barney. He liked the process of the wood-pulp mill. Great flat cars out in the yards, loaded with fourteen-foot hemlock spruce, balsam and jack pine, pungent, redolent of the north. (35)

Although the rag paper mill "made the finest grade of writing paper obtainable," Barney rarely visits it. Although the wood pulp mill sends forth fumes every bit as malodorous as those of the rag-paper mill, it is only the latter's fumes that Barney finds offensive. Why the discrepancy between Barney's reaction to the rag-paper mill and the wood pulp mill? Ferber suggests that on some level Barney realizes that his female workers are suffering from their exposures to the chemicals, and he can hardly stand to witness their daily sacrifices of their health for economic survival. Ferber also suggests that perhaps there is something distressingly "feminine" about the rags—a scrounged, found, endlessly folded, and molten set of materials that originate in domestic interiors and that are less "masculine" than the solid, imposing slabs of "fourteen-foot hemlock spruce" found at the wood pulp mills. Lest we miss Ferber's proto-ecofeminist critique, her narrator even imagines how one might more positively view the processing of the rags as a kind of transformative, fairy-tale process by which "an old shirt or pair of ragged muslin drawers might, Cinderella-like, emerge as a delicately tinted invitation to a ball." That allusion to Cinderella underscores the pathetic economic realities of the women who work in Barney's rag-paper mills and the extent to which they perhaps fantasize about the only possible means of escaping their drudgery. Barney is not so much oblivious to their plight as he is sub-consciously shamed by it, hence, his avoidance of the rag-paper mills.

Consider how Ferber rather heavy-handedly underscores the theme of Barney's patriarchal power in this third passage:

> [Barney] was a great grand duke riding toward his duchy—forests, streams, villages. Fish, deer, birds. He liked to survey largely his holdings—his mills, his lands, his crops, his timber, his employees, their families, keeping a firm possessive hand on all. A Goth turned patriarch, but not yet ready to enjoy the benefits of his ravishments. He never looked on his vast possession as an empire, though it was that. To him it was just so many tons of this, acres of that, pounds or square miles or cords of the other. A tree was potential pulp to him, a river something on which to float boats or drive logs. A hill was a rise of ground which might conceal ore, a free waterfall was unharnessed machine power. (66)

Again, this passage most forcefully exemplifies the extent to which we are invited to see Barney as the dominating and dehumanizing patriarch who equates his workers with the stuff of nature—regarding them all in a proprietary light as his possessions, as his subjects, as fodder for his profit, regardless of the short-sightedness of his schemes. The allusion to the Goths, Teutonic peoples who invaded and settled in parts of the Roman Empire in the third to fifth centuries, establishes Barney's transition from invader to settler to patriarch. "Ravishments" nicely concretizes the connection Ferber wishes us to draw between Barney's actual rape of the land and his unrealized desire to rape/seduce young Lotta Lindbeck.

Finally, in the fourth passage, we are treated to an image of woman as provider of the food that she not only cannot enjoy but that sickens her:

> [Barney's mother Nellie] did man's work . . . The great gross mounds of food which daily she provided for the voracious men sickened her. She ate nothing, finally, but a crust of bread and cup after cup of scalding black tea. (84)

Woman is handmaiden to lumber mill productivity though she is alienated from her work; woman is untempted by the highly desired fruits of her labor. That Barney's mother dies of consumption is one of the more interesting ironies in the early parts of this novel; it suggests that what kills her is some self-destructive element as if she has been starved for so long that her body begins to consume itself. Barney never consciously makes the connection between the premature death of his own mother and the short lifespans of the girls working in his rag-paper mill over at Grand Chute—although perhaps he makes it unconsciously, and this is part of his aversion to the rag-paper mill—but we as readers are encouraged to see that he is unconsciously perpetuating a cycle in which poor women are ground up and spit out as they provide cheap labor and profits for the likes of Barney Glasgow.

As in the fiction of her Victorian literary predecessors (and I am thinking more of Charlotte Bronte than of George Eliot now), women are identified with the provision of food for male appetites, but Ferber, unlike her Victorian predecessors, makes a critical distinction between the older female "martyrs" and the younger, more androgynous, more "selfish" females. While the older women in the novel (like Barney's mother and then like Barney's wife) provide ample feasts for the menfolk, they themselves abstain from eating much at all. Barney's wife Emma Louise, though "by nature a stingy woman," "set a lavish table at Barney's insistence" while "sipping coffee and nibbling dry toast" (15). And, as I just noted, Barney's mother, a cook in a lumberjack camp, slowly dies of consumption. But if one is tempted to conclude that Ferber believes that female desire must always be kept in check while male desire runs rampant, one must qualify this generalization by noting that Ferber depicts younger women like Evelyn and Lotta devouring, without restraint, both food and fortunes. Both Evelyn and Lotta have healthy appetites for food and sex—Evelyn committing adultery with her Italian worker on the eve of her wedding, and Lotta doing whatever is necessary to consolidate her social position.

Ferber's Feminism

Just what kind of a feminist is Ferber? Ferber is like George Eliot in being hard to assimilate comfortably under the category of feminist. Both Eliot and Ferber led lives working in a male-dominated profession, but if one examines their novels, one finds that they do not necessarily provide for their heroines the same sort of pathbreaking boldness that they themselves enjoyed. If Eliot's female protagonists are systematically denied the opportunities to fulfill themselves in some sort of meaningful work (their very paucity of options eliciting our sympathies), Ferber's female protagonists in *Come and Get It* take upon themselves the full-time "work" of trying to manipulate wealthy and powerful men. Unlike Eliot, who attempts to penetrate the opacity of even the self-centered Hetty Sorrels and Rosamond de Vincys in her narrative worlds, Ferber invariably caricatures and condemns such female characters who attempt to eschew hard work by playing upon their feminine wiles; her sympathies are always with the under-appreciated working class women (the nannies, the waitresses) who serve such entitled women. Class privilege, then, becomes the dividing line across which Ferber's sympathies cannot pass—unless, that is, the female who inherits such privilege still takes solace in the stabilizing effects of hard work.

Yet as I mentioned earlier, Ferber herself was an unusually outspoken woman and perhaps slightly ahead of her time, insofar as she was able to succeed in a man's world. In one of her autobiographies, she writes: "If men ever discover how tough women actually are they'll be scared to death. And if women ever decide to throw away that mask, wig and ruffled kimono and be themselves, this will be another [female-dominated] monarchy—and perhaps it's about time" (quoted in Gilbert 82). In *Come and Get It,* she is somewhat interested in depicting power struggles between the sexes, and she is sympathetic to smart women who are deprived of the opportunity to make the best use of their talents in the work force. For example, at one point her narrator expresses sympathy for Barney's daughter Evelyn, who is smart enough to run a paper mill but is forced by social convention into marrying a man she does not love: "Born out of her day she could, ten years later, have run one of her father's mills; driven an ambulance in France; started a career of her own choosing. And now Evelyn was to be married" (21). Ferber also represents sympathetically the hard-working, plain Karie Lindbeck because Karie never loses her down-to-earth self, even among the crowned heads of Europe, and because Karie remains with her social-climbing daughter despite the fact that she "work[s] harder than any servant you got, only I don't get paid for it" (431).

Still, it is perhaps a bit wishful for us to call Ferber a feminist or even a proto-feminist. While a woman writer like George Eliot might be willing to soften her judgment towards those beautiful female characters who end up doing great harm to themselves and others, Ferber has little patience for those beauties like Lotta who trade on their looks in order to advance themselves up the social ladder. Given the premium she puts on the value of hard work, it is entirely understandable that she resent those who need do no work other than apply make-up and then go out and seduce lumber barons. However, one cannot help but wonder—politically incorrectly, of course—if her being the plain sister of a beautiful woman might not have played a role in Ferber's scathing contempt for the opportunistic blond bombshell Lotta. Then again, Ferber never makes any effort to represent sympathetically the bourgeois, horse-faced wife of Barney Glasgow either. Indeed, the narrator seems just as judgmental of Emma Louise as Barney is: "It was incredible that any woman—even a plain woman of 56 who has been married years before for her money, and knows it—could be so utterly lacking in coquetry as to appear before a man in such grim habiliments" (10). Disappointingly, there are no moments in the narrative when Ferber's narrator attempts to enter into the consciousness of Emma Louise, never attempts to imagine what it might feel like to be a homely woman married for one's money. Perhaps the topic was a little too close to home for Ferber, who was—again, like George Eliot—widely regarded as a plain, hard-featured woman.

Conclusions

Would it be fair to call Ferber an early ecofeminist? At times, she seems like one, especially when she writes such lines as "A tree was potential pulp to [Barney], a river something on which to float boats or drive logs. A hill was a rise of ground which might conceal ore, a free waterfall was unharnessed machine power" (66). Although he prides himself on exercising great self-restraint when he does not actually rape Lotta, Barney is equally exploitative of both women and nature: in Karie's words, he thinks he can "come along and help [himself]" to a portion of forest and Lotta. As I have also noted, the title "Come and Get It" reflects not just the call to meal time[2] but Barney's greed in acquiring land cheap from the government in order to rape it of its trees. And the "it" in "Come and Get It" takes on clearly sexual undertones when Barney contemplates the seduction of Lotta.

In her developing of the character Barney Glasgow as a power-hungry, dominating, greedy, ruthless, opportunistic, and wasteful patriarch, Ferber certainly seems to be advancing a proto-ecofeminist critique. Barney is a patriarch tailor-made for an ecofeminist critique, although, to be fair, he also provides the novel with its most vital energies: Ferber realized that as an artist she sacrificed the aesthetic design of her novel when she killed him prematurely.

However, and this is why I feel I must qualify my stance by acknowledging that one is only "tempted" to pronounce her a proto-ecofeminist, Ferber never really sustains a pro-woman or pro-environment stance for very long. Perhaps for all her bravado and swagger in her diaries and autobiography, she sensed in this novel that she was engaging in a kind of cultural critique that was, like Evelyn Glasgow, about fifty years ahead of its time. I suspect she had some reservations about making the truly scathing and sustained challenge to patriarchal authority that she could have made if she were, say, Margaret Atwood.

Finally, the novel is not about progressive ideology so much as it is about the sustaining quality of certain values, an ideological stance of a more traditional sort. Women and men who work hard and never lose their appreciation for the moral value of hard work fare best in this novel. Beautiful women who expect their looks to work for them are ostracized and unhappy; successful men who have stopped working with their hands die prematurely. The message is clear: those who continue to work hard, to endure privation, to avoid being seduced by the trappings of material success into becoming what they are not are those who thrive and live to be 85. If there are seeds of a proto-ecofeminist sensibility in the work of Edna Ferber, they remain intact and identifiable but in a largely dormant state.

Endnotes

[1]Interestingly, in the movie version of the novel, that mistake would not be repeated; director Howard Hawkes insured that Barney would remain alive at the end of the film, unpunished for his sins of lust and greed.

[2]At the end of Hawkes' film based on the novel, Barney sadly witnesses the elopement of Lotta and his son, all the while banging tearfully on a triangle and shouting "Come and get it!" to the guests at his party. It is as if the old man is forced to reconcile himself to his newfound role as passive provider for the appetites of others when his own appetites (for sex, for domination over Lotta) cannot be satisfied. The dinner triangle that he bangs also visually reinforces the idea of a triangulated state of affairs between (failed) father, (successful) son, and the love object (Lotta) whom they both desire.

Works Cited

Dickinson, Rogers. *Edna Ferber: A Biographical Sketch with a Bibliography.* New York: Doubleday, Page & Co., 1925.

Ferber, Edna. *A Kind of Magic.* New York: Doubleday & Company, Inc., 1963.

Ferber, Edna. *A Peculiar Treasure.* New York: Doubleday, Dora & Company, Inc., 1939.

Ferber, Edna. *Come and Get It.* Madison, Wisconsin: Prairie Oak Press, 1991.

Mies, Maria and Vandana Shiva. *Ecofeminism.* New Jersey: Zed Books, 1993.

Warren, Karen J., ed. *Ecofeminism: Women, Culture, Nature.* Indiana: Indiana University Press, 1997.

Ellen Argyros** is an assistant professor of English literature at the University of Wisconsin-Fox Valley. Her book,* The Limits of Sympathy in George Eliot's Novels, *is forthcoming in 1999 from Peter Lang Press. She is also interested in representations of maternal subjectivity in the works of George Eliot, Harriet Beecher Stowe, Virginia Woolf, Toni Morrison, and Louise Erdrich.* ***Address: *UW-Fox Valley, P.O. Box 8002, Menasha WI 54952.*

Ed L. Avery and Kent Niermeyer

Timing of Spawning and Fry Emergence of Brown Trout in a Central Wisconsin Stream

Abstract *The spawning period and timing of peak fry emergence of brown trout* (Salmo trutta) *were studied during 1995–96 in a 1.2-km reach of a central Wisconsin trout stream. This information was collected to help the Wisconsin Department of Natural Resources determine if a potential for egg and pre-emergent fry mortality from angler wading would exist if a special regulation early trout fishing season (1 March to the first Saturday in May) was established in 1997.*

Weekly reconnaissance of the study area was made to count and identify new trout redds. Free-swimming fry counts were made on a weekly basis in three 20-m subsections. The spawning period spanned 3.2 months (12 October 1995 through 19 January 1996) with peak activity (77% of all redds constructed) occurring between 28 October and 8 December. The median date of spawning was 20 November. Emergence of brown trout fry began the week of 15–22 March 1996, peaked around 25 April, and extended into early May. Residence of eggs and pre-emergent fry in streambed gravels approximated five months equivalent to 636 Centigrade thermal units. A potential for trout egg and pre-emergent fry mortalities due to angler wading would exist if an early trout fishing season were implemented. Comparisons of the 1997 year-class strength of trout with long-term average year-class strength in several wisconsin trout streams did not, however, show any effect of an early trout fishing season implemented in 1997.

In 1995, controversy among members of Wisconsin Trout Unlimited chapters, other nonaffiliated trout anglers, and the Wisconsin Department of Natural Resources (DNR) was initiated by a DNR proposal for a special regulation early trout fishing season that would open on 1 March 1997 and extend to the first Saturday in May when the regular trout fishing season started. The proposed "early season" would apply statewide to inland streams and would be limited to catch-and-release only with artificial lures and barbless hooks. The DNR's proposal was made to fulfill a commitment to the angling public to replace a previous (1975–94) early trout fishing season in eight to ten southwestern counties. That early season was closed due to strong local resentment of excessive use of the resource by anglers from outside this small region of the state. Proponents of the new "early season" argued that it would provide additional recreation for anglers, disperse angling pressure over the entire state, not increase annual harvest, and cause little damage to trout populations. Opposing opinion, however, centered around a study done in Montana that revealed high mortality to brown trout, rainbow trout *(Oncorhynchus mykiss),* and cutthroat trout *(Oncorhynchus clarki)* eggs and pre-emergent fry caused by anglers wading on trout redds (Roberts 1988, Roberts and White 1992). This Montana study suggested a linkage between wading-induced egg and fry mortalities in Nelson Spring Creek, a tributary to the Yellowstone River, and reduced adult populations of cutthroat trout in the Yellowstone River.

Unlike cutthroat trout, which is spring-spawning, the two trout species most common in Wisconsin are brook trout *(Salvelinus fontinalis)* and brown trout, both of which spawn in the fall. Because most fry of brook trout and brown trout are free-swimming in Wisconsin when the regular fishing season opens in May, egg and fry mortalities due to anglers wading on redds had not been an issue. However, the proposed early trout fishing season posed a potential for such wading-related mortalities that would be at least partially dependent upon timing of fry emergence from stream-bed gravels.

A search of the scientific literature on egg incubation-fry emergence periods of fluvial brook trout and brown trout in Wisconsin yielded few papers. Miller (1970) quantified the fry emergence period of brook trout in Lawrence Creek in central Wisconsin, and Hausle and Coble (1976) contributed additional observations on the incubation period of brook trout eggs in both natural and artificially constructed redds in Lawrence Creek. Avery (1980) reported observations on brown trout spawning and fry emergence during 1976–78 in Trout Creek in southern Wisconsin. The objective of the present study was to quantify the duration and peak spawning of brown trout as well as the timing of fry emergence in Emmons Creek in central Wisconsin. This information would help the DNR assess potential egg and fry mortality for brown trout from angler wading in the southern half of Wisconsin, where brown trout are the dominant species and where most angling would occur during the proposed early season because of milder weather and ice-free stream conditions.

Study Area

Emmons Creek is typical of many high quality trout streams in central Wisconsin. It originates from 6.5-ha Fountain Lake in Portage County and flows east-northeast 9.7 km before entering the 293-ha Chain O' Lakes in Waupaca County. Numerous springs augment the flow of Emmons Creek throughout its entire length. Gravel substrates are common and provide ample spawning habitat for a wild resident brown trout population that averages 1,740 fish/km (Avery and Hunt 1981). Sand is the dominant substrate. More than half the

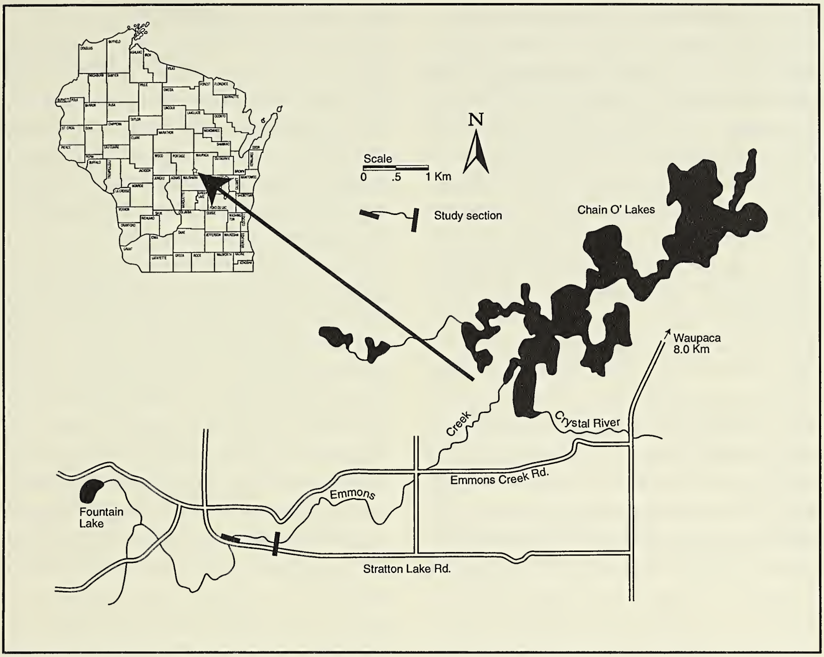


Figure 1. Emmons Creek study area.

stream is in state ownership (public fishing and hunting areas), and little livestock grazing or row-crop agriculture occurs in the watershed. Streamflow is very stable, averaging 0.62 m^3/s. Gradient approximates 2.8 m/km. Stream temperatures rarely exceed 18.5°C, alkalinity ranges from 161–186 mg/l $CaCO_3$, and pH ranges from 7.9–8.2 (Avery and Hunt 1981). Aquatic vegetation is sparse, and the water remains clear except for brief periods following extended heavy rainfall events. The food base for brown trout consists primarily of aquatic and terrestrial invertebrates. Instream habitat is good with undercut banks and woody debris providing important instream cover. In addition to the resident stream population, wild brown trout in the Chain O' Lakes ascend Emmons Creek in the fall to spawn. A 1.2-km reach of Emmons Creek was selected for study in the upper half of the watershed immediately below the Stratton Lake Road bridge (Figure 1).

Materials and Methods

Trout Spawning Period

Weekly reconnaissance of the 1.2-km study area was made between 3 October 1995 and 26 January 1996 to count brown trout redds and determine the spawning period. Each redd identified was numbered consecutively, and the date was recorded. Distance from the "pit" of each redd (Reiser and Wesche 1977) was triangulated (measured) to two numbered wooden stakes driven into the nearest streambank. The two stakes were placed parallel to the streamflow and separated by 3.0–4.5 m. Frequently, from three to six redds were triangulated to the same two stakes. Triangulation of individual redds prevented recounting of previous redds on subsequent visits to the stream and helped determine the occurrence and amount of redd superimposition.

Egg Incubation and Fry Emergence Period

In late January 1996, 20-m stream segments were selected in the upper, middle, and lower reaches of the 1.2-km study area in which trout fry could be visually counted along both stream margins. Stream segments were selected below concentrations of trout redds that had been constructed throughout the entire spawning period. Fry counts were made weekly between 8 February and 25 April. We carefully entered the stream below each study segment and waded slowly up the middle of either the right or left half of the stream, tallying all fry seen within the study segment. Fry were counted in water depths less than 30 cm. This generally excluded the stream thalweg due to its greater depth, higher water velocities, and attendant poor fry visibility. We exited the stream above the study segment, returned to the lower end, and repeated the procedure in the other half of the stream. All fry counts were made between 11:00 and 13:30 hours with the aid of polarized sunglasses. Fry counts were discontinued with the 25 April count because on 3 May fry sought cover so quickly at my approach that an accurate count was impossible.

Stream margins of two of the three 20-m segments were electrofished using a battery-powered, pulsed, dc back-pack electrofishing unit on 15 March 1996 to verify the presence or absence of fry. Similar to the fry counts, electrofishing was conducted in water depths less than 30 cm and excluded the thalweg. Stream margins of all three 20-m segments were electrofished on 19 April 1996 to compare numbers of fry captured with numbers of fry counted.

On 19 April 1996, five redds constructed during the first half of the spawning season were excavated to observe the degree of egg and pre-emergent fry development and to correlate development with the date of redd construction and counts of free-swimming fry. Three additional redds, constructed during the six-week peak spawning period, were excavated on 26 April, and five redds, constructed near the end of the peak spawning period, were excavated on 3 May for the same purposes. A piece of window screen attached to a wooden frame hinged vertically in the middle (effective height and width, 105 x 125 cm) was held downstream from the redds to catch eggs and fry dislodged as the redds were dug up with a shovel. Eggs and pre-emergent fry impinged on the screen were removed either manually with forceps or orally with a plastic suction tube (9.0 mm inside diameter), placed in a container, and counted.

Water temperature was recorded near the lower end of the study area from 29 September 1995 through 17 May 1996 using a RTM 2000 thermograph (Ryan Instruments, Inc., Redmond, Washington) programmed to record hourly. Mean daily water temperatures (MDT) were computed from the hourly readings. Incubation and hatching periods are expressed in terms of both time and accumulative Centigrade thermal units. Centigrade thermal units were calculated as the sum of mean daily water temperatures above 0°C.

Results

The Spawning Period

The spawning period for brown trout in Emmons Creek covered approximately 3.2 months, beginning 12 October 1995 and ending 19 January 1996 (Figure 2; Table 1). During this period, 162 trout redds were constructed in the study area. Peak spawning activity occurred during the six-week period of 28 October through 8 December 1995 when 77% (124) of the identified redds were constructed. The median date of spawning (i.e., the date on which 50% of the redds had been constructed) was 20 November. Spawning began when MDTs dropped below 12.7°C and increased substantially in early November when MDTs dropped below 9.0°C. Mean daily water temperatures during the peak spawning period declined from 8.8°C to 0.6°C.

Approximately 27% (44) of trout redds were at least partially superimposed upon redds constructed from one to six weeks prior (Table 1). Of the superimposed redds, 48% (21) occurred on redds constructed the previous week. Some of the latter redds may have been incomplete when first observed, i.e., part of a multiple-pit spawning site constructed by the same female (Hawke 1978, DeVries 1997), rather than new redds constructed by totally different fish. Peak superimposition, 33 of 44 superimposed redds, occurred during the six-week peak spawning period.

Egg Incubation and Fry Emergence Period

Emergence of brown trout fry from gravel substrates began in mid- to late-March 1996 and peaked during late April (Table 2). Fry were first observed along the stream margins in two of the three reference

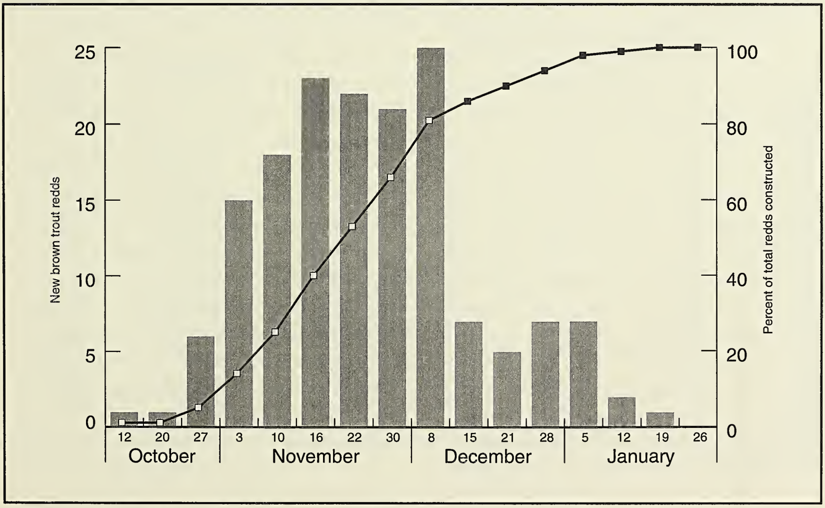


Figure 2. Chronology of brown trout spawning in Emmons Creek, fall/winter 1995–96.

Table 1. Weekly brown trout redd counts, range of mean daily water temperatures (MDT), and accumulative Centigrade thermal units (TU) in Emmons Creek from 10/12/95 through 1/26/96 (superimposed redds in parentheses).

Date	*Number of New Redds*	*Accumulative Redd Total*	*MDT Range C*	*Accumulative TU's*
1995				
10/12	1	1	9.8-12.7	29[a]
10/20	1	2	8.2-10.6	107
10/27	6 (1)	8	7.5- 9.0	164
11/03	15 (1)	23	4.8- 8.8	212
11/10	18 (6)	41	2.9- 6.2	244
11/16	23 (7)	64	3.2- 4.9	267
11/22	22 (6)	86	1.6- 5.1	291
11/30	21 (4)	107	1.7- 4.4	313
12/08	25 (9)	132	0.6- 5.0	338
12/15	7 (2)	139	0.0- 3.3	346
12/21	6 (3)	145	1.7- 3.8	363
12/28	7 (3)	152	0.9- 3.9	380
1996				
1/05	7 (2)	159	1.4- 4.6	403
1/12	2	161	1.3- 4.8	423
1/19	1	162	1.1- 5.0	451
1/25	0	162	1.0- 4.2	468

[a] Computed from 10/10/95.

Table 2. Weekly brown trout fry counts, range of mean daily water temperatures (MDT), and accumulative Centigrade thermal units (TU) in Emmons Creek from 2/02/96 through 5/03/96 (fry captured with electrofishing gear in parentheses).

	Brown Trout Fry Counted					
	Station Number				*MDT Range*	*Acc.*
Date	*1*	*2*	*3*	*Total*	*C*	*TU's*
1996						
2/02	0	0	0	0	0.1- 2.4	477[a]
2/08	0	0	0	0	0.2- 5.7	493
2/15	0	0	0	0	2.9- 5.7	525
2/22	0	0	0	0	2.4- 5.6	554
2/29	0	0	0	0	2.4- 5.8	585
3/08	0	0	0	0	1.7- 4.2	607
3/15	0	0 (0)	0 (0)	0 (0)	3.4- 6.9	646
3/22	8	0	3	11	4.9- 6.0	684
3/29	8	1	1	10	2.7- 6.3	718
4/05	6	0	4	10	5.0- 6.9	759
4/12	5	0	3	8	5.9- 9.7	809
4/19	18 (34)	9 (19)	19 (47)	46 (100)	6.0-11.6	866
4/25	27	15	16	58	9.5-10.7	927
5/03		Fry Not Counted				

[a] Continued from Table 1.

stations on 22 March. The week before, fry were neither observed nor captured with electrofishing gear. Fry observed in late March tended to hold their position along the shallow stream margins at the careful approach of an observer.

On 19 April 1996, 46 fry (0.8 fry/m of stream) were observed in the three stations and represented a four- to six-fold increase from fry numbers observed during each of the four previous weekly counts (Table 2). Electrofishing also captured 19–47 fry per station and provided a conservative estimate that only 47% of the fry present were being counted. Numbers of fry counted in the three stations peaked at 58 (1.0 fry/m of stream) on 25 April. Many fry observed on 25 April were extremely wary and quickly found cover when they detected the observer.

Eleven of thirteen trout redds constructed before (two redds) or during (eleven redds) the six-week peak spawning period (28 October to 8 December 1995) and excavated on or after 19 April 1996 contained primarily dead eggs or fry, corroborating the emergence of most live fry during the last two weeks of April (Table 3.) The two remaining redds (numbers 12 and 13 in Table 3) were excavated on 3 May 1996 and contained primarily live, pre-emergent fry. Since 30 redds (19% of the total) were constructed subsequent to the peak spawning period (Table 1), fry from these late redds probably emerged even later in May. Peak spawning and peak fry emergence approximated 22 November 1995 and 25 April 1996, respectively; therefore, residence of eggs and pre-emergent fry in streambed gravels approximated five months or an equivalent of 636 Centigrade thermal units (Tables 1 and 2).

Discussion

The spawning period and peak spawning activity of brown trout in Emmons Creek were similar to those observed for brown trout in Trout Creek located in southern Wisconsin but much later than in Minnesota, Michigan, and Ontario streams. Avery (1980) observed brown trout spawning in Trout Creek between 19 October and 12 January during 1976–77 and 1977–78, with peak spawning activity occurring in November through mid-December. Sorensen et al. (1995) observed brown trout spawning in Valley Creek, Minnesota, between 12 October and 22 November 1990–92. During 1976–78, Anderson (1983) observed brown trout spawning from the first week of October through November in six other Minnesota streams with peak spawning occurring between 13 October and 14 November. The spawning season approximated 15 October to 10 November in a Lower Michigan stream during 1969–71 (Hansen 1975), while Witzel and MacCrimmon (1983) observed brown trout spawning between 8 October and 19 November in five southwestern Ontario streams during 1977–78.

Although peak emergence of brown trout fry occurred in late April 1996 in Emmons Creek, peak emergence of brown trout fry in Trout Creek occurred four to six weeks earlier in late February through March 1976–78 (Avery 1980). Mean weekly temperatures in Trout Creek averaged 2.2°C warmer in December 1975 through early January 1976 than for the same period in 1995–96 in Emmons Creek. Thus, while brown trout spawn about the same time in central and southern Wisconsin, warmer water temperatures in southern Wisconsin generally contribute to earlier

Table 3. Brown trout eggs and pre-emergent fry observed in 13 redds excavated in Emmons Creek on 19 and 26 April and 3 May 1996 (TU = accumulative Centigrade thermal unit; DE = dead eggs; D = dead; L = live; S = sac; F = fry).

Redd Number	*Date Observed*	*Date Excavated*	*Days in Streambed*[a]	*Accumulative TU's*[a]	*Eggs/Fry Present*
1 & 2[b]	10/20/95	4/19/96	185	798	130 DE
	10/27/95		178	730	
3	11/10/95	4/19/96	164	638	45 DE
					4 DSF
					17 LSF
4	11/16/95	4/19/96	158	611	79 DE
					8 DSF
					15 LF
5	11/30/95	4/19/96	145	564	108 E
6	11/10/95	4/26/96	171	708	46 DE
					6 DF
					6 LF
7	11/16/95	4/26/96	165	681	30 DE
					16 DSF
					2 LSF
					2 LF
8	12/08/95	4/26/96	144	610	260 DE
					3 DSF
					4 LSF
9	12/08/95	5/03/06	151	670	16 DE
10	12/08/95	5/03/96	151	670	6 DE[c]
11	12/08/95	5/03/96	151	670	1 DE[c]
12	12/08/05	5/03/96	151	670	6 DE
					1 DF
					8 LF
13	12/08/05	5/03/96	151	670	5 DE
					1 DF
					8 LF

[a] Computed from 10/10/95, two days prior to the date the first redd was observed.
[b] Redd number 2 was superimposed on redd number 1.
[c] Thousands of white sucker eggs present.

emergence of brown trout fry than in similar high-quality trout streams in central Wisconsin.

In relation to the proposed early trout fishing season opening 1 March in Wisconsin, the majority of brown trout eggs and pre-emergent fry will still be in the gravel when the fishing season opens. Although brook trout spawn one to three weeks earlier than brown trout (Witzel and MacCrimmon 1983, Sorensen et al. 1995) and in central Wisconsin emerge from instream gravels three to four weeks earlier than brown trout (Miller 1970), some eggs and pre-emergent brook trout fry will also be in the gravel when the early fishing season opens. This study clearly suggests that anglers wading in Wisconsin trout streams during March and April could increase egg and fry mortalities by walking on trout redds. Whether or not such wading mortality occurs, and to what extent such additional mortality (if it occurs) will express itself at the population level, will be directly related to the wading activity of anglers and the recruitment dynamics of trout in each stream.

Tentative Management Conclusions

The special regulation early trout fishing season proposed by the DNR in 1995 was approved by the Natural Resources Board in May 1996 and took effect beginning 1 March 1997. As approved, the early season has a "sunset clause" after three years, at which time DNR fisheries staff will review the pros and cons of the season and recommend changes if any are determined to be needed. Comparisons of the fall 1997 year class strength in several central and southern Wisconsin trout streams with the long-term average year class strength in the same streams failed to show any detectable effect of the early trout fishing season on year class strength (L. Claggett, personal communication 1998).

Acknowledgments

Grateful appreciation is extended to Lawrence Claggett, Wisconsin DNR Coldwater Fisheries Ecologist; DuWayne F. Gebken, Wisconsin DNR Aquatic Ecological Systems Section Chief; Robert L. Hunt, retired Wisconsin DNR Cold Water Research Group Leader; Michael Bozek, Assistant Leader Cooperative Fisheries Unit, University of Wisconsin-Stevens Point; William Thorn, Minnesota DNR; and Bruce C. Roberts, Beaverhead-Deerlodge National Forest-Wisdom, Montana, for technical review of manuscript drafts. Funding for this study was provided through the Federal Aid in Sport Fish Restoration program and by the Wisconsin Department of Natural Resources.

Literature Cited

Anderson, D.W. 1983. Factors affecting brown trout reproduction in southeastern Minnesota streams. Minnesota Department of Natural Resources. Investigational Report No. 376, St. Paul.

Avery, E.L. 1980. Factors influencing reproduction of brown trout above and below a flood water detention dam on Trout Creek, Wisconsin. Wisconsin Department of Natural Resources. Research Report 106, Madison.

Avery, E.L., and R.L. Hunt. 1981. Population dynamics of wild brown trout and associated sport fisheries in four central Wisconsin streams. Wisconsin Department of Natural Resources. Technical Bulletin 121, Madison.

DeVries, P. 1997. Riverine salmonid egg burial depths; review of published data and implications for scour studies. *Canadian Journal of Fisheries and Aquatic Science* 54:1685–98.

Hansen, E.A. 1975. Some effects of groundwater on brown trout redds. *Transactions of the American Fisheries Society* 104(1):100–10.

Hausle, D.A., and D.W. Coble. 1976. Influence of sand in redds on survival and emergence of brook trout *(Salvelinus fontinalis). Transactions of the American Fisheries Society* 105(1): 57–63.

Hawke, S.P. 1978. Stranded redds of quinnat salmon in the Mathias River, South Island, New Zealand. *New Zealand Journal of Marine and Freshwater Research* 12:167–71.

Miller, J.M. 1970. An analysis of the distribution of young-of-the-year brook trout, *Salvelinus fontinalis* (Mitchell), in Lawrence Creek, Wisconsin. Ph.D. thesis. University of Wisconsin-Madison.

Reiser, D.W., and T.A. Wesche. 1977. Determination of physical and hydraulic preferences of brown and brook trout in the selection of spawning locations. Water Resources Series No. 64. Water Resources Research Institute, University of Wyoming, Laramie.

Roberts, B.C. 1988. Potential influence of recreational use on Neson Spring Creek, Montana. Master's thesis. Montana State University, Bozeman.

Roberts, B.C., and R.G. White. 1992. Effects of angler wading on survival of trout eggs and pre-emergent fry. *North American Journal of Fisheries Management* 12:450–59.

Sorensen, P.W., J.R. Cardwell, T. Essington, and D.E. Weigel. 1995. Reproductive interations between sympatric brook and brown trout in a small Minnesota stream. *Canadian Journal of Fisheries and Aquatic Science* 52: 1958–65.

Witzel, L.D., and H.R. MacCrimmon. 1983. Redd-site selection by brook trout and brown trout in southwestern Ontario streams. *Transactions of the American Fisheries Society* 112:760–71.

Ed L. Avery *is an Advanced Research Scientist with the Wisconsin Department of Natural Resources. He has published more than 25 peer-reviewed and popular articles focusing on salmonid research and the management of coldwater ecosystems.* ***Address:*** *Department of Natural Resources, Rivers and Streams Research Station, 11084 Stratton Lake Road, Waupaca, Wisconsin 54981.* ***Email:*** *averye@dnr.state.wi.us*

Kent Niermeyer *is a Natural Resource Technician 3 with the Wisconsin Department of Natural Resources. He has spent the past 29 years assisting in salmonid research statewide.* ***Address:*** *Department of Natural Resources, Rivers and Streams Research Station, 11084 Stratton Lake Road, Waupaca, Wisconsin 54981.* ***Email:*** *niermk@dnr.state.wi.us*

Terry Balding

Detections of Red-Shouldered Hawks *(Buteo lineatus)* Using High Volume Tape-Recorded Broadcasts

Abstract *Conspecific tape-recorded broadcasts (N = 196) were used from 1986 to 1989 to evoke 71 detections of the red-shouldered hawk* (Buteo lineatus). *The objective of this study was to determine the effect of decibel (db) level on detections. During 1987–1989 a significantly greater number* ($P < 0.05$) *of red-shouldered hawk detections occurred with a 130 db tape-recorded broadcast when compared to 95 db broadcast. Results suggest that a 130 db tape-recorded broadcast could be used to increase the number of detections of red-shouldered hawks during the courtship and nesting season.*

The U.S. Fish and Wildlife Service (1987) recognizes the red-shouldered hawk *(Buteo lineatus)* as a species of management concern, and the Wisconsin Department of Natural Resources (1991) lists the red-shouldered hawk as a threatened species in Wisconsin. Therefore, it is important to learn more about this species. One method would be to select a permanent survey route, use a tape-recorded broadcast to evoke detections, and then monitor the trend over a period of years.

The red-shouldered hawk in Wisconsin is often associated with heavily wooded flood plain forests (Robbins 1991). In this habitat it usually spends much of its time below the canopy and does not voluntarily vocalize often; consequently it is typically a difficult bird to locate. Johnson et al. (1981) suggested that a broadcast could increase the chances of encountering some species of birds when compared to conventional survey techniques. Conspecific broadcasts have been shown to elicit detections in the red-shouldered hawk (Fuller and Mosher 1981, Balding and Dibble 1984, Fuller and Mosher 1987, Johnson 1989, Mosher et al. 1990, McLeod 1996). Balding and Dibble (1984) reported more detections to conspecific broadcasts than heterospecific hawk broadcasts with red-tailed hawk *(Buteo jamaicensis),* broad-winged hawk *(Buteo platypterus),* and red-shouldered hawk. Great horned owl *(Bubo virginianus)* broadcasts have also been used effectively to produce red-shouldered hawk detections (Iverson 1987, Devaul 1989, Iverson and Fuller 1991, Mosher and Fuller 1996).

Most studies using broadcasts to elicit a raptor detection used a tape player that produced a broadcast volume, measured in decibels (db), of about 100 db (Fuller and Mosher 1987, Devaul 1989, Johnson 1989, Mosher et al. 1990, McLeod 1996). This db level can generally be heard by humans 750 m from the speaker, assuming the human hears well and there are no barriers or background noises (Mosher et al. 1990). Balding and Dibble (1984) suggested that a broadcast with 130 db, which could be heard by humans at 1600 m (pers. obs.), would result in a greater number of detections. However, that work was with three species and did not focus on the red-shouldered hawk. The focus of this study, conducted 1987–1989, was to test whether more stations would have detections using 130 db volume compared to a conventional portable tape-recorder volume (95 db), specifically on red-shouldered hawks, using a conspecific broadcast.

Study Area

Because of the proximity of the Chippewa River in west-central Wisconsin and the occurrence of red-shouldered hawk habitat in the riparian corridor, the lower Chippewa River was established as the study area (Figure 1). A 70 km reach of the Chippewa River from near Rock Falls, Wisconsin, to the confluence with the Mississippi River was used as a transect. Natural landmarks were used to identify twenty-eight permanent broadcast stations along this transect, approximately 2.5 km apart.

Methods

Two surveys were completed each year (1987–1989) between 4–12 April and 5–15 June. These dates were used because by 4–12 April, migrant red-shouldered hawks have passed through the area, and residents are in courtship (Buss and Mattison 1955). During 5–15 June the birds are with nestlings (Buss and Mattison 1955). The incubation period was avoided because of speculation that study activities might increase the risk of nest predation. Broadcasts were not conducted after the nestling period because they may have generated detections from the fledglings and biased the estimate of the adult population. Surveys began at 0800 hr and were completed the same day around 1600 hr and were only conducted on days with <16 kph wind and no precipitation. Data from April and June surveys were paired by year and analyzed using a paired *t*-test ($\alpha <$ = 0.05). Balding and Dibble (1984), using conspecific broadcasts with three *Buteo* species, found when five conspecific broadcasts were given at a broadcast station the majority (93.8%) of the birds were detected during the first three broadcasts. Therefore, in this study only three conspecific broadcasts were used at each station with one-minute intervals between broadcasts to detect red-shouldered hawks either aurally, visually, or both. If a red-shouldered hawk was detected, no further broadcasts were given at that broadcast station. During surveys the speaker was directed toward one shoreline (arbitrarily decided), then the

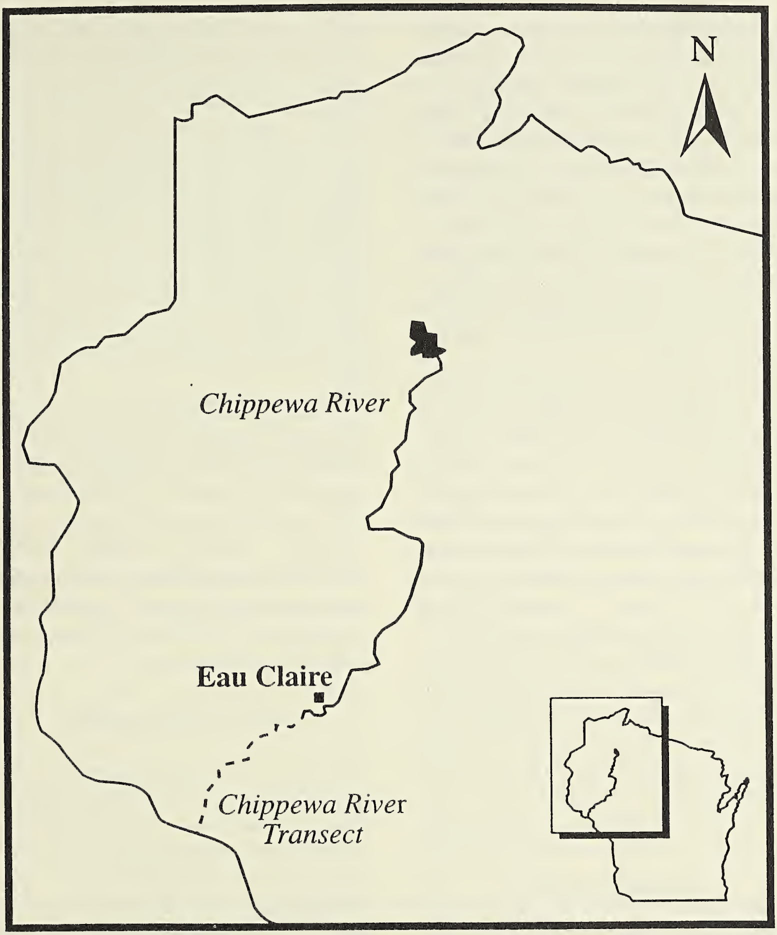


Figure 1. Seventy kilometer transect on the Chippewa River, Wisconsin, for tape-recorded call census of the red-shouldered hawk, 1986–1989.

opposite shoreline, and finally back to the original direction. A boat with an outboard motor was used to carry equipment and move between stations.

At each broadcast station there were two series of three conspecific broadcasts used. The first series of broadcasts used the maximum volume of a Marantz Superscope tape recorder. A Simpson model 886 sound level meter was used to determine that this volume, hereafter referred to as low db, registered 95 db one meter from the speaker. If no response occurred to the first series of low db broadcasts at a station, then a second series of three broadcasts were given, this time using the tape recorder connected to a Sanyo P6060 amplifier and a hand-held Atlas 30-watt speaker. With this combination a broadcast was generated that was 130 db one meter from the speaker, hereafter referred to as high db broadcast. Within years the proportion of detections from high db were paired with the proportion of detections from low db and analyzed using a paired *t*-test ($\alpha < = 0.05$).

The experimental design used (three low then three high db broadcasts at one station) was based on the assumption that detection probability would not increase with the number of broadcasts. This assumption is supported by data from Balding and Dibble (1984), where five sequential high db broadcasts from each station resulted in detections of 38, 26, 28, 2, and 2. Johnson (1989) and McLeod (1996), working with the red-shouldered hawk and using methodology with four conspecific 100 db broadcasts and six conspecific 100–110 db broadcasts, respectively, also observed there was not an increase in birds detected with an increase in the number of broadcasts.

The above design was chosen over visiting the same broadcast station several times and each time randomly choosing three high or three low db broadcasts. Repeated visits to the same broadcast station risk habituation, when animals become non-responsive or less responsive because of repeated exposure to the same stimuli. Johnson et al. (1981) suggested that habituation to repetitive broadcasts may lower detection rates. However, Johnson (1989), Devaul (1990), and Mosher et al. (1990) found little evidence of habituation in the red-shouldered hawk. Additionally, subsequent replications may be broadcast in a different part of the breeding cycle where response rates may be different. McLeod (1996) observed that response rates dropped as the season progressed.

Data collected at each station included date; weather; time of day; broadcast volume; number of birds detected per station; number of broadcasts given before detection; number of vocalizations given per bird; direction from the speaker when the bird was detected; whether the bird was detected aurally, visually, or both; and estimated distance of the broadcast from the detected bird.

The red-shouldered hawk tape recording used in this study was purchased from the Cornell Laboratory of Ornithology and manipulated by University of Wisconsin-Eau Claire media development to consist of three “keeahh’s” and four “keeyip’s” (Crocoll 1994). Using high db broadcasts, a preliminary survey was completed on 26 June 1986 to determine if red-shouldered hawks were present along the transect.

Results and Discussion

Over all years combined, the 1986 preliminary survey and the 1987–1989 surveys, red-shouldered hawks were detected at 36% (71 of 196) of the broadcast stations. Sixty-seven percent (48 of 71) of the responding red-shouldered hawks vocalized more than twice, 38% (27 of 71) moved closer to the broadcast, and 73% (52 of 71) vocalized but were never seen. Likewise, Johnson (1989) reported 70.6% of red-shouldered hawks vocalized but were not seen. In this study, on only one occasion was a bird detected by visual means but not heard vocalizing. It appears the red-shouldered hawk is more likely to be detected when it vocalizes in response to a broadcast rather than be detected only visually.

Comparison of Detections Between Courtship and Nestling Stage

Using high db broadcasts, there was no significant difference (paired *t*-test = 1.73, N = 3 years, $P > 0.05$) in the number of red-shouldered hawks responding between courtship stage and nestling stage. Therefore, in this study high and low db broadcasts from April and June were pooled within years. Mosher et al. (1990), using 100–110 db broadcasts, also noted no difference between red-shouldered hawk contacts among breeding stages, pre-incubation through post-incubation. However, Johnson (1989) and McLeod (1996), using 100 and 100–110 db respectively, found more detections during courtship.

Effect of Volume

Results from the three survey years (1987–1989) indicate that significantly more detections (paired *t*-test = 4.78, N = 3 years, $P < 0.05$) occurred while using high db (mean = 16.3/year) than with low db broadcasts (mean = 3.0/year). On five occasions birds within an estimated 100 m did not respond to the three initial low db broadcasts, but were subsequently detected during the high db broadcasts. It is not known from what distance the red-shouldered hawk can hear a low db broadcast, but if we assume that the red-shouldered hawk can hear the low db at 100 m, it would appear that it responds to the high db and not the low db, because of greater volume. Anecdotally, it is possible the bird is responding to a loud noise similar to the gobbling response wild turkeys *(Meleagris gallopavo)* have to loud noises (pers. obs.).

All detections resulting from low db broadcasts were from an estimated distance of 400 m or less, while 22 of the 49 detections resulting from high db broadcasts were from an estimated distance of more than 400 m. Probably some detections resulting from the high db broadcast were from birds that may not have heard the three low db broadcasts.

The direction that the speaker was pointed also influenced detections. For the years 1987–1989, significantly more birds (38 of 58; $\chi^2 = 5.59$, $P < 0.05$) responded when the speaker was directed toward them, regardless of whether the broadcast was low or high db. Since, when the speaker is pointed toward the bird, it is louder than when it is pointed away, it may have caused the birds to perceive the call as closer than it really was. Because initial speaker direction was arbitrarily decided, it is possible there was a bias of pointing the speaker in the direction a bird was expected. However, there was no significant ($\chi^2 = 0.71$, $P > 0.05$) relationship between the number of birds detected and the direction the speaker was initially pointed.

These data suggest using a high db broadcast (130 db) red-shouldered hawk tape-recording will result in more red-shouldered hawk detections than with the standard portable tape recorder volume. Further, the data indicate there may be more detections from birds that are very close, as well as from more distant birds.

Acknowledgments

I am grateful for the knowledge that Eugene Jacobs so graciously shared with me about the natural history of the red-shouldered hawk. Special thanks are extended to my wife, Nancy Balding, who helped me gather data throughout the study. I appreciate the helpful comments of my colleagues during the preparation of this manuscript, T. Duyfhuizen, D. Lonzarich, J. Rohrer, T. Ho, P. Kleintjes, D. Wittrock, and the article referees.

Literature Cited

Balding, T.A., and E. Dibble. 1984. Responses of red-tailed, red-shouldered, and broad-winged hawks to high volume broadcast recordings. *Passenger Pigeon* 46:71–75.

Buss, I.O., and H.M. Mattison. 1955. A half century of change in bird populations of the lower Chippewa River, Wisconsin. Milwaukee Public Museum Publications in Ornithology 1:11–77.

Crocoll, S.T. 1994. Red-shouldered hawk, *Buteo lineatus* (Falconiformes: Accipitridae). *In The Birds of North America, No. 107.* The Academy of Natural Sciences, Philadelphia, and The American Ornithologist's Union, Washington, D.C. 20 pp.

Devaul, H.D. 1989. A theoretical and empirical evaluation of a method of estimating area occupied for breeding woodland hawks in Maine. M.S. Thesis. University of Maine, Orono. 59 pp.

Fuller, M.R., and J.A. Mosher. 1981. Methods of detecting and counting raptors: a review. *Studies in Avian Biology* 6:235–46.

Fuller, M.R., and J.A. Mosher. 1987. Raptor survey techniques. Pp. 37–65 *in* F.A. Giron Pendleton, B.A. Millsap, K.W. Cline, and D.M. Bird, eds. *Raptor management techniques manual.* National Wildlife Federation Scientific Technical Series No. 10. Washington, D. C.

Iverson, G.C. 1987. Woodland nesting raptor survey. *Eyas* 10:6-7.

Iverson, G.C., and M.R. Fuller. 1991. Area-occupied survey technique for nesting woodland raptors. Pp. 118–24 *in* B. Giron Pendleton, D.L. Krahe, M.N. LeFranc Jr., K. Titus, J.C. Bednarz, D.E. Andersen, and B.A . Millsap, eds. *Proceedings of the Midwest Raptor Management Symposium and Workshop.* National Wildlife Federation Scientific Technical Series No. 15. Washington, D.C.

Johnson, R.R., B.T. Brown, L.T. Haight, and J.M. Simpson. 1981. Broadcast recordings as a special avian censusing technique. *Studies in Avian Biology* 6:68–75.

Johnson, G. 1989. Status and breeding ecology of the red-shouldered hawk in north central New York. M.S. Thesis. State University of New York College of Environmental Science, Syracuse. 100 pp.

McLeod, M.A. 1996. Red-shouldered hawk habitat use and detection to call-broadcast surveys in north-central Minnesota. M.S. Thesis. University of Minnesota.

Mosher, J.A., and M.R. Fuller. 1996. Surveying woodland hawks with broadcasts of great horned owl vocalizations. *Wildlife Society Bulletin* 24:431–536.

Mosher, J.A., M.R. Fuller, and M. Kopeny. 1990. Surveying woodland raptors by broadcast of conspecific vocalizations. *Journal of Field Ornithology* 61:453–61

Robbins, S.D., Jr. 1991. *Wisconsin birdlife.* University of Wisconsin Press, Madison. 702 pp.

U.S. Fish and Wildlife Service. 1987. Migratory nongame birds of management concern in the United States: the 1987 list. U.S. Department of the Interior, Fish and Wildlife Service, Office of Migratory Bird Management, Washington D.C. 27 pp.

Wisconsin Department of Natural Resources. 1991. Endangered and threatened species list. Department of Natural Resources, Wisconsin Bureau of Endangered Resources, Madison. 4 pp.

__Terry Balding__ has been studying red-shouldered hawks and bivalve mollusks of the Chippewa River basin since 1980. Terry is a professor of biology at the University of Wisconsin-Eau Claire. __Address:__ Department of Biology, University of Wisconsin-Eau Claire, Eau Claire, WI 54702. __Email:__ baldinta@uwec.edu

Thomas L. Eddy

A History and Vascular Flora of Mitchell Glen, Green Lake County, Wisconsin

Abstract *Mitchell Glen supports a climax forest "island" that occupies a narrow post-glacial gorge along the Platteville-Galena escarpment three miles southeast of Green Lake in Green Lake County, Wisconsin. Since the time of European settlement in the Green Lake region, circa 1840, and before then by Native Americans, the glen area has been recognized for its high quality natural features and admired for its scenic aesthetic landscape.*

Although a modern-day county flora exists (Eddy 1996), no formal study of the Mitchell Glen flora had been previously undertaken. A total of 234 vascular plants were identified from plant collections obtained during 1997 and 1998, representing 75 families and 177 genera. Voucher specimens are deposited in the University of Wisconsin-Oshkosh Herbarium (OSH).

The known distribution ranges were extended for 23 species previously unreported for the county, including plants with boreal affinities (Eddy 1996). Mitchell Glen's shaded cliffs with cold-air drainage and springs at the base of the gorge render a moist, cool microclimate that sustains certain species more typical of northern Wisconsin.

Oak savanna and tallgrass prairie covered most of the immediate area surrounding Mitchell Glen (Finley 1976). Although most of the prairies and oak openings were placed into cultivation during the latter half of the 1800s, original maple-basswood forest occupies Mitchell Glen and represents the only significant tract of climax woodland in Green Lake County.

The main feature of this report is a catalog of vascular plants, supported by vouchers, that grow in Mitchell Glen, Green Lake County, Wisconsin (Figure 1). Despite its noteworthy geology, prominent topographical features, and apparently rich biological diversity, no systematic collecting or formal study

Figure 1. Location of Green Lake County in east central Wisconsin (U.S. Department of Agriculture 1977).

of the Mitchell Glen flora had been previously undertaken. Besides contributing to the broader regional botanical record, the catalog of species serves as a basis of comparison with the flora of the same area in the future and with the flora of similar southern mesic forests in the upper Midwest.

A secondary objective of this study examines the presettlement flora of Mitchell Glen, circa 1834. The names of specific plants, notably trees, and general references to the vegetation that are mentioned in the original land survey records, old letters and books, and earlier studies, specifically reports of Indian antiquities, are used to establish a historical record of the local flora. Along with this evidence an examination of the history of land use in and around Mitchell Glen documents the environmental impact of both natural processes and human-related activities on the glen flora.

During this study the known distribution ranges were extended for 23 species that had been previously unreported for the county

(Eddy 1996). New county records are mainly due to the fact that rich mesic climax woodlands are scarce in the county and until recently have not been closely examined and methodically botanized.

In contrast to the surrounding open uplands, Mitchell Glen's shaded cliff habitat with cold-air drainage and springs at the base of the gorge render a moist, cool microclimate that sustains certain plants with boreal affinities. Among the species more typical of northern Wisconsin but which occur at Mitchell Glen are *Acer spicatum, Aster macrophyllus, Dirca palustris, Diervilla lonicera, Equisetum pratense, Lycopodium lucidulum,* and *Taxus canadensis.*

The oak savannas and tallgrass prairies that once covered most of the immediate area surrounding Mitchell Glen (Finley 1976) were placed into cultivation during the latter half of the 1800s, but original maple-basswood forest survives in Mitchell Glen and represents the only significant tract of climax woodland in Green Lake County. Although the Mitchell Glen flora is comprised of communities representative of the original vegetation cover that include rare species, no state threatened and endangered plants were observed during the study.

Location

Mitchell Glen is located in the town of Brooklyn, Green Lake County, Wisconsin at parallel 43°48'57" north latitude and the meridian 88°54'54" west longitude. It is situated in NW 1/4 SE 1/4 section 35, Township 16 North and Range 13 East (Figure 2). The study area is comprised of approximately 20 acres.

Two state geographical provinces divide Green Lake County roughly in two (Martin 1965). The northwestern half lies on the western edge of the Central Plain and is characterized by gently rolling topography. The southeastern half of the county, which includes Mitchell Glen, is part of the Eastern Ridges and Lowlands and is interrupted by numerous escarpments and valleys.

Nearly all of Green Lake County, including the area surrounding Mitchell Glen, is classified as natural division 5c (Hole and Germain 1994). Characteristic of this natural division is undulating to rolling topography that supports oak savannas and prairie growing on silt loams over calcareous till. Land classified as division 5cp, directly south and east of Mitchell Glen, historically supported extensive prairies.

The county is slightly below Wisconsin's tension zone, a region of transition between Wisconsin's northern hardwood province and the prairie-forest province (Curtis 1959). Although oak savanna is the dominant vegetation cover throughout the county, some species that are more typical north of the tension zone are established here.

In a 1977 report by the East Central Wisconsin Regional Planning Commission, Mitchell Glen was one of two sites in the region (from a list of 10 potential locations) that were recommended for development as a regional park. While there are no current plans for developing such a park at or near Mitchell Glen, the fact that the area was recognized for its unique aesthetic and natural features underscores the high quality natural landscape for which Mitchell Glen is renowned.

Geology, Soils, Water Resources

Mitchell Glen occupies a narrow post-glacial gorge that was eroded by glacial meltwater from the Green Bay Lobe approximately 12,500 years before the present. The upper bedrock is Platteville-Galena dolomite; beneath this is St. Peter sandstone, which forms

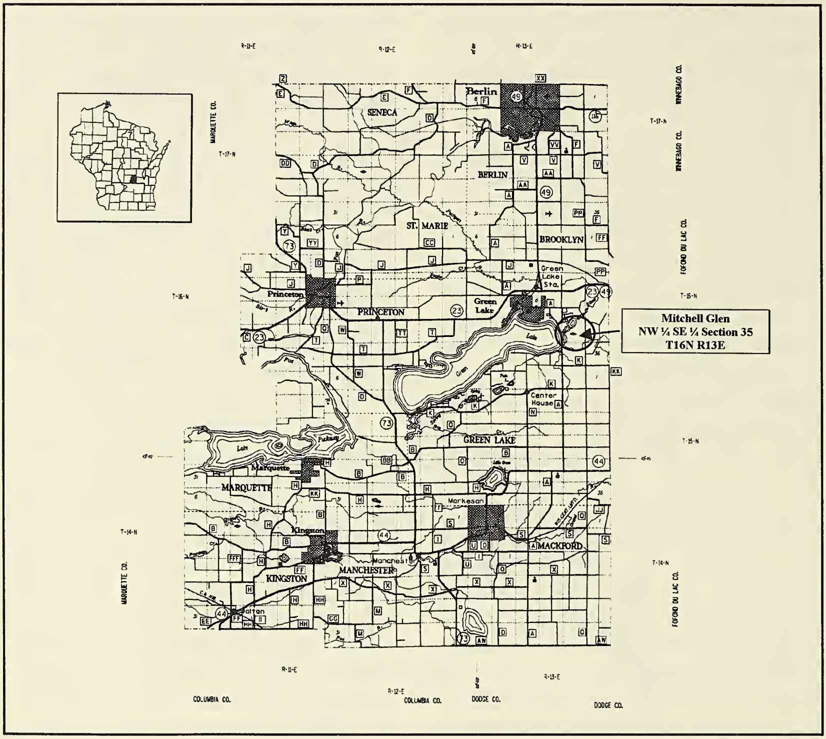


Figure 2. Green Lake County, Wisconsin (Adapted from the Wisconsin Department of Transportation 1988).

the steep-sided walls of the glen. Mitchell Glen, which is approximately 100 ft deep from the floor to the top of the Platteville-Galena escarpment, drains the cultivated uplands that are to the southeast (Figure 3).

Torrential surface runoff that cascades from the crest of the glen empties into Mitchell Glen Creek, a small spring-fed rivulet that begins at the base of the falls. Mitchell Glen Creek is a tributary of Dakin Creek, a minor stream that enters Green Lake's inlet, Silver Creek at NW 1/4 NW 1/4 Section 35, R13E, T16N (Figure 3).

According to the county soil survey (1977), soils of the Kidder-Rotamer-Grellton association that are found at Mitchell Glen vary from moderately well-drained to well-drained loams. The subsoils are mainly of loam, clay loam, and sandy clay loam underlain by calcareous, gravelly sandy loam glacial till.

Three marl pits in the vicinity of Mitchell Glen were excavated in the past and used as a source for "sweetening" acidic soils and as an ingredient for mortar cement and whitewash.

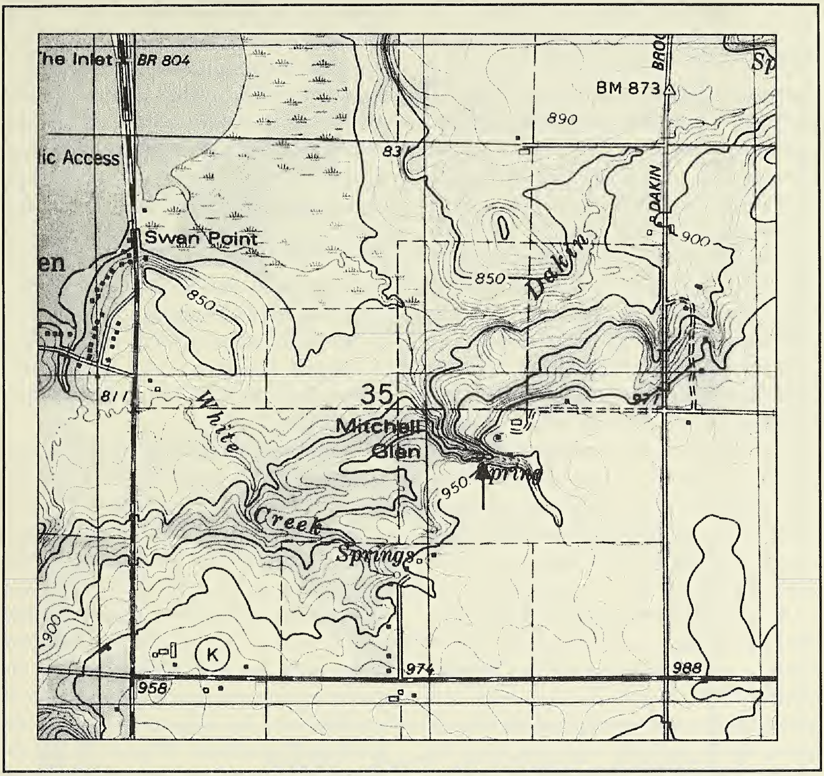


Figure 3. Topographic features of Mitchell Glen and immediate surrounding area. The glen is a post-glacial gorge eroded by glacial meltwater. Note that the elevation at the crest of Mitchell Glen is 950 feet above sea level—the base of the glen is 850 feet. Mitchell Glen Creek (unnamed) begins at the southeast base of the gorge (arrow) and drains into Dakin Creek, a tributary of Silver Creek, Green Lake's inlet (United States Geological Survey 1980).

Original Vegetation Cover

Original Land Survey Records

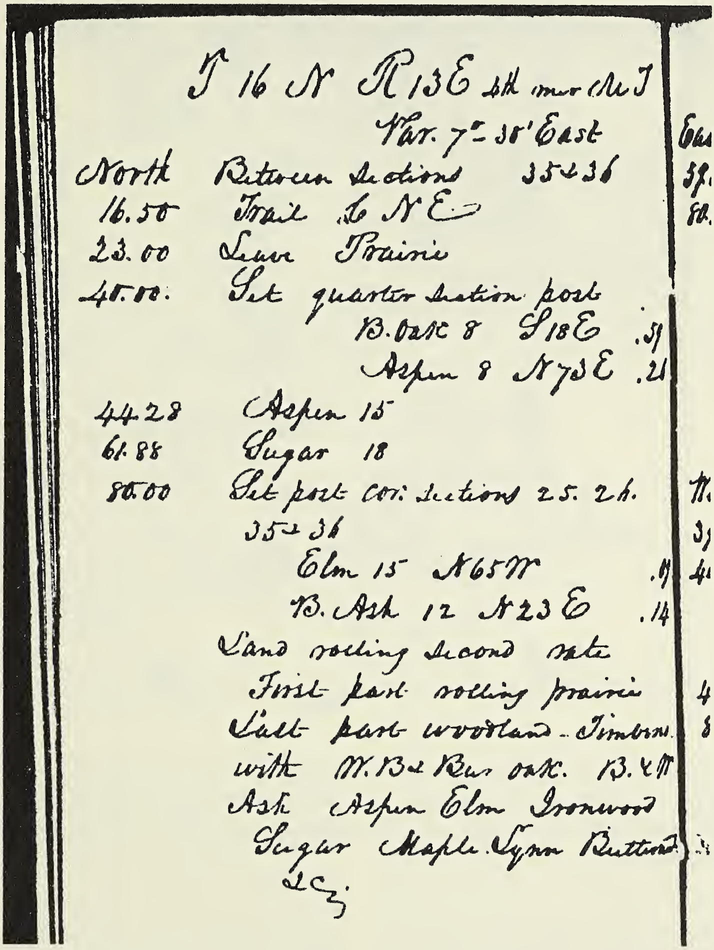
The original government land survey for the Mitchell Glen area, certified in 1835, contains the most comprehensive record of the vegetation prior to European settlement. The field notes of the surveyors contain references to the vegetation, as well as to specific trees, making it possible to interpret the general vegetation cover for the Mitchell Glen area (Figure 4). Wherever possible, individual trees that intersected section lines were recorded, along with bearing trees that helped identify corners. To supplement and verify entries, surveyors recorded a summary of the vegetation along the section lines and often included sketch maps of each township (Figure 5). When the survey of interior section lines of a township was completed, a general summary of the vegetation for the township was written.

According to the surveyors' field notes, the original vegetation cover of Green Lake County was predominantly oak savanna (Finley 1976) (Figure 6). Oak forest was prevalent throughout much of the county, giving way to wetlands vegetation along the lower Grand River and throughout most of the Fox River Valley and its tributaries. Where the canopy was one-half or more open, surveyors often acknowledged the scattered spacing of trees and recorded the vegetation as oak opening, a transitional community between oak forest and grasslands. Because the field notes fail to consistently mention the spacing between trees, it is possible that areas of what is mapped as oak forest may have actually been oak opening (Finley 1976).

Where the oaks diminished in numbers, notably on the flat uplands in the southeastern townships, the landscape was essentially treeless and covered by tallgrass prairie. In the northern half of T15N R13E the prairie succeeded into oak forest and openings. A short distance farther north, in the southwestern quarter of T16N R13E, where the Platteville-Galena escarpment overlooks Silver Creek, the oak openings abruptly gave way to a small area of sugar maple-basswood forest known as Mitchell Glen. Prior to European settlement the forest may have been spared from periodic conflagrations, due in part to prevailing northwest winds, the presence of wetlands to the north and northwest, which helped to contain the blazes, and the irregular topography that may have acted as a natural firebreak.

Completion of the survey of interior lines for T16N R13E, which includes Mitchell Glen (NW 1/4 SW 1/4 section 35), was certified March 31, 1835, by Deputy Surveyors James H. Mullett and John Mullett (General Land Office 1834). Based upon written summaries of the vegetation along section lines and the marker trees recorded in the original land surveys for quarter section and corner posts, section 35 was bounded by tallgrass prairie on the south and southeast (Figure 7). As the grasslands approached Mitchell Glen they graded into oak openings, which were established up to the rim of the glen. Large tracts of oak opening habitat were reported northeast and southwest of Mitchell Glen, while floodplain forest and other wetlands occupied the lowlands to the northwest.

In short, maple-basswood forest at Mitchell Glen existed then, as now, as an "island" climax woodland. A similar climax forest island, South Woods, occurs three miles northeast along the southeast edge of Ripon. Both tracts of maple-basswood forest are established along the Platteville-Galena escarpment where post-glacial gorges indent the edges of the escarpment.



T 16 N R 13 E 4th mer W T

Var. 7° 30' East

North Between Sections 35 & 36

16.50 Trail S N E

23.00 Leave Prairie

40.00 Set quarter section post

B. Oak 8 S 18 E .51

Aspen 8 N 73 E .21

44.28 Aspen 15

61.88 Sugar 18

80.00 Set post cor. sections 25. 26.

35 & 36

Elm 15 N 65 W .17

B. Ash 12 N 23 E .14

Land rolling second rate

First part rolling prairie

Last part woodland - Timber

with W. B & Bur oak. B. & W.

Ash Aspen Elm Ironwood

Sugar Maple Lynn Buttnut

&c.

Figure 4. A copied page from the original land survey field notes for T16N R13E. The entry begins by surveying the section line north between sections 35 (Mitchell Glen) and 36. Note the vegetation changes from prairie to oak opening, then to woodland, all within a mile distance (General Land Office 1834).

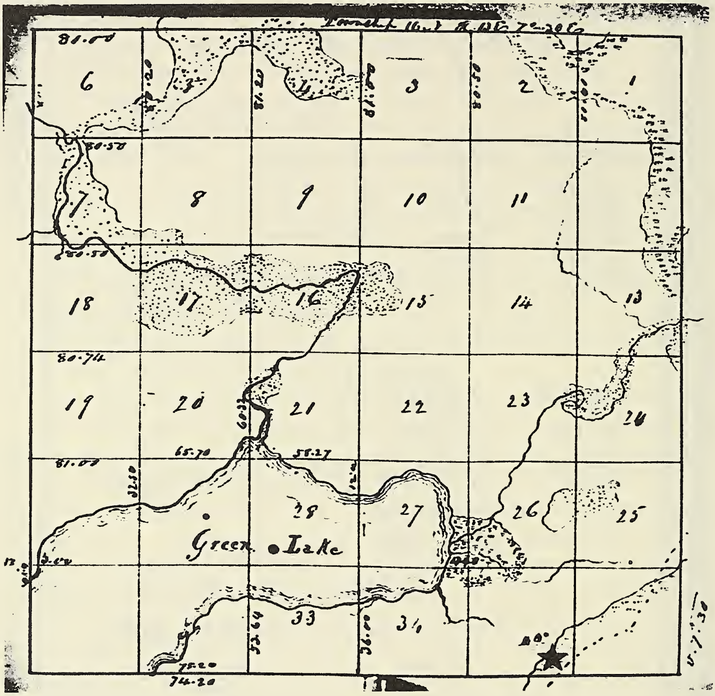


Figure 5. A copy from the original land survey map for "Township No.16 North Range No.13 East in the Territory of Michigan. . . Certified this 31 day of March 1835," showing Mitchell Glen (star), part of present-day Green Lake County, Wisconsin (General Land Office 1834).

Tallgrass prairie is well-documented immediately south and southeast of Mitchell Glen where surveyors "Set post corners Sections 35 and 36 in Mound in Prairie Land High Rolling first Rate." Land along the south section line of section 35 was characterized as ". . . Rolling first rate Prairie and Timbered White Black and Bur Oak." Near here, the field notes refer to a "trail" that occupied the southwest quarter of section 35 and ran diagonally from southwest to northeast of section 36. The trail was originally an Indian trail between Fort Howard, Green Bay and Fort Winnebago, Portage, then later become known as part of the Military Road. Within sections 35 and 36 the trail generally followed the Platteville-Galena escarpment across upland prairies and oak openings.

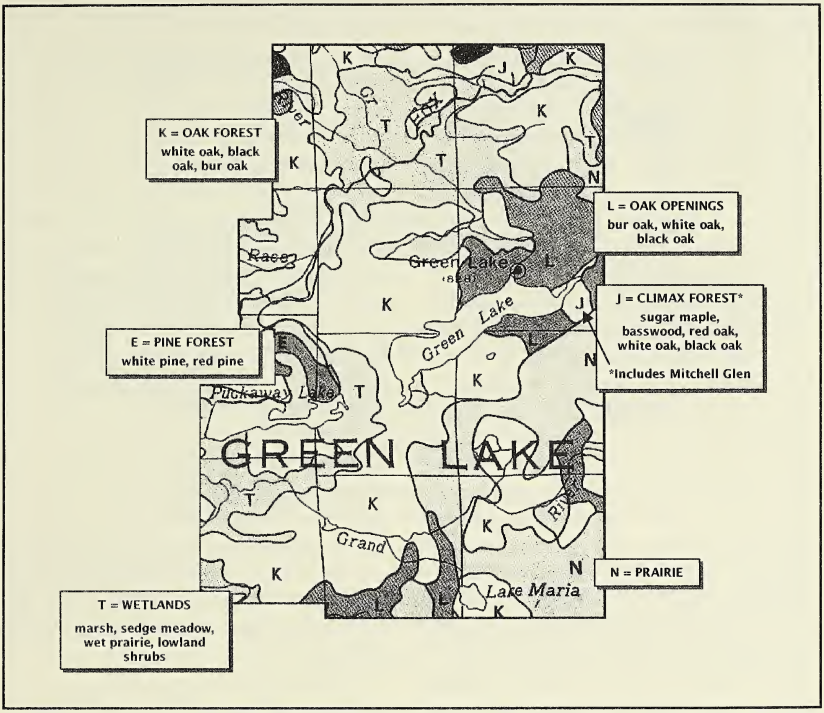


Figure 6. Original vegetation cover of Green Lake County, Wisconsin, circa 1834 (Adapted from Finley 1976).

Surveying north between sections 35 and 36, the land was described as "... rolling second rate First part [southern half] rolling prairie Last part [northern half] woodland—Timbered with W. B & Bur oak [white, black and bur oaks, *Quercus alba, Q. velutina, Q. macrocarpa*]. B. & W Ash [*Fraxinus nigra* and probably green, not white ash, *F. pennsylvanica*] Aspen *[Populus tremuloides]* Elm [*Ulmus* sp.] Ironwood *[Ostrya virginiana]* Sugar Maple *[Acer saccharum]* Lynn [probably linden, i.e., basswood, *Tilia americana*] Butternut *[Juglans cinerea]* etc."

The field notes confirm that oak openings occupied the area between grassland and forest. South of the north corner post between sections 25 and 36 the "... First 20.00 [20 chains or one-quarter mile] Timbered with sugar Maple Lynn [basswood] W & B Ash Ironwood etc. Last part—Thinly timbered with W. B and Bur oak." Following this same section line one mile south (T15N R13E) the field notes state: "Woodland rolling second rate. Scattering W. B & Bur oak Prairie level second rate—Red root *[Ceanothus americanus]* rosin-weed [*Silphium* sp.] rose-willow [*Salix bebbiana*?] etc."

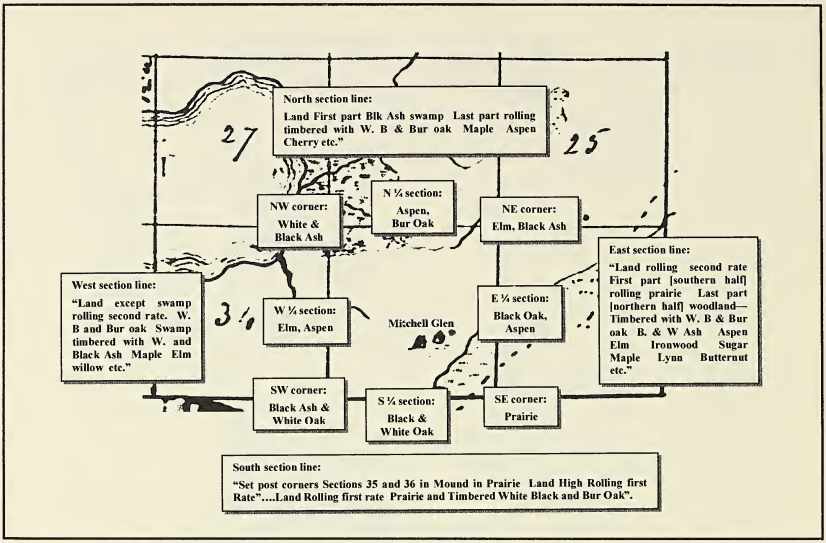


Figure 7. An enlarged portion of original land survey map for section 35 T16N R13E, the area occupied by Mitchell Glen, Green Lake County, Wisconsin. Marker trees and prairie at quarter sections and corner posts, as well as section line summaries from the field notes are displayed (General Land Office 1834).

Floodplain forest was encountered along the north section line between sections 26 and 35. From west to east the surveyors described "Land First part Blk Ash swamp Last part rolling timbered with W. B & Bur oak Maple Aspen Cherry [*Prunus serotina*?] etc." Further evidence of floodplain woodlands was noted at post corner sections 26, 27, 34 and 35: "Land except swamp rolling second rate. W. B and Bur oak Swamp timbered with W. and Black Ash Maple [*Acer saccharinum*?] Elm willow [*Salix* sp.] etc."

Based upon the original land survey records it is apparent that the vegetation cover for most of the immediate area surrounding Mitchell Glen was oak savanna and tallgrass prairie. Upland prairie, which graded into oak opening, flanked the southern margin, while extensive oak openings occupied the areas southwest and northeast of Mitchell Glen. Historically, recurrent fires greatly influenced the vegetation cover by diminishing woody climax succession and favoring oak savanna. Although most of the prairies and oak openings were placed into cultivation during the latter half of the 1800s, the dominant vegetation cover for Mitchell Glen remains maple-basswood forest. It is the only significant tract of climax forest in Green Lake County.

Native Americans and European Settlement

Mitchell Glen and the surrounding lands are noted for having been the site of the largest camp of Winnebago Indians in the Green

Lake area (Heiple and Heiple 1978). There is strong circumstantial evidence that the use of fire by Winnebago Indians, the primary inhabitants of the region, indirectly influenced the vegetation cover (Dorney 1981). The presence of oak savanna and open wetlands throughout Green Lake County, including those surrounding Mitchell Glen, support this view because all of these plant communities originate from recurrent fires and depend on periodic burnings for their continuation.

Among the Indian antiquities in Green Lake County, thirteen Indian campsites, three main planting grounds, and numerous food caches have been discovered within the immediate vicinity of Mitchell Glen (Brown 1917). The Indian planting grounds, which yielded much corn, were found in oak openings and on the prairie where fire may have been utilized to maintain open habitat (Dorney 1981). The nearby oak forests yielded great quantities of acorns, which were ground, dried, and stored in buried caches for use in winter.

In 1840 Anson Dart and his family established the first permanent European settlement on Green Lake. A son, Richard Dart, then twelve years old, later reflected on the resourcefulness of local Native Americans:

> The Winnebago used to make small mounds to preserve their provisions. When plentiful, they dried fish in the sun till they were as dry as powder, then put them in big puckawa sacks. The squaws also picked up bushels of acorns. In deep holes, below frost-line, they would bury their fish and acorns together, twenty bushels or so in a place, and cover them over with a mound of earth. When the deer had gone south, and game was scarceæ they would come and camp on these mounds and dig up fish and acorns for their winter food, and live on this provender until spring opened or game appeared. (Dart 1910)

Maple sugar was made from *Acer saccharum* in at least two localities west and north of Mitchell Glen, SW 1/4 section 35 and SW 1/4 section 26 (Brown 1917). The maple sugar was stored in birch bark baskets that were fashioned from *Betula papyrifera.* ". . . We had no sugar, save maple made by Indians, and this was very dirty. The natives used to pack this sugar in large baskets of birch-bark, and sell it" (Dart 1910).

The area woodlands also supplied wood for fuel, poles and bark for wigwams, and wood for making tools and weapons. Wooden bowls were carved out of ash, *Fraxinus* spp., and American basswood, *Tilia americana* (Heiple and Heiple 1978). Shagbark hickory, *Carya ovata,* and red cedar, *Juniperus virginiana,* both of which are found at Mitchell Glen, were utilized to make hunting bows (Brown 1917).

In 1835, one year after the township was surveyed, the first European settler to occupy land that included the glen was a trader named James Powell (Heiple and Heiple 1978). Twenty-six years later, Archibald and Laura Mitchell purchased 160 acres of land, which included the glen, NW 1/4 SE 1/4 section 35. The Mitchells' third son, Stephan Decatur Mitchell, or S.D. Mitchell, eventually acquired the glen, and this is when the name "Mitchell Glen" became attached to the site.

S.D. Mitchell was an amateur collector and enthusiastic student of Indian antiquities. His letters and reports to Charles E. Brown, then President of the Wisconsin Archaeological Society, were incorporated into Brown's 1917 paper, "The Antiquities of Green Lake." Numerous references to specific trees and the vegetation cover appear in Mitchell's letters to Brown as he related his findings. In a letter dated February 4, 1903, Mitchell described the forest nearby his home: "About Eighty rods to the North west of my residence on same Section [35] you will observe a conical mound this mound was in the limets [sic] of what at one time was one of the finest shugar [sic] bushes *[Acer saccharum]* that I ever saw . . ." (State Historical Society of Wisconsin 1888).

In 1903 Mitchell posted a draft to Brown entitled "Green Lake Report," which included a list of Indian sites and descriptions of the vegetation cover, as well as specific uses of local plants by the Winnebago tribe in and around Mitchell Glen. Mitchell related how the Native Americans utilized local plants and animals, as explained to him by Richard Dart (then 77 years old):

> Before the building of the dam at Dartford there was a bar at the north east portion of the lake to the South and east of where the Plasant [Pleasant] Point Hotell [sic] now stand which was at that time grown up to rushes the watter [sic] about five feet in depth here during the summer the Indians speared thousand and thousands of huge dog fish these they Jurked [sic] or dried over a slow fire and together with acorns they cached or buried these in pits when winter came one [on] and food became scarse [sic] they built their huts or Wigwams over these caches and boiled these fish and acorns together which became a black mass. . . . (State Historical Society of Wisconsin 1888)

Continuing, Mitchell went on to explain the loss of floodplain forest north of Mitchell Glen by the damming of Green Lake:

> It might be well to state here that the intire [sic] shoar [sic] line of the lake was changed by the building of a dam across the out let called the Pucyann [Puchyan] River at Dartford in the year 1844. This dam Raised the level of the lake some Four feet or more flooding a large tract of very heavy timber. . . some years since parties removed the over flowed stumps in the shallow watter [sic] between this [Silver Creek inlet, SW 1/4 section 26] and the Lake. . . . (State Historical Society of Wisconsin 1888)

South from the inlet "This whole tract [NW 1/4 section 35] to the south and west also to the east dureing [sic] the knowlage [sic] of the writer has been one vast tract of heavy timber portions of which has been since removed (from) the land and converted into plowed fields. . . " (State Historical Society of Wisconsin 1888).

Mitchell's references to maple trees further underscored the dependence of Native Americans and early settlers on the tract of climax forest in and around Mitchell Glen. Approximately one mile northwest of Mitchell Glen, a campsite on Silver Creek, SW 1/4 section 26, used by the Winnebago tribe was described as

> . . . a small island known as sugar creek island this is surrounded on the north and west by silver creek and on the south and east by swamps this island formerly was covered with heavy maple timber here again was shown the hacking gouging present of the Indians mode of taping [sic] the maple with his rude implements. . . . (State Historical Society of Wisconsin 1888)

About a quarter mile north of Mitchell Glen, SE 1/4 NW 1/4 section 35, Mitchell states that "This site was one of the finest maple groves *[Acer saccharum]* in the state my Father at one time cut one Maple that made 7 1/2 cords of 4 ft wood These trees all showed that they had been taped [sic] for ages by the Indians. . . . (State Historical Society of Wisconsin 1888).

Oak woods and openings bordered edges of the maple-basswood forest. In a letter to Brown on March 4, 1904, Mitchell described five trees around Indian corn hills in SW 1/4 NW 1/4 section 35 as "... three of Oak [*Quercus* sp.] and two of Cherry *[Prunus serotina]* the largest oak is four ft eight inches in circumference the other is smaller (State Historical Society of Wisconsin 1888).

As the Green Lake area became more settled, more land surrounding Mitchell Glen was placed into pasture and cultivation. By reporting the date when an Indian site was disturbed or destroyed, Mitchell inadvertently documented destruction of the vegetation cover and changes in land use surrounding Mitchell Glen. In 1904, for example, Mitchell laments that "... the timber has been removed [SE 1/4 NE 1/4 section 34] and in the early spring the Octogon [sic] the wolf and part of the cornfield [Indian corn] will be plowed for the first time ... Nearly all the damage [to effigy mounds] ... has been done within the last three years" (State Historical Society of Wisconsin 1888). Mitchell noted even earlier changes to the prairie southeast of Mitchell Glen, NW 1/4 SW 1/4 section 36:

> 1862 first Plowed and yearly since ... The peculiarity about these mounds is their isolation from other mound and distance from watter [sic] they are about one and a half miles east a little south of the lak [sic] on high table land about 400 feet above the lake on the edge of Green Lake Prairie. Alass [sic] there is but little sembalance [sic] to a mound left the distructive [sic] plow has for more than 40 year been accomplishing their ruin.... (State Historical Society of Wisconsin 1888)

Elsewhere, about a quarter mile northwest of Mitchell Glen, SE 1/4 NE 1/4 section 34, Mitchell reports that "... two of the lizard tails [effigy mounds] were plowed about 1858. More were plowed 1903 and more ... will be Plowed this season."

Post-settlement to Present-day

The earliest known formal study to include the Mitchell Glen flora is from 1889 by Mrs. C.T. Tracy, a Ripon College botany instructor. While many of the plants listed in her Catalogue of Plants Growing Without Cultivation in Ripon and the Near Vicinity are known from Mitchell Glen, Mrs. Tracy specifically cites Mitchell Glen as the location for two species: *Impatiens capensis* Meerb. *(I. fulva* as listed by Tracy) and *Coreopsis tripteris* L. While *I. capensis* is common on wet soils along Mitchell Glen Creek, there are no known vouchers of *C. tripteris* for Green Lake County, or Wisconsin for that matter (Theodore S. Cochrane, personal communication, 2 April 1999). (Other old specimens, e.g., *Carex shortiana, Phoradendron serotinum,* and *Silphium asteriscus,* bearing identical Ripon College labels, whether collected by "J. Clark," "Mrs. C. Tracy," or someone else, also must be excluded from the Wisconsin flora for lack of specimen vouchers (Theodore S. Cochrane, personal communication, 2 April 1999).

Although many of the typical woodland ephemerals that grow at Mitchell Glen occur elsewhere in the county, some species are exclusive to the glen. Showy orchis, *Orchis spectabilis,* for example, was "discovered" in 1994 and is known only from Mitchell Glen (Eddy 1996). Similarly, *Hamamelis virginiana, Symphoricarpos albus,* and *Symphoricarpos occidentalis* are not rare in the southern half of Wisconsin but are recognized in the county only from Mitchell Glen.

Cold-air drainage along the shaded cliffs and cold springs at the base of the gorge create a boreal micro-habitat for certain northern plants. Among the species more typical of northern Wisconsin, and which may be viewed as northern relics, are *Acer spicatum, Aster macrophyllus, Dirca palustris, Diervilla lonicera, Equisetum pratense, Lycopodium lucidulum,* and *Taxus canadensis.* The fact that *T. canadensis* is nearly inaccessible because of the very steep slopes on which it grows may explain why it has not been extirpated by browsing white-tail deer.

Twenty-three species are "new" to the county, in that they were not known from the county prior to 1996. These county records listed below represent 2.4% of the total county flora (currently 951 species) and are based on voucher specimens collected after publication of the county flora (Eddy 1996).

Acer spicatum Lam.
Aster macrophyllus L.
Aster shortii Lindley
Carex amphibola Steudel
Carex blanda Dewey
Carex projecta Mackenzie
Cynoglossum amabile Stapf & Drumm.
Dirca palustris L.
Equisetum pratense Ehrh.
Erysimum cheiranthoides L.
Galium concinnum T. & G.
Hamamelis virginiana L.
Hydrophyllum virginianum L.
Lactuca serriola L.
Laportea canadensis (L.) Wedd.
Panicum boreale Nash
Phlox divaricata L.
Rubus occidentalis L.
Symphoricarpos albus (L.) S. F. Blake
Symphoricarpos occidentalis Hook.
Taxus canadensis Marshall
Ulmus rubra Muhl.
Viburnum rafinesquianum Schultes var. *rafinesquianum*

Although the vascular plant diversity of Mitchell Glen compared with similar Wisconsin forests is difficult to measure, the site is evidently richer than average. Based upon plant inventories for southern mesic forests in the State Natural Area system, an average number of vascular plants on a 40-acre tract is roughly 150 species (Thomas Meyer, personal communication, 1 April 1998). According to Meyer, in forests grown on calcareous till or where limestone bedrock nears the surface, which is the case at Mitchell Glen, the number of vascular plants is about 175 species. These data may not be in accord with the 234 species cataloged for the glen and bordering uplands. However, when considering the approximately 40 common weeds that were among the 234 plants collected, as well as several prairie and savanna, not forest species, the variety in Mitchell Glen generally corresponds to the number of species suggested by Meyer.

The origin of Mitchell Glen is similar to that of Parfrey's Glen, a 488-acre state natural area in Sauk County. Parfrey's Glen is a post-glacial gorge cut into Cambrian sandstone conglomerate of the Baraboo Hills and, like Mitchell Glen, receives cold-air drainage that supports a collection of northern plants, as well as shaded cliff plants on steep rock outcrops. Eighty-eight vascular plants are reported in a partial list compiled for Parfrey's Glen (Thomas Meyer, personal communication, 11 November 1998). Of these, 32 species or 36% are common to the Mitchell Glen flora, including plants with northern affinities. Combined with the plants on the Parfrey's list that are identified to genus only, there are 45 species or 51% common to the Mitchell Glen flora. Considering its rich plant diversity, coupled to similarities with other preserved southern mesic forests, Mitchell Glen stands as a high-quality refugium for native biota in east-central Wisconsin.

Past and Present Land Use

Land uses that affect the vegetation cover of Mitchell Glen area are ongoing. Four years ago nearly 30 acres of mature hardwood forest was selectively logged directly northwest of the glen, SE 1/4 NE 1/4 section 35. Harvested trees were mainly red and white oak, but included some bur oak, sugar maple, and basswood (John Koerner, personal communication, 7 January 1999). One year earlier area landowners successfully persuaded a local excavator to abandon plans to quarry gravel at a site less than one mile from Mitchell Glen.

Directly south and east of Mitchell Glen is land that has been under cultivation for over a century, an activity that has obviously destroyed the original vegetation cover. Furthermore, because the row-cropped fields fail to slow and contain water during rains and snowmelts, torrents of surface water stream into the southeast corner of Mitchell Glen, further eroding the edges of the soil grade that borders the gorge. The excessive surface runoff causes silting and flooding along Mitchell Glen Creek and intermittently disrupts the bottomland vegetation. Patches of reed canary grass, *Phalaris arundinacea,* and stinging nettle, *Urtica dioica,* have become firmly established on the moist alluvium.

By comparing the present-day vegetation cover of Mitchell Glen with old photographs and postcards it is evident that the edges of the glen and former openings have become more overgrown with woody growth. Alys Gredler, a former resident of the area commented:

> The greatest impression I had in going through the glen was how different it was from the pictures I have. It was quite obvious that it was almost ninety years older than it appeared in the pictures. The trees were much younger and smaller and the glen was very much less crowded with plant life . . . The upper glen where the Mitchell family cemetery is located must have at one time been fairly clear land but is very wooded now. (Alys Gredler, personal communication, 16 November 1998)

Prairie and savanna groundlayer species can still be observed growing along the margins in semi-shade. Along the north and south rims and on gently sloped terraces overlooking Mitchell Glen Creek, pioneer trees are present. The absence of fire and other habitat disturbances that impede woody succession have allowed aspen, black cherry, and boxelder to become established. Ironically, bur, white, and black oaks, trees once common to nearby oak openings, were not observed growing within the study area.

In addition, in oak openings and woodlands that were logged and pastured, European buckthorn, *Rhamnus cathartica,* has become naturalized and at times forming thickets. Left unmanaged, buckthorn develops a dense understory that shades out native species.

Both accidental and deliberate introductions have adversely affected the groundlayer cover. For example, periwinkle, *Vinca minor,* was planted many years ago in the Mitchell family cemetery. It has since spread to the surrounding area, forming large evergreen mats that crowd out native groundlayer species.

The present-day landholders of Mitchell Glen are cognizant of the need for its long-term protection by implementing sustainable land management practices. One option to achieve this aim is to prepare a conservation easement that specifies what land uses are acceptable and unacceptable. When attached to a deed, a conservation easement can assist protecting the land into perpetuity.

Methodology and Catalog Design

Plant collections were obtained during the 1997 and 1998 growing seasons. In addition to the glen, common weeds growing along buildings and lanes, and in lawns and cultivated fields were collected. Voucher specimens were identified and deposited in the University of Wisconsin-Oshkosh Herbarium (OSH). Besides plant collections, numerous 35 mm slide photographs of individual plants and entire communities were taken to further document the Mitchell Glen flora and general vegetation cover.

Plant families in the catalog are alphabetized within the major plant groups, as are the genera and species within a family. Nomenclature strictly follows Gleason and Cronquist (1991). The treatment of narrowly defined species and most infraspecific taxa is avoided, as is the listing of synonyms.

General locations, brief habitat descriptions, and the frequencies are stated for most species. Plants collected during this study that are not included in the Green Lake County flora (Eddy 1996) are noted as county records. Collection numbers cited are my own and correspond to the voucher specimens deposited at OSH.

Summary of Taxa

Presently, the total number of cataloged vascular plants at Mitchell Glen is 234 species (Table 1). A summary of the number of families, genera, and species for the three largest dicot and three largest monocot families is compiled in Table 2.

A single family, the Asteraceae, represents about one-fifth or 21% of the total number of dicots. The monocots are largely represented by the Poaceae and Cyperaceae, which when combined, account for 67% of the total number of monocots. The combined number of species of the three largest dicot and three largest monocot families accounts for 43% of the total Mitchell Glen flora (Table 2).

Table 1. Summary of Major Plant Taxa at Mitchell Glen.

Plant group	*Families*	*Genera*	*Species*
Pteridophytes	6	9	11
Gymnosperms	3	3	3
Dicotyledons	59	129	169
Monocotyledons	7	36	51
Totals	**75**	**177**	**234**

Table 2. A comparison of the three largest dicot and three largest monocot families.

Dicots	*Genera*	*Species*	*% of Total Mitchell Glen Flora*
Asteraceae	23	35	15%
Rosaceace	9	12	5%
Ranunculaceae	8	11	5%
Monocots			
Poaceae	20	24	10%
Cyperaceae	1	10	4%
Liliaceae	9	10	4%
Totals	**70**	**102**	**43%**

CATALOG OF SPECIES

PTERIDOPHYTES

LYCOPODIACEAE (Clubmoss Family)

Lycopodium lucidulum Michx. Rare, one site; moist shaded sandstone shelf above Glen Creek. (4235, 4531)

EQUISETACEAE (Horsetail Family)

Equisetum hyemale L. var. *affinis* (Engelm.) A. A. Eaton. Rich shaded slope, growing beside *E. pratense.* (4604)

E. pratense Ehrh. Rare, one site; rich shaded slope. COUNTY RECORD. (4312, 4533)

ADIANTACEAE (Maidenhair Family)

Adiantum pedatum L. ssp. *pedatum.* Rich wooded slopes. Locally common. (4346)

ASPLENIACEAE (Spleenwort Family)

Asplenium rhizophyllum L. Local on shaded sandstone cliffs. (4497)

Cystopteris bulbifera (L.) Bernh. Shaded sandstone outcrops. Uncommon. (4336, 4494)

Dryopteris carthusiana (Villars) H.P. Fuchs. Rich woods along Glen Creek. Common. (4361)

D. intermedia (Muhl.) A. Gray. Rich woods along Glen Creek. Common. (4535)

Woodsia obtusa (Sprengel) Torr. Locally abundant on shaded sandstone outcrops. (4335, 4492, 4496, 4534)

OSMUNDACEAE (Royal Fern Family)

Osmunda claytoniana L. Rich woods along Glen Creek. Uncommon. (4530)

POLYPODIACEAE (Polypody Family)

Polypodium virginianum L. Locally common on moist shaded sandstone cliffs. (4234, 4493, 4628)

GYMNOSPERMS

CUPRESSACEAE (Cypress Family)

Juniperus virginiana L. Dry disturbed woods. Common. (4279, 4305)

PINACEAE (Pine Family)

Pinus resinosa Aiton. Local on rocky ledge along north rim of glen; four mature trees. (4639)

TAXACEAE (Yew Family)

Taxus canadensis Marshall. Local on steep wooded rocky slopes along south wall of Mitchell Glen. COUNTY RECORD. (4509)

DICOTYLEDONS

ACERACEAE (Maple Family)

Acer negundo L. Common in disturbed woods, fencerows, clearing. (4295)

A. saccharum Marshall. Throughout rich woods. (4300)

A. spicatum Lam. Local on steep wooded slopes along south wall of Mitchell Glen. COUNTY RECORD. (4338, 4347, 4647)

AMARANTHACEAE (Amaranth Family)

Amaranthus hybridus L. Common weed. (4523, 4553)

ANACARDIACEAE (Cashew Family)

Rhus glabra L. Dry opening along northeast rim of Mitchell Glen. Common. (4633)

Toxicodendron radicans (L.) Kuntze. Occasional in disturbed woods, paths, clearings. (4519, 4656)

APIACEAE (Carrot Family)

Cryptotaenia canadensis DC. Rich woods. Uncommon. (4345)

Osmorhiza claytonii (Michx.) C.B. Clarke. Rich woods. Common. (4275)

APOCYNACEAE (Dogbane Family)

Vinca minor L. Planted and escaped about shaded pioneer cemetery. (4241)

ARISTOLOCHIACEAE (Birthwort Family)

Asarum canadense L. Rich wooded slopes along Glen Creek. (4264)

ASCLEPIADACEAE (Milkweed Family)

Asclepias incarnata L. One plant in old field. (4559)

A. syriaca L. Field lanes, old fields. Common. (4478)

A. verticillata L. Field lanes, old fields. (4637, 4660)

ASTERACEAE (Aster Family)

Achillea millefolium L. Field lanes, dry wooded openings. Common. (4464)

Ambrosia artemisiifolia L. Common weed. (4582)

A. trifida L. Common weed. (4589)

Antennaria plantaginifolia (L.) Richardson. Dry wooded openings. (4254, 4280)

Aster ericoides L. Dry wooded openings, field lanes. Common. (4626)

A. lateriflorus (L.) Britt. Open woods, oak openings. Common. (4607, 4616)

A. macrophyllus L. Dry wooded opening along northern rim of Mitchell Glen. COUNTY RECORD. (4617)

A. sagittifolius Willd. Oak openings. Common. (4625, 4636)

A. shortii Lindley. Dry wooded opening along northern rim of Mitchell Glen. COUNTY RECORD. (4622, 4631)

Cirsium vulgare (Savi) Tenore. Common weed. (4502, 4579)

Chrysanthemum leucanthemum L. Common weed. (4293)

Erigeron annuus (L.) Pers. Common weed. (4501)

E. pulchellus Michx. Dry open woods. Common. (4314)

Eupatorium rugosum Houtt. Rich woods, thickets. Common. (4595, 4605)

Gnaphalium obtusifolium L. Dry openings. Common (4621)

Helianthus hirsutus Raf. Dry open woods. Common. (4575)

Heliopsis helianthoides (L.) Sweet var. *scabra* (Dunal) Fern. Open fields. Common. (4356, 4527, 4569)

Hieracium aurantiacum L. Common weed. (4325)

H. caespitosum Dumort. Common weed. (4480, 4482, 4651)

H. scabrum Michx. Dry open woods, oak openings. Common. (4598, 4620, 4658)

Krigia biflora (Walt.) S.F. Blake Oak opening above Glen Creek. Locally common. (4349)

Lactuca canadensis L. Common weed. (4600)

L. serriola L. Field lanes, open disturbed soils. COUNTY RECORD. (4583)

Matricaria matricarioides (Less.) Porter. Common weed. (4557)

Prenanthes alba L. Local on semi-shaded sandstone shelf above Glen Creek. (4615)

Rudbeckia hirta L. Oak openings. Common. (4561, 4653)

Senecio pauperculus Michx. One site; oak opening on natural terrace above Glen Creek. (4296)

Solidago canadensis L. Field lanes, old fields. Common. (4558, 4594)

S. flexicaulis L. Dry woods, oak openings. Common. (4606)

S. rigida L. var. *rigida* One site; dry opening along northeast rim above Mitchell Glen waterfalls.

S. ulmifolia Muhl. Oak openings. Common. (4608)

Sonchus oleraceus L. Common weed. (4591)

Taraxacum officinale Weber. Common weed. (4273)

Tragopogon pratensis L. Field lanes, open habitats. (4499)

Xanthium strumarium L. Common weed. (4545, 4576, 4577)

BALSAMINACEAE (Touch-me-not Family)

Impatiens capensis Meerb. Damp soils along Mitchell Glen Creek. Common. (s. n.)

BERBERIDACEAE (Barberry Family)

Caulophyllum thalictroides (L.) Michx. Rich woods. Common. (4267)

Podophyllum peltatum L. Throughout woods. (4278)

BETULACEAE (Birch Family)

Betula papyrifera Marshall. Occasional along edges of glen. (s. n.)

Ostrya virginiana (Miller) K. Koch. Throughout rich woods. (4567, 4599)

BORAGINACEAE (Borage Family)

Cynoglossum amabile Stapf & Drumm. Garden escape; waste ground along old building. COUNTY RECORD. (4603)

Hackelia virginiana (L.) I. M. Johnst. Dry woods. Common. (4540, 4580)

BRASSICACEAE (Mustard Family)

Barbarea vulgaris R. Br. Common weed. (4242)

Brassica nigra (L.) Koch. Common weed. (4556)

Cardamine concatenata (Michx.) O. Schwartz. Throughout rich woods. (4245)

Erysimum cheiranthoides L. Disturbed habitats. COUNTY RECORD. (4517)

Hesperis matronalis L. Common garden escape. (4274)

CAMPANULACEAE (Harebell Family)

Campanula rapunculoides L. Garden escape. (4571)

Lobelia siphilitica L. Damp soils along Glen Creek. Common. (4613)

L. spicata Lam. var. *spicata* Oak openings. Common. (4471)

CAPRIFOLIACEAE (Honeysuckle Family)

Diervilla lonicera Mill. Dry and rocky wooded openings. Uncommon. (4510, 4619)

Lonicera x *bella* Zabel. Woods, thickets. (4281, 4302)

Sambucus canadensis L. Woods, thickets. Common. (4253, 4488)

S. racemosa L. ssp. *pubens* (Michx.) House. Rich shaded slopes. Common (4573)

Symphoricarpos albus (L.) S.F. Blake Rare county-wide; dry wooded opening along northern rim of Mitchell Glen. COUNTY RECORD. (4614, 4629)

S. occidentalis Hook. Rare county-wide; wooded clearing above Glen Creek. COUNTY RECORD. (4624).

Viburnum lentago L. Occasional throughout woods. (4487)

V. rafinesquianum Schultes var. *rafinesquianum.* Dry woods along southern rim of Mitchell Glen. COUNTY RECORD. (4511, 4623)

CARYOPHYLLACEAE (Pink Family)

Arenaria lateriflora L. Woods, openings. Common. (4344)

Cerastium vulgatum L. Common weed. (4289)

Silene latifolia Poiret. Field lanes, disturbed habitats. Common. (4330, 4505, 4521)

CHENOPODIACEAE (Goosefoot Family)

Chenopodium album L. Common weed. (4518, 4526, 4549)

CLUSIACEAE (Mangosteen Family)
Hypericum punctatum Lam. Field lanes, dry openings. Common. (4568)

CONVOLVULACEAE (Bindweed Family)
Convolvulus arvensis L. Common weed. (4547)

CORNACEAE (Dogwood Family)
Cornus rugosa Lam. Rocky woods. Common. (4532, 4645)

CUCURBITACEAE (Gourd Family)
Echinocystis lobata (Michx.) T. & G. Edges of woods, thickets. Common. (4546)

EUPHORBIACEAE (Spurge Family)
Euphorbia corollata L. var. *corollata.* Dry wooded openings, field lanes. Common. (4592, 4650)

FABACEAE (Bean Family)
Amphicarpaea bracteata (L.) Fern. Throughout woods, openings. (4612)
Coronilla varia L. Roadside. (4515)
Medicago lupulina L. Common weed. (4307, 4525)
M. sativa L. Common along field lanes, old fields. (4481)
Trifolium campestre Schreb. Common weed. (4322)
T. pratense L. Common weed. (4327)
T. repens L. Common weed. (4328)
Vicia sativa L. ssp. *nigra* (L.) Ehrhart. Field lanes. Common. (4483)

FAGACEAE (Beech Family)
Quercus rubra L. Throughout woods. (4564)

FUMARIACEAE (Fumitory Family)
Dicentra cucullaria (L.) Bernh. Rich wooded slopes along Glen Creek. (4262)

GROSSULARIACEAE (Gooseberry Family)
Ribes cynosbati L. Rich woods. (4259, 4339, 4642)

HAMAMELIDACEAE (Witch Hazel Family)
Hamamelis virginiana L. Local on shaded slopes along Glen Creek. COUNTY RECORD. (4529)

HYDROPHYLLACEAE (Waterleaf Family)
Hydrophyllum virginianum L. Rich wooded slopes. Uncommon. COUNTY RECORD. (4308)

JUGLANDACEAE (Walnut Family)
Carya cordiformis (Wangenh.) K. Koch. Rich woods above Glen Creek. Uncommon. (4351, 4528)
Juglans cinerea L. Occasional throughout woods. (4282)

LAMIACEAE (Mint Family)
Leonurus cardiaca L. Common weed. (4465)
Monarda fistulosa L. var. *fistulosa.* Old fields, oak openings. Common. (4550)
Nepeta cataria L. Common weed. (4489)
Prunella vulgaris L. Common weed of damp soils. (4572)

MALVACEAE (Mallow Family)
Abutilon theophrasti Medikus. Common field weed. (4584)

MONOTROPACEAE (Indian Pipe Family)
Monotropa uniflora L. Dry woods, openings. Uncommon. (4562)

OLEACEAE (Olive Family)
Fraxinus pennsylvanica Marshall. Occasional throughout woods. (4472, 4627)

ONAGRACEAE (Evening Primrose Family)

Circaea alpina L. Local on moist shaded sandstone cliff beside waterfalls of Glen Creek. (4491)

C. lutetiana L. Throughout rich woods. (4363)

Oenothera parviflora L. Field lanes, old fields. (4590)

OXALIDACEAE (Oxalis Family)

Oxalis stricta L. Common weed. (4321, 4334)

PAPAVERACEAE (Poppy Family)

Sanguinaria canadensis L. Rich woods. Common. (4266)

PLANTAGINACEAE (Plantain Family)

Plantago major L. Common weed. (4544)

P. rugelii Decne. Common weed. (4504)

POLEMONIACEAE (Phlox Family)

Phlox divaricata L. One site; edge of woods along northeast rim of Mitchell Glen. COUNTY RECORD. (4244)

POLYGONACEAE (Smartweed Family)

Polygonum pensylvanicum L. Field lanes, open disturbed habitats. Common. (4589)

P. persicaria L. Common weed. (4555)

Rumex acetosella L. Common weed. (4585)

R. crispus L. Common weed of damp waste places. (4323, 4485)

R. obtusifolius L. Damp disturbed soils. (4536)

R. salicifolius J.A. Weinm. Wet soils along Glen Creek. (4467)

PORTULACACEAE (Purslane Family)

Claytonia virginica L. Throughout rich woods. (4250)

Portulaca oleracea L. Common weed. (4581)

PRIMULACEAE (Primrose Family)

Dodecatheon meadia L. Locally abundant in dry openings along southern and northern rims of Mitchell Glen. (4277)

PYROLACEAE (Shinleaf Family)

Pyrola elliptica Nutt. Rare, one site; oak opening on natural terrace above Glen Creek. (4652)

RANUNCULACEAE (Buttercup Family)

Actaea rubra (Aiton) Willd. Throughout rich woods. (4261, 4286, 4287)

Anemone quinquefolia L. Throughout rich woods. (4233)

A. virginiana L. Dry wooded openings. Common. (4343, 4357, 4362)

Caltha palustris L. Wet soils along Glen Creek. (4263)

Hepatica americana (DC.) Ker Gawler. Rich wooded slopes along Glen Creek. (4260)

Isopyrum biternatum (Raf.) T. & G. Rich woods. Uncommon. (4248)

Ranunculus abortivus L. Dry woods. Common. (4238)

R. fascicularis Muhl. Wooded openings. Common. (4284)

R. recurvatus Poiret. Rich woods. Uncommon. (4288)

Thalictrum dioicum L. Woods. Common. (4232)

RHAMNACEAE (Buckthorn Family)

Rhamnus cathartica L. Common, generally naturalized in woods and openings. (4297)

ROSACEAE (Rose Family)

Agrimonia gryposepala Wallr. Dry woods, oak openings. Common. (4554)

Amelanchier spicata (Lam.) K. Koch. Dry woods, openings. (4251, 4640, 4644)

Crataegus coccinea L. One site; beside a lane in wooded opening on southwest edge of Mitchell Glen. (4596)

Fragaria virginiana Duchesne. Dry wooded openings. (4237)

Geum canadense Jacq. Throughout dry woods. Common. (4355, 4548)

Potentilla recta L. Common weed. (4484)

P. simplex Michx. Field lanes, disturbed habitats. Common. (4350)

Prunus americana Marshall. Wooded openings, thickets. (4240)

P. pensylvanica L. f. Fencerow. (4643)

P. serotina Ehrh. Occasional throughout woods. (4301)

Pyrus ioensis (A. Wood) L. H. Bailey. Woods. Uncommon. (4271)

Rubus occidentalis L. Dry woods along southern rim of Mitchell Glen. COUNTY RECORD. (4337)

RUBIACEAE (Madder Family)

Galium aparine L. Woods. Common. (4272)

G. concinnum T. & G. Occasional in dry woods. COUNTY RECORD. (4473)

G. triflorum Michx. Throughout dry woods. (4655)

RUTACEAE (Rue Family)

Zanthoxylum americanum Mill. Disturbed woods, openings along northern rim of Mitchell Glen. Common. (4316)

SALICACEAE (Willow Family)

Populus tremuloides Michx. Disturbed woods. (4503)

Salix humilis Marshall. One site; beside field lane on eastern border of Mitchell Glen. (4294)

SANTALACEAE (Sandlewood Family)

Comandra umbellata (L.) Nutt. var. *umbellata.* Dry wooded openings along southern rim of Mitchell Glen. (4313)

SCROPHULARIACEAE (Figwort Family)

Aureolaria grandiflora (Benth.) Pennell var. *pulchra* Pennell. Adjacent to old lane and local in wooded opening along southern rim of Mitchell Glen. (4593)

Pedicularis canadensis L. Oak opening on natural terrace above Glen Creek. Uncommon. (4352)

Scrophularia lanceolata Pursh. Edge of woods on eastern border of Mitchell Glen. (4578)

Verbascum thapsus L. Common weed. (4520)

Veronica serpyllifolia L. Common lawn weed. (4276, 4490)

SOLANACEAE (Nightshade Family)

Physalis longifolia Nutt. Old field next to field lane. Common. (4479)

Solanum dulcamara L. Field lanes, open woods, thickets. Common. (4160)

S. nigrum L. Open disturbed soils. (4524, 4602)

TILIACEAE (Linden Family)

Tilia americana L. Throughout rich woods. (4299)

THYMELAEACEAE (Mezereum Family)

Dirca palustris L. Locally common in woods along southern rim of Mitchell Glen. COUNTY RECORD. (4649)

ULMACEAE (Elm Family)

Ulmus americana L. Occasional dry woods along southern rim of Mitchell Glen. (4303, 4618)

U. rubra Muhl. Occasional in rich woods. COUNTY RECORD. (4601)

URTICACEAE (Nettle Family)

Laportea canadensis (L.) Wedd. Partially shaded wet soils along Glen Creek. COUNTY RECORD. (4348, 4597)

Urtica dioica L. var. *procera* (Muhl.) Wedd. Disturbed damp soils. Common. (s. n.)

VERBENACEAE (Vervain Family)

Phryma leptostachya L. Throughout dry woods. (4563)

Verbena hastata L. Damp open habitats. Common. (4560, 4565)

VIOLACEAE (Violet Family)
Viola pubescens Aiton. Woods. (4230, 4265)
V. sororia Willd. Woods. (4231, 4239, 4243, 4249)

VITACEAE (Grape Family)
Parthenocissus vitacea (Knerr) A. Hitchc. Throughout woods. (4304, 4469)

MONOCOTYLEDONS

ARACEAE (Arum Family)
Symplocarpus foetidus (L.) Nutt. Wet soils in low woods and openings along Glen Creek. Common. (4258)

CYPERACEAE (Sedge Family)
Carex amphibola Steudel. Woods. Uncommon. COUNTY RECORD. (4311)
C. blanda Dewey Throughout rich woods. Common. COUNTY RECORD. (4298, 4332, 4500)
C. cephalophora Muhl. Dry open woods. (4511)
C. gracillima Schwein. Low woods. Uncommon. (4292)
C. pensylvanica Lam. Throughout woods and openings. (4236, 4246, 4252, 4269, 4270, 4309, 4331)
C. projecta Mackenzie. Low woods. Rare. COUNTY RECORD. (4475)
C. rosea Schk. ex Willd. Low woods. (4310, 4474)
C. sparganioides Willd. Woods, thickets. Common. (4358)
C. sprengelii Dewey. Rich woods. Uncommon. (4290)
C. vulpinoidea Michx. Wet soils along Glen Creek. Uncommon. (4486)

JUNCACEAE (Rush Family)
Juncus tenuis Willd. Various damp habitats. (4466)
Luzula multiflora (Retz.) Lej. Woods, clearings. Common. (4318)

LILIACEAE (Lily Family)
Allium canadense L. Oak opening on natural terrace above Glen Creek. Common. (4353)
A. tricoccum Aiton. Rich woods bordering Glen Creek. (4537)
Asparagus officinalis L. Common garden escape. (4283, 4507)
Erythronium albidum Nutt. Throughout rich woods. (4247)
Hypoxis hirsuta (L.) Cov. Oak opening on natural terrace above Glen Creek. Common. (4315)
Polygonatum biflorum (Walter) Elliott. Open woods, thickets. Common. (4333, 4498)
Scilla sibirica Andr. Planted and spreading about buildings. (4256)
Smilacina racemosa (L.) Desf. Throughout woods, openings. (4317)
Trillium grandiflorum (Michx.) Salisb. Throughout rich woods. (4255)
Uvularia grandiflora Sm. Rich woods along Glen Creek. (4257)

ORCHIDACEAE (Orchid Family)
Liparis lilifolia (L.) Rich. Two sites; local in oak openings. (4342)
Orchis spectabilis L. Rare, one site; beside a wooded path along northern rim of Mitchell Glen. (4181, 4285)

POACEAE (Grass Family)
Agrostis gigantea Roth. Open woods. Common. (4512, 4514, 4543)
Andropogon gerardii Vitman. Dry opening along northeast rim above Mitchell Glen waterfalls. (4634, 4661)
Bromus inermis Leysser. Field lanes, disturbed sites. Common. (4326, 4506)
Cinna arundinacea L. Low woods, thickets. (4320)
Dactylis glomerata L. Common weed. (4306, 4324)
Danthonia spicata (L.) P. Beauv. Old fields, dry woods. Common. (4470, 4566, 4654)

Digitaria sanguinalis (L.) Scop. Common weed. (4587)

Elymus canadensis L. Dry opening along northeast rim of Mitchell Glen. (4632)

E. hystrix L. Woods, openings. Common. (4539, 4570, 4659)

Elytrigia repens (L.) Nevski. Lawns, disturbed habitats. Common. (4508)

Festuca subverticillata (Pers.) E. Alexeev. Rich woods. Uncommon. (4477)

Glyceria striata (Lam.) A. Hitchc. Damp soils along Glen Creek. Common. (4476, 4495)

Leersia virginica Willd. Damp soils along Glen Creek. Common. (4574, 4611)

Lolium perenne L. Common weed. (4516, 4588)

Milium effusum L. Rich woods along Glen Creek. Uncommon. (4542)

Muhlenbergia frondosa (Poiret) Fern. Low woods. Common. (4610)

Panicum boreale Nash. Wooded opening. Uncommon. COUNTY RECORD. (4353)

P. leibergii (Vasey) Scribn. Dry oak opening. Uncommon. (4340, 4341)

P. miliaceum L. ssp. *ruderale* (Kitigawa) Tzvelev. Edge of cultivated field. (4551)

Phalaris arundinacea L. Various damp to wet open habitats. Common. (4329)

Phleum pratense L. Field lanes, old fields, clearings. (4359)

Poa compressa L. Field lanes, wooded openings. Common. (4291, 4319, 4468, 4513)

Setaria glauca (L.) P. Beauv. Common weed. (4609)

S. viridis (L.) P. Beauv. Common weed. (4552)

SMILACACEAE (Catbrier Family)

Smilax herbacea L. Occasional in damp woods. (4635)

S. lasioneura Hooker. Dry woods along northern rim of Mitchell Glen. (4360)

Acknowledgments

First, I wish to thank the Smith family for granting me access to study the Mitchell Glen flora. Their warm hospitality and friendship made this study a "labor of love."

Second, I'm beholden to Eric Ratering, who transcribed the S.D. Mitchell and Charles E. Brown letters and reports on local Indian antiquities and shared them with me.

Neil A. Harriman, OSH, was always available for consultation, answering an endless barrage of inquiries, and he made the coffee strong. Thank you, Neil. Thanks is extended also to Steve Ellis, Brian Neil, and Tom Schultz, who assisted me with collecting at various times. Special thanks are extended to Steve Ellis, Neil Harriman, and two anonymous reviewers for proofreading the manuscript—their suggestions greatly enhanced the quality of the report.

Literature Cited

Brown, Charles E. 1917. The antiquities of Green Lake. *Wisconsin Archeologist* 16:1–55.

Curtis, John T. 1959. *The Vegetation of Wisconsin.* University of Wisconsin Press, Madison. 657 pp.

Dart, Richard. 1910. Settlement of Green Lake County. *Proceedings of the State Historical Society of Wisconsin (57th annual meeting).* pp. 252–72.

Dorney, John R. 1981. The impact of native Americans on presettlement vegetation in southeastern Wisconsin. *Transactions of the Wisconsin Academy of Sciences, Arts & Letters* 69:26–36.

East Central Wisconsin Regional Planning Commission. 1977 (March). *Regional Park System, Outdoor Recreation and Open Space Plan for East Central Wisconsin.*

Eddy, Thomas L. 1996. A vascular flora of Green Lake County, Wisconsin. *Transactions* *of the Wisconsin Academy of Sciences, Arts & Letters* 84:23–67.

Finley, Robert W. 1976. Original Vegetation Cover of Wisconsin (map). (St. Paul: North Central Forest Experiment Station, Forest Service, U. S. Department of Agriculture).

General Land Office. 1834. Land surveyors' field notes for T16N R12E. State of Wisconsin, Board of Commissioner of Public Lands.

Heiple, Robert W., and Emma B. Heiple. 1978 (2nd ed.). *A Heritage History of Beautiful Green Lake Wisconsin.* McMillan Printing Company, Ripon, Wisconsin.

Hole, Francis D., and Clifford E. Germain. 1994. Natural Divisions of Wisconsin (map). Wisconsin Department of Natural Resources.

Martin, Lawrence. 1965. *The physical geography of Wisconsin.* 3rd ed. Wisconsin Geological and Natural History Survey Bulletin 36.

Paull, Rachel Krebs, and Richard A. Paull. 1977. *Geology of Wisconsin and Upper Michigan (Including Parts of Adjacent States).* Kendall/Hunt Publishing Company, Dubuque, Iowa. 232 pp.

State Historical Society of Wisconsin. 1888. Catalogue of the S.D. Mitchell Archaeological Collection from Green Lake and Marquette counties, Wisconsin (January 1st, 1888). Archives Division, Register of the Charles E. Brown Papers, 1889–1946 (Box 26 Folder 1).

Tracy, Mrs. C.T. 1889. Catalogue of plants growing without cultivation in Ripon and the near vicinity. (Unpublished).

United States Department of Agriculture. 1977. Soil Survey of Green Lake County, Wisconsin. (Soil Conservation Service).

United State Geological Survey. 1980. Green Lake quadrangle (map), 7.5 minute series.

University of Wisconsin-Extension, Geological and Natural History Survey. 1981. Bedrock Geology of Wisconsin (map).

Wisconsin Department of Transportation. 1988. Green Lake County (highway map). State Office Building, Madison, WI.

***Thomas Eddy** is a past recipient of the National Association of Biology Teacher's OBTA (Outstanding Biology Teacher Award) and the Kohl Teaching Fellowship Award. He teaches for the Green Lake School District and for Marian College, Fond du Lac. Mr. Eddy is a founding member of the Green Lake Conservancy Foundation, Inc. and serves on numerous committees and organizations involved with natural areas preservation. He is author of "A Vascular Flora of Green Lake County, Wisconsin," which appeared in the 1996* Transactions. ***Address:** 426 Walker Avenue, Green Lake, WI 54941. **Email:** tleddy@vbe.com*

This paper is dedicated to a young man who loved Mitchell Glen like no other 17-year-old could. For those of us who shared time in the glen with him, a walk through Mitchell Glen will never be the same. So, Augie, this Mitchell Glen flora is fondly dedicated to you.

In Memoriam
August DeForest Zebediah Smith
June 16, 1980 – January 20, 1998

Joan Jass and Jeanette Glenn

Measuring the Degree of Variation in Wisconsin *Pyganodon grandis* (Say 1829) (Mollusca: Bivalvia: Unionidae)

Abstract *Variation in the ubiquitous and abundant freshwater bivalve* Pyganodon grandis *was studied using museum specimens collected across Wisconsin from 1973 to 1977. Data on six shell traits were gathered for each specimen: 1) beak sculpture, 2) overall length, 3) height, 4) width, 5) anterior-to-beak length of the right valve, and 6) darkness of the periostracum. Data from the Wisconsin specimens were subsequently pooled into three regional groupings representing sites from the northeast, the southwest, and an intermediate tension zone. Comparison of three groups revealed statistically significant differences and indicated a high degree of intraspecific variation.*

Variation in populations of the ubiquitous and abundant freshwater bivalve genus *Anodonta* was analyzed in Canada by Clarke (1973). In order to assess the taxonomic importance of such variation, Clarke conducted a statistical analysis of shell traits and compared the results to ecological and geographic data from Canadian collecting sites. In the past the extreme variability displayed by *Anodonta* has given rise to a number of subspecific divisions. In Wisconsin for example, F.C. Baker (1928) found two subspecific level taxa in addition to the standard *Anodonta grandis.* Turgeon et al. (1998) have placed this species in the genus *Pyganodon.*

Clarke's analysis revealed strong correlations between site geography and the following shell traits: 1) beak sculpture, 2) anterior-to-beak length/length overall, 3) width/length overall, and a lesser degree of correlation to 4) height/length overall. He also found good to fair correlations between site ecology and anterior-to-beak length/length overall, as well as darkness of the periostracum.

In Wisconsin, this taxon is also widespread and abundant. Mathiak's five-year survey (1973–1977) (Mathiak 1979) ranked it second in both number of sites from which he collected it (N = 202) and in total number of specimens collected (N = 1039). The Mathiak site map for this species shows collecting localities well distributed over the state. The Milwaukee Public Museum (MPM) subset of the Mathiak collection includes *Pyganodon grandis* (giant floater) specimens from two-thirds of Wisconsin's 72 counties. We measured these specimens to examine the degree of variation present within the state. A high degree of within-state variability in aquatic invertebrate traits was reported by Parejko (1987), who found statistically significant north/south differences in the life history parameters of several Wisconsin species.

Methods

The traits in Clarke's study that showed some significance were those measured in MPM specimens of *P. grandis:* 1) beak sculpture, which Clarke scored 1-4 (1,2 = not in Wisconsin, 3 = double loop, 4 = nodulous); 2) length overall; 3) height; 4) width; 5) anterior-to-beak length, right valve (traits 2-5 measured to the nearest tenth of a millimeter with a dial caliper); 6) darkness of the periostracum, arbitrarily scored as light = 1, medium = 2, dark = 3. Four of these traits (2-5) represent morphometric variables, while traits 1 and 6 represent continuous, nonnumeric traits that have been assigned to numeric classes for purposes of analysis.

For possible correlations with geography, shells collected by Harold Mathiak (1979) in a statewide survey of Wisconsin waterways were chosen for this study (N = 139). Data from these specimens, part of a representative subset of his collection selected for donation to MPM by Mathiak, were expected to give a good indication of the degree of geographic variation to be found within the state, since his study included localities from across Wisconsin. Collecting sites were subsequently pooled into three ecological regions, following Curtis's division of Wisconsin into a northeastern province of northern hardwoods, an intermediate tension zone, and a southwestern province of prairie-forest (Curtis 1971). He divided the state into these three regions by mapping the ranges for 182 species that reached their northern or southern limits in Wisconsin. North of the area where these range lines cross the state is the northeastern province, south of it is the southwestern province, and the summed region covered by the 182 range lines is the tension zone, where geology, climate, and environmental factors have combined to exert a defining selective pressure on those species. Our pooling of Mathiak's collecting sites included creeks and rivers from both Great Lakes and Mississippi River drainage basins in the northeastern as well as in the southwestern region. A *t*-test was used to compare northeastern and southwestern shells, using the means of the six measured traits (SAS 1987), with a *P* value of 0.05 or less as the level chosen to indicate statistical significance.

Results

Table 1 shows the results of *t*-tests on six measured shell traits as well as the results from tests on three ratios derived from the original measurements. All tests showed a statistically significant difference between northeastern and southwestern groups of shells. The *P* values for these tests ranged from a very highly significant level of less

Table 1. North/south comparison of shell traits in Wisconsin.

	North Mean (N)	*South Mean (N)*	*Value of t*	*Degrees of Freedom*	*P*
Beak sculpture	3.50 (54)	3.18 (44)	3.42	96	0.0009
Width (mm)	31.2 (77)	43.8 (45)	7.53	120	<0.00001
Height (mm)	46.8 (77)	66.9 (45)	8.88	120	<0.00001
Length (mm)	85.0 (77)	115.5 (45)	7.93	120	<0.00001
Anterior (mm)	24.8 (77)	38.1 (45)	9.36	120	<0.00001
Darkness	2.65 (77)	2.24 (45)	3.95	120	0.0001
Anterior/length	0.29 (77)	0.33 (45)	6.72	120	<0.00001
Width/length	0.37 (77)	0.38 (45)	2.04	120	0.0431
Height/length	0.55 (77)	0.58 (45)	4.25	120	<0.00001

than 0.00001 to 0.0431, all falling below the 0.05 level chosen for statistical significance. Northern shells had darker color, beak sculpture less consistently double-looped, and widths, heights, lengths, and anterior-to-beak measurements that were smaller than those in the southern group.

Tension zone shells (N = 17) had means that were generally intermediate between north and south values: beak = 3.21, width = 33.8 mm, height = 52.4 mm, length = 91.0 mm, anterior-to-beak = 27.7 mm, darkness = 2.35, anterior-to-beak/overall length = 0.30, width/overall length = 0.37, height/overall length = 0.58.

Discussion

C.T. Simpson (1896) produced one of the early summaries dealing with classification in the group he called the "pearly freshwater mussels." Among the features he considered key characteristics for this group were the beak with its sculptural details and "remains of the nuclear shell." Simpson followed the biological rule of reliance on the characteristics of embryonic stages to determine the relationships within a group under study.

However, a disadvantage to relying heavily on such traits as beak sculpture is that they may be shown only in very young or well-preserved shells. Though beak details can be definitive for such specimens, by the time they have reached adulthood, many shells have beaks significantly damaged by mechanical erosion and/or dissolution from acidic waters. In certain areas, virtually every shell collected may show such damage. Clarke and Berg (1959) created a key to northeastern North American species of Unionacea that would allow most identifications to be made without the use of beak sculpture characters, because they were so often obliterated in adult specimens. Nearly 20% (N = 27) of the specimens in our Wisconsin dataset had the beak too damaged for scoring.

As other studies had done, Clarke and Berg (1959) compared typical members of this species to its described subspecies on the bases of shell measurements and ratios derived from them. As mentioned previously, Baker (1928) found two subspecies in the state in addition to the typical *A. grandis, A. g. plana* and *A. g. footiana*. He additionally listed as other species entities that today are considered part of the *P. grandis* complex: *A. gigantea, A. kennicottii, A. marginata* and *A. corpulenta*. While our study did not focus on possible taxonomic implications of morphometric variation, data from Wisconsin specimens illustrate the high degree of variability of shell traits within this taxon, whether the material studied is considered to be representative of several species as it was by malacologists of the past such as Baker or as an entity that includes several of those formerly accepted species in synonymy as more recent researchers have done. Table 2 gives a comparison of these variables from Wisconsin specimens.

The most basic geographical correlation with measured shell traits that Clarke (1973) found in his analysis of Canadian specimens was the smaller size of northern populations due to a shorter growing season. Our results show that this contrast can also be seen in the analysis of specimens collected over a much smaller area, in a statewide rather than a countrywide survey. However, an alternate pooling of data from the Wisconsin collecting sites on the basis of their township values, which are calculated simply on distance north of the Illinois state line, yielded a correlation less strong than the results we present in Table 1, which were based on the ecological regions of Curtis (1971). Therefore the regions of Curtis, which were originally derived from plant species ranges, gave the better key to analysis of zoogeographic variability in the state, presenting a more sophisticated picture of the climatic and other similar phenological stresses on Wisconsin species than straightforward north/south differences.

Cummings and Mayer (1992) confirm that *P. grandis* is widespread and common throughout the entire Midwest. Habitats they list as typical range from ponds to creeks and rivers. This ability to survive in widely differing habitats is no doubt key to the widespread distribution of this species. In fact, had *P. grandis* been like many other relatively thin-shelled species that are more restricted to pool habitats, it would not have ranked where it did in Mathiak's tabulated results (Mathiak 1979). Mathiak generated lists ranking all of the species he collected: one list was based on the number of collecting sites where each species was found (frequency), and another was based on the number of specimens collected of each species (abundance). *Pyganodon grandis* ranked sec-

Table 2. Range of measurements, *Pyganodon grandis* complex.

	Length (mm)	*Height/length*	*N*	*Source*
A. grandis	67–190	0.56–0.67	6	Baker 1928
A. g. plana	58–145	0.52–0.59	8	Baker 1928
A. g. footiana	23–115	0.56–0.65	8	Baker 1928
A. gigantea	85–159	0.67–0.72	2	Baker 1928
A. kennicottii	56–90	0.54–0.62	6	Baker 1928
A. marginata	30–120	0.49–0.59	9	Baker 1928
A. corpulenta	103–153	0.67–0.74	5	Baker 1928
P. grandis — North	55–140	0.49–0.69	77	This study
P. grandis — South	50–168	0.49–0.65	45	This study
P. grandis — Tension Zone	66–110	0.51–0.68	17	This study

ond to only one other of the 45 species in both of these lists. The totals for the top-ranked species were 236 sites and 1161 specimens; the third-ranked species' numbers fell to 169 and 721. Further evidence of the wide tolerance of *P. grandis* is the record this species holds for survival at a water depth of very low oxygen and temperature (living at a depth of 102 ft in Lake Michigan, Reigle 1967).

Cummings and Mayer (1992) also point out the extreme variability in this taxon; for example, they note that the umbos are located more toward the center than the anterior in the large-river form of the species they call *P. grandis* var. *corpulenta* (= Baker's *Anodonta corpulenta*, Table 2). Buchanan (1980) still listed *A. grandis corpulenta* as a subspecies, as did Burch (1975). These researchers differentiated the subspecies by its length/height ratio of less than 1.6 and anterior/length ratio almost up to 0.5.

Any wide-ranging species, such as *P. grandis,* is usually assumed to be made up of a series of subpopulations, each with its own morphological as well as physiological characteristics. These characteristics include seasonal growth patterns and reproductive phenology. For example, Surber (1914) reported finding gravid *A. corpulenta* in the spring (April) and fall (October, November) but gravid *A. grandis* in the fall only (September, October). A species complex such as that represented by *P. grandis* may thus be expected to contain considerable diversity in life history traits as well as morphological traits.

In spite of a degree of diversity so high that some prior researchers have divided the taxon into subspecies, we have considered all specimens in our study as simply *P. grandis.* Our focus was zoogeographic rather than taxonomic, to use shell traits to analyze the degree of variation within specimens collected during one five-year survey of Wisconsin's waterways. Statistical analysis of *P. grandis* shell traits showed significant differences correlating with the ecological regions delimited for Wisconsin by Curtis (1971). This met our two goals of highlighting the great deal of variation within this taxon and also, more specifically, of showing that this variability follows a zoogeographic pattern in which significant differences occur between populations in northern and southern ecological regions of Wisconsin.

Acknowledgments

We gratefully acknowledge the donation from Harold A. Mathiak of *Pyganodon grandis* specimens collected during his statewide survey to the Milwaukee Public Museum collection and the comments of Marian E. Havlik, La Crosse, Wisconsin, and Dr. David H. Stansbery, Curator of Mollusca, The Ohio State University Museum of Biological Diversity, Columbus, Ohio, on earlier versions of this paper. Initially a poster presentation at the 1998 annual conference of the Wisconsin Academy of Sciences, Arts & Letters, our manuscript subsequently received significant beneficial input from *Transactions* reviewers.

Literature Cited

Baker, F.C. 1928. *The freshwater Mollusca of Wisconsin. Part II. Pelecypoda. Bulletin 70.* Wisconsin Geological and Natural History Survey. Madison, Wisconsin. 495 pp.

Buchanan, A.C. 1980. *Mussels (Naiades) of the Meramec River Basin, Missouri. Aquatic Series No. 17.* Missouri Department of Conservation. Jefferson City, Missouri. 68 pp.

Burch, J.B. 1975. *Freshwater Unionacean clams (Mollusca: Pelecypoda) of North America. U.S.*

Environmental Protection Agency Identification Manual No. 11. Malacological Publications, Hamburg, Michigan. 204 pp.

Clarke, A.H. 1973. The freshwater molluscs of the Canadian Interior Basin. *Malacologia* 13(1–2):1–509.

Clarke, A.H., and C.O. Berg. 1959. The freshwater mussels of central New York with an illustrated key to the species of northeastern North America. *Cornell University Agricultural Experiment Station Memoir* 367:1–79.

Cummings, K.S., and C.A. Mayer. 1992. *Field guide to freshwater mussels of the Midwest. Manual 5.* Illinois Natural History Survey. Champaign, Illinois. 194 pp.

Curtis, J.T. 1971. *The vegetation of Wisconsin, an ordination of plant communities.* University of Wisconsin Press, Madison. 657 pp.

Mathiak, H.A. 1979. *A river survey of the unionid mussels of Wisconsin 1973–1977.* Sand Shell Press, Horicon, Wisconsin. 75 pp.

Parejko, K. 1987. A phenological study of aquatic invertebrates. *University of Wisconsin-Stevens Point Museum of Natural History Reports* 13:72.

Reigle, N. 1967. An occurrence of *Anodonta* (Mollusca, Pelecypoda) in deep water. *American Midland Naturalist* 78:530–31.

SAS Institute Inc. 1987. *SAS system for elementary statistical analysis.* SAS Institute Inc. Cary, North Carolina. 416 pp.

Simpson, C.T. 1896. The classification and geographical distribution of the pearly freshwater mussels. *Proceedings of the U.S. National Museum* 18:295–343.

Surber, T. 1914. Identification of the glochidia of fresh-water mussels. *U.S. Bureau of Fisheries, Report of the U.S. Commissioner of Fisheries for the Fiscal Year 1912*:1–10.

Turgeon, D.D., J.F. Quinn, Jr., A.E. Bogan, E.V. Coan, F.G. Hochberg, W.G. Lyons, P.M. Mikkelsen, R.J. Neves, C.F.E. Roper, G. Rosenberg, B. Roth, A. Scheltema, F.G. Thompson, M. Vecchione, and J.D. Williams. 1998. *Common and scientific names of aquatic invertebrates from the United States and Canada: mollusks.* 2nd ed. American Fisheries Society, Bethesda, Maryland. 526 pp.

Joan Jass *is an assistant curator in the Zoology Section of the Milwaukee Public Museum. Among her curatorial responsibilities is the museum's mollusk collection, which includes over 20,000 specimens from Wisconsin, the museum being an officially designated repository for collections from the state.* ***Address:*** *Zoology Section, Milwaukee Public Museum, 800 West Wells Street, Milwaukee, WI 53233.*
Email: *jass@mpm.edu*

Jeanette Glenn *has been a volunteer in the Milwaukee Public Museum's Zoology Section since 1983. With her assistance, data from the Wisconsin mollusks have been entered into a computerized dataset that documents voucher material deposited in the collection by a number of state researchers, including Harold Mathiak.*

Jeffrey J. Ripp

Fisheries Management in the Great Lakes: The Evolution of the Great Lakes Fishery Commission

Abstract *The responsibility for managing the fishery resources of the Great Lakes is fragmented between two national governments, eight states, one province, and two Indian fishery management authorities. The lack of coordination between government agencies that have authority over the fisheries of the Great Lakes has hindered effective fisheries policy in the past. The Great Lakes Fishery Commission (GLFC) was established under the 1955 binational Convention on Great Lakes Fisheries to address issues that were beyond the ability of each agency to deal with singularly. Since the formation of the Commission, the ecology and economy of the Great Lakes basin has changed significantly, and the Commission has changed its focus to address new concerns in innovative ways. The last decade has seen the emergence of a new era of cooperative resource management following the principles of ecosystem management. The GLFC, through the development of the Strategic Great Lakes Fisheries Management Plan, provides a forum for raising fishery issues and coordinating the efforts of the government agencies charged with managing Great Lakes fisheries and habitat. The GLFC has achieved mixed success in fostering the ecosystem management approach. This paper provides an institutional analysis of the Great Lakes Fishery Commission, describes how the Commission's role has changed, and evaluates the Commission's successes in implementing ecosystem management approaches.*

The Great Lakes Fishery Commission (GLFC) is a binational organization that was created in 1955 under the Convention on Great Lakes Fisheries to advise the governments of the United States and Canada on the sustainable management of Great Lakes fisheries, promote fisheries research, and control the sea lamprey *(Petromyzon marinus).* Since 1955, both the political climate and the fisheries of the Great Lakes region have changed, and the institutions for managing the fisheries have adapted to address new concerns. The GLFC has played a quiet but important role in coordinating management efforts among two national governments, eight states, one province, and two Native American fishery agencies. The GLFC's effort to establish an ecosystem-based management approach has allowed it to expand beyond its original study-and-advise mandate. Despite the success of the GLFC in coordinating fishery management, several hurdles must be overcome before fishery management can be integrated with other Great Lakes management efforts such as the Great Lakes Water Quality Agreement.

In the 1980s, the GLFC recognized that maintaining sustainable fish stocks in the Great Lakes would require an integrated, systems-oriented approach focused on the development of stable, self-sustaining fish communities. The approach has been termed "ecosystem management" and can be described as a shift from a media-based, program-focused approach to one that is place-based and ecosystem-oriented (Donahue 1988*a;* MacKenzie 1990; Holland 1996; Regier, unpublished). Ecosystem management has been described in many different ways. In most contexts, ecosystem management is defined as a management philosophy that accounts for the interrelationships among the land, air, water, and all living things, including humans (Hartig et al. 1998). Unfortunately, this definition does not truly describe what ecosystem management "is" or how it is implemented. In practice, ecosystem management represents a shift from single-issue approaches that treat the symptom, rather than the cause, of a problem to more holistic approaches that attempt to address the underlying causes. A good start towards a working definition of the ecosystem approach is "an action-based, adaptive planning and management process that accounts for the interrelationships among ecological components, including humans" (Hartig et al. 1998). This working definition gives some insight into how ecosystem approaches are used in practice. One of the basic tenets of ecosystem management is the reliance on involving stakeholders in the decision-making process. Under ecosystem management, stakeholders are defined as any user or group that is affected by the resource or has the potential to impact the resource. This concept of stakeholder involvement is crucial for the success of ecosystem-based approaches.

The driving force for pursuing an ecosystem approach in fisheries management is the acknowledgment that the traditionally narrow focus of resource management agencies is insufficient to deal with the complexity of the ecosystem. The failure of Great Lakes institutions to effectively confront large scale problems is a result of fragmented authority for managing the resource. In many cases, the authority for regulating pollution and managing fisheries resides in separate government agencies. Further, conflicting social values and uncertainty associated with management initiatives complicate fisheries management. The joint Strategic Great Lakes Fisheries Management Plan (Strategic Plan) was prepared and adopted in 1980 by Great Lakes fishery management authorities under the direction of the GLFC to recognize common agency goals and establish a commitment to interjurisdictional coordinated fishery management based upon the ecosystem approach (GLFC 1997*a*).

In the Great Lakes, fishery management is only one component of a larger integrated environmental management framework. The most studied manifestations of ecosystem management in the Great Lakes are the Lakewide Management Plans (LaMPs) and Remedial Action Plans (RAPs) for the 43 Areas of Concern established under the 1987 amendments to the Great Lakes Water Quality Agreement. Despite considerable overlap with fish management activities, the LaMPs and RAPs have been criticized for not adequately representing fish management goals (Hartig et al. 1996*a*, Hartig et al. 1996*b*). Under the Strategic Great Lakes Fisheries Management Plan, the various state, tribal, federal, and provincial natural resources agencies call upon the GLFC to provide the institutional capacity to coordinate fishery and environmental management and maintain the necessary stakeholder partnerships.

This paper describes the institutions in place for managing the Great Lakes fishery, explains the development of ecosystem-based management approaches, and evaluates the GLFC's efforts to improve the fishery. The focus of this paper is the expanded role of the GLFC under the Strategic Great Lakes Fisheries Management Plan. The paper concludes with a discussion of the challenges facing the GLFC in implementing ecosystem-based fishery management and an investigation of lake trout rehabilitation. The author conducted telephone interviews with eight people involved with Great Lakes fishery management from both the United States and Canada, including current and past GLFC staff, a former GLFC commissioner from Canada, fish managers from Wisconsin, academics, and sport fishery stakeholders. The criteria for evaluating the success of the ecosystem approach are based primarily upon the goals and objectives set forth in the Strategic Plan and the Great Lakes Fishery Commission's Strategic Vision for the Decade of the 1990s (GLFC 1992), but additional criteria have been borrowed from Donahue (1988*a*).

Overview of the Great Lakes Fishery

Every spring and fall, thousands of migrating Pacific salmon (*Oncorhynchus* spp.), steelhead *(Oncorhynchus mykiss),* and brown trout *(Salmo trutta)* surge up the tributaries flowing into the Great Lakes to spawn. None of these fish species are native to the Great Lakes. Historical commercial fishing records show that less than 50 years ago, these species were not among the top catches in these lakes. In fact, many of these species were not even commonly found in the lakes until as recent as the 1980s (Jude and Leach 1993). Over the last 100 years, the aquatic community of the Great Lakes has been drastically altered by human activities, including both planned and accidental species introductions. Deterioration in water quality, loss of habitat, and dramatic changes in aquatic biota parallel the increasing use of the region's resources through mining, fishing, logging, agriculture, hydropower development, and industry. Despite changes in fish communities, the Great Lakes fishery remains today an important resource for the region, contributing to the economies of the eight riparian U.S. states and the Canadian province of Ontario.

Historically, the Great Lakes supported a tremendous commercial fishery of lake trout *(Salvelinus namaycush),* sturgeon *(Acipenser fulvescens),* whitefish *(Coregonus clupeaformis),* walleye *(Stizostedion vitreum vitreum),* lake herring *(Coregonus artedii),* and blue pike *(Stizostedion vitreum glaucum)* (Baldwin et al. 1979). Throughout most of the twentieth century, the reported annual commercial fish harvest in the Great Lakes has remained near 45,000 tons, but the composition of the catch has changed significantly (Kelso et al. 1996). Most native fish populations in the Great Lakes suffered dramatic declines between the mid-1800s and mid-1900s. The collapse of these fisheries has been attributed to the combined pressures of decades of overfishing, habitat degradation, and the invasion of the exotic sea lamprey (Jude and Leach 1993). The sea lamprey is a fish parasite believed to have been introduced into Lake Ontario via the Hudson River and Erie Canal and was first observed in the 1830s. The lamprey migrated into Lake Erie in 1921 after the opening of the Welland Canal and made its way into Lake Superior by 1938 (GLFC 1999). Lake trout became extinct in Lakes Michigan, Ontario, and Erie, nearly extinct in Lake Huron, and reduced to dangerously low levels in Lake Superior by the mid-1950s (Jude and Leach 1993). Basin-wide commercial lake trout harvest declined from 5,248,000 pounds in 1926 to 503,100 pounds in 1960, forcing Great Lakes states to ban commercial lake trout fishing (Baldwin et al. 1979).

In 1955, the United States and Canada signed the binational Convention on Great Lakes Fisheries, establishing the Great Lakes Fishery Commission to implement lamprey control measures, coordinate fishery research activities, and advise the two governments on how to best manage their common fish stocks for maximum sustained productivity. By 1966, the lamprey population had been brought under control through selective lampricide treatment of spawning streams in Lakes Superior, Michigan, and Huron. Concurrently, stocking programs were underway to introduce Pacific salmon into the Great Lakes to control burgeoning alewife *(Alosa pseudoharengus)* populations, an exotic forage species that responded favorably to the disappearance of lake trout from the ecosystem. Eventually, lamprey control and salmon stocking were undertaken in all five of the Great Lakes (Jude and Leach 1993).

Today, the sport fishery based on non-native salmonids is an important component of the regional economy. The expanding sport fishery generates between two to four billion dollars annually in the Great Lakes region (Talhelm 1988). The American Sportfishing Association estimates that in Wisconsin alone, the total economic impact of the Great Lakes sport fisheries is $199 million, which includes angler spending and subsequent stimulated economic activity (Maharaj and Carpenter 1996). In contrast, the annual commercial harvest in the Great Lakes region is valued at $270 million (Talhelm 1988). While these numbers are not directly comparable, they demonstrate the increasing importance of sport fishing in the region. As a result, fishery managers have felt increasing pressure to expand sport fishing opportunities (primarily non-native species), often at the expense of commercial fishing.

Despite significant improvements in water quality since 1970 and a resurgence in some native fish populations, rehabilitating native fish stocks and stabilizing the aquatic ecosystem remain elusive goals that are often at odds with one another. Lake trout rehabilitation efforts, with the exception of Lake Superior, have generally failed to achieve stable reproducing populations due to loss of genetic strains, poor habitat, and competition with non-native species (Jude and Leach 1993). Overfishing remains a concern for many species. Exotic nuisance species, such as the sea lamprey, continually challenge natural resource agencies' budgets and ability to manage the resource. Long-lived toxic chemicals affect the wholesomeness of fish as human food. Habitat degradation through wetland loss and shoreline development continue to reduce the available spawning and rearing habitat for many species. Further, changing social conditions over the last 40 years have forced management institutions to address new public values and concerns. These changes include a reduction in commercial fishing of native stocks in favor of recreational fishing of introduced species, the emergence of tribal groups exercising legitimate commercial and subsistence rights that did not exist 50 years ago, increasing public concern about Great Lakes environmental quality issues, and well-organized environmental groups.

Authorities for Great Lakes Fishery Management

Donahue (1988*a*) describes the complex milieu of actors involved with managing the Great Lakes as an "institutional ecosystem" consisting of local, state, federal, and international entities. In the Great Lakes region, management responsibilities for the fishery resource fall primarily under the jurisdiction of eight states and one province, although tribal agencies and the two federal governments play a major role in many aspects of fishery management.[1] Great Lakes management is particularly complicated by the fact that the responsibility for environmental protection and resource management are often divided between separate agencies. Experiments in regional government are also common in the Great Lakes. Organizations such as the Great Lakes Fishery Commission, International Joint Commission, Great Lakes Commission, and Council of Great Lakes Governors all play a role in Great Lakes management.

Canadian responsibilities for managing the fishery resource are divided between the federal government and the Province of Ontario. Under the British North America Act of 1867, the federal government has exclusive legislative jurisdiction over protection and development of the fisheries. The federal government also has indirect jurisdiction through its authority to intervene in interprovincial and international matters. Under British common law, the provinces are the proprietors of the natural resources within their boundaries. The Canada-Ontario Fisheries Agreement clarified the dual federal-provincial responsibilities somewhat; the federal government may legislate for the regulation and protection of the Great Lakes fishery, but the provinces may exercise their proprietary rights to allocate the fish under their jurisdiction as long as these acts are consistent with federal legislation (Thompson 1974). Canadian federal authority is demonstrated primarily through its focus on research, environmental quality, habitat issues, and the establishment of treaties with the United States. Provincial authority is manifest through licensing, permitting access to the resource, and setting harvest restrictions and goals (Dochoda, unpublished). On the southern side of the border, the Great Lakes states have supreme control over fisheries, including the right to stock fish, manage habitat, and regulate harvest with one limitation, the Commerce Clause of the United States Constitution. The U.S. federal role for managing the Great Lakes fishery is still being defined but is expressed primarily in matters of navigation, environmental quality, habitat protection, endangered species, exotic species, and international treaties. The U.S. federal government has played a role supportive to the states and tribal governments through research, fish stocking, and law enforcement. In the U.S., these arrangements reflect a strong states' rights bias in fishery management.

Native American rights in the Great Lakes basin vary widely between the U.S.

and Canada. In the U.S., off-reservation fishing rights are rooted in treaties with the federal government. The U.S.-Ottawa treaty of 1836 preserves tribal fishing rights in the northern Michigan waters of Lakes Superior, Michigan, and Huron. In Wisconsin, the 1842 treaty with the Chippewa preserves tribal fishing rights for the Red Cliff and Bad River tribes in Lake Superior. Tribes with off-reservation fishing rights have established intertribal agencies to regulate their members' activities. The Great Lakes Indian Fish and Wildlife Commission and the Chippewa-Ottawa Fishery Management Authority have considerable authority to manage fisheries and, for the most part, operate independently of state regulations. The rights of Native Americans in Canada are much less clear and are still being defined in the Canadian Supreme Court. In these cases, the Court has devised a test that assigns aboriginal fishing rights a high priority along with commercial fishing, and less priority to recreational fishing. In general, the provinces retain authority to regulate Indian fishing, and it is unlikely that Canadian Native Americans will achieve the same control over fisheries that has been reserved by the U.S. tribes (Dochoda, unpublished).

The Great Lakes Fishery Commission

In spite of obvious declines in shared fish stocks, efforts to establish an international fishery authority for the Great Lakes between 1893 and 1952 failed repeatedly. Ontario, being outnumbered by the states, desired a convention that would allow full representation of its interests on a one-to-one basis with the states. Attempts at establishing a convention between Canada and the U.S. included the 1908 Treaty between the United States and Great Britain on Fisheries in the U.S. and Canadian Waters and the 1946 Convention between the United States of America and Canada for the Development, Protection, and Conservation of the Fisheries of the Great Lakes. The U.S. Congress failed to ratify these agreements due to the unwillingness of the states to relinquish management authority to an international body (Dochoda, unpublished). Initiatives by the states and provinces to coordinate among themselves were opposed by the U.S. Department of State and the U.S. Congress on the grounds that they violated the Supremacy Clause of the U.S. Constitution.[2] The crisis that precipitated true cooperation on fisheries management in the Great Lakes was the destructive power of the exotic sea lamprey. Recognizing that state and provincial fish managers were incapable of responding effectively to the sea lamprey, the governments of the United States and Canada ratified the 1955 Convention on Great Lakes Fisheries, establishing the binational Great Lakes Fishery Commission.

The Commission was charged with a set of duties that can be characterized as primarily "study-and-advise" (GLFC 1983). Under the 1955 Convention, the Commission was authorized to formulate a research program designed to determine what measures were necessary to maximize the sustained production of fish stocks of concern in the Great Lakes, publish results of this research, and recommend appropriate management measures to the United States and Canada. In addition to the Commission's general role in coordinating fisheries research, the Commission was charged with the specific task of formulating and implementing a comprehensive program for the purpose of eradicating or minimizing the impacts of the sea lamprey in the Great Lakes.

The Commission consists of four[3] appointed commissioners from each nation for a total of eight, each with a single vote. Appointments to the Commission are made by the President of the United States and the Privy Council of Canada for staggered six-year terms. Two commissioners in each section represent federal interests and two represent state or provincial interests. Carroll D. Besadny, former secretary of the Wisconsin Department of Natural Resources, served as a United States commissioner between 1990 and 1996. The Convention stipulates that any decision or recommendation from the Commission requires approval from both the U.S. and Canadian sections. The Convention allows each section of the Commission to establish an advisory committee for each of the Great Lakes, and the advisors have the right to attend all sessions of the Commission. To carry out the duties set forth in the Convention, the GLFC has the authority to conduct investigations, implement lamprey control measures, and hold public hearings in the United States and Canada. The Convention authorizes the Commission to appoint an executive secretary, retain staff, acquire facilities, contract with other parties, and spend money to cover the joint expenses of carrying out its duties.

The U.S. enabling legislation, the Great Lakes Fisheries Act of 1956, established a mechanism for appointing advisors to the GLFC and defined the terms of reference for advisors. Under the terms of reference, advisors are appointed to the Commission from each lake, based upon recommendations of the governor of each state. Each state is allowed up to four advisors for each lake, representing the state agency with jurisdiction over the fishery, the commercial fishery, the sport fishery, and one public-at-large interest. Typically, the advisors are agency officials and influential fishery people. The Canadian section has never established a strong relationship with its advisors nor has it developed a structured mechanism for choosing advisors. Dr. Henry Regier, a former Canadian commissioner, believes that this lack of interest in advisors can be attributed in part to the absence of strong federalism objections from Ontario with respect to Canadian federal involvement with Great Lakes fisheries (Henry Regier, former GLFC commissioner, personal communication 11 Oct 1998).

The Commission is jointly funded by the U.S. and Canada. Administrative costs are split evenly among the two nations, while sea lamprey control costs are split 69% from the U.S. and 31% from Canada, according to historic lake trout harvest records. U.S. appropriations come primarily from the U.S. State Department, and Canadian funding comes out of the budget of Fisheries and Oceans Canada. This funding arrangement is vehemently supported by the eight Great Lakes states and the tribes, who view the State Department as being a neutral force in the dynamic interactions of the region, as opposed to a competitive funding source among the state, tribal, and federal fisheries programs (Jim Addis, director, Wisconsin Department of Natural Resources Bureau of Integrated Science Services, former Wisconsin fisheries director, personal communication 3 Nov 1997). Additional funding is sometimes available through grants from agencies such as the U.S. National Oceanic and Atmospheric Administration under the Department of Commerce and through partnerships with federal and state agencies implementing the GLFC's programs.

The GLFC maintains a full time staff (the Secretariat) in Ann Arbor, Michigan. The Secretariat carries out the administrative responsibilities of the GLFC, providing support, leadership, and institutional memory for the various management committees and technical boards. The Secretariat also plays an important role in carrying out the Commission's duties under the joint Strategic Plan. The Commission is required by the Convention to "in so far as feasible, make use of the official agencies of the Contracting parties and of their Provinces or States and may make use of private or other public organizations, including international organizations, or of any person" (GLFC 1983). The Commission has contracted with the U.S. Fish and Wildlife Service, U.S. Geological Survey, U.S. Army Corps Engineers, and the Department of Fisheries and Oceans Canada to conduct fisheries research, implement lamprey control measures such as lampricide application in spawning streams and construction of lamprey barriers, and maintain fish hatcheries for use in rehabilitative lake trout stocking programs.

The Commission supports the work of several management committees and boards to carry out its responsibilities. The Sea Lamprey Integration Committee is responsible for coordinating the GLFC's lamprey management program and consists of a variety of members from academia and government agencies. The Board of Technical Experts serves as an independent, expert, and professional panel to advise the GLFC on technical matters relevant to the Commission's mandate. Board members are selected without consideration of agency or institutional affiliation. The Board currently has established four task groups dealing with biodiversity, habitat, lake trout rehabilitation, and alternative sea lamprey control. The Habitat Advisory Board is charged with identifying current and emerging habitat issues that may impede fishery goals, proposing strategies for habitat rehabilitation, assisting Lake Committees develop environmental objectives in fish management plans, and communicating the GLFC's habitat goals to resource managers, interest groups, and the public. Habitat Advisory Board members represent federal environmental agencies, federal fishery agencies, academia, tribal management agencies, the International Joint Commission, and non-governmental environmental organizations. Members of these boards are appointed by the Great Lakes Fishery Commission. The Commission also supports several state and provincially appointed boards and committees, including the Lake Committees, Fish Health Advisory Committee, and Law Enforcement Committee. Decisions on these boards and committees are made by consensus of the members, and when consensus cannot be reached, all viewpoints are presented to the Commission in technical reports.

State, provincial and tribal authorities participate on formal Lake Committees that exist independently of the GLFC. These Lake Committees are arguably the most important management institutions with respect to the Great Lakes fishery. Although the Lake Committees do not report directly to the GLFC, their activities are intricately linked to the Commission's mission. Thus, the Lake Committees are often viewed as the implementing arms of the Commission. The GLFC originally helped to establish a Lake Committee for each of the Great Lakes to coordinate implementation of the sea lamprey control program and to carry out many of its research and advisory duties. The Lake Committees consist of one senior fish manager from each agency with jurisdiction over the lake and include tribal representation.[4] The federal governments are not represented on the Lake Committees. The Council of Lake Committees is comprised of twenty-one members selected from the various Lake Committees. The Council's primary function is to coordinate activities among the Lake Committees, respond to requests made by any of the Lake Committees, and consider issues pertinent to or referred by the GLFC. The Council provides a forum for state, provincial, and tribal agencies to develop and coordinate joint research projects, share data, establish harvest objectives, and consider issues of common concern to member agencies. The Lake Committees have been tremendously successful at bringing the managers together to discuss fish management issues. Dochoda reports that state and provincial satisfaction with progress under the Lake Committees was so high that the Great Lakes states rejected an opportunity to form a regional fishery management council under the U.S. Magnuson Fishery Act of 1976 (Dochoda, unpublished). Instead, the state and provincial agencies requested, through the Lake Committee forums, that the Commission assist with the development of the joint Strategic Great Lakes Fishery Management Plan (Fetterolf 1988).

Emerging Roles: The Joint Strategic Plan

The signing of the joint Strategic Great Lakes Fishery Management Plan was the most important advance in Great Lakes fishery management. Francis and Regier (1995) claim that such advances occur when ecosystems, institutions, and societies become congruent. These advances are characterized by "inevitable bursts of human learning" that proceed with "less conflict and more creativity" (Francis and Regier 1995). The Strategic Plan was developed during the era of New Federalism in the early 1980s, as federal oversight in state and regional management activities was finding disfavor. The states saw an opportunity to delineate their authority and preclude intervention from well-funded federal agencies with broad mandates (Jim Addis, personal communication 3 Nov 1997). The development of the plan was a logical activity for the GLFC under its study-and-advise mandate.[5] The GLFC facilitated the plan by providing funding, policy guidance, and a neutral forum to develop mutually beneficial strategies for fishery management. The Commission secured the commitment of each agency by creating a Committee of the Whole, consisting of natural resource agency directors, each with veto power (Fetterolf 1988). This support was necessary to ensure that the agencies would take ownership of the plan and become implementers and advocates (Jim Addis, personal communication 3 Nov 1997).

The original Strategic Plan was signed in 1981 by top-level state, provincial, and federal agency directors to express their mutual commitment to interjurisdictional and interdisciplinary coordinated fishery management. In 1986, the Chippewa-Ottawa Treaty Management Authority and the Great Lakes Fish and Indian Wildlife Commission joined the original twelve fishery agencies in endorsing and signing the memorandum of acceptance for the plan. Prior to the establishment of the joint Strategic Plan, arrangements for coordinating Great Lakes fishery management among the array of actors were informal, typically involving meetings among state fish biologists with jurisdiction over common lakes. These arrangements did not fully address the binational profile of the resource, nor did they regularly involve non-fishery–related Great Lakes managers (Carlos Fetterolf, retired executive secretary, Great Lakes Fishery Commission, personal communication 6 Nov 1997). The plan remained essentially the same until 1997, when it was revised at the request of the signatories to establish a stronger ecosystem management focus, ensure mutual accountability in steps to implement the plan, enable periodic review of the plan, and provide guidance to the implementing agencies.

While ceding none of their statutory and constitutional authority, the agencies agreed to work with the Great Lakes Fishery Commission through the Lake Committees and the Council of Lake Committees. These became the primary forums for addressing management problems that exceeded each agency's authority and ability to address individually. These problems include lost fishing opportunities, overharvest, instability of fish communities due to sea lampreys, introduction of exotic species, inadequate environmental quality due to conflicting objectives of fishery and environmental managers, competition and conflicts among users of the fishery resource, and climate change. The agencies agreed that changes to the plan should be made by consensus of all of the signatories. The Strategic Plan establishes four fundamental strategies for achieving common goals. These strategies deal with the following areas: consensus-based decision making, agency accountability, ecosystem focus, and information management (GLFC 1997*a*):

> Consensus must be achieved when management will significantly influence the interests of more than one jurisdiction. . . . Fishery management agencies must be openly accountable for their performance. . . . The Parties must exercise their full authority and influence in every available arena to meet the biological, chemical and physical needs of the desired fish communities. . . . Fishery agencies must cooperatively develop means of measuring and predicting the effects of fishery and environmental management decisions.
>
> —Strategic Great Lakes Fishery Management Plan, 1997

The Great Lakes Fishery Commission pledged to maintain and support the goals and processes outlined in the Strategic Plan and facilitate the plan's implementation. The Strategic Plan calls upon the Great Lakes Fishery Commission to resolve differences among the jurisdictions, undertake research for measuring and predicting the effects of management decisions, and provide institutional memory to avoid repeating past management errors. The Commission's specific duties under the Strategic Plan include the following:

- Maintaining and supporting the activities of the Lake Committees for the development of fish community objectives and identification of environmental issues impeding fish community objectives.
- Providing a mechanism for conflict resolution. If the Lake Committees cannot reach consensus on fish community objectives, the problem will be taken to the Great Lakes Fishery Commission for non-binding mediation or arbitration.
- Representing fishery interests in unresolved environmental issues to the appropriate body (e.g., the International Joint Commission, U.S. Environmental Protection Agency, Environment Canada).
- Establishing the expert Habitat Advisory Board to assist each Lake Committee in developing ecosystem objectives and identifying critical habitats essential to achieving its fishery objectives.
- Coordinating the development and implementation of standards for recording and maintaining fishery management and assessment data.
- Maintaining current internet links to the parties' databases and a catalog of fishery assessment and research data to facilitate access by the parties.

- Publishing a summary of the Lake Committee reports in the Commission's annual reports to the federal governments and the public.

In 1992, the GLFC issued its Strategic Vision for the Great Lakes Fishery Commission for the Decade of the 1990s (GLFC 1992). The vision statement renewed the Commission's commitment to the ecosystem approach and covered three interrelated areas: 1) maintain healthy Great Lakes ecosystems, 2) continue to apply integrated pest management approaches for sea lamprey control, and 3) develop and maintain institutional and stakeholder partnerships. The purpose of the Strategic Vision was to focus the direction of the Commission's programs and provide a framework to ensure that the programs were consistent with and complimentary to the Strategic Plan. The Strategic Vision provides milestones for measuring the progress towards implementation of the Strategic Plan. These milestones set goals for no net loss of habitat, lake trout restoration, reduction of toxic substances, integrated lamprey management, and delivery of complimentary programs through the Lake Committees. In summary, the Strategic Vision emphasizes the GLFC's commitment to providing leadership to the Lake Committees, coordinating fish management programs, developing coordinated programs for research, and strengthening partnerships among fish management agencies and non-agency stakeholders.

Implementing Ecosystem Management: Evaluation of the GLFC

In addition to maintaining its ongoing programs for Great Lakes research and lamprey control, the major activity of the GLFC in recent years has been implementing the Strategic Plan. The Commission has undertaken several initiatives under the Strategic Plan and the Strategic Vision, with variable success. These can be grouped into three broad categories: 1) facilitating interjurisdictional cooperation among fishery agencies, 2) establishing interdisciplinary coordination among natural resources and environmental agencies, and 3) implementing unilateral initiatives for ecosystem management and developing partnerships with non-agency stakeholders.

Interjurisdictional Cooperation

Overall, the GLFC and its various boards and committees enjoy a mutually beneficial relationship with state, provincial, and tribal agencies. An informal survey conducted by the Commission shows that the agencies generally believe that the Lake Committees, Council of Lake Committees, and the Commission's technical boards are serving a useful purpose, providing adequate forums for discussion and are appropriately charged (GLFC, unpublished). State and provincial support for the Great Lakes Fishery Commission can be attributed to the limited role assigned to the Commission under the terms of the 1955 Convention. Specifically, the Commission's limited autonomy and lack of regulatory power pose little threat to state management authority (Donahue 1998*b*). Because each nation has chosen to retain the sovereign right to manage its own resources in the way that maximizes national interests, the Great Lakes Fishery Commission has often played a quiet role in Great Lakes management, serving mainly as a forum for coordinating management activities through the Lake Committees and allowing the states to take the credit (Carlos Fetterolf, personal communication 6 Nov 1997). State fishery interests feel that the Lake Committees provide a valuable, non-hierarchical forum for high-level fish managers to share data, develop fish community objectives, and test new fish management approaches in the basin.

One of the most important initiatives under the Strategic Plan is the development of fish community objectives (FCOs) through the Lake Committees. The FCOs are essentially lake-wide fish management plans that describe the desired state of the resource. Fish community objectives are described by a species mix and the necessary ecological qualities (stability, balance, sustainability, and diversity) that will enable the communities to persist. Fish community objectives also contain measures of the fishing opportunities that the community offers (yield, allowable harvest, and recreational fishing hours). The objectives reflect the understanding that natural systems are dynamic and attempt to provide some flexibility to allow the agencies to adjust management approaches to meet changing conditions. Fish community objectives serve as the mechanism through which the states, tribes, and provinces work out their specific fish community, allocation, and harvest goals for the resource. The development of objectives requires each agency to identify its operational plans for achieving the FCOs and to submit changes to these plans to the Lake Committees. The Strategic Plan stipulates that the fish community objectives be determined by consensus. Any management activity that may affect one of the other parties must be brought forward in the Lake Committees. The Lake Committees are to work in concert with the lake-wide management plans (LaMPs) established under the Great Lakes Water Quality Agreement to identify issues that may impede achievement of the fish community objectives.

The Lake Committees have been successful in establishing fish community objectives for Lakes Superior, Huron, and Michigan. Draft fish community objectives have been established for Lakes Ontario and Erie, but have not been finalized because they have not been supported by the public and local politicians (Margaret Dochoda, fisheries biologist, Great Lakes Fishery Commission, personal communication 5 Nov 1997 and 17 Nov 1997). The establishment of fish community objectives represents significant progress towards interjurisdictional cooperation on fishery management. However, fish community objectives have been criticized as being an inadequate tool for coordinating habitat management, controlling exotic species, and meeting public demands for the resource. One of the criticisms is that the fish community objectives often lack adequate support (political and public) in the home jurisdiction. In particular, the decision to emphasize lake trout restoration in the fish community objectives was reached by the state and provincial fish chiefs, who were not always in a position to negotiate their agency's interests, especially in states with vocal sport fishery interests (Lee Kernen, retired Wisconsin Department of Natural Resources fisheries director, personal communication 4 Nov 1997). Several managers have questioned the effectiveness of establishing quantitative objectives in light of the rapidly changing resource conditions. Many managers feel that the fish community objectives are not sufficiently comprehensive and principle-based to serve as the basis for environmental planning in a dynamic resource (Lee Kernen, personal communication 4 Nov 1997). Further, there is no formal commitment to follow the fish community objectives in the home state until they are promulgated as state law, and there is no regulatory "hammer" to enforce the plans once they are published. The GLFC's sole influence in the development of fish community objectives is the technical assistance provided by the Habitat Advisory Board, and its financial support of the Lake Committees.

Nonetheless, the lack of enforceability has not impeded the implementation of the fish management plans. One of the unquantifiable advantages of the formal Lake Committees is that the agencies have been able to exert peer pressure on one another to improve cooperation in allocating the resource among jurisdictions, establishing common consumption advisories, coordinating lamprey control efforts, and identifying the best use of federally stocked fish (Carlos Fetterolf, personal communication 6 Nov 1997). A good example of how the Lake Committees function to manage the fishery is the recent announcement of chinook salmon stocking decreases in Lake Michigan for 1999. Concern over the forage base (primarily alewife) and a desire to avoid a population crash similar to what was experienced in the 1980s led Wisconsin and Michigan fish managers to agree on 27% decreases in chinook salmon stocking (*Wisconsin Outdoor Journal* 1999).

The cooperation among the different jurisdictions on the Lake Committees has been forced, in some instances, by the possibility of using the Commission to mediate differences on the Lake Committees, as provided for in the Strategic Plan. To date, the Lake Committees have only requested the Commission's intervention twice: once pertaining to the introduction of disease through stocked fish and once in Lake Erie due to a dispute over the allocation of yellow perch between Ohio and Ontario. In both cases, the parties settled their disagreements before the Commission could produce a non-binding recommendation (Margaret Dochoda, personal communication 5 Nov 1997 and 17 Nov 1997). The non-use of the Commission's mediation powers suggests that the states and province are unwilling to set a precedent by using the Commission to formally settle differences, for fear of relinquishing their authority to a regional institution. However, the results of a 1995 survey conducted by the Great Lakes Fishery Commission indicated that the Lake Committees have been frustrated by the lack of the Commission's ability to arbitrate differences on fish community objectives (GLFC, unpublished). The Strategic Plan was revised in 1997 to broaden the possibilities for alternative dispute resolution, including appointing a third party mediator or arbitrator. This provision has not been used, and it is difficult to predict how successful conflict resolution will be in the future. In all likelihood, the conflict resolution mechanisms will not be used, but the fact that they are present may exert enough pressure on the Lake Committees to reach consensus.

Interdisciplinary Coordination

Resource management and environmental protection have evolved under separate auspices. In an attempt to restore and maintain the chemical, physical, and biological integrity of the Great Lakes Basin ecosystem, the International Joint Commission (IJC), U.S. Environmental Protection Agency (EPA), and Environment Canada have undertaken comprehensive, lake-wide management planning activities (LaMPs). Remedial Action Plans (RAPs) have been developed to rehabilitate the severely degraded 43 Areas of Concern (AOCs) that do not meet one or more of the beneficial uses established by the Great Lakes Water Quality Agreement. Of the fourteen impairments to beneficial uses, several pertain directly to fishery management and fish habitat. These include restrictions on fish consumption, degradation of fish populations, fish tumors and deformities, degradation of phytoplankton and zooplankton communities, and loss of fish habitat. The RAP and LaMP initiatives have often failed to include fishery managers in the decision-making process. The concern over lack of participation is not new. In 1976, the GLFC issued a brief to the IJC titled "Environmental Quality and Fishery Resources of the Great Lakes." The brief addressed eutrophication, power plants, thermal pollution, dredging and spoils disposal, shoreline and nearshore habitat modification, toxic contaminants, and flow regulation (Johnson 1980). The primary concern was with the command-and-control approach to water quality management. The GLFC wanted to be able to influence water-quality management decisions, and the brief called for the development of a mutually productive consultative mechanism to address habitat issues. One of the thrusts of the Strategic Plan was to provide this consultative mechanism using the Lake Committees and the newly created Habitat Advisory Board. In 1986, the Habitat Advisory Board developed guidelines for fish habitat management and planning in the Great Lakes and actively engaged the Lake Committees to become more involved in habitat issues. Increasingly, RAP teams, the LaMPs, and the Lake Committees have mutually acknowledged that the loss of habitat is a serious concern (Hartig et al. 1996). However, many habitat rehabilitation efforts undertaken in the Areas of Concern (AOCs) are still not directly related to fish community objectives.

In an effort to achieve greater coordination and strengthened partnerships between environmental and fishery planners, the U.S. EPA, Environment Canada, and the GLFC's Habitat Advisory Board held a workshop in 1993 to discuss fish community goals in RAPs and to develop recommendations for achieving better coordination (Hartig 1993). Although fishery management planning has been initiated in all 43 AOCs, successful integration of fish and water quality goals has only occurred in Green Bay, Hamilton Harbor, and several AOCs in Canadian Lake Superior. The success of these remedial action plans was attributed to the availability of sufficient funding, numerous dedicated individuals who moved the RAP forward, and the proximity to high quality research facilities (Hartig 1993). Attempting to build upon the success of these RAPs, workshop participants emphasized that agreement on clear, quantifiable fish community and habitat objectives was necessary to direct remedial efforts and measure progress. The workshop called for accelerating the establishment of fish community objectives to guide water-quality planning efforts. Another recommendation was for fish managers with responsibilities in AOCs to work directly with the RAP teams to set quantitative targets. The workshop recognized that both top-down (senior agency staff) and bottom-up support (coordinated by local RAP teams) were required for successful integration of management activities.

Integrating water quality and fishery management in the Great Lakes continues to be one of the most difficult challenges, not only for the Great Lakes Fishery Commission, but also the parties involved in developing RAPs and LaMPs. One reason for the difficulty is that the RAPs and LaMPs tend to be planning-led activities that set specific targets for water quality and define actions to achieve those targets, while the fish management plans and fish community objectives tend to be more adaptive and learning-led (Margaret Dochoda, personal communication 5 Nov 1997 and 17 Nov 1997). This distinction is best demonstrated by the difference in time scales expected to achieve the goals. The RAPs often focus on short-term goals, while the fish community objectives address long-term ecosystem objectives. Another difficulty is that many of the fish community objectives were drafted before undertaking a complete assessment of physical habitat needs. The effort involved in reaching consensus on these objectives among the fishery agencies may preclude revisiting and redesigning the plans to accommodate the LaMP and RAP processes (GLFC, unpublished). Coordination has been achieved to some degree, with the Lake Superior Committee providing the Binational Program (Lake Superior LaMP) with aquatic ecosystem indicators and feedback on proposed initiatives. The best opportunities for coordination exist in Lakes Erie and Michigan, where the LaMP team has actively engaged the Lake Committees (Margaret Dochoda, personal communication 5 Nov 1997 and 17 Nov 1997). On a more basic level, many fish managers are simply not interested in participating in the RAP and LaMP processes because they view them as endless planning cycles with no teeth. In some cases fishery management agency personnel are already stretched too thin to participate in the RAP teams. Those fish managers that do participate in the process often do so on their own initiative, with no support from their agency (Lee Kernen, personal communication 4 Nov 1997).

Both the Great Lakes Fishery Commission and the International Joint Commission continue to attempt integration of these efforts, but the development of habitat objectives to link water quality and fish communities ultimately depends upon the state or province's ability to designate resources to address the problem. Neither the IJC nor the GLFC has any formal authority to coordinate these activities. The biggest challenges for integrating management initiatives are the lack of formal recognition of each other's authority and the absence of rules of engagement for consultation between planning groups. The GLFC continues to represent fishery interests on advisory and decision-making groups involved with environmental quality, but the Commission cannot force fishery managers to get involved with these groups (Fetterolf 1988). The 1993 workshop recommended that the terms of reference of either the GLFC or the IJC be expanded to ensure integration of environmental quality initiatives. This has not happened. In the meantime, more informal mechanisms including Lake Committee-LaMP initiatives and the IJC's biennial State of the Lakes Conference continue to be the primary mechanisms for integrating fisheries and water quality management.

Unilateral Initiatives

Underlying all fishery management activities in the Great Lakes is sea lamprey control. The lamprey problem has been described as a "coiled spring" that must be constantly managed or the population will bounce back. Without lamprey control, all of the other fishery management activities would be pointless (Carlos Fetterolf, personal communication 6 Nov 1997). Under the Strategic Vision, the Commission is attempting to move away from the use of expensive lampricides that are publicly unfavorable to more integrated lamprey control measures, including the release of sterile males and barrier dams, such as those found on the Brule River in northwestern Wisconsin. Integrated lamprey control draws on the experiences of integrated pest management strategies that use multiple mechanisms to control pest species. The GLFC relies heavily on input from the Lake Committees and technical committees to direct its lamprey efforts. Almost all parties would agree that the Commission has done a fine job in implementing its lamprey control strategy. In addition to lamprey control, the GLFC has sponsored a series of successful symposia on a wide variety of topics pertaining to the Great Lakes. These symposia have generated considerable interest in ecosystem management initiatives and have allowed fishery managers to interact with environmental managers on a professional level. The GLFC has also been successful in implementing the Strategic Plan's management information strategy. The Habitat Advisory Board has developed standard methods for evaluating habitat, and other technical committees have devised standards for stocking fish and measuring lamprey wounding rates. These activities have allowed the fishery agencies to share data. The GLFC has provided an on-line database of fish stocking efforts and sport and commercial harvest data from each state and for each lake in the basin. Lee Kernen, former director of fisheries for the State of Wisconsin, believes that the sharing and standardization of information has been the biggest success of the Great Lakes Fishery Commission (Lee Kernen, personal communication 4 Nov 1997).

Another priority under the Strategic Vision is improving the GLFC's partnerships and strengthening the role of its advisors in Great Lakes management. The Canadian Section has not established a strong advisory committee. According to Carlos Fetterolf, retired executive secretary of the GLFC, Canada did not clearly define the role for its advisors and none were initially appointed. Fetterolf pushed for the Canadian section to name an advisory committee. In the 1980s, the section authorized five appointments, although only two have been filled (Carlos Fetterolf, personal communication 6 Nov 1997). In contrast, the states have appointed advisors to the U.S. section, but the U.S. advisors have suffered from a lack of direction and guidance. In general, the advisors have not been effective in shaping the Commission's policies. The U.S. advisors are supposed to provide alternative viewpoints on the Lake Committees but generally represent a narrow range of vocal commercial and sport (primarily charter boat) fishing interests (Ed Michaels, Trout Unlimited, personal communication 18 Nov 1997). Despite the enhanced emphasis on the advisors, many people believe that the Commission failed to bring the right representation into the process from the start. One of the criticisms of the advisors is that they do not represent non-consumptive uses of the fishery, such as environmental interests, local citizens, navigation, and other industry (Ed Michaels, personal communication 18 Nov 1997; Dan Thomas, Great Lakes Sportfishing Council, personal communication 5 Nov 1997).

Achieving the 1955 Convention's goal of maximizing the sustained productivity of the fishery depends upon promoting healthy ecosystems and controlling the sea lamprey. The Strategic Plan recognizes that this will require flexible, adaptive management to deal with changing environmental conditions and scientific uncertainty. Adaptive management strategies are becoming widely used where management actions often have unintended consequences. Because managers rarely fully understand the complexity of the system they are trying to manage, adaptive management provides a way for assessing the impacts of management decisions and redirecting efforts as research demonstrates that change is needed. Hartig et al. (1996*b*) maintain that adaptive management requires adequate assessment, research, and monitoring to define the problems, establish cause and effect relationships, evaluate remedial options, and document effectiveness.

The Commission has continued to develop a research program to determine the appropriate measures for supporting healthy Great Lakes ecosystems and for controlling the sea lamprey. Commission-sponsored research takes advantage of the skills of a variety of fisheries experts. The GLFC cooperates with governmental and nongovernmental agencies to carry out its research program. For instance, the Commission contracts with the Great Lakes Science Center, the Department of Fisheries Oceans, the Ontario Ministry of Natural Resources, universities, and tribal agencies. The states rely on the Commission's research to investigate issues that they cannot tackle alone. This research provides vital information for both the Commission and fish managers to develop science-based fishery programs and has been used to improve coordination among fish management agencies. Based on its research programs, the Commission distributes funds to the Lake Committees through its Coordinated Activities Program. Recent research initiatives have addressed the need for tighter ballast management to prevent exotic species introductions, examined the life history of the sea lamprey to develop integrated control techniques, investigated fish diseases transmitted through stocked fish, and supported the development of environmental objectives through partnerships with the Habitat Advisory Board, Board of Technical Experts, U.S. EPA, and Environment Canada (GLFC 1995). The level of research support the Commission will be able to provide is threatened because funding for the GLFC's research activities has not kept pace with needs. This has hindered many initiatives that are critical to evaluating new management actions and supporting current programs in the Great Lakes.

The Great Lakes Fishery Commission, like many agencies, is being forced to do more with less. Table 1 demonstrates the funding level for the Fishery Commission for 1995, the latest year for which numbers are readily available. Sea lamprey management is the largest expense for the GLFC. Beginning in 1992, the Commission began submitting budget requests based upon actual program needs instead of anticipated government contributions. The annual program requirements and cost estimates are submitted at two levels: one that will deliver a base program of lamprey control and one that will deliver the base program plus additional initiatives necessary to meet the Commission's mandate. In 1997, the Commission requested a 66% funding increase (over 1995) to offset level funding throughout the 1990s. The 1997 budget requested $21.5 million to deliver the objectives outlined in the Strategic Vision for the 1990s (GLFC 1997*b*). Despite this request, funding for 1996, 1997, and 1998 remained stagnant at $12.5 million. This trend may be changing. The minister of Fisheries and

Table 1. 1995 Funding.

	United States	*Canada*	*Total*
Sea lamprey management	$8,173,750	$ 3,748,177	$ 11,921,927
Administration and general research	$ 629,250	$ 549,250	$ 1,178,500
Total	$8,803,000	$4,4297,427	$ 13,100,427

Source: GLFC 1995 Annual Report.

Oceans, Canada, announced that Canada will provide $6 million in fiscal year 1999 to support the sea lamprey control program. This represents a substantial increase over the previous year and will allow the Commission to continue to fund other programs and important research in 1999 (GLFC 1998).

Without additional funding, the Great Lakes Fishery Commission will find it increasingly difficult to commit resources to non-lamprey–related Great Lakes research and the Lake Committees. As is typical of learning-led management institutions, the Lake Committees have limited autonomous financial resources. The individual agencies have cooperated to pool resources, but these activities are threatened as state government cutbacks force agencies to use their resources in other areas. As support dwindles, the Lake Committees will not be able to constructively engage the relatively well-funded LaMPs (Dochoda, unpublished). The commitment to adaptive management made in the Strategic Plan requires a strong commitment to research to evaluate the results of management activities. As funds become limited, the Commission must focus a larger proportion of its budget on lamprey control (Carlos Fetterolf, personal communication 6 Nov 1997). The Great Lakes states, Province of Ontario, and tribal agencies have supported the Commission's requests for additional funding to provide for more sea lamprey control and research, especially in the St. Mary's River, which produces lampreys that kill nearly 50% of the lake trout in Lake Huron. It is estimated that it will cost $1.2 million annually to treat the St. Mary's for lamprey (GLFC 1997*b*). The additional resources provided by Canada for fiscal year 1999 will allow the Commission to begin necessary lamprey control programs on the St. Mary's River.

Challenges for the Future

The Commission was initially established to eliminate the sea lamprey and, indirectly, to protect the commercial fishery. Since 1980, the Commission has been able to transform itself into an integral partner in Great Lakes management, and its programs have undergone a transition away from lamprey control towards ecosystem management. This transition has been possible because the broad scope of the 1955 Convention allows the GLFC considerable flexibility in implementing its responsibilities for "maximizing the sustained productivity" of fish stocks. Even with the flexibility afforded to the Commission under the Convention, implementing an ecosystem approach to fishery management in the Great Lakes will require overcoming many institutional challenges. Francis and Regier (1995) recognize that Great Lakes organizations are driven by their policy and legal mandates, not intergovernmental agreements. These agreements are not accountability-forcing documents, and nobody is ultimately responsible for achieving ecosystem integrity or ecosystem health. The challenge for the Great Lakes Fishery Commission will be to improve interjurisdictional cooperation and interdisciplinary coordination on issues of common concern without regulatory oversight. Past efforts to coordinate water quality and fishery goals have not been entirely effective, and new mechanisms for achieving integration must be sought. One feasible approach would be to combine the Great Lakes Fishery Commission's State of the Lakes Reports with the International Joint Commission's Biennial Report on the Great Lakes Water Quality Agreement or cosponsoring a State of the Lakes Conference, similar to the IJC's State of the Lakes Conference but with expanded terms of reference to engage the other management interests.

Another challenge will be to clearly define the goals of ecosystem management for the Great Lakes Basin and translate these goals into implementable actions. Since there is a general reluctance to relinquish state and provincial authority to a regional authority such as the GLFC, this will necessarily include fostering greater stakeholder participation in fishery management activities. Experience has shown that successful ecosystem management requires effective coordination among multiple resource management authorities, participatory planning by local interests, consensus-based decision making, interdisciplinary team building, conflict resolution, and adaptive strategies for dealing with unforeseen consequences of management activities (MacKenzie 1990, Hennessey 1994, Holland 1996). The success of the Strategic Plan and, ultimately, ecosystem management in the Great Lakes will depend on engaging the appropriate stakeholders in management decisions. The Commission has failed to achieve the milestones set forth in the Strategic Vision for improving stakeholder participation. Without public support for the ecosystem approach, it is unlikely that the Commission will be able to secure the necessary support from the governments of the United States and Canada to continue many of its critical research and coordinative functions.

One way to improve cooperation among the participating agencies and stakeholders would be the adoption of a Great Lakes code of conduct for responsible fisheries under the model developed through the United Nations Convention on the Law of the Sea (United Nations 1982). The Canadian Department of Fisheries and Oceans has already adopted a Canadian Code of Conduct for Responsible Fisheries. Many of the articles of the United Nations Convention have been informally implemented in the Great Lakes Basin, and the GLFC should play a key role in bringing the United States and Canada together to fully develop a workable code of conduct for the Great Lakes (Henry Regier, personal communication 11 Oct 1998). Bringing the necessary parties to the table to discuss a Code of Conduct is a daunting task. The difficulty in defining the role of public participation in ecosystem management can be illustrated by briefly reviewing the controversy that exists regarding lake trout rehabilitation, which has been termed a metaphor for the larger issue of whether fishery management should be principally concerned with the optimization of human uses of the resource or with the restoration and protection of ecological structure and function (Lange and Smith 1995).

The oligotrophic Great Lakes fish communities were traditionally dominated by lake trout, and lake trout restoration is the cornerstone of the fish community objectives developed by the various Lake Committees. In spite of a concerted effort in all of the Great Lakes to rehabilitate lake trout with stocking, lake trout populations, with the exception of Lake Superior, have not responded as well as mangers had hoped (Kernen 1995). The management rationale for lake trout rehabilitation continues to be that an ecosystem that ensures abundant, reproducing diverse stocks of lake trout would certainly protect most other constituents of the cold-water community. The lake trout is a long-lived predator species that could naturally reproduce and lend ecosystem stability that is not obtainable under an artificial stocking program. But it is also a species that, because of its fatty flesh, concentrates lipophilic substances and may not provide a safe-to-eat sport fish. Fish managers have come to realize the dichotomy of the two distinctly different goals of restoring self-sustaining populations and providing recreational fishing opportunities (Lange and Smith 1995). The impediments to lake trout restoration are not only biophysical, but socioeconomic.

A recent survey showed that state and provincial Great Lakes fish managers remain committed to rehabilitating lake trout (Knuth et al. 1995), but many are reevaluating their fish community priorities in light of increasing political pressure from sport fishing interests. State and provincial managers showed stronger support for maintaining artificial fish communities than federal agencies, due to the traditional relationship between anglers and state managers (i.e., the license fee). Although fragmented, sport fishing interests (particularly charter boat captains) view lake trout rehabilitation as in direct competition to their preferred species, the Pacific salmon, and are often vehemently opposed to rehabilitation efforts (Dan Thomas, personal communication 5 Nov 1997). Some in the sport fishing community would rather see the money spent on propagating and stocking non-native species, rather than continuing to fund failing rehabilitation efforts. Other sport fishing groups, such as Trout Unlimited, view the re-establishment of native fisheries as the ultimate goal for fish management in the Great Lakes (Ed Michaels, personal communication 18 Nov 1997). Commercial fishermen view the lake trout as a hindrance to capturing their preferred species, due to restrictions placed on gillnetting for perch and whitefish. Although the lake trout have historically been a large portion of the commercial catch, for the foreseeable future, there will not be a sufficient population to allow a directed harvest. Sport and commercial fishing interests are in direct competition with each other for a limited resource. As the sport fishery expands, sport fishermen view the commercial harvest as a threat to their fish and blame the state managers for failing to control commercial harvest. Another important stakeholder in the fish community includes non-consumptive users, such as environmentalists and environmental agencies working to improve water quality. They support lake trout rehabilitation because the lake trout serves as a way to measure water quality improvements and ecosystem health (Marshall et al. 1987).

The fish-community objectives are an attempt to give direction to management actions undertaken by the various fishery agencies by focusing on a set of ecological principles. But these ecological principles must be tempered by social values. Historically, the states have not opened up the decision-making process to a wide range of fishery stakeholders. Fish managers have assigned differing priorities to stakeholder viewpoints, with the state or provincial fishery agency being the most important, followed by the GLFC, federal fisheries agencies, provincial or state environmental agencies, agency-appointed advisory groups, the angling public, commercial fisheries, tribal governments and local legislators, sportsmen's associations, Great Lakes environmental groups, and lastly, charter boat captains (Knuth et al. 1995). Public support can only be guaranteed by involving all of the stakeholders in the decision-making process to set the priorities for fish management activities through the Lake Committees. Although the GLFC does not have direct authority to implement management programs, it can encourage discussion between government managers and fishery stakeholders through the Lake Committees. The Great Lakes Fishery Commission should encourage discussion among the fish managers about their role in educating the public about the value of maintaining native stocks. The Commission could play a larger role in publishing information about the value of native fisheries, using their web site, press releases, and technical reports.

Simply engaging and educating the stakeholders will not be sufficient to meet everyone's goals for the resource. Lee Kernen, former Wisconsin Department of Natural Resources fisheries director, believes that a native lake trout and Pacific salmon fishery are not exclusive, but merely different routes to the same goals. Instead of an all-or-nothing approach, Kernen recommends following a more balanced management scheme that will continue to provide sport fishing opportunities while allowing more time for lake trout rehabilitation to occur. This approach recognizes that the fish communities will never return to what they were before human perturbations, and public perceptions about the fishery should be included in management decisions. The approach advocated by Kernen is similar to the rapid biotic and ecosystem response strategy proposed by Doppelt et al. (1993) for the Pacific Northwest, which calls for protecting refuges of undisturbed habitats first and then attempting restoration on a priority system. If this approach is to be successful in the Great Lakes, fish managers must manage sport anglers' expectations for the resource, rather than increasing stocking to meet demands. They must also tighten commercial harvest quotas to compensate for the efficiency of modern technology. Kernen believes that the future of the fishery will depend on managers listening more to both consumptive and non-consumptive users because management decisions based on science alone cannot provide resolution for competing values (Kernen 1995). Regardless of scientific soundness, policies that lack support within society's views and values will fail.

> The public doesn't identify well with a [mayfly] hatch or a one-meter improvement in Secchi-disk value. The public is pragmatic. Their support is needed to fund programs to clean the Great Lakes. . . . the current challenge is to develop strategies without destroying the fisheries and losing public support.
>
> — Lee Kernen, 1991

Conclusion

The Great Lakes have been managed as an international resource for over 90 years by the United States and Canada. Both countries are proud of their history of cooperation in managing this shared multipurpose resource. The continuation of the Great Lakes Fishery Commission is critical to maintaining this cooperation on fishery issues. In the short term, fish management goals may be in conflict with ecosystem management. This can be resolved by expanding the temporal scale of fish rehabilitation. The life span of lake trout is over twenty years long, and efforts to rehabilitate the species will expand over more than one professional career. Thus, long-term political support and institutional memory will be required to fully rehabilitate the Great Lakes. Fishery managers need to expand their definition of stakeholders and fully include all interests in the decision-making process. Improved communication and participation with stakeholders can be achieved by emphasizing successes and fostering a sense of public ownership in the process. Building an ecosystem management framework in the Great Lakes will require developing institutional mechanisms that enable long-term agency commitments. This task is difficult because the arrangements for Great Lakes management reflect the dispute over centralized (regional and federal) versus decentralized (state and provincial) control. Further, Donahue (1988*a*) claims that political realities cannot be avoided while searching for the optimal management framework for the Great Lakes. These realities include the experimental nature of regional institutions, aversion to large-scale institutional reform, lack of commitment to cooperative management, and the failure of existing institutions to exercise their full powers under their mandates. While the ideal management framework may be indescribable and unattainable, the GLFC's flexible mandate will allow it meet the needs of the resource and provide the institutional leadership for fishery management. The GLFC's activities continue to be supported by tribal, state, provincial, and federal agencies, and the Commission is uniquely poised to emphasize ecosystem management for the entire region.

Ackknowledgments

The author would like to thank the following for their patience and assistance in preparing this manuscript: Margaret Dochoda (GLFC), Carlos Fetterolf (GLFC), Marc Gaden (GLFC), Jim Addis (Wisconsin Department of Natural Resources), Lee Kernen (Wisconsin Department of Natural Resources), John Magnuson (University of Wisconsin-Madison), Ed Michaels (Trout Unlimited), Henry Regier (GLFC), Dan Thomas (Great Lakes Sport Fishing Council).

Endnotes

[1] Government agencies responsible for Great Lakes fish management are (alphabetically): Canada Department of Fisheries and Oceans, Chippewa-Ottawa Treaty Fishery Management Authority (U.S.), Great Lakes Indian Fish and Wildlife Commission (U.S.), Illinois Department of Natural Resources, Indiana Department of Natural Resources, Michigan Department of Natural Resources, Minnesota Department of Natural Resources, National Marine Fisheries Service (U.S.), New York State Department of Environmental Conservation, Ohio Department of Natural Resources, Ontario Ministry of Natural Resources, Pennsylvania Fish and Boat Commission, U.S. Fish and Wildlife Service, U.S. Geological Survey (Biological Resources Division), and the Wisconsin Department of Natural Resources.

[2] The Great Lakes Basin Compact of 1955 was not ratified by the U.S. Congress until 1964, after provisions allowing membership for Ontario and Quebec were rewritten to give the provinces solely a consultative role. Although not specific to fishery issues, the GLBC was an attempt to coordinate many aspects of Great Lakes management.

[3] The number of Commissioners was increased by a diplomatic memorandum from three to four per section, with one U.S. alternate, primarily to address U.S. concerns about inadequate representation from the lower lakes.

[4] Lake Ontario Committee: New York, Ontario. Lake Erie Committee: Michigan, New York, Ohio, Ontario, Pennsylvania. Lake Huron Committee: Michigan, Ontario, Chippewa-Ottawa Treaty Fishery Management Authority. Lake Michigan Committee: Illinois, Indiana, Michigan, Wisconsin, Chippewa-Ottawa Treaty Management Authority. Lake Superior Committee: Michigan, Minnesota, Ontario, Wisconsin, Chippewa-Ottawa Treaty Management Authority, Great Lakes Indian Fish and Wildlife Commission.

[5] Initially, recalcitrant states claimed that the agreement was a violation of Article I of the U.S. Constitution which states "No State shall enter into any Treaty, Alliance or Confederation." However, the U.S. State Department construed the Strategic Plan to be simply rules of engagement, and not to empower the GLFC with new authorities or create a new alliance.

Literature Cited

Baldwin, N.S., R.W. Saalfeld, M.A. Ross, and H.J. Buettner. 1979. Commercial fish production in Great Lakes, 1867–1960. Great Lakes Fisheries Commission Technical Report 79. Ann Arbor, MI. 192 pp.

Dochoda, M. Unpublished manuscript. Authorities, responsibilities and arrangements for managing fish and fisheries in the Great Lakes Ecosystem.

Donahue, M.J. 1988*a*. Institutional arrangements for Great Lakes management. Pp. 115–40 *in* L.K. Caldwell, ed. *Perspectives on Ecosystem Management in the Great Lakes.* State University of New York Press, Albany.

Donahue, M.J. 1988*b*. Great Lakes institutions and the policy process: issues in interstate and international resource management. Pp. 1–10 *in* D.H. Hickcox, ed. *The Great Lakes: Living with North America's inland waters.* Proceedings of the symposium American Water Resources Association.

Doppelt, B., M. Scurlock, C. Frissell, and J. Karr. 1993. *Entering the watershed: a new approach to save America's river ecosystems.* Island Press, Washington D.C. pp. xix–87.

Francis, G.R., and H.A. Regier. 1995. Barriers and bridges to the restoration of the Great Lakes ecosystem. Pp. 239–91 *in* L.H. Gunderson, C.S. Holling, and S.S. Light, eds. *Barriers and bridges to the renewal of ecosystems and institutions.* Columbia University Press, New York.

Fetterolf, C.M. 1988. Uniting habitat quality and fishery programs in the Great Lakes. Pp. 85–100 *in* N.W. Schmidtke, ed. *Toxic contamination in large lakes, volume II: impact of toxic contaminants on fisheries management.* Lewis Publishers, Chelsea, MI.

Great Lakes Fishery Commission. Unpublished. Results of a 1995 survey: successes and problem areas for the integration of the joint strategic plan for management of Great Lakes fisheries.

Great Lakes Fishery Commission. 1983. Convention between the United States and Canada on Great Lakes Fisheries (1955). Great Lakes Fishery Commission, Ann Arbor, MI.

Great Lakes Fishery Commission. 1992. Strategic vision of the Great Lakes Fishery Commission for the decade of the 1990s. Great Lakes Fishery Commission, Ann Arbor, MI.

Great Lakes Fishery Commission. 1995. Annual report of the Great Lakes Fishery Commission for 1995. Great Lakes Fishery Commission, Ann Arbor, MI.

Great Lakes Fishery Commission. 1997*a*. A joint strategic plan for management of Great Lakes fisheries. Great Lakes Fishery Commission, Ann Arbor, MI. (Supersedes 1980 and 1994 versions).

Great Lakes Fishery Commission. 1997*b*. Fiscal year 1997 program requirements and cost estimates. Great Lakes Fishery Commission, Ann Arbor, MI.

Great Lakes Fishery Commission. 1998. Press release April 3, 1998. Fisheries and Oceans minister David Anderson announces increased support for the Great Lakes Fishery Commission. Great Lakes Fishery Commission, Ann Arbor, MI.

Great Lakes Fishery Commission. 1999. Fact Sheet 3: Sea Lamprey: A Great Lakes Invader. Available on the Fishery Commission's web site at http://www.glfc.org.

Hartig, J.H. 1993. Toward integrating remedial-action and fishery-management planning in Great Lakes Areas of Concern. Great Lakes Fishery Commission, Ann Arbor, MI. 34 p.

Hartig, J.H., D.P. Dodge, D. Jester, J. Atkinson, R. Thoma, and K. Cullis.

1996*a*. Toward integrating remedial action planning and fishery management planning in Great Lakes areas of concern. *Fisheries* 21(2):6–13.

Hartig, J.H., J.R. Kelso, and C. Wooley. 1996*b*. Are habitat rehabilitation initiatives uncoupled from aquatic resource management objectives in the Great Lakes? *Canadian Journal of Fisheries and Aquatic Sciences* 53 (Suppl. 1):424–31.

Hartig, J.H., M.A. Zarull, and N.L. Law. 1998. An ecosystem approach to Great Lakes management: practical steps. *Journal of Great Lakes Research* 24(3):739–50.

Hennessey, T.M. 1994. Governance and adaptive management for estuarine ecosystems: The case of Chesapeake Bay. *Coastal Management* 22:119–45.

Holland, M.M. 1996. Ensuring sustainability of natural resources: focus on institutional arrangements. *Canadian Journal of Fisheries and Aquatic Sciences* 53 (Suppl. 1):432–39.

Johnson, M.G. 1980. Great Lakes environmental protection policies from a fisheries perspective. *Canadian Journal of Fisheries and Aquatic Sciences* 37(7):1196–2104.

Jude, D.J., and J. Leach. 1993. The Great Lakes fisheries. Pp. 517–51 *in* C.C. Kohler and W.A. Hubert, eds. *Inland fisheries management in North America.* American Fisheries Society, Bethesda, Maryland.

Kernen, L.T. 1991. Environmental objectives for fish community remediation. Pp. 35–38 *in* R.L. Eshenroder, J.H. Hartig, and J. E. Gannon, eds. *Lake Michigan: an ecosystem approach for remediation of critical pollutants and management of fish communities.* Great Lakes Fisheries Commission Special Publication 91-2.

Kernen, L.T. 1995. Lake trout: valuable native fauna or just grease? Pp. 198–201 *in* J.H. Selgeby, R.L. Eshenroder, C.C. Krueger, J.E. Marsden, and R.L. Pycha, eds. *Proceedings of the international conference on restoration of lake trout in the Laurentian Great Lakes.*

Kelso, R.M., R.J. Steedman, and S. Stoddart. 1996. Historical causes of change in Great Lakes fish stocks and the implications for ecosystem rehabilitation. *Canadian Journal of Fisheries and Aquatic Sciences* 53 (Suppl. 1):10–19.

Knuth, B.A., S. Lerner, N.A. Connelly, and L. Gigliotti. 1995. Fishery and environmental managers' attitudes about and support for lake trout rehabilitation in the Great Lakes. Pp. 185–97 *in* J.H. Selgeby, R.L. Eshenroder, C.C. Krueger, J.E. Marsden, and R.L Pycha, eds. *Proceedings of the international conference on restoration of lake trout in the Laurentian Great Lakes.*

Lange, R.E., and P.A. Smith. 1995. Lake Ontario fishery management: The lake trout restoration issue. Pp. 470–76 *in* J.H. Selgeby, R.L. Eshenroder, C.C. Krueger, J.E. Marsden, and R.L Pycha, eds. *Proceedings of the international conference on restoration of lake trout in the Laurentian Great Lakes.*

MacKenzie, S.H. 1980. On the challenge of implementing ecosystem management plans in the Great Lakes basin. Pp. 69–77 *in* J.E. FitzGibbon, ed. *International and transboundary water resources issues.* American Water Resources Association.

Maharaj, V., and Carpenter, J.E. 1996. The 1996 Economic Impact of Sport Fishing in the United States. American Sportfishing Association, Alexandria VA.

Marshall, T.R, R.A. Ryder, C.J. Edwards, and G.R. Spangler. 1987. Using the lake trout as an indicator of ecosystem health-application of the dichotomous key. Great Lakes Fisheries Commission Technical Report 49. Ann Arbor, MI.

Regier, H.A. Unpublished. A case study on the Great Lakes-St. Lawrence River Basin. Invited paper for a 1995 workshop on bioregional organizations in Portland, Oregon.

Talhelm, D.R. 1988. Economics of Great Lakes fisheries: A 1985 assessment. Great Lakes Fisheries Commission Technical Report 54. Ann Arbor, MI. 54 pp.

Thompson, P.C. 1974. Institutional constraints in fisheries management. *Journal of the Fisheries Research Board of Canada* (31):1965–81.

United Nations. 1982. United Nations Convention on the Law of the Sea. Adopted December 10, 1982. United Nations Sales Publications, United Nations, NY. Document E.83.V.5.

Wisconsin Outdoor Journal. 1999. Lake Michigan chinook stocking to be cut 27%. *Wisconsin Outdoor Journal* January 1, 1999.

Jeffrey Ripp** holds a master's degree in Water Resources Management from the University of Wisconsin-Madison and currently is a fellow with the U.S. House of Representatives' Committee on Resources in Washington, D.C.* ***Address: *2211 N. Somerset Street, Arlington, VA 22205.* ***Email:*** *jeff.ripp@mail.house.gov*

Wisconsin Academy of Sciences, Arts and Letters

Your membership will encourage research, discussion and publication in the sciences, arts and letters of Wisconsin.

Wisconsin Academy of Sciences, Arts and Letters
1922 University Avenue
Madison, Wisconsin 53705

Telephone (608) 263-1692

Wisconsin Academy of Sciences, Arts and Letters
1922 University Avenue
Madison, Wisconsin 53705

ISSN 0084-0505

Telephone (608) 263-1692

TRANSACTIONS

of the Wisconsin Academy of Sciences, Arts and Letters

Volume 88 • 2000

TRANSACTIONS

of the Wisconsin Academy of Sciences, Arts and Letters

Volume 88 • 2000

Editor William J. Urbrock
Department of Religious Studies
University of Wisconsin Oshkosh
Oshkosh, Wisconsin 54901

Managing Editor Patricia Allen Duyfhuizen
321 Heather Court
Eau Claire, Wisconsin 54701

ISSN 0084-0505

For information on membership in the Academy,
call (608) 263-1692.

Contents

TRANSACTIONS
Volume 88 • 2000

From the Editor

Rocks and more rocks! That phrase provides an apt description of the two weeks my spouse and I enjoyed in England's West country and in Wales this past summer. During the first of those weeks, we were among the thirty people enrolled in a course on "West Country Geology and Scenery" taught by Peter Hardy for the Summer Academy 2000 at Bristol University. Armed with information and images from rock and fossil samples we examined in the classroom, from Peter's fascinating slide-illustrated lectures, and from his book on *The Geology of Somerset* (Bradford on Avon: Ex Libris Press, 1999), we thirty amateur geologists eagerly embarked on our daily bus trips. We climbed and crawled, slogged and scrambled, from Burrington Combe and Cheddar Gorge in the Mendip Hills to Portishead along the Severn estuary, from the coast at Watchet to the Malvern Hills in Worcestershire, and from the wetlands of Somerset and the sandy formations at Bridport on the English Channel to the high quarries and mining sites at Ham Hill and the Forest of Dean. We re-entered the Paleozoic and Mesozoic Periods as we studied Devonian red sandstones, carboniferous shales and oolitic limestones, siltstone and red and gray banded marls from the Triassic, and the fossil-rich dark-gray shales and limestones of the lower Lias, the first unit of the Jurassic.

Rocks and more rocks! A highlight of our second week was the time we spent in breathtakingly beautiful Snowdonia National Park in Wales, including a full day's outing up and down the flanks of magnificent Mt. Snowdon, which reaches to some 3500 feet above sea level. Up we went in 90 minutes by Snodownia Railway (steam-driven); down we returned by foot, hiking for four hours along a rocky pathway trodden by thousands of others over the years.

Our rocky vacation was notable, too, for the fascinating fossils we came across on several of our outings. We were especially taken by the scores of ammonites we encountered, especially in the shales of the tidal flats at Watchet. These cephalopod molluscs with coiled plane-spiral shells lived in the sea during the Jurassic and Cretaceous Periods and then became extinct. At Watchet, site of the first scientific recording of the species *Psiloceras planorbis,* the ammonites range in size from some only as big as a fingernail to others nearly a foot and a half across and in variety from smooth to strongly-ribbed types. The specimens that garnered most of our oohs and aahs, however, were those of *Caloceras johnstoni,* amazingly preserved with their original mother-of-pearl luminescence that shimmers in shades of red and green.

Rocks and more rocks! One of the realizations that came to us during our visit to the English West country was that we were treading on land that, millions of years ago, had been sandwiched much more closely between what are now the continents of Europe and North America. In fact, we were in a place that, like the place we now call Wisconsin, may have lain astride or been near the equator in Paleozoic times! The old roadsign we used to pass in Door County, "Halfway to the North Pole," still brings a chuckle when we consider the Silurian limestone, rife with fossils of ancient tropical reefs, that is visible all over the county.

The current issue of *Transactions*, it must be admitted, is not devoted to rocks! Furthermore, unlike those long-extinct ammonite fossils at Watchet, the life-forms discussed in this year's articles generally are still with us. Some of them, however, are under threat of extinction in Wisconsin or elsewhere. **James Evrard and M. Eloise Canfield** provide information about the status of the Blanding's turtle, a threatened species in Wisconsin, in the wetlands of the Crex Meadows Wildlife Area. In a second article, **James Evrard** surveys archaeological and historical records to document the wildlife found in the Northwest Pine Barrens of Wisconsin during the period 1650–1850. In a third article **Evrard** reports survey results on the status of several species of birds and amphibians that currently inhabit the little-known pine barrens wetlands in and adjacent to the Namekagon Barrens Wildlife Area. Another of Wisconsin's protected areas, the Necedah National Wildlife Refuge, is a home to the Karner blue butterfly, listed as a federally endangered species. **Richard King** evaluates the reliability of three standard survey methods used to monitor the populations of these endangered beauties and to provide information that might be useful to helping their recovery. One common threat to the native biodiversity of any region comes from invasions of exotic species. **D. Timothy Gerber** reports on the extent and impact of the exotic eurasian watermilfoil on the distribution and abundance of native aquatic plants in Forest Lake within Kettle Moraine State Forest in Fond du Lac County. Archaeologist **James Theler** provides a survey of the abundance of animal species evident in occupational remains at nearly three dozen archaic, woodland, and Oneota Native American sites in western Wisconsin and neighboring areas. One sobering statistic is provided by the large shell "middens" (refuse heaps) that testify to the great quantities of freshwater mussels (several species of which are now unknown in the region) that once were harvested by native peoples in parts of the Upper Mississippi River Valley.

A major contribution towards mapping and understanding the mosaic of ecoregions in our state is provided by **James Omernik, Shannon Chapman, Richard Lillie,** and **Robert Dumke**, in their presentation on "Ecoregions of Wisconsin." This study is designed to aid integrated assessment and management of Wisconsin's environmental resources across agency and program lines.

In an article rich in human interest, **Cathleen Palmini** brings together the self-narrated migration stories of four women from Scotland, Germany, Vermont, and New York. Their writings convey fascinating descriptions of the ups and downs of their challenging boat journeys—including seasickness, homesickness, and shipwreck—

across the Atlantic Ocean and through the Great Lakes on the way to settlement in Wisconsin during the mid 1800s.

Finally, as a parting salute to the many special events that marked last year's observance of the fiftieth anniversary of *A Sand County Almanac,* we are pleased to feature one more article on Wisconsin's now legendary "Land Ethic" proponent Aldo Leopold. Curt Meine, of the International Crane Foundation in Baraboo, provides an insightful assessment of how a variety of responses to and adaptations of Leopold's work and ideas reflect developing trends in conservation history. Meine's concluding question, "Whither Leopold's legacy?," invites all who care about Earth (including the rocks!) to remain actively engaged in discovering how best to live on and with the land.

Rocks and more rocks—and turtles and butterflies and mussels and aquatic plants and ecoregions and pioneering women and Aldo Leopold! All of us who worked together to produce this issue of *Transactions* hope that its contents will inform, delight, and challenge all its readers.

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.

Curt Meine

The Secret Leopold, or Who Really Wrote *A Sand County Almanac?*

"Aldo Leopold was a forester and wildlife ecologist who wrote *A Sand County Almanac,* a collection of essays about the natural world and conservation. The book was published posthumously in 1949. *A Sand County Almanac* went on to become one of the key texts of the environmental movement. Leopold is closely identified with 'The Land Ethic,' the final essay in the *Almanac,* in which he argued that people are part of the 'land community,' and so bear moral responsibilities that extend beyond the realm of the human to include the nonhuman parts of that community."

This would be a fair and accurate answer to the question "Who was Aldo Leopold?" But is it a sufficient answer? To conservationists and historians, at least, the question is increasingly urgent. Leopold defined challenges that remain at the core of conservation thought and practice more than a half-century after his death, even as conservation concerns increasingly overlap other issues in contemporary life. The social, philosophical, political, economic, and cultural demands being made upon Leopold's legacy are increasing. At the same time, the living memory of Leopold must inevitably fade as direct connections to Leopold slip into the all-welcoming past. Paradoxically, it will become both harder and easier to answer the question: "Who *really* wrote *A Sand County Almanac*?" What we may gain in detachment and critical judgment, we shall lose by having first-hand impressions no longer available to us.

That these concerns are of more than passing importance is plain. We may turn, for example, to the January 1998 issue of the *Journal of Forestry,* the field's premier professional journal. Its cover featured Aldo Leopold and beckoned with the question: "Has Leopold Supplanted Pinchot?" (i.e., as the guiding philosophical force behind American forestry). The lead article, by a professor of forestry, offered "Another Look at Leopold's Land Ethic"—a harsh critique of the ideas in

Leopold's famous essay. The first sentence of the article read: "Aldo Leopold's influence is based largely on a brief essay, 20 pages long, that outlines what he calls the 'land ethic.'"[1] The author's argument, and a counter-argument by environmental philosopher and Leopold scholar J. Baird Callicott in the same issue, prompted intense discussion among foresters and others, and led to further rounds of discussion within the journal.[2]

The point here is not to examine the play in this particular volley of critique and response, but to note that our knowledge of Leopold is, and must be, increasingly contingent not on the reality of the living human being, but on the received images and impressions of that reality. Leopold the human being belongs to the ages. Leopold the source and symbol has been and will be shaped according to the ideas, questions, and requirements—and also the fears, blind spots, and prejudices—of subsequent generations.

The above-quoted lead sentence from the *Journal of Forestry* article illustrates how time inevitably narrows the field of impressions of the rich, complex, multi-dimensional reality that is an individual human life. In the case of Aldo Leopold, attention has often focused largely on his writings in *A Sand County Almanac* (or even, as in the above instance, just one essay within the *Almanac*). This focus has profoundly shaped our ways of thinking about Leopold. There is Aldo Leopold, who lived a life, and wrote toward the end of it a memorable book. Then there is "The Author of *A Sand County Almanac,*" a figure who for fifty years has been a mirror to our relationship with the natural world, and has borne the burden of our environmental hopes and fears. There is some confusion between the two.

A Legacy Entire

For readers, reviewers, and scholars, Aldo Leopold displays as many facets as there are perspectives. Consider the variety of fields that can—and do—legitimately claim Leopold as an important figure in their development: forestry, wildlife ecology and management, outdoor recreation, range management, sustainable agriculture, wilderness protection, conservation biology, restoration ecology, environmental history, environmental ethics, environmental law, environmental policy, environmental education, literature.[3] Leopold remains a compelling figure, and *A Sand County Almanac* an irresistible focal point, in part because all these perspectives were tightly integrated in his personality and prose. There are, in a sense, many Leopolds. How, then, do we reconcile these many Leopolds with the singularity of Aldo Leopold as a human being?

We may begin with a brief review of the basic facts of Leopold's life and the wide range of his contributions. For those who know of Leopold purely through *A Sand County Almanac,* the story bears retelling.[4]

Leopold belonged to the first generation of trained American foresters, graduating from Yale University's Forest School in 1909. In a nearly twenty-year career with the U.S. Forest Service, he gained expertise in a wide range of sub-fields, including soil and water conservation, game protection, range and watershed management, and recreational planning. Leopold earned a reputation within the Forest Service as one of its most able and creative leaders, highly regarded for his innovations in forest administration. In the 1920s he spearheaded the movement to protect wildlands under the jurisdiction of the Forest Service, and was largely responsible for designation of the nation's first wilderness area, the Gila, on the

Gila National Forest, in 1924. A decade later, in 1935, he helped to found the Wilderness Society, providing a broad philosophical and professional base for the new organization. Leopold also conducted important field research in forest ecology during his Forest Service years, and in 1924 was appointed assistant director of the Forest Products Laboratory in Madison, Wisconsin. He remained in that position for four years.

After leaving the Forest Service in 1928 Leopold devoted himself to game (later wildlife) management as it emerged as a distinct field within conservation. Drawing upon contemporary advances in animal ecology, Leopold provided the field with its first textbook, *Game Management,* published in 1933.[5] He was named the nation's first professor of game management, also in 1933, at the University of Wisconsin. He guided the field through its first important decade, leading it beyond its original mission of perpetuating populations of game animals and integrating it with other conservation fields. In the process he provided foundations for later developments in ecology, sustainable agriculture, and conservation biology.

Leopold was also an early advocate and practitioner of ecological restoration—professionally at the University of Wisconsin's arboretum and other lands, and personally at his farm property in Sauk County, Wisconsin (which the Leopold family acquired in 1935). He was a widely respected communicator, constantly writing and speaking to varied audiences on a wide range of conservation topics. As a teacher he instructed leading professionals as well as hundreds of undergraduate students at the University of Wisconsin. He participated actively in dozens of professional societies and conservation organizations at the local, state, national, and even international levels, and was a prominent player in the development of conservation policy throughout his career.

As notable as Leopold's achievements were, all of the foregoing (and much else besides) occurred before he had even begun to contemplate the collection of essays through which the world would come to know him. Leopold's list of professional accomplishments was impressive long before he began work on the manuscript that became *A Sand County Almanac*—before, in fact, the voice of the *Almanac* had matured.

When did that voice first emerge, and how did it find its full expression in the *Almanac*? *A Sand County Almanac* was the product of the last ten years of Leopold's life.[6] Leopold would work some earlier materials into his evolving manuscript, but he began to sound the new tone in his essay-writing only after two hunting trips, in 1936 and 1937, to Mexico's Sierra Madre Occidental. After the first trip, Leopold prepared an essay he called "The Thick-Billed Parrot of Chihuahua," published in the ornithological journal *The Condor* in early 1937 (it would eventually appear in the *Almanac* as "Guacamaja"). Shortly thereafter, Leopold composed "Marshland Elegy," his moody reflection on Wisconsin's cranes and wetlands. *American Forests* published it later in 1937.

These new expressions reflected a new turn in Leopold's work. Increasingly in the late 1930s Leopold found himself teaching and writing toward a non-professional audience. In 1938, he published the first in an ongoing series of popular essays on wildlife conservation for the *Wisconsin Agriculturist and Farmer,* and in 1940 he wrote two more essays about Mexico and the Arizona, "Song of the Gavilan" and "Escudilla."[7] Leopold was not yet thinking about collecting these essays into a book. However, he was encouraged by the positive response of friends and colleagues and continued to write in this new vein.

The voice of Aldo Leopold in *A Sand County Almanac,* then, was late in its development. It first emerged in the late 1930s, just as Leopold was fully integrating his conservation ideas (a phase culminating in 1939 with publication of his essay "A Biotic View of Land" in the *Journal of Forestry*).[8] The Aldo Leopold that most of the world knows, admires, and criticizes is really the late Leopold, and then only that part of himself that is found in the pages of the *Almanac.* It was of course one of the ironies of Leopold's life that he would not live to see *A Sand County Almanac* published or to know its influence. Indeed, he would never even know his book by that title, which was assigned posthumously; his name and the book title became paired only after Leopold's death in April 1948.

Changing Perspectives on Leopold

What perspectives on Aldo Leopold's legacy do we inherit? How has public understanding and appreciation of his work changed? Because Leopold's legacy is still being discovered by environmental professionals and by the general public, and is revisited constantly by those who do know it, the answers to these questions remain dynamic. In retrospect, however, we can identify several general phases in the evolution of Leopold's public reputation. Those phases, in turn, tell us much about what various audiences have sought out—or neglected—in the record of Leopold's experience.

Leopold among His Contemporaries

We can begin by assessing Leopold's reputation during his own lifetime, or more precisely in the last years of his life, as he was pulling together the manuscript that became *A Sand County Almanac.* It is useful to distinguish between Leopold's local and "more-than-local" reputation. Within the state of Wisconsin, and especially at the University of Wisconsin, Aldo Leopold was a recognized figure, though by no means "famous." He had played a leading role in several important conservation policy initiatives at the state level in the late 1920s. In 1933 he joined the university, assuming a new and experimental Chair of Game Management within the College of Agriculture's Department of Agricultural Economics. Leopold was not an academic by background, and his field of expertise had not yet gained intellectual definition or professional acceptance. Securing wildlife conservation's foothold in academe would be one of Leopold's premier accomplishments in the remaining fifteen years of his life.

For some time, Leopold remained, according to Arthur Hawkins, one of his early graduate students, "suspect." Hawkins recalled that Leopold was "not part of the academic crowd" and "a real novice" in understanding the social ecology of the university campus.[9] In the words of another student of the time, Frances Hamerstrom, he was "very thoroughly respected by a rather small, select group; in general, he wasn't even noticed."[10] By the late 1930s and early 1940s, when Hawkins and Hamerstrom worked most closely with him, Leopold had acquired a large circle of good friends and colleagues within Madison, but continued to lead a relatively quiet academic life.

By contrast, Leopold was very well known and highly regarded among his professional colleagues in conservation around the country. His national reputation had risen steadily over the decades, especially as wildlife management staked out its own territory among the conservation professions in the

1930s. Another student, H. Albert Hochbaum, with whom Leopold collaborated during the early stages of the *Sand County Almanac* manuscript, saw that this wider reputation had to color Leopold's writing. He wrote to Leopold in 1944: "If you will put yourself in perspective, you might realize that within your realm of influence, which is probably larger than you know, Aldo Leopold is considerably more than a person; in fact, he is probably less a person than he is a Standard. . . . Just for fun, then, as you round out this collection of essays, take a sidewise glance at this fellow and decide just how much of him you want to put on paper. . . ."[11]

Of those few who were reading Leopold's draft essays, Hochbaum most deeply appreciated the task of self-reflection and self-expression Leopold had taken on. He may also have had the keenest sense of how others viewed Leopold. In 1947, after attending a conference of wildlife managers, Hochbaum wrote to Leopold, "For a long time the crowd has been more or less following (and sometimes objecting to) the *rules* of wildlife management that you have prescribed. Now they are beginning to follow your *philosophies*, by and large without realizing whence they came. That is progress!"[12] Hochbaum, a pioneer in waterfowl biology who was also a skilled illustrator and writer, saw into dimensions of Leopold's private life and public persona that others missed, and he understood well the larger creative challenge that Leopold had assumed in the *Almanac* essays.

During his lifetime, Leopold's reputation reflected many qualities: his facility with words, the effectiveness of his teaching, the breadth of his conservation philosophy, and especially the degree to which he matched word and thought with deed. His professional impact was far-reaching, especially within wildlife management and forestry. By the end of his life Leopold was well aware of his professional prominence, and it is fair to say that he was quietly proud of it. At the same time, the older he grew—particularly in the last three years of his life, from the end of World War II until his death—the more he could look back on his accomplishments with a mature and self-confident modesty. He was certainly humbled by his own earlier mistakes. He communicated this most notably and famously in the essay "Thinking Like a Mountain," in which he recounted his role in the extirpation of the wolf from the American Southwest.[13]

Leopold, however, was far from universally admired by his contemporaries. He often found himself caught in thickets of controversy. The most prominent instance of this derived from his role in Wisconsin's "deer wars," the drawn-out and vitriolic battles over the state's deer management policy in the 1940s. Leopold's determined advocacy of herd reduction made his name well known—and oft-blasted—among some portions of Wisconsin's populace (including many hunters, anti-hunters, and resort owners). Leopold neither welcomed nor enjoyed the notoriety. Although decades of front-line conservation battles had thickened his skin, he now felt as viscerally as ever the difference between his view of conservation and that of "that collective person, the public."[14] Out of such controversies came the self-awareness that Leopold expressed only rarely and guardedly, the calm sadness in his observation that "one of the penalties of an ecological education is that one lives alone in a world of wounds."[15]

The deer management fight was only one of many instances in which Leopold staked out unpopular or controversial positions. He continued to wage wilderness protection battles up until the end of his life. He did not hesitate to use his voice directly and forcefully to protect threatened wild lands, to counter indiscriminate wartime incursions into untrammeled country, to slow the post-war juggernaut of dam-building, to restrict what he saw as inappropriate uses of designated wilderness areas. He remained an adamantly active member of the Wilderness Society until his death. The cause of wilderness protection had not yet achieved the wider acceptance that would come with the battle of the early 1950s over the proposed Echo Park dam within Dinosaur National Monument. As America entered the era of post-war economic boom and political paranoia, Leopold occasionally found himself at odds even with old colleagues within the conservation movement over the wilderness issue.

Leopold was known among his peers as a hard-headed critic, though a fair, constructive, and thoughtful one. In the last decade of his life Leopold became increasingly blunt in his view of the direction taken by universities and government agencies. He was notably critical of the trend toward increasing specialization and toward what he called "power science" within the academy. He wrote in 1946, "Science, as now decanted for public consumption, is mainly a race for power. Science has no respect for the land as a community of organisms, no concept of man as a fellow passenger in the odyssey of evolution."[16] Some of Leopold's most forceful prose (published and unpublished) addressed this theme. In many ways, "The Land Ethic" itself was the ultimate expression of his concern.

At the end of Leopold's life, then, his conservation work was well known, widely appreciated, and occasionally contentious, but he himself was little known outside of the professional conservation world. He was one of several voices from within the movement (including especially William Vogt and Fairfield Osborn) that in the immediate post-war years sought to communicate the importance of the science of ecology to a broader public. As the manuscript of *A Sand County Almanac* went to press, however, its author remained "very thoroughly respected by a rather small, select group."

Leopold Reaches a Broader Audience

A second phase in public awareness of Leopold began with the publication of *A Sand County Almanac* and extended roughly to the mid-1960s. This spans the time from the first appearance of *A Sand County Almanac* to its later re-publication as a mass paperback. During these years two essentially opposing trends played out: on the one hand, the level of popular environmental awareness rose dramatically; on the other hand, the traditional conservation fields found themselves internally divided over the fundamental principles that Leopold and others had sought to define.

A Sand County Almanac helped to stimulate environmental literacy among the American public; conversely, readership of *A Sand County Almanac* and recognition of Leopold's contributions grew along with that increasing awareness. This mutually reinforcing process can be traced back to the earliest reviews of the book. The book was widely reviewed both locally and nationally, both by readers familiar with Leopold and by those learning of him for the first time. Because of the confluence of events, many reviews served in essence as obituaries of Leopold, as reviewers used the occasion to reflect upon Leopold's legacy. The reviews of the day thus provide a fair portrait of the state of his public persona.

August Derleth, perhaps Wisconsin's best known regional writer, reviewed *A Sand*

County Almanac for Madison's *Wisconsin State Journal.* Derleth knew of Leopold's work and was well familiar with the Wisconsin landscapes described in the *Almanac.* Although he and Leopold were not themselves intimates, they shared many acquaintances. Derleth wrote in his review, "All genuine conservationists throughout Wisconsin and the Midwest generally realize that in the death of Aldo Leopold, Wisconsin lost one of its most able men in the field of conservation. Posthumous publication of his book offers ample evidence that his death deprived us *also of an author of no mean merit.* His book is one of those rare volumes to which sensitive and intelligent readers will turn again and again"[emphasis added].[17] Derleth's phrasing is instructive. For most readers, Aldo Leopold would be known first and foremost, and often only, as an author. For Leopold's contemporaries, and especially local contemporaries, Leopold was known primarily as a conservationist.

Many of the national reviews of *A Sand County Almanac* were marked by a similar tone of surprise, delight, and deep respect, although the reviewers knew little if anything of Leopold's professional accomplishments. Lewis Gannett, in the *New York Herald-Tribune,* wrote: "Aldo Leopold died fighting a neighbor's fire in the spring of 1948. I am sorry, for I should like to have known him. I do not recall ever hearing his name until I stumbled on this book; to read it is a deeply satisfying adventure. This was a man who wrote sparsely, out of intense feeling and long experience. You will find here no statistics about erosion, no screaming warnings to 'do something about the soil.' Aldo Leopold was primarily concerned with the importance of feeling something. He himself felt deeply, and his feeling gives a rich texture to this too-short book."[18] Gannett did not know, of course, about Leopold's years of devoted statistic-taking on erosion, his many forceful pleas for action, his constant emphasis on the vital role of scientific research in conservation. Yet, all that was beside the point. Gannett was quite correct; in *A Sand County Almanac,* Leopold *was* "primarily concerned with the importance of feeling something."

It is an important point. New readers from beyond Leopold's personal or professional circles found here something unusual. The tone and style of *A Sand County Almanac* were quite different from that of other prominent conservation books of the time, in particular Vogt's *Road to Survival* and Osborn's *Our Plundered Planet,* both of which were published in 1948. These two prescient books on the state of the global environment were chock-full of statistics and warnings. Their authors read the future, and it was not pretty. Both books gained an immediate, sizable, and influential audience. Leopold shared their profound concern—he in fact knew both Vogt and Osborn and had read Vogt's book in manuscript—but he spoke in subtler tones. Leopold's book sold more modestly but, as it turned out, more steadily. *A Sand County Almanac* continued to gain readers through the 1950s and into the 1960s. By the mid-1960s, some twenty thousand copies had been sold, but mostly among dedicated conservationists and readers of natural history.

The significance of the *Almanac* becomes clearer when viewed in relation to the second general trend in this period: the ambivalence with which many conservation professionals regarded (if they regarded it at all) the path that Leopold and his like-minded colleagues had blazed. Through the 1950s, the professions in a sense left behind Leopold and those who shared his more integrated outlook on conservation challenges and solutions. In "The Land Ethic," Leopold had expressed concern over the growing division between conservationists who "[regard] the land as soil, and its function as commodity production," and those who "[regard] the land as a biota, and its function as something broader."[19] The former were gaining a firm upper hand.

Through the post-war era, the professions and disciplines became increasingly segregated. Engineering solutions replaced more agronomic or naturalistic approaches. "We are remodeling the Alhambra with a steam-shovel," Leopold lamented in "The Land Ethic, "and we are proud of our yardage." Soil conservation, agriculture, forestry, recreational planning, and range, fisheries, and wildlife management bent increasingly toward utilitarian ends, while ecology turned increasingly experimental, quantitative, and model-oriented. As the professions "modernized," Leopold and his generation came to be seen as important albeit old-fashioned predecessors. The kernel of their legacy—the integration of the natural sciences and humanities in the service of conservation—fell under the heavy tread of the steam-shovels.[20]

Leopold and the Environmental Awakening

That seed, however, would prove hardy. A third phase in public appreciation of Leopold began in the mid-1960s and would last roughly into the mid-1980s. Paperback editions of *A Sand County Almanac,* published in 1966 and 1970, brought Leopold to the very forefront of the incipient environmental movement. Rachel Carson's *Silent Spring* (1962), Stewart Udall's *The Quiet Crisis* (1963), and other books of the period created a growing critical mass of readers as *A Sand County Almanac* reappeared in its more accessible and affordable form.

As the paperback worked its way into the backpacks and reading lists of the baby boomers, a generation gap began to emerge in perceptions of Leopold and the application of his ideas. On one side were the more senior conservationists, many of whom personally knew and worked with Leopold or his contemporaries. On the other side stood the growing corps of younger environmentalists who knew of Leopold only through the *Almanac* essays. These younger devotees came into their environmental awareness as the landmark legislation of the era—the Wilderness Act (1964), the National Environmental Protection Act (1970), the Clean Air Act (1970), the Clean Water Act (1972), the Endangered Species Act (1973)—redefined the context of the older conservation movement.

Older and younger readers alike would invoke Leopold in support of their causes and adapt him in their approaches, but those causes and approaches did not always jibe. Underlying differences in (to cite just a few examples) the aims of resource management, attitudes toward hunting, appreciation of wilderness, and the role of political activism in solving environmental problems divided these audiences. Importantly, however, Leopold also served as a bridge across the generations. All were reading from the same book, a fact that would prove highly significant in the long run.

Leopold and the Re-integration of Conservation

By the 1980s, another demographic shift began to play out. Within the conservation professions, elders from the post-World War II generation began to approach their retirement years; older baby boomers rose through the professional ranks; and younger baby boomers, trained in the post-Earth Day era, entered those ranks. Meanwhile, non-professional readers of *A Sand County Almanac* went about their lives in their communities, the paperbacks still residing on their bookshelves, the words still working their quiet influence.

By the late 1970s and early 1980s, changes in society, in politics, and in the environment itself cast Leopold's words in new light. Systemic environmental problems—increasingly vitriolic disputes over national forest management policy, groundwater pollution problems due to intensified agricultural practices, climate change, global-scale threats to biological diversity, incessant suburban sprawl, and on down the list of modern conservation dilemmas—demanded more systemic solutions. Such solutions came to be explored under many names, including *ecosystem management, conservation biology, ecological economics, community-based conservation,* and *sustainable agriculture.* New terms—*biodiversity* and *sustainability* prominent among them—were invoked to broaden the conceptual ground on which conservation stood.[21] These responses, while novel in name, often returned for grounding to the fundamentals of integrated conservation, as outlined by Leopold and his contemporaries. As a result, Leopold's intellectual stock continued to rise through the 1980s and 1990s.

As we are still working within this most recent phase, we are unable to read it with clarity. But as the waves of passion in the conservation and environmental movements have swelled and subsided, Leopold's legacy has ridden through them all, and remained robust. Why and how? It has to do in part, of course, with the historic record of his accomplishments and the quality of his writing and thinking. But it has also to do with the welter of forces that keep Leopold relevant, that bring us invariably back to him, more sober but more ready perhaps to consider the subtleties of his work. These forces might include the following:

• **The fact of continuing environmental degradation, and the need for more integrated responses that are informed by ethics.** For those who see our fragmented approach to landscapes, their biota, and their human communities as a primary cause of environmental degradation, the search for solutions leads back to the integrated view that Leopold articulated finally in "The Land Ethic." Leopold's declaration of the ethical underpinnings of conservation has continued to gain attention and to have substantial impacts on national policy (through, for example, the shift toward ecosystem management in the land management agencies and in many conservation organizations).[22] Leopold regarded the lack of attention from philosophy and religion as "proof that conservation [had] not yet touched [the] foundations of conduct"; the consolidation of environmental ethics and the greening of religion may now be regarded as proof that it has at least begun to touch those foundations.[23]

• **The anti-environmental "wise use" movement.** As forces of opposition to conservation and environmentalism assumed greater power in the 1980s and 1990s, many younger environmentalists were compelled to revisit their roots and to learn (often for the first time) their connections to the older conservation movement. Likewise, more conservative conservationists were also led to examine their political loyalties. Even staunch conservatives began to rethink their priorities when Ronald Reagan named James Watt his Secretary of the Interior. For many in this period, Aldo Leopold stood out as one who did not place his politics before his conservation commitments. The relationship between political conviction and conservation action has always been complex. In his writing Leopold does not come across as an ideologue, and in life he was not. He has remained a relevant and flexible voice during a period of intense politicization of conservation.

• **The erosion of community.** During these same years many have sensed and tried to define the changes that are transforming our human communities.[24] Somewhere between the shoals of unwarranted nostalgia and uncritical economic optimism lies (we may hope) safe passage, but the route is difficult to discern. Renewed attention to communitarian values is an important part of contemporary social criticism. A parallel expression has emerged from within conservation, emphasizing the need to *re-place* communities, to see them in terms of the biophysical environments in which they are embedded. "Community" was a key word in Leopold's lexicon, and the "extension" of community that Leopold advocated in "The Land Ethic" has accordingly assumed increased importance.

• **The interdisciplinary imperative.** This pertains particularly to academia, where hyperspecialization and reductionism move on apace, opportunities for "thinking time" shrink, and the selective pressures on success continue to intensify. Such trends tend to overwhelm efforts to maintain connections among the sciences, arts, and letters. Leopold's characteristic interdisciplinary approach carries authority here. He stands as an example and reminder of a time before the need to specialize was ratcheted up several additional notches, and a greater share of rewards still accrued to those whose training, teaching, and work were broad and diverse.

These forces—and no doubt many others—have allowed Leopold's readers to see him in a new light, as one who identified tendencies that would increasingly characterize American society and the American landscape through the twentieth century. The implicit messages in Leopold's essays, spoken amid the bugling of cranes and the songs of wild rivers, have become more explicit. Yet, new readers can still respond to the faith Leopold felt down to his very marrow: that the future of the human enterprise on this (and any other) continent is tied fundamentally, if not always clearly, to the future of our wild co-inhabitants and landscapes.

A Taxonomy of Responses

Since *A Sand County Almanac* was published, most of its readers have remained unaware of the life that gave it shape, responding not so much to Aldo Leopold the historical personage as to "The Author of *A Sand County Almanac*." For the general reader, this may be of small consequence; a good book stands on its own, and its quality endures regardless. (Does it matter that we know so little of the author of the Book of Job? That Shakespeare's life remains opaque to us? We know the author through the words and the story.)

It is the duty, however, of the historian and literary biographer to fill in the facts, to weigh the text against the life, and to provide the book with a sort of narrative *habitat.* Such scrutiny enriches our understanding of the creature itself—robbing it perhaps of some of its immediate mystery, but providing a richer appreciation of its existence. With such perspective, we may see in our prior responses and images a little less of Leopold and a little more of ourselves. What do we see when we reexamine "The Author of *A Sand County Almanac*"?

Leopold the Prophet

We encounter first, of course, Leopold the environmental "prophet." Leopold's daughter Nina Leopold Bradley, when asked to speak of her father's conservation philosophy, has sometimes referred to "that poor old land ethic." It is a great deal to ask one essay, or book, or person, to bear the weight of society's need to transform its relationship with the natural world. Over the decades, a disproportionate amount of that weight has fallen upon Aldo Leopold.

Among Leopold's contemporaries were several who recognized the full depth of Leopold's conservationist critique and first employed the all-but-inevitable tag of "prophet." Roberts Mann, a Leopold friend and superintendent of the Cook County (Illinois) Forest Preserve District, published an article in 1954 entitled "Aldo Leopold, Priest and Prophet."[25] Ernie Swift, another friend and colleague who led Wisconsin's Conservation Department, followed in 1961 with "Aldo Leopold, Wisconsin's Conservation Prophet."[26] Historian Roderick Nash, in his classic 1967 book *Wilderness and the American Mind,* called his chapter on Leopold simply "Aldo Leopold, Prophet."[27] The trope has endured. Wallace Stegner, not one given to hyperbole, regarded *A Sand County Almanac* as "the utterance of an American Isaiah. . . almost a holy book in conservation circles."[28] *A Sand County Almanac* continues to be referred to regularly as the "Bible" or "scripture" of the environmental movement.

This "prophet" tradition, whether one regards it as appropriate invocation or unnecessary overstatement, is instructive. Aldo Leopold has reflected a strong social need. Any social movement (especially in its emergent phase) requires a prophetic voice to give itself coherence and direction. Martin Luther King was the pre-eminent prophetic voice of the modern civil rights movement. For complex reasons, there was no equivalent iconic figure in the environmental movement. But environmental reformers could and did look back to find not only Leopold, but John Muir, Henry David Thoreau, and, among contemporaries, Rachel Carson and David Brower, Sigurd Olson and Barry Commoner, Edward Abbey and Gary Snyder. They became the movement's "prophets." As conservation itself continued to evolve at the turn of the twenty-first century, Leopold (among these others) continued to fulfill the prophet function.

Leopold the All-purpose Hero

One key factor set Leopold apart even within the pantheon of environmental prophets: he coupled the inspiration of his prose, thought, and activism with the authority of his experience. Leopold, unlike the others, wrote from a varied professional background in on-the-ground forestry, range management, wildlife management, wilderness protection, and restoration work. He was a respected figure in each of these fields and could speak to all his professional colleagues in their own languages. And so Leopold served another posthumous function: as an all-around, acceptable and accessible "conservation hero," able to appeal to a broad range of conservation factions—at least as long as the deeper tensions within conservation lay dormant.

One of the more interesting variations on this image of Leopold involved an unlikely source. The February 18, 1956, edition of the *Saturday Evening Post* featured a realistic sketch of Leopold in a full-page advertisement for the Weyerhauser company. The ad depicted Leopold, on bended knee with a fawn under his protective watch, against a clear-cut mountainside in the background. Aldo Leopold by this time was apparently seen as a reasonable conservationist who could support, as the text of the ad put it, "*true conservation* through the wise use and perpetuation of industrial forest uses" [emphasis in original].[29]

This Leopold-as-conservation-hero motif reflected conservation's growing mainstream constituency. By 1956 conservation, however vague, fuzzy, and pliable its definition, had become acceptable across a broad demographic spectrum. As long as Leopold represented the kindly and constructive school of *reasonable* conservation, even a major industrial force such as Weyerhauser could present his image in one of their prominent advertisements. It could, for the time being, ignore the fact that Leopold was a dedicated activist, a critical scientist, politically involved and often courageous, and not one to shrink from unseemly controversies involving conservation policy.

Leopold the Radical Environmentalist

If Leopold's work and words had helped to build a broader, more popular, better funded, more respectable, more mainstream environmental movement, it also inspired the counter-response. As environmentalism became more acceptable, it became, in the view of others, more diluted. And so we find another reading of Leopold's legacy in ascendance: Leopold as radical environmentalist and deep ecologist.

The most prominent example of this "redeployment" of Leopold came through the actions of the 1980s Earth First! movement. When Dave Foreman, Edward Abbey, and their compatriots launched the movement, they drew heavily upon Leopold in raising high the bar of compromise in conservation politics. Leopold's powerful image of the faltering "green fire" in the eyes of the dying wolf of "Thinking Like a Mountain" came to symbolize for this new generation of wilderness activists the loss of the North American wilds. "A militant minority of wilderness-minded citizens," they read in Leopold's essay "Wilderness, "must be on watch throughout the nation and available for action in a pinch."[30] At the same time, their philosophical standard-bearers in the deep ecology movement could point to "The Land Ethic" as a foundational document.[31]

Of course, counter-responses ensued. Hence the disgruntled forester, who groused in the *Journal of Forestry* that Leopold was merely a "starry eyed. . . pipe-smoking academician." Another suggested that the pipe held more sinister substances, noting that he [the reader] had "seen nothing that Aldo Leopold had to say that does not make me think that he was anything but the original pot-head."[32]

What do we learn from Leopold the Deep and Radical Ecologist? He reflected the increasingly polarity within the environmental movement as its influence rose through the 1970s and 1980s. During these years, the ranks of environmental professionals and bureaucrats burgeoned. Prior to that, if one were engaged in environmental work, one was likely an amateur—poorly paid (if paid at all) and engaged primarily out of a sense of public duty. By the mid-1970s, the scene was changing. Membership in the major environmental organizations was on the rise. As paid staffs expanded, professional expertise began to overshadow grassroots activism. Passion was nice, but a master's degree got you the job and respect. As the environmental professional class grew, however, the grassroots activists, driven by powerful social, political, and spiritual motives, hardly went away. The result, in a sense, was a splitting of the Leopold legacy. Suited professionals could see Leopold as a sort of master diplomat and spokesman, able to speak to all sides on environmental issues. Activists could see Leopold as a committed and deeply honest radical, whose message provided intellectual armor.

Leopold the Naïve Interloper

This category encompasses an entire suite of images. It refers to the response evoked as Leopold's interdisciplinary influence has come to be felt in fields not his own. This response may be traced in any number of fields; it will suffice here to examine it in philosophy, politics, and conservation itself.

As J. Baird Callicott has pointed out, that Leopold in fact *made* any contribution to philosophy is not a view that all philosophers have shared.[33] Consider the following statements. H. J. McCloskey, an Australian philosopher, suggested that "there is a real problem in attributing a coherent meaning to Leopold's statements, one that exhibits his 'Land Ethic' as representing a major advance in ethics rather than a retrogression to a morality of a kind held by various primitive peoples." Far from an advance in ethics, then, Leopold offered only retrogression. Another regarded Leopold the philosopher as "something of a disaster, and I dread the thought of the student whose concept of philosophy is modeled principally on these extracts from Leopold's writings." Another reviewer saw "The Land Ethic" as "dangerous nonsense."[34] In short, for a few of the more formally trained philosophers, Aldo Leopold's forays in this field are hardly worthy of serious consideration.

How does Leopold fare among politicians and political theorists? Somewhat better, actually, especially in recent years. Because Leopold's conservation politics defied conventional ideological pigeonholing, those searching for deeper political lessons have found his work in this arena especially instructive.[35] The same maverick quality, however, has also left Leopold open to easy criticism. Such criticism has come, on the one hand, from those who have preferred a more direct political approach to environmental issues. Thus, in 1974, still in the wake of the high wave of the environmental movement, we find an article entitled "The Inadequate Politics of Aldo Leopold." The author found Leopold's politics to be "wholly conventional, some would say naïve. From one point of view the wonder is not that he accomplished so much as a political operator, but that he accomplished so little. . . . One reason for Leopold's frustration was his own inability to face the likelihood that so fundamental a change in people's attitudes as he advocated would involve concomitant changes in the economic system and probably in the political superstructure. Again and again in his writing he seemed on the verge of some sort of ideological breakthrough, but appeared to draw back from the brink of discovery. In the political and administrative sector. . . this inexperienced administrator had little to offer for implementation of his 'land ethic' beyond a very traditional reliance on high-minded moral persuasion."[36]

If some saw Leopold's politics as naïve and inadequate in the highly politicized context of 1970s environmental activism, others would see his approach in a new light as that context continued to change. A decade later, Leopold's biographer (i.e., this author) could receive inquiries from a conservative journal interested in an article on Aldo Leopold, because they felt he was "an environmentalist we could live with." This is not as surprising as it may seem. Conservatives and libertarians can find much to agree with in "The Land Ethic." A core component of "The Land Ethic" is in fact Leopold's belief that individuals had to assume greater responsibility for the health of the land; that absent such responsibility, governments would inevitably need to step in, and governments simply could not assume or carry out all necessary conservation functions. The editors evidently saw here an opportunity to explore these "conservative" elements of "The Land Ethic."[37]

Aldo Leopold's politics were not naïve. As Susan Flader has shown, Leopold's sense of citizenship and civic responsibility was keen and evolved along with the changing currents in the conservation movement.[38] That we can read his politics as conservative and progressive, naïve and sophisticated, personal and public, again tells us as much about ourselves as it does about Leopold. It says, perhaps, that we have yet to evolve a politics that can respond in a healthy and democratic fashion to complex conservation dilemmas; that we are still struggling to find ways to protect, in Leopold's words, "the public interest in private land"[39]; that we continue to paw among our traditional political ideologies in search of solutions and find it very difficult to imagine where constructive alternatives may lie. For those deeply involved in the struggle to forge new relationships on and with the land and among the people who inhabit it, Leopold's politics, far from being naïve, remain instructive and encouraging. (And, yes, inspiring.)

The Leopold-as-naïve-interloper view has occasionally found currency within the conservation world as well. Many of Leopold's precepts of conservation were beyond the pale in his own day, and many remain so. More specifically, the breadth of perspective he brought to conservation was highly unusual, so that those who inhabited one portion of the conservation spectrum could not always appreciate his comprehensive view. (The story is told, for example, of the joke that went around the hallways of Wisconsin's state Conservation Department, about how to spell this word "aesthetic" that the Professor was always using).

Leopold was both a specialist (in several fields) and a generalist. But as the conservation professions specialized further in the years following his death, it became very easy for some to look back and regard Leopold as a dilettante in their increasingly insular fields. Hence, for example, latter day foresters could ignore Leopold's credentials in the field and claim in effect that he wasn't much of a forester after all.

Another "sub-heading" in this particular category involves the problematic (for some) fact that Aldo Leopold was also a life-long hunter. For this, Leopold has received his share of criticism from at least some anti-hunters, activists, and environmental ethicists. Conversely, he has been held high by conscientious hunters as a premier example of the ethically sophisticated and environmentally committed sportsman.

Leopold confronted the chasm in attitudes toward hunting directly and regularly in his own lifetime. The chasm grew only deeper in the years that followed. No less a figure than Rachel Carson, for example, had an outright disdain for the only Leopold, apparently, that she knew: the one of *Round River,* the collection of Leopold's hunting journal entries first published in 1953.[40] Carson's conservation ethic, of course, was more closely aligned with Albert Schweitzer's "reverence for life" philosophy than with a Leopoldian land ethic. *Round River*'s portrait of Leopold the hunter was more than she could tolerate. The same response can be found, again, in the recent *Journal of For-*

estry critique, where we find the following lambaste: "Leopold preached the extension of ethics to all fellow members of the land community, and he practiced killing them until the end of his life."[41] Suffice it to say that this critic chose the bluntest of rhetoric to address one of the most sensitive issues in conservation and one of the most complex of human behaviors—one, it is safe to say, that Leopold pondered carefully and consciously on a daily basis for decades.

These dismissals of Leopold by selected philosophers, political activists, and even conservationists again track broad trends in society. In them we can read the impact of increased specialization and politicization in conservation. Divided into areas of special knowledge and special interest, conservation like other fields struggles to find coherent connections between the present and the past, the abstract and the actual, the sciences and the arts, philosophy and practice. By contrast, Leopold's written record reveals a mind at ease with complexity, open to mystery as well as to new data, and resistant to reductive tendencies in both science and politics.

He was, by all but unanimous consent of historical sources, a decent and delightful person to know and to work with, an inspiration to those working in conservation, tolerant of human foibles, and lacking in hidden demons. Ironically, such qualities may account for the challenge some have in "handling" Leopold. Modern readers, accustomed to irony and alienation and sensitive to political subtexts, may find Leopold's personality an increasingly difficult kind to get a hold on. In our contemporary attempts to resolve postmodern dilemmas, we may project them onto Leopold.

Several illustrations may serve to make the point. For years, a portrait of Leopold has hung on the walls of the Department of Wildlife Ecology at the University of Wisconsin in Madison. The artist chose to depict Leopold with cigarette in hand (an intermittent smoker, he preferred his pipe to cigarettes). Graduate students—if not the genuflectors—have appreciated the humanity in that particular icon. Then there was the survey question in *Sierra* magazine. The editors asked readers to respond to the query, "Can you eat meat and consider yourself an environmentalist?" Among the responses: "Remember: Aldo Leopold ate meat, Adolph Hitler did not."[42] The past calls out to us. . . from the far side of the postmodern minefield.

Leopold the Eco-fascist

More extreme examples of the above may be found on the far fringes. Because Aldo Leopold is a focal point for discussion of environmental ideas and strategies, he is occasionally criticized as an advocate of oppressive social and governmental actions to safeguard the environment. The reasoning is this: Leopold in "The Land Ethic" places the good of the collective, the community, the whole, the ecosystem, above the good of the constituent parts; he, therefore, would have the whole impose its will on the constituent members of that whole. (The irony, of course, is easily lost on many such critics, i.e., that Leopold saw individual responsibility, as articulated in "The Land Ethic," as the only sure antidote to such eventualities).

Many of these criticisms arise out of reasoned consideration of the difficult questions that Leopold's work—indeed, that conservation generally—poses. These arguments, well developed and thoughtful, appear in our academic journals and conference proceedings. So do effective counter-arguments.[43] Not all such exchanges, however, are so rational. One of the strangest, a 1993 letter to the editor of *Iowa State Daily,* criticized the mission of Iowa State University's Leopold Center for Sustainable Agriculture. Not content to question the institution, the letter-writer attacked Leopold as "racist," stating that "He believed in the superiority of the Nordic race. He believed that population growth has to be stopped; he rejected the sanctity of life and he scorned human beings so much that he believed the population of a country could be managed like an animal reservation."[44] However bizarre such rantings may seem, they are not to be dismissed lightly. We read into Leopold (however undeserving) not only our hopes and concerns, but our uneasiness and our fears.

There are, no doubt, other "Leopolds" that bear consideration. As the taxonomy fills out, we can begin to identify the several basic tendencies that mark much Leopold commentary and criticism. The most common, noted above, is to assume that Aldo Leopold existed only as "The Author of *A Sand County Almanac*"; that it is unnecessary to take into account other aspects of his conservation career; that the historical and personal context of the *Almanac,* however interesting, is of incidental importance. One may find this view among Leopold's devotees as well as his detractors.

A second common tendency is to divorce Leopold's publications from his practice. Leopold was a man of action as well as words, and the dynamic between these two spheres of his life may be the most significant of his many contributions. He tried to define a workable standard for conservation to follow and work toward. But he also worked toward it himself, and thereby humanized it.

A third common tendency is to read only that part of Leopold with which one feels most comfortable or conversant and to avoid confronting the entirety of the person, his expertise, and his record. Hence we find the critic who attends only to one of the several disciplines Leopold worked in, or one of the professions he practiced. Evidence of this tendency can be found in many the fields to which Leopold contributed, from wildlife ecology and agriculture to economics and philosophy.

Finally, another common tendency is to consider Leopold's work only up to a certain point in time. Hence, for example, the occasional wildlife manager who will read *Game Management* and appreciate it as the profession's founding volume, while ignoring or slighting the epic progression from *Game Management* (1933) to *A Sand County Almanac* (1949). Again, evidence of this tendency is widely distributed.

Leopold, in short, has been a mirror to our environmental responses. We see in him a succession of reflections over the decades since his death. In the years immediately following World War II, awareness of widespread environmental problems increased, and our fears grew apace. Leopold offered a way of understanding the human dimensions of these problems, and of imagining possible solutions. He cast warnings, as did others of the time, but tempered the warnings with wonder and wry humor, humility and poetry. In one essay after another, he leavened his conservation message not only through his expressions of love for "things natural, wild, and free," but also through his understanding of the human condition and of human shortcomings (including, of course, his own).

As the environmental movement coalesced in the 1960s and early 1970s, many found inspiration in Leopold's words. Leopold recognized clearly the harsh realities of environmental degradation, but provided a positive response to those realities.

In the academic and policy arenas, he showed how the sciences, literature, history, and philosophy not only could be, but *had* to be, brought together to address problems and suggest solutions. He contributed to the foundations upon which new, more integrated environmental policies and programs could be built.

Into the 1970s and 1980s, Leopold's words provided guidance not only for far-reaching policy changes, but in a sense for their complement: a well tempered understanding that conservation problems could not merely be legislated or administered away, but had to be addressed from within—within our selves, communities, cultures, agencies, businesses, organizations, and institutions. A sense of the limits of purely technical or political solutions gained ground. Stated another way, Leopold's land ethic was now read not just as a rationale for short-term technical fixes or policy initiatives, but as a guide to necessary longer-term social and cultural changes.

Finally, it seems of late that readers are responding increasingly to the degree of personal commitment that they find in Leopold. Leopold, although profoundly aware of harsh conservation realities, avoided the mire of despair. One of his most notable character traits was his capacity to face squarely and honestly a difficult conservation dilemma and to address it in a constructive manner despite overwhelming odds. This trait marked his literary endeavors as well, and never more so than in completing "The Land Ethic." Despite serious health problems and other difficult personal circumstances, he found the internal resources to pull together "The Land Ethic" as he completed his collection of essays in the summer of 1947. That strength of character rests between every line of *A Sand County Almanac.*

Whither Leopold's Legacy?

How will future generations respond to the Leopold legacy? What will they look for there, and what will they find? How will Leopold's work and thought reflect back upon them? Those questions are of course unanswerable, but we may speculate around the fringes.

The various disciplines and professions to which Leopold contributed are still struggling to gain historical self-awareness. Few foresters are taught the history of forestry. Few wildlife managers are taught the history of wildlife management. Ecologists are sometimes taught the history of ecology. Most professionals have a strong curiosity about their professional past, and seek it out, but only recently have more formal opportunities to understand this past arisen. Many still find Leopold's *A Sand County Almanac* a better history text than anything they receive through their formal training. Environmental history has emerged to fill in some of these gaps, but we still lack comprehensive treatments of the development of conservation through the nineteenth and twentieth centuries. This situation, if nothing else, will ensure that attention will continue to focus on Leopold, for the simple reason that his life provides a unique medium through which to address recurring issues, debates, developments, and trends in conservation. His life story will continue to offer critical insights into not only the past, but the future.

An inescapable dilemma will need to be taken into account. As noted above, Leopold's legacy is likely to become even more important with time, even as the immediate connections to that legacy inexorably fade. Conservationists will continue to examine that legacy, but Leopold's insights cannot serve if they are regarded as inert museum specimens. Leopold's legacy, if it is to remain vital, must be able to grow and evolve, to tolerate dissent, resist dogma, and welcome criticism.

Leopold's legacy already comes with built-in defenses. He was in many ways his own sharpest critic and anticipated many of the forces that might have led to the fossilization of his ideas. Many a critic will yet discover that Leopold was often there first and had already taken his own weakest points into account. Moreover, Leopold was not alone in his prescient views. He was, to borrow his words from "The Land Ethic," part of a "thinking community" that struggled to meet the conservation challenges of its day. We build upon the work, not simply of Leopold, but of a generation whose achievements and frustrations he articulated.

Students of Leopold's work are fortunate to have the testimony of primary sources, many of whom in the year 2000 are still with us. They have as well a generous inheritance of recorded impressions of Aldo Leopold upon which to draw. Alfred Etter, who studied with Leopold, penned in 1948 one of the more sensitive accounts. It appeared as an obituary, and described a day afield with Leopold. Etter's account captured well the enduring personal qualities of Leopold. At the family's shack, wrote Etter, "[Leopold] tried to piece together answers to the questions which Nature so often tempted him to solve. From pads of moss or patches of quack grass he learned a piece of history. From a tangle of ash logs a suggestion of some principle dawned upon him. From a broken pine a brief diagram of the balance of the forces in the environment was devised. Above all, this farm was a place where his children could learn the meaning of life and gain confidence in their ability to investigate small problems and discover things which no one knew."[45]

For those who consult the historic record, this understanding of Leopold's way of thinking and observing and conducting himself offers resistance to distortion. Paul Errington, another contemporary, also spoke to this, again in a 1948 obituary: "Let no one do [Leopold] the disservice of fostering Leopoldian legends or Leopoldian dogmas. Knowing him as I have, I can say that he would not wish these to arise from his having lived. I can imagine his gentle scorn at the thought of anything like elaborate statuary in his memory, while despoliation and wastage of the land and its biota continue as usual."[46]

Readers returning to Leopold will no doubt continue to find their own growth reflected in his words. Not uncommonly, readers who first encountered Leopold through *A Sand County Almanac* in their idealistic youth return years later to its pages to find the earlier inspiration now enriched by more subtle wisdom. For many, Leopold has become the proverbial parent who has "grown *so much wiser* since *I* was young."

A fine example of this can be found in a 1988 essay published in the *North Dakota Quarterly*. The author, Patrick Nunnally, recalled that he had first read *A Sand County Almanac* in the politically charged 1970s, when he was involved in wilderness protection battles in the southern Appalachians. He later moved to Iowa, where he found himself interacting more regularly with farmers. He also found himself asking what Leopold had to offer under those different circumstances. Nunnally recalls returning to the *Almanac*, only to find a broader appreciation of its value:

> [Leopold] establishes a grounding, a framework for conversation, without foreclosing much in the way of intelligent reflection and inquiry. It seems to me that I formerly used

Leopold to end conversations: "This is what Leopold says, and that is the final word." Instead, I look to him now to keep me focused and to keep me reminded of the larger conversation and stakes of which individual land protection discussions are a part. His principles provide a steady foundation that guides my discussions with individual farmers about the possibilities for conservation tillage and that grounds abstract philosophizing about the need to overthrow the Western world view for an ecologically-just society. He still has value as a source for quotations—he writes better on this subject than nearly anyone else who has tried, and his particular phrases ring better than any of my own. But it is more important to me now that he provides exemplary inquiry to complicated problems, with more than one viable position but only one best position. What formerly I cited as received dogma, now, I hope, I can use as wisdom of a thinker who has preceded me in the land conservation debate.[47]

This is the more measured and better-balanced view of Leopold that we can anticipate and work toward. Finally, five decades after Leopold's death, we may appreciate his continuing influence without having to make him over into a deity or a devil, a hero or a threat, without having to regard him as naïve, radical, old-fashioned, or prophetic. This is the kind of critical attitude that pays due honor to Leopold by reflecting not merely our desires or our fears, but our *growth.*

Notes

1. Boris Zeide, "Another Look at Leopold's 'Land Ethic,'" *Journal of Forestry* 96,1 (January 1998), 13-19.
2. J. Baird Callicott, "A Critical Examination of 'Another Look at Leopold's "Land Ethic,"'" *Journal of Forestry* 96, 1 (January 1998), 20-26. The April 1998 issue of the *Journal of Forestry* featured eight further commentaries. These articles were reprinted by the Society for American Foresters in a Forestry Forum publication, *The Land Ethic: Meeting Human Needs for the Land and Its Resources* (Bethesda, Md.: SAF, 1998).
3. For a compilation of Leopold's writings, with commentary, in these diverse fields, see Curt Meine and Richard L. Knight, *The Essential Aldo Leopold: Quotations and Commentaries* (Madison, Wisc.: University of Wisconsin Press, 1999).
4. For biographical treatments of Leopold, see Susan L. Flader, *Thinking Like a Mountain: Aldo Leopold and the Evolution of an Ecological Attitude Toward Deer, Mountains, and Forests* (Columbia: University of Missouri Press, 1974; reprinted by the University of Wisconsin Press, 1994); Curt Meine, *Aldo Leopold: His Life and Work* (Madison, Wisc.: University of Wisconsin Press, 1988); Marybeth Lorbiecki, *Aldo Leopold: A Fierce Green Fire* (Helena and Billings, Mont.: Falcon Publishing Co., 1996).
5. Aldo Leopold, *Game Management* (New York, Charles Scribner's Sons, 1933; reprinted by the University of Wisconsin Press, 1986).
6. See Dennis Ribbens, "The Making of *A Sand County Almanac*," pp. 91-109 in J. Baird Callicott, ed., *Companion to* A Sand County Almanac: *Interpretive & Critical Essays* (Madison, Wisc.: University of Wisconsin Press, 1987); Curt Meine, "Moving Mountains: Aldo Leopold & *A Sand County Almanac,*" *Wildlife Society Bulletin* 26:4 (1998), 697-706.
7. Aldo Leopold, "The Thick-billed Parrot in Chihuahua," *The Condor* 39:1 (January-February 1937), 9-10; Leopold, "Marshland Elegy," *American Forests* 43:10 (October 1937), 472-474; Leopold, "Song of the Gavilan," *Journal of Wildlife Management* 4:3 (July 1940), 329-332; Leopold, "Escudilla," *American Forests* 46:12 (December 1940), 539-540. The *Wisconsin Agriculturist and Farmer* essays can be found in J. Baird Callicott and Eric T. Freyfogle, eds., *For the*

Health of the Land: Previously Unpublished Essays and Other Writings (Washington, D.C. and Covelo, Calif.: Island Press, 1999).

8. Aldo Leopold, "A Biotic View of Land.," *Journal of Forestry* 37:9 (September 1939), 727-730; pp. 266-273 in Susan L. Flader and J. Baird Callicott, eds. *The River of the Mother of God and Other Essays by Aldo Leopold* (Madison, Wisc.: University of Wisconsin Press, 1991).
9. Arthur Hawkins, interview with author, 4 December 1999.
10. Frances Hamerstrom, quoted in Meine, *Aldo Leopold: His Life and Work*, 378. The most extensive first-person account of Aldo Leopold's activities and interests during his later Wisconsin years is Robert E. McCabe, *Aldo Leopold: The Professor* (Madison, Wisc.: Rusty Rock Press, 1987).
11. H. Albert Hochbaum, quoted in Meine, *Aldo Leopold: His Life and Work*, 456-457.
12. H. Albert Hochbaum, quoted in Meine, *Aldo Leopold: His Life and Work*, 511.
13. Aldo Leopold, *A Sand County Almanac and Sketches Here and There* (New York: Oxford University Press, 1949), 129-133.
14. Aldo Leopold, "Adventures of a Conservation Commissioner," pp. 149-154 in Flader and Callicott.
15. Aldo Leopold, *Round River: From the Journals of Aldo Leopold* (New York: Oxford University Press, 1953), 165.
16. Leopold, "On a Monument to the Passenger Pigeon," pp. 3-5 in *Silent Wings* (Madison, Wisc.: Wisconsin Society for Ornithology, 11 May 1947).
17. August Derleth, "Of Aldo Leopold," *Capital Times* (Wisc.), 5 November 1949.
18. Lewis Gannett, "Books and Things," *New York Herald Tribune*, 27 October 1949.
19. Leopold, *A Sand County Almanac*, 221.
20. Curt Meine, "The Oldest Task in Human History," pp. 7-35 in Richard L. Knight and Sarah F. Bates, eds., *A New Century for Natural Resources Management* (Washington D.C. and Covelo Calif.: Island Press, 1995). Leopold's reference to the Alhambra may be found in *A Sand County Almanac*, 225.
21. Curt Meine, "Conservation Biology and Sustainable Societies: A Historical Perspective," pp. 35-61 in Max Oelschlaeger, ed., *After Earth Day: Continuing the Conservation Effort* (Denton, Texas: University of North Texas Press, 1992).
22. See Richard L. Knight and Peter B. Landres, *Stewardship Across Boundaries* (Washington D.C. and Covelo Calif.: Island Press, 1998); Eric T. Freyfogle, *Bounded People, Boundless Lands: Envisioning a New Land Ethic* (Washington D.C. and Covelo Calif.: Island Press, 1998).
23. Leopold, *A Sand County Almanac*, 210.
24. See Daniel Kemmis, *Community and the Politics of Place* (Norman: University of Oklahoma Press, 1990); Wes Jackson, *Becoming Native to This Place* (Lexington: University of Kentucky Press, 1994); Ted Bernard and Jora Young, *The Ecology of Hope: Communities Collaborate for Sustainability* (Gabriola Island, B.C. and East Haven, Conn.: New Society Publishers, 1997); William Vitek and Wes Jackson, eds., *Rooted in the Land: Essays on Community and Place* (New Haven and London: Yale University Press, 1996).
25. Roberts Mann, "Aldo Leopold: Priest and Prophet," *American Forests* 74, 2 (February 1954), 23, 42-43.
26. Ernest Swift, "Aldo Leopold: Wisconsin's Conservation Prophet," *Wisconsin Tales and Trails* 2,3 (Fall 1961), 2-5.
27. Roderick Nash, *Wilderness and the American Mind*, 3rd ed. (New Haven and London: Yale University Press, 1982; original edition 1967), 182-199.
28. Wallace Stegner, "Living on Our Principal," *Wilderness* 48, 168 (Spring 1985), 5-21. Reprinted as "The Legacy of Aldo Leopold," pp. 233-245 in Callicott, *Companion to* A Sand County Almanac.
29. "Making Forestlands Serve America Better Through Good Management," *Saturday Evening Post*, 18 February 1956.
30. Leopold, *A Sand County Almanac*, 200.
31. In the extensive literature of deep ecology, see,

for example: Bill Devall and George Sessions, *Deep Ecology: Living as if Nature Mattered* (Salt Lake City: Peregrine Smith Books, 1985); Dave Foreman, *Confessions of an Eco-warrior* (New York: Harmony Books, 1991); and Max Oelschlaeger, *The Idea of Wilderness: From Prehistory to the Age of Ecology* (New Haven and London: Yale University Press, 1991). See also Susan Zakin, *Coyotes and Town Dogs: Earth First! and the Environmental Movement* (New York: Viking Press, 1993).

32. Letters to the editor in the *Journal of Forestry* 88,2 (February 1990), 4; and *Journal of Forestry* 89,9 (September 1991), 5.

33. J. Baird Callicott, "The Conceptual Foundations of the Land Ethic, " pp. 75-99 in *In Defense of the Land Ethic: Essays in Environmental Philosophy* (Albany, N.Y.: State University of New York Press, 1989).

34. Quoted in Callicott, *In Defense of the Land Ethic*, 75-76, 279 n. 4.

35. See, for example, Robert Paehlke, *Environmentalism and the Future of Progressive Politics* (New Haven and London: Yale University Press, 1989); C. Brant Short, *Ronald Reagan and the Public Lands: America's Conservation Debate, 1979-1984* (College Station: Texas A&M Press, 1989); Bryan G. Norton, *Toward Unity Among Environmentalists* (New York: Oxford University Press, 1991); and H. Lewis Ulman, "'Thinking Like a Mountain': Persona, Ethos, and Judgment in American Nature Writing," pp. 46-81 in Carl G. Herndl and Stuart C. Brown, eds., *Green Culture: Environmental Rhetoric in Contemporary America* (Madison, Wisc.: University of Wisconsin Press, 1996).

36. Norris Yates, "The Inadequate Politics of Aldo Leopold," pp. 219-221 in *Proceedings of the Fifth Midwest Prairie Conference* (Ames, Iowa: Iowa State University, 1978).

37. At the time, I was a busy graduate student, and had no time to take on the article. As I remember, my response at the time was: "I'll tell you what. I'll write the article, and if you can get *The Progressive* to publish it simultaneously, I'll do it." Nothing came of the suggestion.

38. Susan Flader, "Aldo Leopold and Environmental Citizenship, " *Transactions of the Wisconsin Academy of Sciences, Arts and Letters* v. 87 (1999), 23-35.

39. Flader and Callicott, 215.

40. Meine, *Aldo Leopold: His Life and Work*, 525.

41. Zeide, "Another Look as Leopold's 'Land Ethic.'"

42. "Can You Eat Meat and Consider Yourself an Environmentalist?" *Sierra* 76, 6 (November/December 1991), 122.

43. J. Baird Callicott, "The Conceptual Foundations of the Land Ethic"; Michael Nelson, "Holists and Fascists and Paper Tigers. . . Oh My!," *Ethics and the Environment* 1(2):103-117.

44. Francis Lepine, "Shut Down Leopold," *Iowa State Daily*, 26 February 1993.

45. Alfred G. Etter, "A Day with Aldo Leopold," *The Land* 7,3 (Fall 1948); reprinted, pp. 384-389 in Nancy P. Pittman, ed., *From The Land* (Washington D.C. and Covelo, Calif.: Island Press, 1988).

46. Paul Errington, "In Appreciation of Aldo Leopold," *Journal of Wildlife Management* 12,4 (October 1948), 341-350.

47. Patrick Nunnally, "A Mind at Work: Aldo Leopold's *A Sand County Almanac*," *North Dakota Quarterly* 56, 3 (Summer 1988), 79-86.

Curt Meine is a conservation biologist and writer with the International Crane Foundation in Baraboo, Wisconsin, and director of conservation programs at the Wisconsin Academy of Sciences, Arts and Letters. He is author of the biography Aldo Leopold: His Life and Work *(University of Wisconsin Press, 1988) and co-editor with Richard L. Knight of* The Essential Aldo Leopold: Quotations and Commentaries *(University of Wisconsin Press, 1999). Address: International Crane Foundation, P.O. Box 447, Baraboo, WI 53913-0447.*
Email: curt@savingcranes.org

James O. Evrard

Presettlement Wildlife in Northwest Wisconsin Pine Barrens

Abstract *Archeological and historical records were used to document wildlife found in Wisconsin's Northwest Pine Barrens during the two hundred-year period from European discovery (1650) to European settlement (1850). The Northwest Pine Barrens, a relatively narrow strip of xeric sandy soils, is a fire-dominated ecotonal community between western prairies and eastern forests. Archeological records of wildlife exist along the St. Croix River and its major tributary, the Namekagon River, and at the site of two fur trading posts on the Yellow River. Historical wildlife records exist in the journals of French explorers, French and English fur traders, and American traders, missionaries, and government officials. The open pine barrens supported a wildlife community not unlike that of today with the exception of large ungulates including the buffalo, moose, elk, some furbearers like the marten, and a few birds like the passenger pigeon.*

Knowledge of the species composition, population sizes, and range distribution of Wisconsin's wildlife prior to European settlement is important. Environmental conditions that existed at the time of exploration and settlement are generally accepted as desired future states by the emerging discipline of restoration biology. Agreement on common ground such as presettlement vegetation or wildlife is needed by the many varied interest groups involved in developing increasingly important ecosystem management plans (Kay 1994, Neumann 1995). Finally, accounts of early wildlife misinterpreted either in error or by a conscious effort to revise history need to be identified and corrected.

The objectives of this article are to document presence and distribution of some wildlife species that existed in the Wisconsin's Northwest Pine Barrens during the two hundred-year period from European discovery and exploration (1650) to European settlement (1850).

The Barrens

A pine barrens is a transitional ecosystem, an ecotone between forest and prairie, born of fire and maintained by fire. Pine barrens are savannas which were described by Curtis (1959) as

> a peculiar combination of grassland and forest, in which the bulk of the land was occupied by grasses and a few shrubs, but which also had widely spaced tall trees, frequently of a given species at a given place.

The Northwest Pine Barrens is an area of sandy soils approximately 12–15 miles wide and 125 miles long from the Sterling Barrens in Polk County in the southwest to the Moquah Barrens in Bayfield County to the northeast (Figure 1).

The northwest pine barrens have been described in detail by Curtis (1959), Vogl (1970), Mossman et al. (1991), Niemuth (1995), and Radeloff et al. 1999. Murphy (1931) described the "barrens" as "where coniferous forests and open expanses of sweet fern and grassy barrens dwarf into insignificance the few evidences of man's present occupancy and use of the land." He further stated, "The grassy and sweet fern barrens . . . are desolate open tracts where only a charred stump, a cluster of jack pines, or a scrub oak bush breaks the monotonous sweep of the rolling, thinly clad ground surface." Originally there were about 2.3 million acres of pine barrens in Wisconsin, but today only a few percent of the ecosystem's early seral stages remains (Curtis 1959, Shively 1994), a victim of wildfire control, forest succession, and tree plantations.

Sources of Records

In order to discuss presettlement wildlife and habitat we must examine available wildlife records. One source is the oral history of Native Americans or Indians in the region. Another source is prehistoric evidence gathered by archeologists. A third source is the historical record left in the form of letters, journals, and books written by early European discoverers and explorers.

Oral History

Oral history of present Native Americans, despite romantic appeal, is subject to doubt. Indians passed their largely spiritual history from generation to generation through story telling. This tradition was severely damaged by the federal government in misguided attempts to force these people into the dominant white culture. Indian children were taken from their families and placed into boarding schools where they were punished for participating in any part of their native culture including using their native language and story telling (Edgar Oerichbauer, Burnett County Historical Society, personal communication 1993). The oral chain of history was damaged and perhaps broken in many cases. The most reliable information we have about presettlement indigenous cultures and their relationships to wildlife is from materials written by Europeans, despite the possibility of non-Indian biases.

Archeological Records

Archeological records are not abundant in this region of Wisconsin. Both prehistoric man and early historic man traveled along and lived near water. It is in this shoreline habitat that limited archeological material is found.

After the St. Croix National Scenic Riverway (SCNSR) was created, the U.S. National Park Service initiated archeological investigations of the property (Perry 1986). A series of sites from the lower St. Croix River to the upper or its major tribu-

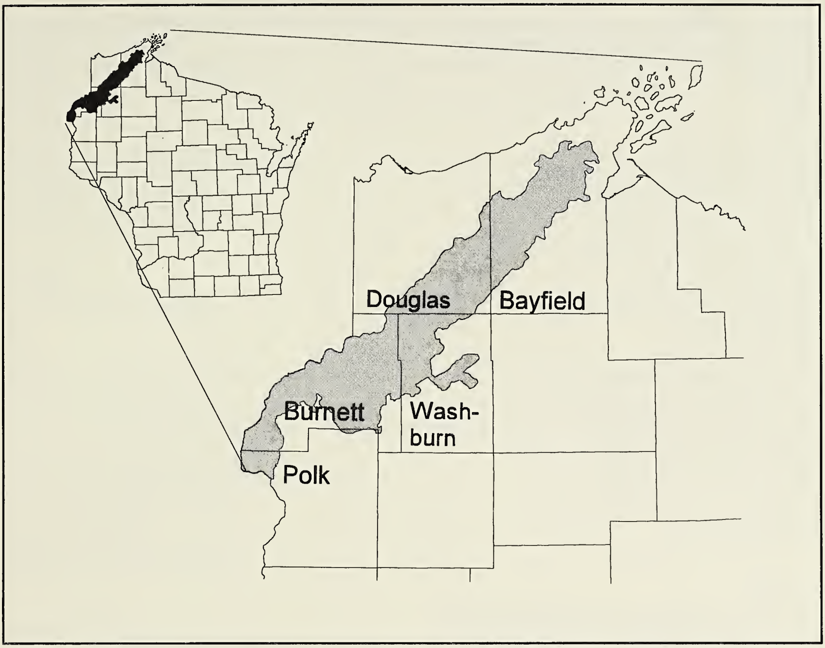


Figure 1. Northwest Wisconsin Pine Barrens (from Radeloff et al. 1999).

tary, the Namekagon River, were excavated from 1976 to 1982. Most of the upper SCNSR sites appeared to have been inhabited by humans for varying lengths of time during the Woodland Period (200 BC–1650 AD). Mammalian bones were the predominant (95%) artifacts found. This does not necessarily imply that mammals made up a large part of the aboriginal diet since fish and bird bones are more fragile and less apt to survive the ravages of time than mammalian bones.

The prehistoric fauna suggested by the specimens recovered from the sites does not differ noticeably from the modern fauna of the area with the exception of several specimens of elk or wapiti (Table 1). White-tailed deer was the dominant species. Other identifiable mammals included the dog or wild canids, beaver, muskrat, raccoon, striped skunk, snowshoe hare/white-tailed jackrabbit, eastern cottontail, woodchuck, porcupine, and pocket gopher. Pocket gopher remains were thought to be natural intrusions in the sites where encountered, not cultural artifacts. Although bird bones were found, none were identifiable. Reptile remains included the Blanding's turtle, snapping turtle, box/water turtle, and map/false map turtle. Fish identified at upper riverway sites included the northern pike, walleye, white bass, and catfish. Along the lower river, mussels are found at the sites along with greater number of fish remains.

Table 1. Wildlife records obtained from archeological and historical sources in Wisconsin's Northwest Pine Barrens.

Species	*Source*[a]
Birds	
Swans (*Cygnus* spp.)	6
Canada Goose *(Branta canadensis)*	4-5
Mallard *(Anas platyrhynchos)*	4
Northern pintail *(Anas acuta)*	4
Blue-winged teal *(Anas discors)*	4
Redhead duck *(Aythya americana)*	4
Merganser (*Mergus* spp.)	7
Wild turkey *(Meleagris gallopavo)*	4-7-10
Crane (*Grus* spp.)	5
Plover *(Charadriidae)*	9
Passenger pigeon *(Ectopistes migratorius)*	9
Belted kingfisher *(Ceryle alcyon)*	9
Red-headed woodpecker *(Melanerpes erythrocephalus)*	9
Yellow-shafted flicker *(Colaptes auratus)*	9
Eastern kingbird *(Tyrannus tyrannus)*	9
Gray catbird *(Dumetella carolinensis)*	9
American robin *(Turdus migratorius)*	9
Blackbird *(Icteridae)*	9
Mammals	
Snowshoe hare/white-tailed jackrabbit *(Leporidae)*	1
Eastern Cottontail rabbit *(Sylvilagus floridanus)*	1
Woodchuck *(Marmota monax)*	1
Thirteen-lined ground squirrel *(Citellus tridecemlineatus)*	9
Pocket gopher *(Geomys busarius)*	1
Beaver *(Castor canadensis)*	1-4-5-6
Muskrat *(Ondatra zibethicus)*	1-4-5
Porcupine *(Erethizon dorsatum)*	1-8
Wild canids *(Canidae)*	1
Timber wolf *(Canis lupus)*	5
Black Bear *(Ursus americanus)*	2-4-5-6-8
Raccoon *(Procyon lotor)*	1-4
Marten *(Martes americana)*	4-5
Fisher *(Martes pennanti)*	4-5
Weasels (*Mustela* spp.)	5
Mink *(Mustela vison)*	4-5
Badger *(Taxidea taxus)*	4
Striped skunk *(Mephitis mephitis)*	1
River otter *(Lutra canadensis)*	4-5-6
Mountain lion *(Felis concolor)*	2-4
Lynx/bobcat (*Lynx* spp.)	4-5
Elk *(Cervus canadensis)*	1-2-4-5-11
White-tailed deer *(Odocoileus virginianus)*	1-2-5-6-8
Moose *(Alces alces)*	2-5-8-9-12
Caribou *(Rangifer caribou)*	2
Buffalo *(Bison bison)*	2-3

Table 1, continued.

Species	*Source*[a]
Turtles	
Snapping turtle *(Chelydra serpentina)*	1
Blanding's turtle *(Emydoidea blandingii)*	1
Painted turtle *(Chrysemys picta)*	4
Map/false map turtle (*Graptemys* sp.)	1
Box/water turtle *(Emydidae)*	1
Snakes	
Fox snake *(Elaphe vulpina)*	9
Fish	
Sturgeon *(Acipenser fulvescens)*	5-6
Whitefish *(Coregoninae)*	5
Northern pike/muskellunge (*Esox* sp.)	1-4-5-6
Buffalo (*Ictiobus* sp.)	4-6
Redhorse *(Moxostoma erythrurum)*	4-6
White sucker *(Catostomus commersoni)*	4-6
Other suckers *(Catostomidae)*	4-5
Catfish *(Ictalurus)*	1-4-5
White bass *(Morone chrysops)*	1
Walleye *(Stizostedion vitreum)*	1-4-5-6
Invertebrates	
Mussels *(Unionidae)*	1

[a]1 – Perry 1986; 2 – Adams 1961; 3 – Schorger 1937; 4 – Ewen 1983; 5 – Thwaites 1911; 6 – Nelson 1947; 7 – Birk and White 1979; 8 – Ely 1835; 9 – Mossman 1994; 10 – Schorger 1942a; 11 – Schorger 1954; and 12 – Schorger 1956.

Mammal remains found at the sites are from forest-dwelling species with the exception of elk and possibly white-tailed jackrabbit and pocket gopher, which are more typically creatures of grasslands and savannas.

Another significant source of information about early wildlife resources in the area was an archeological excavation of the historic NW and XY Company fur trading forts on the Yellow River, just downstream of Little Yellow Lake, Burnett County. These adjacent posts, rediscovered in 1969 and named Forts Folle Avoine, were occupied during the winters of 1802–03 and 1803–04 (Oerichbauer and Mueller 1988).

Refuse pits at the Forts Folle Avoine yielded the remains of 13 mammal, 6 bird, 1 turtle and 7 fish species (Ewen 1983).

White-tailed deer again dominated the number of specimens recovered followed by the beaver, black bear, otter, raccoon, muskrat, fisher, badger, lynx/bobcat, marten, and mink (Table 1). In addition, there were possible elk or wapiti and mountain lion remains found at the site. Birds identified included the Canada goose and four duck species: the mallard, pintail, blue-winged teal, and redhead. In addition, a wild turkey bone was tentatively identified. The painted turtle was the only reptile found. Fish species included the northern pike/muskellunge, walleye, buffalo, white sucker, redhorse sucker, other suckers, and catfish. Wild rice (*Zizania aquatica)* and corn *(Zea mays)* were also found at the site.

Historical Records

Historical records begin in the 1620s when the Frenchman Etienne Brule explored the south shore of Lake Superior, possibly reaching Chequamegon Bay (Holzhueter 1986). Brule was followed by Radisson, who explored and traded furs with the Indians of northwest Wisconsin during 1658–62 (Adams 1961). The Frenchman, in their wanderings from Madeline Island in Chequamegon Bay of Lake Superior to Lac Court Orielles to the Mississippi River, reported killing *stagg* [elk], *boeuf* [buffalo], *oriniack* and *elan* [moose], *fallow does and bucks* [white-tailed deer], *carribouck* [caribou], *bear* [black bear], and *mountain lions* (Table 1).

Radisson mentioned that "Buffs [buffalo] . . . come to the upper lake [Lake Superior] but by chance." Schorger (1937), in an examination of Radisson's journal, concluded that Radisson probably first encountered buffalo near the Brule-St. Croix waterway [in the pine barrens], ranging east of the St. Croix River. Schorger lists Burnett and Polk counties in the southern part of the northwest pine barrens as being within the range of the buffalo.

Radisson also mentioned that the *Sault* [Ojibwa or Chippewa] Indians were at war with the *Nation* [Sioux} Indians at that time. In 1680, the French *coureur de bois,* Daniel Greysolon, *Sieur Du Llut* [Duluth], traveled up the Bois Brule River from Lake Superior and down the St. Croix River to the Mississippi River (Turner 1970). Duluth established Fort St. Croix at the portage between the Brule River and the St. Croix River. The French named a river that entered the St. Croix River just south of the outlet of St. Croix Lake, *river au boeuf* [ox or buffalo River]. The French fur traders traveled the waterways, trading with the Chippewa Indians centered in La Pointe on Madeline Island in Chequamegon Bay and the Sioux Indians centered in the region of the Upper Mississippi River. The two tribes had been at war until Duluth negotiated peace between them to facilitate trading.

Indian life had an annual cycle. Turner (1970) stated:

> The Indians, returning from the [winter] hunting grounds to their [permanent] villages in the spring, set the squaws to making maple sugar, planting corn, watermelons, potatoes, squashes, etc., and a little hunting was carried on. The summer was given over to enjoyment, and in the early period to wars. In the autumn they collected their wild rice, or their corn, and again were ready to start for the hunting grounds, sometimes 300 miles distant.
>
> The Chippeways had an institution called by them by a term signifying "to enter one another's lodge." whereby a truce was made between them and the Sioux at the winter hunting season.

In 1763, the English gained control of the fur trade in northwest Wisconsin as a result of their victory over the French in the French and Indian War (Turner 1970). With the French gone, warfare between the Chippewa and Sioux resumed.

According to Hickerson (1988), a "contested" or "debatable" zone up to 200 miles wide from northwest Wisconsin to northwest Minnesota (Figure 2) developed between the two tribes by 1780 and continued until 1850. No permanent villages were found in this buffer zone located in the ecotone between the forest to the north and the prairie to the south. Both Chippewa and Sioux ventured into the zone only to make war and

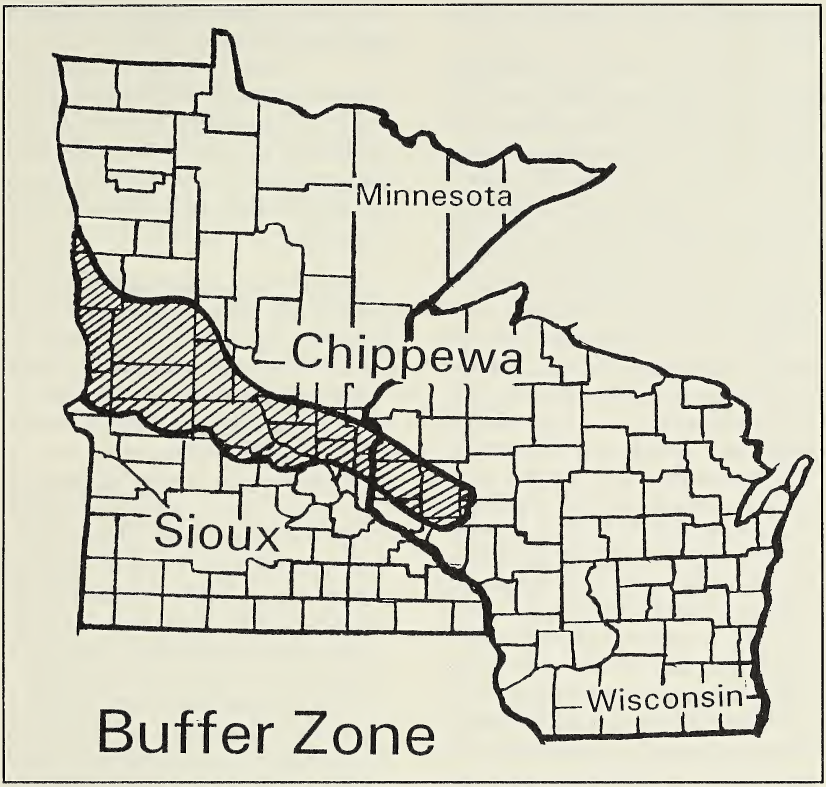


Figure 2. Buffer zone of Hickerson (1988).

hunt at the risk of their lives. The effect of this buffer zone on wildlife was dramatic. Hickerson (1988) stated:

> Warfare between members of the two tribes had the effect of preventing hunters from occupying the best game region intensively enough to deplete the [game] supply. . . . In the one instance in which a lengthy truce was maintained between certain Chippewa and Sioux, the buffer, in effect a protective zone for the deer, was destroyed, and famine ensued.

Hickerson's conclusions were based upon reports by Carver in 1767, Perrault in 1785–86, Pike in 1805–06, Johnson in 1809, Cass and Doty in 1820, and Schoolcraft in 1824 and 1831. Irving (1835) reported a similar intertribal buffer zone containing an abundance of wildlife in present-day Oklahoma, and Jackson (1993) reported another intertribal battle zone with abundant wildlife in the Bear Valley of Idaho. Kentucky, probably the Kentucky Barrens (Schorger 1943), was also an early game-rich battleground of the tribes east of the Mississippi (Jackson 1993).

The existence of several journals maintained by fur traders stationed at the Forts Folle Avoine and the Connor Post, a contemporary fur trading site on the Snake River, a tributary of the St. Croix River in Minnesota 28 miles west of Yellow Lake, provides a rare opportunity to compare historic records with archeological evidence. All trade was with the Chippewa Indians for both furs and food (Ewen 1983).

While the traders did some of their own hunting, their subsistence depended upon the Indian hunters. Journal entries from both forts (Thwaites 1911, Gates 1965) indicated that hunters took their game within 20–30 miles of the trading posts.

The best records were kept by Michael Curot at Forts Folle Avoine from September 16, 1803, to May 9, 1804 (Thwaites 1911). Curot, a clerk for the XY Company, recorded the pelts and meat he traded for to feed himself and his co-workers. Furs and hides were from approximately 247 beaver, 88 muskrats, 68 deer, 42 lynxes (includes bobcats), 23 otter, 15 bear, 13 fisher, 6 weasels, 4 moose, 3 marten, 2 mink, and 1 possible elk or "red deer" (Table 1). The beaver pelts were shipped to Grand Portage, Minnesota in 3 packs weighing approximately 90 pounds each. He also shipped 6 packs of other fur. The adjacent NW post shipped 21 packs of pelts including 6 beaver packs. Curot also recorded the presence of wolves in the area.

Curot traded for the meat of 41 deer, 4 elk or "machichinse," 3 bear, 22 ducks, 9 geese, and 1 crane. He also acquired fawn skins filled with wild rice, cakes of fat, and maple (*Acer* spp.) sugar. In addition, the trader and his hunters netted and speared nearly 700 fish including sturgeon, pike, walleyes, suckers, catfish, and whitefish during the nearly eight month period.

The lack of grouse traded for food was explained by Schorger (1942b):

> Game-birds, though numerous, were seldom molested since the [relatively-expensive lead] ball [for a black-powder muzzle- loading rifle] required to secure a sharp-tailed grouse *[Tympanuchas phasianellus]* could fell a deer as readily.

George Nelson, a fur trader for the XY Company, who spent the previous winter of 1802–03 at the same post wrote of his experience some years later (Nelson 1947). His sketchy records describe the area surrounding the fort in somewhat more detail than Curot. He stated:

> The Indian name is "Yellow water lake" [Yellow Lake] from the yellow sand in the bottom. . . . At the S.E. side it is flat & miry; & an immense quantity of rice grows there; and in their Season, ducks of various Sorts [20 species], Geese & Swans in multitudes. There is also plenty of fish, Carp of several sorts, some of monstrous size, pickeral, pike &c.
>
> In the morning Early I would steal out after taking a careful survey of the coast [for Sioux Indians, mortal enemies of the Chippewa and possibly white men trading and living with the Chippewa], go to the river & firing one or two shots killing 3 or 4 ducks.
>
> Deer in great numbers & bears of every colour from deep black to a light brown, nearly yellow . . . Beaver & raccoons & porcupine. . . . Beaver and otter . . . no troute nor catfish (Barbotte), Carp [probably suckers] of several varieties & good, one sort particularly, very large, almost enormous, & very fat. Pickeral & Pike a variety of Pike, some of which are very large and excellent. Sturgeon . . . eels . . . turtle, some of 18 ins. diameter.

Both Nelson and Curot worried about the presence of Sioux Indians, enemies of the

Chippewa, since the location of their trading posts were just north of the buffer zone described by Hickerson (1988).

The Snake River, Minnesota, post was occupied during the winter of 1804–05 (Gates 1965). John Sayer was the clerk stationed at that post and was assisted by trader Thomas Connor. Sayer kept a detailed journal (Birk and White 1979), much like that of Curot.

The wildlife pelts and meat obtained in trade with the Chippewa Indians were similar to that of Curot. Exceptions include "shelldrakes" or mergansers and a "Outarde" or wild turkey (Evrard 1993). The Minnesota fur traders apparently included more deer and ducks and fewer fish in their diets compared to the more diverse diet of the Wisconsin traders.

In 1816, the Americans took control of the fur trade from the English as a result of the War of 1812. In 1835, the Protestant missionary Edmund Ely recorded the hunting results of 5 Chippewa men from the Yellow Lake area of present-day Burnett County. From November 15 until January 15, they killed 13 moose, 9 bears, and 2 deer (Ely 1835). In addition, the Indian hunters also harvested porcupines, rabbits, grouse, and "furred game."

Henry Schoolcraft made several trips through northwest Wisconsin during 1831–34 and reported extensively on the vegetation of the area in addition to the wildlife (Schoolcraft 1834 and 1851, Mossman 1994). He stated:

> The country [the lower Namekagon River] as we decend assumes more the appearance of upland prairie, from the repeated burnings of the forest. The effect is, nearly all the small trees have been consumed, and grass has taken their place. One result of this is, the deer are drawn up from the more open lands of the Mississippi, to follow the advance of the prairie and open lands towards Lake Superior.
>
> The moose is also an inhabitant of the Namekagun. The Chippewas, at a hunting camp we passed yesterday, said they had been on the tracks of a moose, but lost them [the tracks] in high brush. Ducks and pigeons [the now-extinct Passenger pigeon] appear common.
>
> Among smaller birds are the blackbird [probably the red-winged blackbird *(Aegelaius phoeniceus)* or Brewer's blackbird *(Euphagus cyanocephalus)*], robin *(Turdus migratorius)*, catbird *(Dumetella carolinensis)*, red-headed woodpecker *(Melanerpes erythrocephalus)*, kingfisher *(Ceryle alcyon)*, kingbird *(Tyrannus t.)*, plover [probably killdeer *(Charadrius vociferos)* or upland sandpiper *(Bartramia longicauda)*, but possibly also spotted sandpiper *(Actitus macularia)* or migrant shorebirds] and yellowhammer [possibly the yellow-shafted flicker *(Colaptes auratus)*].
>
> The copper head snake [probably fox snake *(Elaphe vulpina)*] is found at the Yellow River [in Burnett and/or Washburn counties]; also the thirteen striped squirrel *(Citellus tricemlineatus)*. . . . Its [Yellow River] banks afford much of the open ground [barrens] which are favorable the thirteen-striped or prairie squirrel.

Schoolcraft also discussed vegetation in the Northwest Pine Barrens. He remarked on the abundance of the *whortleberry* [blueberry or *Vaccinium* spp.] along the Namekagon River.

> Both banks of the river are literally covered with the ripe whortleberry — it is large and delicious. The Indians feast on it. Thousands and thousands of bushels of this fruit could be gathered with very little labor.

Schoolcraft mentioned a "plain" that existed in 1832 near present-day Gordon. He also discussed the impact of fire on the landscape to the east of the pine barrens region. On the Sawyer/Washburn County line just south of the present city of Hayward, he stated:

> Just after passing the middle pause [on the portage from the Namekagon River to Lac Court Orielles], the path mounts and is carried along a considerable ridge, from which there is a good view of the country. It is open as far as the eye can reach. Sometimes there is a fine range of large pines: in by far the largest space ancient fires appear to have spread, destroying the forest and giving rise to a young growth of pines (*Pinus* spp.), aspen (*Populus* spp.), shadbush (*Amelanchier* sp.), and bramble (*Rubus* spp.).

It is obvious from the description of the vegetation of the Northwest Pine Barrens that the character of the landscape was open and the wildlife species found there reflected that openness.

Other records during this period reinforce the concept. Schorger (1942a) mentions "John Lewis Peyton . . . in 1848 . . . saw some wild turkeys while crossing a plain between La Pointe and the St. Croix River." In another work, Schorger (1954) reported that a Reverend Brunson traveled by horse and wagon from Prairie du Chien to La Pointe in 1843 before any roads existed, an indication of the openness of the country.

The open landscape and its wildlife inhabitants were a function of climate, soils, topography, and the Native American use of fire. Indians used fire extensively for warmth and to prepare and preserve food, to stimulate food production such as blueberries, to simplify wood collecting, to reduce insect pests, to clear land, to drive and attract game, and to harass and attack their enemies (McKinney 1959, Muir 1913, Murphy 1931, Schroger 1937 and 1943, Appleman 1975, Dorney and Dorney 1989. Simms 1992, Stolzenburg 1994, Ashworth 1995, MacCleery 1995, Mills 1995, Pyne 1995, Quaife 1995, Mirk 1997, Schneider 1997, and Loope and Anderton 1998).

As a result of a series of treaties ending in 1842, the Chippewa and Sioux Indians made peace with each other, ceded their lands to the U.S. Government, and were confined to reservations in northern Wisconsin and Minnesota. This opened the area to European settlement. Scandinavian settlers first arrived in Burnett County in the 1850s and became the first permanent white residents in the pine barrens. Cessation of Indian burning and uncontrolled subsistence hunting, farming, and logging activities of the settlers were largely responsible for changes in the wildlife community inhabiting northwest Wisconsin in the late nineteenth century.

Buffalo disappeared from the region by 1830 (Schorger 1937) before the arrival of European settlers, elk by 1860 (Schorger 1954), and the moose by 1890 (Schorger 1956). Deer remained in good numbers until 1890 (Schorger 1953). Birds, especially waterfowl and grouse prospered in the early part of the twentieth century (Schorger 1943 and 1945) then declined, setting the stage for the rise of the modern-day conservation movement.

Conclusions

The northwest Wisconsin pine barrens during the 200 years from discovery (1650) to European settlement (1850) was a mosiac of grassland, brushland, and forest. This fire community owed its existence to xeric, sandy soils that were warmed and dried by prevailing southwest winds, allowing frequent fires, set by lightning and Indians, to sweep its length.

The openness of the Northwest Pine Barrens vegetation was reflected by the wildlife community inhabiting the region. The high grass component of the ecosystem provided forage for large ungulates including the buffalo in the southern part of the barrens and the elk throughout the barrens. Other grass- and brushland wildlife reported in the barrens included the white-tailed deer, thirteen-lined ground squirrel, pocket gopher, red-winged and/or Brewer's blackbird, catbird, kingbird, red-headed woodpecker, yellow-shafted flicker, Blanding's turtle, and fox snake.

Some wildlife species such as the buffalo, caribou, and passenger pigeon disappeared. The passenger pigeon is extinct, and the caribou was a creature of Wisconsin's boreal forest and bogs, not the barrens. Most species including the white-tailed deer, black bear, and sandhill crane, were reduced to low numbers but have recovered spectacularly in the last 50 years. Some extirpated species returned, either with human help (fisher, Canada goose, trumpeter swan *(Cygnus buccinator),* and wild turkey) or with our relatively newly acquired tolerance of wildlife (moose and timber wolf). Several species such as the elk and marten have been successfully reintroduced elsewhere in Wisconsin but have not yet recolonized the northwest pine barrens. In addition, there are unconfirmed observations of mountain lions roaming the barrens again and the reintroduction of the whooping crane *(Grus americana)* is now being contemplated.

If the habitat base of the Northwest Pine Barrens ecosystem can be preserved in the face of increasing human development pressures, the wildlife community we know today should remain with us into the foreseeable future.

Acknowledgments

I wish to thank E. Oerichbauer of the Burnett County Historical Society for guidance to historical and archeological records and J. Schaeppi of the National Park Service for additional archeological records. I also wish to thank Keith McCaffery and two anonymous referees for critical review of the manuscript. Partial funding for this study was provided by the Federal Aid to Wildlife Restoration under Pittman-Robertson Wisconsin Project W-141-R.

Literature Cited

Adams, A. T., ed. 1961. *The explorations of Pierre Esprit Radisson. Ross and Haines, Incorporated.* Minneapolis, Minnesota. 258 pp.

Appleman, R. E. 1975. *Lewis and Clark: historic places associated with their transcontinental exploration (1804–06).* Vol. 8 of the National Survey of Historic Sites and Buildings. U.S. National Park Service, Washington, D.C. 429 pp.

Ashworth, W. 1995. *The economy of nature — rethinking the connections between ecology and economics.* Houghton Mifflin Company, Boston. 340 pp.

Birk, D. A., and B. M. White. 1979. Who wrote the "Diary of Thomas Connor"? *Minnesota History* 46(5):170–88.

Curtis, J. T. 1959. *The vegetation of Wisconsin.* University of Wisconsin Press, Madison. 657 pp.

Dorney, C. H., and J. R. Dorney. 1989. An unusual oak savanna in northeastern Wisconsin: the effect of Indian-caused fire. *American Midland Naturalist* 122:103–13.

Ely, E. F. 1835. The Journal of Edmund Franklin Ely, missionary, Yellow Lake, 1835. *In* Oerichbauer, E. 1988. *Two worlds meeting in Ouiconsin frontier — Fort Folle Avoine historical park.* Burnett County Historical Society.

Evrard, J. O. 1993. Were wild turkeys found historically in northwest Wisconsin? *Transactions of the Wisconsin Academy of Sciences, Arts and Letters* 81:59–63.

Ewen, C. R. 1983. Fur trade zooarcheology: a faunal interpretation of two wintering posts in northwestern Wisconsin. M. A. Thesis, Florida State University, Tallahassee.

Gates, C. M. 1965. *Five fur traders of the northwest.* Minnesota Historical Society Press, St. Paul. 296 pp.

Hickerson, H. 1988. *The Chippewa and their neighbors — A study in ethnohistory.* Waveland Press, Incorporated. Prospect Heights, Illinois. 151 pp.

Holzhueter, J. O. 1986. Madeline Island and the Chequamegon region. State Historical Society of Wisconsin, Madison. 59 pp.

Irving, W. 1835. *A tour of the prairies.* John Murray, London. 335 pp.

Jackson, J. C. 1993. *Shadow on the Tetons: David E. Jackson and the claiming of the American west.* Mountain Press Publishing Company, Missoula, Montana. 241 pp.

Kay, C. E. 1994. Aboriginal overkill. *Human Nature* 5:359–98.

Loope, W. L., and J. B. Anderton. 1998. Human vs. lightning ignition of presettlement surface fires in coastal pine forests of the upper great lakes. *American Midland Naturalist* 140:206–18.

MacCleery, D. 1995. Is there a landscape archeologist in the house? Pp. 7–9, 19 *in* the summer 1995 issue of *Horizons,* newsletter of the Sigurd Olson Institute, Northland College, Ashland, Wisconsin.

McKinney, T. L. 1959. *Sketches of a tour to the lakes of the character and customs of the Chippeway Indians and the incidents connected with the treaty of Fond du Lac.* Ross and Haines, Inc., Minneapolis, Minnesota (originally published in Boston in 1827). 494 pp.

Mills, S. 1995. *In service of the wild.* Beacon Press, Boston. 237 pp.

Mirk, W. 1997. An introduction to the tall grass prairie of the upper Midwest: its history, ecology, preservation and reconstruction. Prairie Enthusiasts, Boscobel, Wisconsin. 80 pp.

Mossman, M. J., E. Epstein, and R. M. Hoffman. 1991. Birds of Wisconsin pine and oak barrens. *Passenger Pigeon* 53:247–53.

Mossman, M. J. 1994. H. R. Schoolcraft and natural history on the western frontier, part 5: the 1831 expedition. *Passenger Pigeon* 56:39–72.

Muir, J. 1913. *The story of my boyhood and youth.* University of Wisconsin Press, Madison. 227 pp.

Murphy, R. W. 1931. The geography of the northwestern pine barrens of Wisconsin. *Transactions of the Wisconsin Academy of Sciences, Arts and Letters* 26:69–120.

Nelson, G. 1947. A fur trader's reminiscences. *In* Barton, R. and G. L. Nute, eds. A Winter in the St. Croix Valley, 1802–03. *Minnesota Historical Society* 28(1):1–14, 28(2):142–224, 28(3):225–40.

Neumann, T. W. 1995. The structure and dynamics of the prehistoric ecological system in the eastern woodlands: ecological reality versus cultural myths. *Journal of Middle Atlantic Archeology* 11:125–38.

Niemuth, N. D. 1995. Avian ecology in Wisconsin pine barrens. Ph.D. Dissertation, University of Wyoming, Laramie. 185 pp.

Oerichbauer, E., and M. Mueller. 1988. Two worlds meet on the Ouiconsin frontier — Fort Folle Avoine historic park. Burnett County Historical Society. 24 pp.

Perry, L. A. 1986. Archeology along the St. Croix Riverway, 1981. USDI National Park Service, Midwest Archeological Center., Lincoln, Nebraska.

Pyne, S. J. 1995. *World of fire — the culture of fire on earth.* Henry Holt and Company, New York. 379 pp.

Quaife, M. M., ed. 1995. *My life on the plains by General George A. Custer.* Promitory Press, New York. 388 pp.

Radeloff, V. C., D. J. Mladenoff, H. S. He, and M. S. Boyce. 1999. Forest landscape changes in the northwest Wisconsin pine barrens from pre-European settlement to the present. *Canadian Journal of Forest Research* 29:1649–1659.

Schneider, P. 1997. *The Adirondacks - a history of America's first wilderness.* Henry Holt and Company, New York. 368 pp.

Schoolcraft, H. R. 1834. *Narrative of an expedition through the upper Mississippi to Itasca Lake, the actual source of this river; embracing an exploratory trip through the St. Croix and Burntwood (or Broule) rivers; in 1832.* Harper and Brothers, New York. 307 pp.

Schoolcraft, H. R. 1851. *Personal memoirs of residence of thirty years with the Indian tribes on the American frontiers: with brief notices of passing events, facts, and opinions, A.D. 1812 to A.D. 1842.* Lippencott, Grambo, & Company, Philadelphia. 703 pp.

Schorger, A. W. 1937. The range of the bison in Wisconsin. *Transactions of the Wisconsin Academy of Sciences, Arts and Letters* 30:117–30.

Schorger, A. W. 1942a. The wild turkey in early Wisconsin. *Wilson Bulletin* 54:178–83.

Schorger, A. W. 1942b. Extinct and endangered mammals and birds of the upper great lakes region. *Transactions of the Wisconsin Academy of Sciences, Arts and Letters* 34:23–44.

Schorger, A. W. 1943. The prairie chicken and sharp-tailed grouse in early Wisconsin. *Transactions of the Wisconsin Academy of Sciences, Arts and Letters* 35:1–59.

Schorger, A. W. 1945. The ruffed grouse in early Wisconsin. *Transactions of the Wisconsin Academy of Sciences, Arts and Letters* 37:35–90.

Schorger, A. W. 1953. The white-tailed deer in early Wisconsin. *Transactions of the Wisconsin Academy of Sciences, Arts and Letters* 42:197–247.

Schorger, A. W. 1954. The elk in early Wisconsin. *Transactions of the Wisconsin Academy of Sciences, Arts and Letters* 43:5–23.

Schorger, A. W. 1956. The moose in early Wisconsin. *Transactions of the Wisconsin Academy of Sciences, Arts and Letters* 45:1–10.

Shively, M. M. R. 1994. Wisconsin pine-shrub-grassland (pine barrens) ecosystems: an ecosystem recovery plan. M.S. Thesis, University of Wisconsin, Madison.

Simms, S. R. 1992. Wilderness as a human landscape. Pp. 183-201 *in* Zeveloff, S. I., L. M. Vause, and W. H. McVaugh, eds. *Wilderness tapestry: an ecletric approach to preservation.* University of Nevada Press, Reno. 306 pp.

Stolzenburg, W. 1994. New views of ancient times. *Nature Conservancy* 44:10–15.

Thwaites, R. G., ed. 1911. Wisconsin's fur-trader's journal, 1803-04. *Wisconsin Historical Collections* 20:396–471.

Turner, F. J. 1970. The character and influence of the Indian trade in Wisconsin. Burt Franklin: Research and Source Works Series 467. American Classics in History and Social Science 119. New York. 75 pp.

Vogl, R. E. 1970. Fire and the northern Wisconsin pine barrens. *Proceedings of the Tall Timbers Fire Ecology Conference* 10:175–209.

---

*James O. Evrard is a retired wildlife research biologist for the Wisconsin Department of Natural Resources at Grantsburg. **Address:** 630 North Pine Street, Grantsburg, WI 54840. **Email:** evrardsc@win.bright.net*

James O. Evrard

Birds and Amphibians of Selected Pine Barrens Wetlands

Abstract *Wildlife inhabiting the wetlands of the pitted outwash section of Wisconsin's northwest pine barrens are little known. Six small and relatively infertile wetlands located in and adjacent to the Namekagon Barrens Wildlife Area were surveyed in 1996 and 1997 to determine the distribution and abundance of birds and amphibians. Three frog and two bird surveys were conducted in each wetland. Pitfall traps associated with drift fences adjacent to three of the wetlands were also used to capture amphibians. Incidental wildlife observations were recorded. Nine frog species, two salamander species, and twenty-five bird species were observed in, over, and immediately adjacent to the six wetlands. The value of the pine barrens wetlands for some wildlife species probably has been underestimated based upon the perceived infertility of the wetlands. These wetlands should continue to provide secure habitat for a wide range of wildlife due to little human development and large-block public and private forest ownership.*

The northwest Wisconsin pine barrens is an area of sandy soils approximately 12–15 miles wide and 125 miles long extending from the junction of Wolf Creek and the St. Croix River in Polk County in the southwest to Bayfield County about 12 miles south of Lake Superior in the northeast (Strong 1880) (Figure 1).

The "barrens," an ecosystem born in fire and maintained by frequent wild fires, was described by Murphy (1931) as "where coniferous forests and open expanses of sweet fern and grassy barrens dwarf into insignificance the few evidences of man's present occupancy and use of the land." He further stated, "The grassy and sweet fern barrens . . . are desolate open tracts where only a charred stump, a cluster of jack pines, or a scrub oak bush breaks the monotonous sweep of the rolling, thinly clad ground surface."

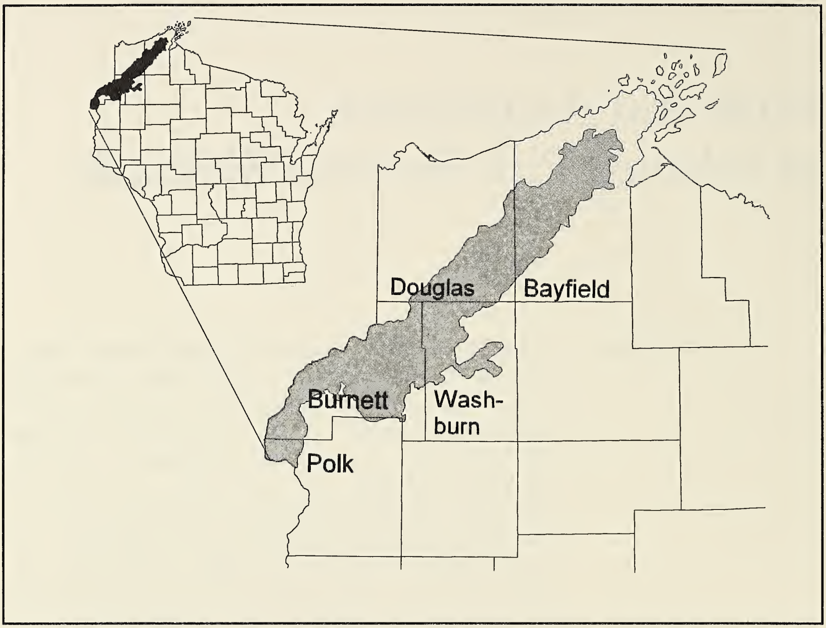


Figure 1. Wisconsin's northwest pine barrens (from Radeloff et al. 1998).

Originally, there were about 2.3 million acres of pine barrens in Wisconsin, but today only about 1% of the ecosystem's early seral stages remains (Curtis 1959), a victim of wild fire control, forest succession, and tree plantations. Much of the land is still wild, being in large-block public and private land ownership dominated by forestry activities (Riegler 1995).

Murphy (1931) divided the northwest pine barrens into three geographic sections: the northeastern hill section, the pitted sand plain section, and the southwestern marsh section. The northeastern hill section was earlier termed the Kettle Range by Sweet (1880). Mossman et al. (1991) devoted only part of one paragraph of their lengthy paper on the birds of Wisconsin's pine and oak barrens to birds observed in pine barrens wetlands. Faanes (1981) failed to discuss wetland birds in the northwest pine barrens other than those inhabiting the large sedge meadows in the vicinity of Grantsburg in the southwestern section.

Wildlife inhabiting these extensive marshes are relatively well known. A bibliography developed by Evrard (1997) lists over 25 citations dealing specifically with birds inhabiting the large wetlands in western Burnett County.

In contrast, wildlife inhabiting the lakes and wetlands in the pitted sand plain and northeastern hill or Kettle Range sections of the northwest pine barrens are little known. Jahn and Hunt (1964) discussed the limited value to waterfowl of two types of naturally occurring wetlands in this pitted sand plain subsection, the "soft-water bog lakes and sand-lined kettle lakes."

Similarly, the amphibians inhabiting these kettle wetlands are not well known. Hay (1995) stated that little was known about the abundance, health, or effects of habitat management on herptile populations in the barrens ecosystem. Vogt (1981), later updated by Casper (1996), summarized what little was known of amphibians occurring in the Wisconsin's northern pine barrens wetlands.

The objective of this study was to determine the species and relative abundances of the birds and amphibians inhabiting six selected wetlands located in and adjacent to the Namekagon Barrens Wildlife Area in the northwest Wisconsin pine barrens.

Study Area

The pitted sand plain consists of drift material originating from receding glaciers. The pits or depressions were formed by melting blocks of ice left imbedded in the sand and gravel drift. Many of the depressions are occupied by lakes and marshes, while others are dry. Some depressions are relatively shallow, and some exceed 30 m in depth (Strong 1880). Some have sloping sides, but many have characteristic abrupt banks from wetland margins to the nearly uniform plain.

The Namekagon Barrens Wildlife Area is located within the pitted sand plain near the junction of the Namekagon and St. Croix rivers in Burnett County. The Namekagon Barrens Wildlife Area is owned by Burnett County but is leased by the Wisconsin Department of Natural Resources and managed primarily for sharp-tailed grouse *(Tympanuchus phasianellus)* using prescribed burning (Vogl 1970).

Six wetlands were studied within or adjacent to the NBWA including four unnamed wetlands in Section 12 and two wetlands (Richart and Bradley lakes), in Section 24, T42N, R14W, Town of Blaine, Burnett County (Figure 2). Aquatic vegetation of each wetland was mapped and sampled in mid-summer of 1996 using the line intercept method (Greig-Smith 1964). Two lines, perpendicular to the shoreline in each wetland, beginning at the high water mark and extending 30 m into the wetland, were used to identify and quantify aquatic vegetation. Wetland A was a 4.1-ha semi-permanent marsh with 95% of its surface area covered by emergent aquatic vegetation dominated primarily by slender sedge *(Carex lasiocarpa)* and blue-joint grass *(Calamagrostis canadensis)* with several "islands" of cranberry *(Vaccinium oxycoccos)* and Sphagnum moss (*Sphagnum* sp.). Wetland B was a 7.5-ha permanent pond with 50% of its surface covered by floating and emergent vegetation. Emergent aquatics were dominated by slender sedge, blue-joint grass, and three-way sedge *(Dulichium arundinaceum).* Floating vegetation was dominated by spatterdock *(Nuphar variegatum).* Wetlands A and B were surrounded by fire-managed "brush prairie," first named by Strong (1880).

Wetland C was a semi-permanent marsh, 4.1 ha in size, and was surrounded by recently clear-cut and burned jack pine *(Pinus banksiana)* and oak *(Quercus ellipsoidalis)* vegetation. Its surface is totally covered by aquatic vegetation dominated by slender sedge and manna grass *(Glyceria canadensis).* Wetland D was a smaller (2.6-ha) shallow semi-permanent marsh with 100% of its surface area covered by emergent vegetation. This wetland was more bog-like with emergent vegetation dominated by slender sedge, cranberry, and sphagnum moss.

The northern lobe of Richart Lake (Wet-

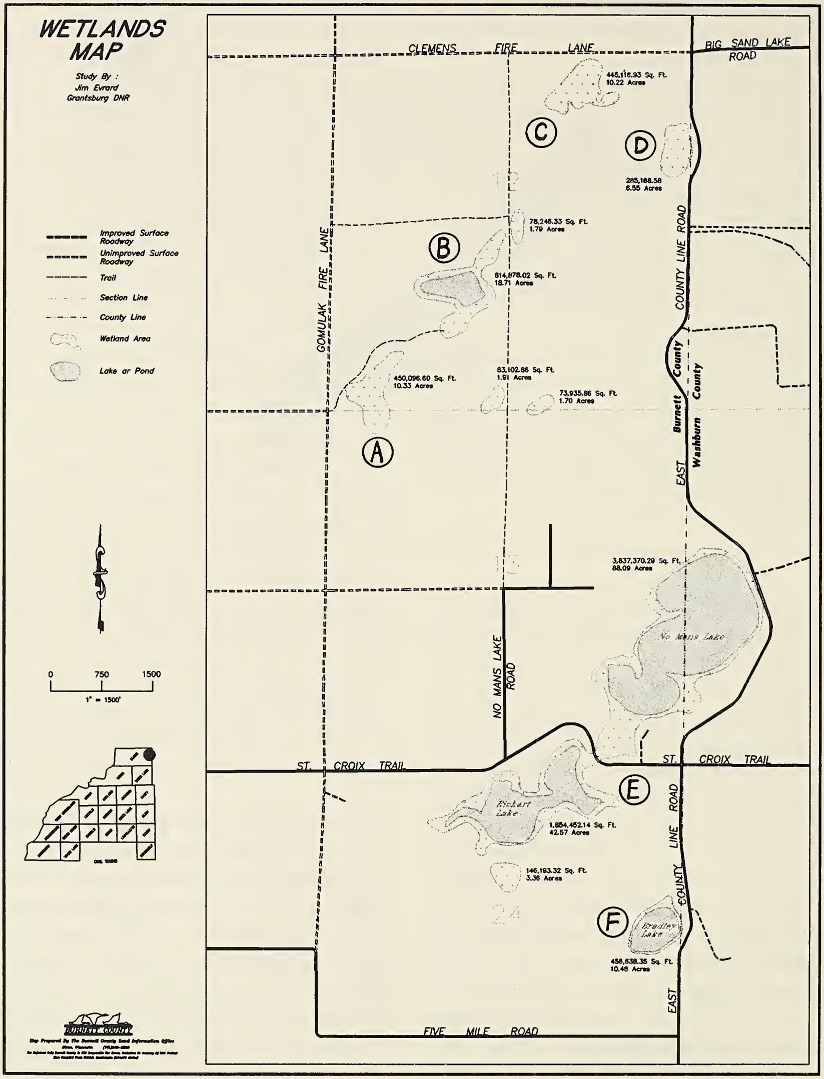


Figure 2. Study area wetlands.

land E), about 25% of the 17-ha permanent wetland, was included in this study. About 35% of the surface of the lobe was covered by floating-leaf and emergent vegetation, mostly water smartweed *(Polygonum amphibium)* and soft-stem bulrush *(Scirpus validus).* The smaller (4.2 ha) but deeper Bradley Lake (Wetland F) had concentric bands of aquatic vegetation extending out from its shores to a mean distance of 25 m. Dominant plant species included water lily *(Nymphaea odorata),* manna grass, and slender sedge. Both Rickart and Bradley Lakes were surrounded by jack pine/oak forest.

There was no difference in the water chemistry of Wetlands A, B, and D when tested in June 1997—slightly acidic with a pH of 6.0 and with a methyl orange total alkalinity of 18 ppm (Water Ecology Kit Model AL-36B, Hach Company, P.O. Box 389, Loveland, CO 80539). The waters of Wetland C and Richart Lake, however, were less acid (6.5 pH), but with the same total alkalinity (18 ppm). The water in Bradley Lake was neutral (7.0 pH) and had higher total alkalinity (36 ppm) than the other five wetlands. Total alkalinity less than 40 ppm is considered low, and aquatic vegetation, plankton, and fish populations in such water are normally sparse (Moyle 1956).

Methods

Frog and bird surveys were conducted in cooperation with the Marsh Monitoring Program of Environment Canada and the Long Point Bird Observatory (Anonymous 1996). Three frog surveys (early and late May and early June, 1996–97) were conducted after 10 p.m. Three minutes were spent at each station or wetland, recording and mapping frog species by call level and the number of individuals calling within a 180° semi-circle facing towards the wetland away from the station marker, a 2-m high steel fence post.

Amphibians also were captured in pitfall and funnel traps associated with drift fences (Vogt and Hine 1982). The drift fences were operated for 6-day periods in late April, early and late May, and early June 1996–97. Traps were opened after a major precipitation event, beginning with snow melt in late April, and checked every second day during the four periods. All captured amphibians were released after being identified.

One drift fence was installed immediately adjacent to each of Wetlands B, C, and D. Eleven pitfall traps and five funnel traps were spaced along the 15-m-long, 46-cm-high metal sides of each T-shaped drift fence. Pitfall traps were made of 19-l plastic pails buried flush with the ground surface. At least 3 cm of water was maintained in each trap to prevent desiccation and death of captured amphibians. Triangular funnel traps (60 x 30 cm) were made of welded wire mesh lined with aluminum screening (after Immler 1945). Both ends of the funnel trap were fitted with an inverted aluminum screen cone having a 5 x 8-cm elliptical opening.

The study wetlands were surveyed for birds twice each year, once in late May and again in mid-June 1996–97, beginning after 6 p.m. A playback audio tape was played on a cassette player for 5 minutes followed by 5 minutes of silent listening at each station. The playback tape consisted of 30 seconds each of calls of the Virginia rail *(Rallus limicola),* sora rail *(Porzana carolina),* least bittern *(Ixobrychus exilis),* pied-billed grebe *(Podilymbus podiceps),* and combination common moor hen *(Gallinula chloropus)/* American coot *(Fulica americana),* followed by 30 seconds of silent listening between each species. All adult birds seen and heard within a 100-m radius semi-circle centered on the station marker were recorded and mapped. The area surveyed in each wetland was 1.57 ha. Birds recorded included territorial birds and aerial foragers and birds associated with aquatic habitat that were seen flying through the sampled area. In addition, observations of birds and amphibians in the wetlands made incidental to other study activities were recorded.

Results

Amphibians

Eight frog species were recorded during the thrice-yearly auditory censuses during 1996–97 (Table 1). Incidental observations added a ninth species, the mink frog *(Rana septentrionalis).* The number of species heard per wetland ranged from five to eight, but only three species, the gray treefrog *(Hyla versicolor),* northern spring peeper *(Pseudacris c. crucifer),* and chorus frog *(P. triseriata)* were heard in all six wetlands. Cope's gray treefrog *(Hyla chrysoscelis)* was found in five of the six wetlands, not being recorded in Richart Lake.

Wetland B had the most species of the six wetlands, including the mink frog heard in mid-July 1997. Eastern American toads *(Bufo a. americanus)* also were heard incidentally in Wetland C in 1996 but were not recorded during the formal auditory surveys.

Bullfrogs *(Rana catesbeiana)* were recorded in Wetlands E and F, but only in 1997. Green frogs *(R. clamitans malanota)* were much more numerous in 1997 than in 1996. Northern leopard frogs *(R. pipiens)* were heard in only three of the six wetlands.

Only five amphibian species were captured in the pitfall traps associated with drift fences adjacent to Wetlands B, C, and D (Table 2). These species included two salamanders, the blue-spotted salamander *(Ambystoma laterale)* and the eastern tiger salamander *(A. t. tigrinum),* and three frogs, the eastern American toad, chorus frog, and northern spring peeper. The blue-spotted salamander was by far the most numerous amphibian captured in the pitfall traps. Only one tiger salamander was captured in two years.

Birds

Eighteen bird species were recorded during the twice-yearly bird censuses during 1996–97 (Table 3). Only three species, the mallard *(Anas platyrhynchos),* tree swallow *(Tachycineta bicolor),* and red-winged blackbird *(Agelaius phoeniceus)* were recorded on all six wetlands. Wetlands A and B were richer (more species observed) and more productive (more individual birds counted) than the other wetlands.

Ten bird species were recorded in Wetland A during the surveys in 1996 and 1997. The Virginia rail was recorded only in Wetland A and only in 1997, once during a formal survey and once incidentally. Miscellaneous observations added to the number of species and individuals using the wetland. There was a possible breeding pair of Canada geese *(Branta canadensis)* in the wetland, along with breeding pairs of mallards, ring-necked ducks *(Aythya collaris),* and pied-billed grebes. In addition, the northern harrier *(Circus cyaneus),* belted-kingfisher *(Ceryle alcyon),* eastern kingbird *(Tryannus tryannus),* barn swallow *(Hirundo rustica),* yellow warbler *(Dendroica petechia),* and common yellowthroat *(Geothlypis trichas)* were seen in the wetland. A brood of pied-billed grebes was recorded in July 1997.

Wetland B was similar to Wetland A in terms of number of species and individuals recorded (Table 3). A single common loon *(Gavia immer)* was recorded in the wetland in addition to breeding pairs of mallards, ring-necked ducks, pied-billed grebes, and up to four male wood ducks *(Aix sponsa).*

Table 1. Numbers of frogs recorded in audio surveys in selected northwest Wisconsin pine barrens wetlands, 1996–97.

	Wetland											
	A		*B*		*C*		*D*		*E*		*F*	
Species	*96*	*97*	*96*	*97*	*96*	*97*	*96*	*97*	*96*	*97*	*96*	*97*
Eastern American toad	1	1	1				2	2				
Chorus frog	4	2	1	1	2	2	1	3	1		3	4
Northern spring peeper	*	11	*	8	11	*	*	*	*	4	*	*
Cope's gray treefrog	4	4	9	1	2	3	3	3			2	4
Eastern gray treefrog	2	2	2	1	1	3	3	3		1	2	3
Bullfrog										4		2
Green frog				6		2		3	1	10	1	2
Northern leopard frog	2	1	1	1		1						

*Too many frogs calling to count individuals.

Table 2. Numbers of amphibians captured in pitfall and funnel traps associated with drift fences adjacent to selected northwest Wisconsin pine barrens wetlands, 1996–97.

	Wetland					
	B		*C*		*D*	
	1996[a]	*1997*[b]	*1996*	*1997*	*1996*	*1997*
Blue-spotted salamander	11	6	18	6	84	23
Tiger salamander		1				
American toad	1					4
Chorus frog	1	1	6	1	2	1
Spring peeper		1	3		3	5

[a] Four trapping periods (4/22-28, 5/6-12, 5/26-31, 6/17-24).

[b] Four trapping periods (4/18-24, 5/12-20, 5/28-6/4, 6/16-21).

Incidental observations of other species in Wetland B included a red-necked grebe *(Podiceps grisegena)* and a pair of green-winged teal *(Anas crecca)*, both considered visitors, and migrant bufflehead *(Bucephala albeola)* and lesser yellowlegs *(Tringa flavipes)*. In addition, a breeding pair of common loons was confirmed, along with breeding pairs of Canada geese, hooded mergansers *(Lophodytes cucullatus)*, blue-winged teal *(Anas discors)*, and northern harriers. A brood of ring-necked ducks was seen in 1997. A sora rail also was heard in the wetland.

Wetland C had only six bird species recorded during surveys (Table 3). Incidental observations added only one additional species, migrant lesser yellowlegs, in the two years. The 1996 surveys failed to detect breeding mallards, sora rails, and eastern kingbirds, which were seen incidental to other work.

Wetland D was similar to Wetland C, with only seven species recorded during surveys. Incidental observations added species (breeding pairs of Canada geese and mallards, common snipe *[Gallinago g.]*, killdeer *[Charadrius vociferus]*, and migrant lesser yellowlegs).

Few species or individual birds were surveyed in Wetlands E (Richart Lake) and F (Bradley Lake). The only observation of a

Table 3. Birds recorded in 1.57-ha samples of selected northwest Wisconsin pine barrens wetlands, 1996–97.

	Wetland											
	A		*B*		*C*		*D*		*E*		*F*	
Species	*96*	*97*	*96*	*97*	*96*	*97*	*96*	*97*	*96*	*97*	*96*	*97*
Common loon			1	2						1	1	
Pied-billed grebe		1		3								
Great blue heron										1		
Canada goose	1	1										*
Mallard		2	2	1		3		2	*			*
Green-winged teal				2								
Ring-necked duck		2	3						2			
Hooded merganser	*											
Virginia rail		1										
Sora rail	2	2				2	1	1				
Common snipe								*				
Belted kingfisher										1		
Eastern kingbird			1	1		1	1	2				
Tree swallow	6	1	3	3	2			1	2	2		1
Barn swallow				1								
Yellow warbler		*		*		1		1				
Common yellowthroat			1	*								1
Red-winged blackbird	4	5	4	2	3	2	4	5	1			1
Total	**13**	**15**	**15**	**16**	**5**	**9**	**6**	**12**	**5**	**5**	**1**	**3**

*Flew over wetland, not recorded in wetland.

great blue heron *(Ardea herodias)* was made on Richart Lake. Incidental observations added only increased numbers of ring-necked ducks and mallards in Richart Lake in 1996 and confirmed a pair of breeding loons using Bradley Lake in 1997.

Discussion

Northern spring peepers, chorus frogs, and treefrogs were the most frequently recorded frogs in the study area wetlands despite the green frog and eastern American toad being considered common and ubiquitous in Wisconsin (Vogt 1981, Casper 1996).

A possible reason for the relatively low frequency of green frogs recorded in this study could be the cool spring of 1996. Green and bullfrogs are among the last frog species to begin calling in the spring (Vogt 1981), with night-time temperatures influencing the initiation and intensity of calling (Anonymous 1996). Cooler weather could also be the reason bullfrogs were not recorded in 1996 but were heard calling in the warmer spring of 1997, the first record for this species in Burnett County (Casper 1996). The bullfrog has a patchy distribution in Wisconsin due to human introductions and overexploitation for bait and food (Vogt 1981, Casper 1996).

Spring peepers have been reported to have declined in Wisconsin during the past decade (Mossman and Hine 1984, 1985) but appear to be abundant in the study area wetlands. The Cope's gray treefrog is a savanna species (Jaslow and Vogt 1977, Vogt 1981) and apparently the northwest pine barrens are suitable habitat, judging by the numbers recorded in this study.

The northern leopard frog was formerly widespread and common in Wisconsin (Vogt 1981), but the population crashed in the 1970s (Hine et al. 1981) and has not recovered (Casper 1996). This decline could be the reason for the low numbers and limited distribution in the study wetlands. The relatively low volume of their calls and the brief annual calling period might also have contributed to the low frequency of calls recorded.

The boreal mink frog is at its southern range limit in Burnett County (Casper 1996), which could explain the single record in two years of surveys. Finally, no wood frogs *(Rana sylvanica)* were found in the study area wetlands, despite the species being common and widespread in Wisconsin (Casper 1996). Their apparent absence could be explained by the audio censuses being conducted too late in the spring for the very early calling species and by their preference for wooded habitat (Vogt 1981).

There were more blue-spotted salamanders captured adjacent to study area wetlands in 1996 than in 1997. This difference may be due to the cooler and moister spring of 1996, which are conditions that promote salamander movements (Anonymous 1996). The blue-spotted salamander is the most abundant salamander in Wisconsin (Casper 1996) and in the study wetlands. This species is often found in areas with very sandy soil (Vogt 1981).

Despite the tiger salamander being considered a savanna species inhabiting prairie ponds, marshes, and kettle potholes (Vogt 1981), only one individual was captured in my study, perhaps a reflection of the methods used to detect this species rather than its abundance.

All the bird species recorded incidentally and during the formal surveys were known to nest in northwest Wisconsin, with the exception of the bufflehead and lesser yellowlegs (Robbins 1991).

The common loon used the larger wetlands (B, E, F) consistently and was suspected to nest in the area, although no nests or young were observed. Loons are known to feed and nest in wetlands as small as 5 and 6 ha in the southwest marsh area of the northwest Wisconsin pine barrens (Evrard 1995) and may nest in the larger study area wetlands in the future. The presence of successfully nesting pied-billed grebes in the wetlands indicates that aquatic food resources are probably adequate for this species.

The red-necked grebe, which is endangered in Wisconsin (Anonymous 1997), was seen once in April 1996 in Wetland B and must be considered a visitor, although the species presently nests 37 air miles southwest in the large pine barrens marshes near Grantsburg (Gieck 1988, James Hoefler, Wisconsin Department of Natural Resources, personal communication, 1997)

Waterfowl use of study area wetlands was greater than anticipated given the relative infertility of the wetlands. Breeding pairs of mallard were recorded on all but Wetland F. Ring-necked duck breeding pairs were found on Wetlands A, B, and E, and a female with a brood was seen on Wetland B. Breeding Canada geese were found in Wetland A in 1996 and 1997 and were suspected of nesting. A Canada goose pair with a brood was observed on Wetland E but outside of the area studied. Pairs of green-winged and blue-winged teal, lone hooded mergansers, and molting male wood ducks were recorded in the wetlands, indicating breeding birds in the region (Jahn and Hunt 1964, March et al. 1973) but not necessarily nesting in or near the wetlands studied. Because waterfowl are not very vocal compared to other groups of birds and their presence was mostly detected by sight rather than sound, the dense emergent aquatic vegetation in some of the wetlands may have allowed some birds to go undetected.

The value of pine barrens wetlands for breeding mallards and ring-necked ducks may have been underestimated. Ring-necked ducks historically nested throughout Wisconsin but retreated to the northern third of state by the 1950s because of habitat destruction and human disturbance (Jahn and Hunt 1964). In the 1950s, the ringneck represented 4–19% of the breeding ducks in Wisconsin and by the late 1960s had declined to only 1–4% of the total breeding community (March et al. 1973).

Sora rails were found in Wetlands A, C, and D, which had 95–100% of their surface area covered by emergent aquatic vegetation. The Virginia rail was heard on two occasions in Wetland A. The surface area of Wetlands B, E, and F may have been too open to provide suitable habitat for the rails.

The northern harrier was observed hunting over the grassy and shrubby margins of Wetlands A and B, habitat of the yellow warbler and common yellowthroat. Eastern kingbirds and many tree swallows were seen flying over the surface of the wetlands, feeding on insects.

The red-winged blackbird was the most numerous species in the wetlands studied, and it is the most common summer bird in Wisconsin (Robbins 1991). Based on the area censused, there was a mean of 1.7 territorial males/ha in the six wetlands studied in 1996 and 1.6/ha in 1997. Densities ranged from a low of 0.6 males/ha in Wetlands E and F in 1996 and 1997 to a high of 3.2/ha in Wetlands A and D in 1997, a five-fold difference. The low densities in Wetlands E and F are due to a scarcity of nesting habitat (tall grasses and low shrubs) along the wetland margins.

Conclusions

The little-known wetlands in the pitted outwash plain section of Wisconsin's northwest pine barrens support a surprising variety and number of amphibians and birds. While these wetlands are not as productive as the more fertile southern wetlands, they have been less affected by man. The value of these wetlands may have been underestimated and may contribute significantly to statewide populations of certain wildlife species. The lack of human development and the large-block public and private industrial forest ownership increases the importance of these wetlands as wildlife habitat now and in the future.

Acknowledgments

I wish to thank L. Rantala of the Wisconsin Department of Natural Resources for drift fence trapping and vegetation sampling assistance; K. Swingle, Burnett County Surveyor, for GIS mapping of study area wetlands; and two anonymous reviewers for critical review of the manuscript. The Marsh Monitoring Program provided audio tapes (training and broadcast calls), stake markers, instructions, and data forms. Partial funding for this study was provided by the Federal Aid to Wildlife Restoration under Pittman-Robertson Wisconsin Project W-141-R.

Works Cited

Anonymous. 1996. Marsh monitoring program. Long Point Bird Observatory and Environment Canada. 41 pp.

Anonymous. 1997. The endangered and threatened vertebrate species of Wisconsin. Bureau of Endangered Resources, Wisconsin Department of Natural Resources Publication ER-

091. 103 pp.

Casper, G. S. 1996. *Geographic distributions of the amphibians and reptiles of Wisconsin.* Milwaukee Public Museum, Inc. Milwaukee, WI. 87 pp.

Curtis, J. T. 1959. *The vegetation of Wisconsin: an ordination of plant communities.* University of Wisconsin Press, Madison. 657 pp.

Evrard, J. O. 1995. Common loon population changes in Crex Meadows, Wisconsin, 1976–94. *Passenger Pigeon* 57:171–76.

Evrard, J. O. 1997. Bibliography for the Glacial Lake Grantsburg Wildlife Management Complex, Burnett County, Wisconsin. Unpublished report, Wisconsin Department of Natural Resources, Grantsburg. 6 pp.

Faanes, C. A. 1981. Birds of the St. Croix River Valley: Minnesota and Wisconsin. North American Fauna, Number 73. Washington, D.C. 196 pp.

Gieck, C. M. 1988. Wisconsin red-necked grebe recovery plan. Wisconsin Department of Natural Resources. Endangered Resources Report 40. 27 pp.

Greig-Smith, P. 1964. *Quantitative plant ecology.* Butterworth and Co. Ltd., London. 256 pp.

Hay, B. 1995. Herptiles of Wisconsin's pine barrens. Pp. 13-14 *in* E. A. Borgerding, G. A. Bartelt, and W. M. McCown, eds. *The future of pine barrens in northwest Wisconsin: a workshop summary.* Wisconsin Department of Natural Resources PUBL-RS-913-94.

Hine, R. L., B. L. Les, and B. F. Hellmich. 1981. Leopard frog populations and mortality in Wisconsin, 1974–76. Wisconsin Department of Natural Resources. Technical Bulletin 122. 39 pp.

Immler, R. H. 1945. Bullsnakes and their control on a Nebraska wildlife refuge. *Journal of Wildlife Management* 9:265–73.

Jahn, L. R., and R. A. Hunt. 1964. Duck and coot ecology and management in Wisconsin. Wisconsin Conservation Department. Technical Bulletin 33. 212 pp.

Jaslow, A. P., and R. C. Vogt. 1977. Identification and distribution of *Hyla versicolor* and *Hyla chrysoscelis* in Wisconsin. *Transactions of the Wisconsin Academy of Sciences, Arts, and Letters* 81:81–89.

March, J. R., G. F. Martz, and R. A. Hunt. 1973. Breeding duck populations and habitat in Wisconsin. Wisconsin Department of Natural Resources. Technical Bulletin 68. 37 pp.

Mossman, M. J., and R. L. Hine. 1984. The Wisconsin frog and toad survey: establishing a long-term monitoring program. Wisconsin Department of Natural Resources. Endangered Resources Report 9. 13 pp.

Mossman, M. J., and R. L. Hine. 1985. The Wisconsin frog and toad survey, 1984. Wisconsin Department of Natural Resources. Endangered Resources Report 16.

Mossman, M. J., E. Epstein, and R. M. Hoffman. 1991. Birds of Wisconsin pine and oak barrens. *Passenger Pigeon* 53: 137–63.

Moyle. J. B. 1956. Relationships between the chemistry of Minnesota surface waters and wildlife management. *Journal of Wildlife Management* 20:303–19.

Murphy, R. E. 1931. Geography of the northwestern pine barrens of Wisconsin. *Transactions of the Wisconsin Academy of Sciences, Arts and Letters* 26:69–120.

Radeloff, V. C., D. J. Mladenoff, K. L. Manies, and M. S. Boyce. 1998. Analyzing forest landscape restoration potential: pre-settlement and current distribution of oak in the northwest Wisconsin pine barrens. *Transactions of the Wisconsin Academy of Sciences, Arts and Letters* 86:189–206.

Robbins, S. D., Jr. 1991. *Wisconsin Birdlife.* University of Wisconsin Press, Madison. 702 pp.

Riegler, M. 1995. Development of a pine barrens recovery plan. Pp. 28–33 *in* E. A. Borgerding, G. A. Bartelt, and W. M. McCown, eds. *The future of pine barrens in northwest Wisconsin: a workshop summary.*

Wisconsin Department of Natural Resources PUBL-RS-913-94.

Strong, M. 1880. The geology of the upper St. Croix district. *In The Geology of Wisconsin* 3:363–428.

Sweet, E. T. 1880. Geology of the western Lake Superior district. *In The Geology of Wisconsin* 3:303–62.

Vogl, R. J. 1970. Fire and the northern Wisconsin pine barrens. *Proceedings of the Tall Timbers Fire Ecology Conference* 10:175–209.

Vogt, R. C. 1981. *Natural history of amphibians and reptiles in Wisconsin.* Milwaukee Public Museum, Inc., Milwaukee, WI. 205 pp.

Vogt, R. C., and R. L. Hine. 1982. Evaluation of techniques for assessment of amphibian and reptile populations in Wisconsin. Pp. 210–17 *in* N. J. Scott, Jr., ed. Herpetological Communities. U.S. Fish and Wildlife Service Research Report 13.

James O. Evrard is a retired wildlife research biologist for the Wisconsin Department of Natural Resources at Grantsburg. ***Address:*** *630 North Pine Street, Grantsburg, WI 54840.* ***Email:*** *evrardsc@win.bright.net*

James O. Evrard and M. Eloise Canfield

Blanding's Turtles in the Crex Meadows Wildlife Area

Abstract *Little is known about the Blanding's turtle* (Emydoidea blandingii), *a threatened species in Wisconsin. The study's objective was to determine the status of the species in the extensive wetlands of the Crex Meadows, Wisconsin's largest wildlife management area. From 10 June to 17 July 1997, 51 Blanding's turtles were captured, measured, marked, and released to determine sex and age and estimate the population size. Eleven Blanding's turtles were recaptured, providing population estimates for Crex Meadows that ranged from 107 to 161 turtles. The sex ratio was highly skewed towards females, which was probably an artifact of the sampling methods used. Because 95% of the turtles captured were adult females, the population estimate provided only an estimate of the numbers of female, not male, Blanding's turtles. The age ratio was highly skewed towards adults. This again could be sampling bias or could be due to high nest and juvenile mortality. The many deep and permanent marshes and open brush prairie uplands of the Crex Meadows Wildlife Area apparently provide good habitat for the Blanding's turtle.*

The Wisconsin Natural Heritage Inventory lists the pine barrens as rare globally (G3) and imperiled in the state (S2) (Temple 1995), with only 1% of the original 2.3 million acres of pine barrens remaining in Wisconsin (Curtis 1959). These remnants are fragmented and isolated (Shively 1994), potentially endangering the continued existence of plant and animal species, including the Blanding's turtle.

The State of Wisconsin lists the Blanding's turtle as a threatened species (NR 27.03, effective October 1979). The Blanding's turtle is a long-lived species, not reaching sexual maturity until 15 to 20 years of age (Ross 1989, Rowe 1992, Congdon et al. 1993, McGown 1999). Long-lived species need high juvenile survival or large numbers of offspring to maintain a stable population. Recent declines in nest survival, measured by low recaptures of juvenile turtles and attributed to increases in mammalian and avian predators (Congdon et al. 1993, McGown 1999), have caused concern for the species. Despite its wide geographical distribution in the state (Casper 1996), the status of the species in Wisconsin is poorly known. Only one study of the Blanding's turtle has been completed in Wisconsin, and that was conducted in the central part of the state (Ross 1985). Little is known about the Blanding's turtle in the northwest pine barrens (Hay 1993).

This study attempted to determine the status of the Blanding's turtle inhabiting the extensive wetlands and pine barrens of the Crex Meadows Wildlife Area in northwest Wisconsin.

Study Area

Crex Meadows is the largest state-owned wildlife management area in Wisconsin and the largest restored pine barrens in the state. Crex Meadows Wildlife Area is a 10,800-ha brush prairie-wetland complex managed by the Wisconsin Department of Natural Resources (Vogl 1964, Zicus 1964). It is an area of many large deep marshes, numerous small shallow wetlands, and an extensive system of all-weather roads. The slightly rolling uplands surrounding the wetlands consist of brush prairie (Strong 1880), maintained by intensive prescribed burning, and young jack pine *(Pinus banksiana)*, Hill's oak *(Quercus ellipsoidalis)*, and aspen *(Populus tremuloides)* forests.

Methods

Blanding's turtles were captured by hand by slowly driving on roads in June and July 1997, looking for turtles on or adjacent to the roads. Turtles were also captured in hoop-net traps (Lagler 1943, Legler 1960) and seine nets from 10 June to 16 July 1997 in roadside wetlands where turtles were observed.

Turtles were aged by counting plastral annuli (Sexton 1959). Annuli develop by periods of rapid growth (summer), followed by periods of slow growth (winter). However, the annuli of older turtles are worn and difficult or impossible to count. Annuli lengths were measured to the nearest mm using dial calipers. Plastron and carapace lengths were measured to the nearest mm using outside calipers.

The sex of the turtles was determined by plastron and tail characteristics (Graham and Doyle 1977), with males having concave plastrons and females having flat plastrons and an anal opening on the tail anterior to the carapacial margin.

Turtles were weighed to the nearest 0.1 g on a spring scale, marked with notches in the carapace (Cagle 1939), and released at the capture site. Recapture of marked turtles provided population estimates using the marked/recapture methods developed by Schnabel (1938) and Schumacher and Eschmeyer (1943). Recaptures, especially in the future, could provide information about recruitment, survival, and habitat use.

Results and Discussion

Sixty-two Blanding's turtles were captured, of which 51 individuals were first-time captures and 11 were recaptures of turtles previously marked in this study. In addition, two mortalities were recorded. One unmarked turtle was found dead in a cultivated field, and a marked turtle was found killed by a vehicle on a road.

The locations of the 62 captures and recaptures were as follows: 54 on road, 5 in hoop nets, 2 in hand nets, and 1 in a seine net.

The first turtle was marked on 10 June 1998 and the last turtle on 17 July, a period of 41 days. Eighty-four percent of the turtles were captured and marked during the first 10 days of the sampling period. Peak capture success occurred from 15 to 20 June when an average of eight turtles was captured per day.

Marked/recapture estimates of the population size of Blanding's turtles in Crex Meadows ranged from 107.3 (Schnabel 1936) to 161.3 (Schumacher and Eschmeyer 1943) turtles (Canfield and Evrard 1997). Because these estimates don't agree, their validity is questionable. Koper and Brooks (1998) recently compared mark-recapture population estimates with known population sizes of painted turtles *(Chrysemys picta)* and found that almost all the estimates were far below the true population sizes. Based on their findings, our highly variable population estimates of Blanding's turtles in the Crex Meadows Wildlife Area should probably be considered a minimum estimate.

Because the population estimate of 107–161 turtles was based upon a sample of animals that was 95% female, the population size is more correctly an estimate of the number of nesting female Blanding's turtles rather than the total population inhabiting Crex Meadows.

In our study, the sample of turtles captured was skewed heavily towards adult females (48 females vs. 3 males or 16:1). Other studies (Congdon and van Loben Sels 1991, Piepgras et al. 1998) have reported sex ratios favoring female Blanding's turtles, but none were as skewed as in this study. This skewed ratio is understandable since female turtles select sandy road edges for nesting, and 44 of the 54 turtles captured on roads were female. All 3 males and 4 females were captured in the water. The sex ratio for those turtles captured in the water was less skewed (1.3:1) and similar to that range reported in earlier research (Joyal 1996).

Mean carapace lengths and widths were similar between 47 female and 3 male Blanding's turtles, although the male sample size was limited (Table 1). This

Table 1. Measurements of Blanding's turtles captured in the Crex Meadows Wildlife Area, Wisconsin, 1997.

		Carapace Length[a]		*Carapace Width*[a]		*Plastron Length*[a]		*Weight*[b]	
Sex - Age	*Number*	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*
Female	47	234.2	10.6	157.6	6.6	186.1	9.7	1942.0	253.4
Male	3	234.3	20.8	158.0	13.4	173.7	16.9	1866.7	365.3
Annuli									
4	1	105.0	0.0	81.0	0.0	80.0	0.0	200.0	0.0
10	2	231.0	60.0	154.5	36.0	182.0	49.0	1850.0	825.0
11	11	228.5	11.6	154.4	7.5	181.5	13.3	1859.1	251.7
12	7	228.0	10.1	155.3	7.7	181.2	10.0	1804.2	224.4
13	6	234.2	12.0	156.0	7.3	188.3	9.9	1937.5	236.2
14	7	232.9	9.6	159.3	7.6	182.4	7.2	1885.7	219.9
15	5	234.0	3.6	158.6	3.6	184.2	3.9	1920.0	119.8
16	3	236.3	0.9	160.0	2.4	187.3	1.9	2000.0	204.1

[a]millimeters
[b]grams

similarity agrees with previous work done by Rowe (1987), Congdon and van Loben Sels (1991), Rowe (1992), and Joyal (1996).

However, there appear to be differences in Blanding's turtle sizes from one geographic area to another (Joyal 1996). For 47 female Blanding's turtles in our study, the mean carapace length was 234 mm, the mean carapace width was 158 mm, and the mean plastron length was 186 mm (Table 1). Sizes of Blanding's turtles in adjacent Minnesota were similar—mean carapace length for 37 adult females was 237 mm (Piepgras et al. 1998) and 245 mm for 42 adult females (Sajwaj et al. 1998).

However, mean carapace lengths for 11 adult females in southern Maine and for 20 adult females in Nebraska were 206 mm and 185 mm respectively (Joyal 1996, Germano et al. 1998). Differences also apparently existed between mean measurements for males from northwest Wisconsin and from southern Maine. However, this comparison is questionable due to small male sample sizes in our study.

Age structure and/or food quality and availability could possibly be responsible for these size differences (Quinn and Christiansen 1972, Graham and Doyle 1977).

The age structure, determined by counting plastron annuli, indicated that the Blanding's turtle population inhabiting Crex Meadows apparently has many adults but very few young. Another explanation might be that capture techniques used in this study could be unsuitable for sampling young turtles.

Male Blanding's turtles reach sexual maturity at approximately 12 years of age (Graham and Doyle 1977) and females at 14–20 years (Petokas 1977, Ross 1989, Congdon and van Loben Sels 1991). Twenty-seven or 66% of the turtles captured were breeding adults (≥12 years of age), 13 or 32% were subadults (10 and 11 years old), and only 1 or 2% was a juvenile (4 years old).

Other Blanding's turtle studies have reported finding very few young animals (Gibbons 1968, Graham and Doyle 1977, Congdon et al. 1983, Kofron and Schreiber 1985, Petokas 1987, Ross 1989, Joyal 1996, Standing et al. 1997, Germano et al. 1998, Piepgras et al. 1998, Sajwaj et al. 1998). Either nest success is very low and/or survival of young turtles is low due to predation, or juvenile turtles' behavior or habitat (Ross 1989, Pappas and Brecke 1992, Congdon et al. 1993, Herman et al. 1998, McMaster and Herman 1998, Morrison et al. 1998) is considerably different than that used by adult turtles (Sexton 1995).

The limited information gathered in this study did not permit determining habitat preferences of Blanding's turtles. However, in general, the deep, large, permanent marshes interspersed with upland brush prairie of the Crex Meadows Wildlife Area apparently were preferred compared to nearby heavily wooded river valleys. In an extensive two-year survey of turtles on the nearby St. Croix River, Donner-Wright (1997) found only one Blanding's turtle.

Joyal (1996) in southern Maine found that Blanding's turtles preferred permanent, deep marshes in large wetland complexes in areas sufficiently open for abundant sunlight to reach the wetlands. She also found that the turtles needed open uplands for nesting, short-term basking, long-term estivation, and travel between wetlands. Linck and Moriarity (1998) found that recently burned upland prairies are important nesting habitat in Minnesota. Crex Meadows provides the appropriate wetland and upland habitat, but the many roads may provide barriers and danger to migratory turtles (McGown 1999).

Recommendations

The apparent absence of young Blanding's turtles in this study and other studies (Standing et al. 1997), whether a reflection of actual numbers or inadequate sampling techniques, might be a factor limiting the population of this threatened species. Small radio transmitters attached to newly hatched turtles (Herman et al. 1998, McMaster and Herman 1998, Morrison et al. 1998, Tanck and Thiel 1998, McGown 1999) as they emerge from their nests might help determine juvenile turtle survival and habitat preferences or reveal potential techniques to increase their capture. Transmitters attached to adults of both sexes could also reveal habitat preferences and mortality patterns. This knowledge could ensure the continued survival of the Blanding's turtle in Crex Meadows.

Acknowledgments

We wish to thank Paul Kooiker, Jim Hoefler, Steve Hoffman, Lyman Lang, and Orlie Luedtke of the Wisconsin Department of Natural Resources, Grantsburg, for field assistance and two anonymous reviewers for critical review of the manuscript. Partial funding for this study was provided by the Society of Tympanuchus Cupido Pinnatus, Ltd. and the Federal Aid to Wildlife Restoration under Pittman-Robertson Wisconsin Project W-141-R.

Works Cited

Cagle, F. R. 1939. A system of marking turtles for future identification. *Copeia* 1939:170–73.

Canfield, M. E., and J. O. Evrard. 1997. Blanding's turtle population study. Unpublished report, Wisconsin Department of Natural Resources, Grantsburg. 3 pp.

Casper, G. S. 1996. *Geographic distributions of the amphibians and reptiles of Wisconsin.* Milwaukee Public Museum. 87 pp.

Congdon, J. D., D. W. Tinkle, G. L. Breitenbach, and R. C. van Loben Sels. 1983. Nesting ecology and hatching in the turtle *Emydoidea blandingii. Herpetologica* 39:417–29.

Congdon, J. D., and R. C. van Loben Sels. 1991. Growth and body size in Blanding's turtles *(Emydoidea blandingii):* relationships to reproduction. *Canadian Journal of Zoology* 69:239–45.

Congdon, J. D., A. E. Dunham, and R. C. van Loben Sels. 1993. Delayed sexual maturity and demographics of Blanding's turtles *(Emydoidea blandingii):* implications for conservation and management of long-lived organisms. *Conservation Biology* 7:826–33.

Curtis, J. T. 1959. *The vegetation of Wisconsin.* University of Wisconsin Press, Madison. 657 pp.

Donner-Wright, D. M. 1997. Distribution and abundance of turtles along the St. Croix River, Minnesota and Wisconsin. M.S. Thesis. University of Wisconsin-Stevens Point. 47 pp.

Germano, D. J., R. B. Bury, and M. Jennings. 1998. Growth and demographics of a population of *Emydoidea blandingii* from western Nebraska. *Proceedings of the Blanding's Turtle Workshop, Minneapolis, MN, 6–9 May 1998.*

Gibbons, J. W. 1968. Observations of the ecology and population dynamics of the Blanding's turtle *(Emydoidea blandingii). Canadian Journal of Zoology* 46:288–90.

Graham, T. E., and T. S. Doyle. 1977. Growth and population characteristics of Blanding's turtle, *Emydoidea blandingii,* in Massachusetts. *Herptologica* 33:410–14.

Hay, B. 1993. Herptiles of Wisconsin's pine barrens. Pp. 13–14 *in* E. A. Borgerding, G. A. Bartelt, and W. M. McCown, eds. *The fu-*

ture of pine barrens in northwest Wisconsin: a workshop summary. Wisconsin Department of Natural Resources PUBL-RS-913-94.

Herman, T., I. Morrison, and N. McMaster. 1998. Recovery of a threatened Blanding's turtle population: is headstarting a viable conservation tool? *Proceedings of the Blanding's Turtle Workshop, Minneapolis, MN, 6–9 May 1998.*

Joyal, L. A. 1996. Ecology of Blanding's *(Emydoidea blandingii)* and spotted *(Clemmys guttata)* turtles in southern Maine: population structure, habitat use, movements, and reproductive biology. M.S. Thesis. University of Maine. 144 pp.

Kofron, C. P., and A. A. Schreiber. 1985. Ecology of two endangered aquatic turtles in Missouri: *Kinosternon flavescens* and *Emydoidea blandingii. Journal of Herpetology* 19:27–40.

Koper, N., and R. J. Brooks. 1998. Population estimators and unequal catchability in painted turtles. *Canadian Journal of Zoology* 76:458–65.

Lagler, K. F. 1943. Methods of collecting fresh water turtles. *Copeia* 1943:21–25.

Legler, J. M. 1960. A simple and inexpensive device for capturing aquatic turtles. *Proceedings of the Utah Academy of Sciences, Arts and Letters* 37:63–66.

Linck, M., and J. J. Moriarity. 1998. Blanding's turtle use of a restored prairie and wetland complex in Crow-Hassan park reserve, Minnesota. *Proceedings of the Blanding's Turtle Workshop, Minneapolis, MN, 6–9 May 1998.*

McGown, E. 1999. Tracking turtles. *Milwaukee Public Museum Lore* 49(2):2–8.

McMaster, N., and T. Herman. 1998. Movements and habitat selection of juvenile Blanding's turtles *(Emydoidea blandingii)* in Kejimkujik National Park, Nova Scotia. *Proceedings of the Blanding's Turtle Workshop, Minneapolis, MN, 6–9 May 1998.*

Morrison, I., T. Herman, and L. Standing. 1998. Movements and habitat selection of headstarted hatchlings in a threatened population of Blanding's turtles *(Emydoidea blandingii)* in Kejimkujik National Park, Nova Scotia. *Proceedings of the Blanding's Turtle Workshop, Minneapolis, MN, 6–9 May 1998.*

Pappas, M. J., and B. J. Brecke. 1992. Habitat selection of juvenile Blanding's turtles *Emydoidea blandingii. Journal of Herpetology* 26:233–34.

Petokas, P. J. 1987. Patterns of reproduction and growth in the freshwater turtle *Emydoidea blandingii.* Ph.D. Dissertation. University of New York, Binghamton.

Piepgras, S., T. Sajwaj, M. Hamerick, and J. W. Lang. 1998. Blanding's turtle *(Emydoidea blandingii)* in the Brainerd/Baxter region: population status, distribution, and management considerations. Final Report, Nongame Wildlife Office, Minnesota Department of Natural Resources, Brainerd.

Quinn, A. J., and J. L. Christensen. 1972. The relationship between pond bottom type and growth rate of western painted turtle *Chrysemys picta belli* in Iowa, a preliminary report. *Proceedings of the Iowa Academy of Science* 78:67–69.

Ross, D. A. 1985. Habitat use and movements of a Blanding's turtle *(Emydoidea blandingii)* population in central Wisconsin. M.S. Thesis, University of Wisconsin-Stevens Point.

Ross, D. A. 1989. Population ecology of painted and Blanding's turtles *(Chrysemys picta* and *Emydoidea blandingii)* in central Wisconsin. *Transactions of the Wisconsin Academy of Sciences, Arts and Letters* 77:77–84.

Rowe, J. W. 1992. Observations on body size, growth, and reproduction in Blanding's turtle *(Emydoidea blandingii)* from western Nebraska. *Canadian Journal of Zoology* 70:1690–95.

Sajwaj, T. D., S. A. Piepgras, and J. W. Lang. 1998. Blanding's turtle *(Emydoidea blandingii)* at Camp Ripley: critical habitats, population status and management guidelines. Final Report, Nongame Wildlife Office, Minnesota Department of Natural Resources, Brainerd.

Schnabel, Z. E. 1938. Estimation of the total fish population of a lake. *American Mathematics Monthly* 45:348–52.

Schumacher, F. X., and R. W. Eschmeyer. 1943. The estimation of fish populations in lakes and ponds. *The Journal of the Tennessee Academy of Science* 18:22–249.

Sexton, O. J. 1959. A method of estimating the age of painted turtles for use in demographic studies. *Ecology* 40:716–18.

Sexton, O. J. 1995. Miscellaneous comments on the natural history of Blanding's turtle *(Emydoidea blandingii). Transactions of the Missouri Academy of Sciences* 29:1–13.

Shively, M. M. R. 1994. Wisconsin pine-shrub-grassland (pine barrens) ecosystems: an ecosystem recovery plan. M.S. Thesis, University of Wisconsin, Madison.

Standing, K. L., T. B. Herman, D. D. Hurlburt, and I. P. Morrison. 1997. Postemergence behavior of neonates in a northern peripheral population of Blanding's turtle, *Emydoidea blandingii,* in Nova Scotia. *Canadian Journal of Zoology* 75:1387–95.

Strong, M. 1880. The geology of the upper St. Croix district. *In The Geology of Wisconsin* 3:363–428.

Tanck, J. D., and R. P. Thiel. 1998. Blanding's turtle population studies—Sandhill Wildlife Area, Wood County, Wisconsin. *Proceedings of the Blanding's Turtle Workshop, Minneapolis, MN, 6–9 May 1998.*

Temple, S. A. 1995. Biodiversity, landscape-scale management and the ecological importance of the pine barrens community. P. 2 *in* E. A. Borgerding, G. A. Bartelt, and W. M. McCown, eds. *The future of pine barrens in northwest Wisconsin: a workshop summary.* Wisconsin Department of Natural Resources PUBL-RS-913-94.

Vogl, R. J. 1964. Vegetational history of Crex Meadows, a prairie savanna in northwestern Wisconsin. *American Midland Naturalist* 72:157–75.

Zicus, M. C. 1974. A study of the giant Canada goose *(Branta canadensis maxima)* nesting at Crex Meadows, Wisconsin. M.S. Thesis, University of Minnesota, St. Paul.

James O. Evrard is a retired wildlife research biologist for the Wisconsin Department of Natural Resources at Grantsburg. Address: 630 North Pine Street, Grantsburg, WI 54840. Email: evrardsc@win.bright.net

M. Eloise Canfield was a graduate student with the University of Indiana at the time of the study. Address: 45 Inwood Road, Chatham, NJ 07928

D. Timothy Gerber

Floating-leafed and Submersed Aquatic Macrophyte Distribution and Abundance, With Emphasis on Eurasian Watermilfoil *(Myriophyllum spicatum)* in Forest Lake, Fond Du Lac County, Wisconsin

Abstract *Exotic species invasions play an important role in reducing native biodiversity. Tracking the spread, distribution, and abundance of the exotic submersed aquatic macrophyte eurasian watermilfoil* (Myriophyllum spicatum) *in Wisconsin and cataloging native biodiversity within the lakes it invades is of interest to state aquatic biologists, lake managers, and lake property owners. The purpose of this paper is to assess, through the use of a nondestructive sampling method, both the spread and distribution of this exotic species and the distribution of native aquatic flora in Forest Lake, Fond du Lac County, Wisconsin. I found twenty-two species of aquatic macrophytes, including eurasion watermilfoil, within the lake. Some significant differences in abundance and depth distribution were found for six of the most dominant aquatic species. Although eurasion watermilfoil was not listed in previous plant surveys of Forest Lake, it has become well established. An additional exotic emergent aquatic species, purple loosestrife* (Lythrum salicaria), *was also found, and its distribution was determined.*

Exotic species invasions have historically played an important role in reducing native biodiversity (Devine 1998). Since the early 1960s, invasion of the exotic Eurasian watermilfoil (*Myriophyllum spicatum*, hereafter EWM) in southern Wisconsin (Engel 1993) has negatively affected native aquatic macrophyte communities and thus has had an impact on many organisms that interact with these plants. Tracking the spread, distribution, and abundance of EWM in

Wisconsin and cataloging native biodiversity within the lakes it invades is therefore of interest to aquatic biologists, lake managers, and lake users.

Forest Lake (T13N, R19E, sec. 12, Hydrologic unit 04040003, Fond du Lac County, WI) is a 20.4-ha kettle lake located in the terminal moraine of the Green Bay glacier. This single basin lake receives no permanent surface water inflow and has no stream outlet (Wisconsin Department of Natural Resources 1970, U.S. Geological Survey 1994). With a mean depth of 3.3 m, Forest Lake supports a diverse assemblage of rooted, floating-leafed and submersed aquatic plant species that cover much of the lake's bottom. The 47.6-ha watershed surrounding Forest Lake is moderately to steeply sloped with a loam soil that supports primarily woody vegetation (47 ha). The remaining area (0.6 ha) is marsh and shrub wetland (Wisconsin Department of Natural Resources 1970). The watershed has been extensively developed on the northern and eastern sides (private homes and cottages) where shoreline disturbance (sand beach development) is greatest. During the 1960s, dredging at the northern end of the lake caused additional disturbance to the native aquatic plant community.

As of 1968 (Wisconsin Department of Natural Resources 1970), EWM was not found in Forest Lake; however, since then this exotic species has become a problem. Because of interest in exotic species distribution and control in Wisconsin, a systematic survey of Forest Lake's aquatic macrophyte community was conducted to determine the extent of the EWM invasion. The purpose of this paper is to (1) quantitatively and qualitatively document the native aquatic macrophytes and EWM in Forest Lake, (2) describe the within-lake distribution of native macrophytes and EWM at present, (3) assess if changes in macrophyte distribution have occurred since the 1968 survey, (4) determine if other exotic species occur, and (5) determine sediment characteristics within disturbed areas of the lake.

Methods

Data Collection

A qualitative and quantitative aquatic vegetation survey was conducted during July 1993. To minimize disturbance to aquatic plant beds, a nondestructive sampling technique (Titus 1993) was used. Twenty evenly spaced (approximately 107 m between) transects were established perpendicular to the shoreline to assess species composition, frequency, and abundance (Figure 1). Four 0.25-m^2 sample sites were located along each transect, one site at each depth interval (0.5, 1, 2, and 3 m) for a total of 80 sample sites. The maximum depth interval was set at 3 m because aquatic plant growth was limited to 3.7 m (Wisconsin Department of Natural Resources 1970). Each transect was assessed visually for the presence or absence of plants and percent cover of each species using snorkel or SCUBA equipment. An abundance score was determined for each site based on the percent cover for each species (see below). Voucher specimens of each species were deposited in the University of Wisconsin-Milwaukee herbarium.

To determine the range of sediment characteristics under which EWM grows within the most disturbed extreme northern region of Forest Lake, six 200-g samples of sediment were randomly collected within EWM beds at 1-2 m depth during September 1993. Each sample was dried and sent to the University of Wisconsin-Extension Soil and Plant Analysis Lab (5711 Mineral Point Road, Madison, WI) for analysis of pH, organic matter (percent organic matter

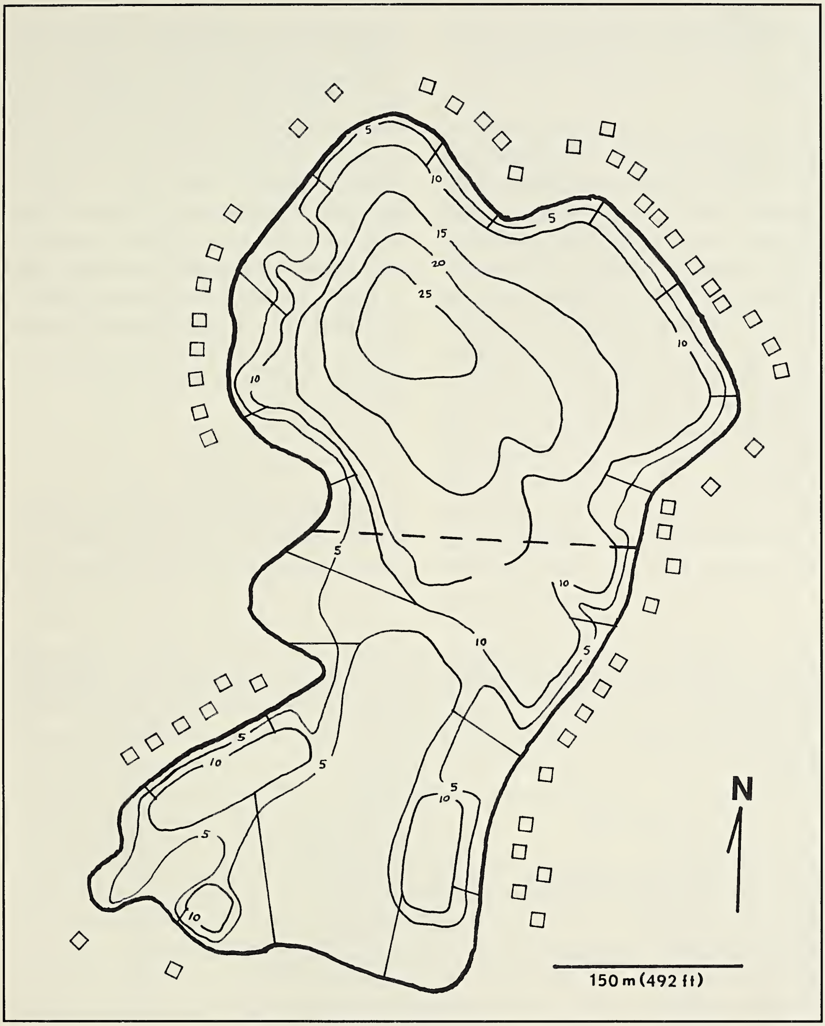


Figure 1. Locations of the 20 transects (lines perpendicular to shore) used for the vegetation survey of Forest Lake. Squares represent private homes or cottages on the lake. The dotted line separates the lake into northern and southern regions. Contour lines are drawn at 5 ft (1.5 m) intervals.

by titration), texture (percent silt, percent sand, percent clay), and mineral content.

Analyses

In a 1968 Department of Natural Resources aquatic plant survey (Wisconsin Department of Natural Resources 1970), differences were found between the northern and southern regions of Forest Lake; therefore, the lake was again divided into northern and southern regions for this study. Abundance, relative abundance, frequency, and relative frequency were calculated using an abundance score (modification of Titus 1993) to determine how common each species was in the northern versus southern regions and within the whole lake. For each sample site, an abundance score was determined in the field for each species using the following designations: 0 (Absent); 1 (Present) = single plant to plants covering < 1% of 0.25-m^2 sampling area; 2 (Abundant) = plants covering 1-50% of sampling area; 3 (Common) = plants covering > 50% of sampling area. Mann-Whitney U tests were performed on the most abundant species to determine if significant differences exist for abundance between northern and southern regions. Abundance differences were also determined for the most dominant species at two depth levels for the entire lake: shallow (0.5 m and 1 m depths combined) and deep (2 m and 3 m depths combined). Wilcoxon's Signed Ranks tests were performed on depth distribution (shallow vs. deep) within the entire lake.

Results

Twenty-two aquatic macrophyte species were found within Forest Lake (Table 1). Three native emergent species (*Sagittaria* sp.,

Table 1. Aquatic macrophyte species in Forest Lake, Fond du Lac County, Wisconsin (taxonomy follows Gleason and Cronquist 1991) by region. N = northern, S = southern.

Scientific Name	*Common Name*	*Region*
Ceratophyllum demersum L.	Coontail	N, S
Chara sp.	Muskgrass	N, S
Eleocharis acicularis (L.) Roemer & Schultes.	Spike Rush	N, S
Lythrum salicaria L.	Purple Loosestrife	N, S
Myriophyllum sibericum Komarov	Northern Watermilfoil	N, S
Myriophyllum spicatum L.	Eurasian Watermilfoil	N, S
Najas flexilis (Willd.) Rostk. & Schmidt	Bushy Pondweed	N, S
Nuphar variegata Durand	Yellow Water Lily	N
Nymphaea oderata Aiton	White Water Lily	S
Polygonum amphibium L.	Water Smartweed	S
Potamogeton amplifolius Tuckerman	Large-leafed Pondweed	N, S
Potamogeton foliosus Raf.	Leafy Pondweed	N
Potamogeton gramineus L.	Variable-leaf Pondweed	N, S
Potamogeton natans L.	Floating-leaf Pondweed	S
Potamogeton pectinatus L.	Sago Pondweed	N, S
Potamogeton pusillus L.	Slender Pondweed	N, S
Potamogeton zosteriformis Fern.	Flat-stemmed Pondweed	N, S
Sagittaria sp.	Arrowhead	N, S
Scirpus validus Vahl	Soft-stem Bulrush	N, S
Typha sp.	Cattail	S
Vallisneria americana L.	Water-celery	N, S
Zosterella dubia (Jacq.) Small.	Water star-grass	N, S

Scirpus validus, and *Typha* sp.) and one exotic emergent species (purple loosestrife, *Lythrum salicaria*) were excluded from abundance and frequency analyses. The native floating-leafed *Nuphar variegata,* found in the lake but not within any sampling sites, was also excluded from analyses. Only the seventeen true aquatic species (i.e., floating-leafed and submersed) found within sampling sites were considered for abundance and frequency analyses. The number of species at individual sampling sites ranged from zero (8 sites) to six (1 site).

Six dominant species (RA_W > 10% or RF_W > 10%; Tables 2 and 3) were found within Forest Lake: *Chara* sp., *Najas flexilis, Myriophyllum sibiricum, Myriophyllum spicatum* (EWM), *Potamogeton pusillus,* and *Vallisneria americana.* Significant differences ($P \leq 0.05$) in abundance among these six species existed between the northern and southern halves of Forest Lake. EWM (P = 0.004) was significantly more abundant in the northern region, whereas *Najas flexilis* (P = 0.002) and *Potamogeton pusillus* (P = 0.001) were more abundant in the south. No significant differences in abundance between northern and southern regions were found for *Myriophyllum sibiricum* (P = 0.971), *Chara* sp. (P = 0.684), and *Vallisneria americana* (P = 0.529). Of aquatic macrophytes other than the six dominant species, *Potamogeton foliosus* was present in the northern region but absent in the southern region. *Nymphaea odorata, Polygonum amphibium,* and *Potamogeton natans* were present in the southern region but not the northern region.

Species abundance differs at different depths in Forest Lake. Within the entire lake, *Myriophyllum sibiricum* (P = 0.015), *Chara* sp. (P = 0.017), and *Potamogeton pusillus* (P = 0.023) were found in higher abundance in deep water. No significant differences in abundance for depth were found for *Najas flexilis* (P = 0.134), EWM (P = 0.279), and *Vallisneria americana* (P = 0.209).

Purple loosestrife, an exotic emergent aquatic species, was found growing in sparse patches within the lake and in dense patches in surrounding wetlands. A visual inspection of the wetlands was made to determine distribution of this species. Because of the interest in exotic species control, distributions for both EWM and purple loosestrife were mapped (Figure 2).

Sediments found within EWM plant beds at the extreme northern end of Forest Lake were assigned a designation of sand to sand-loamy. Sediment texture composition ranged from 95–85% sand, 14–6% silt, and <1% clay. Organic matter content was low (4.24–0.97%). This was probably due to human disturbance along the northern lake shore, where property owners use sand to maintain beaches. Sediment pH values ranged from 7.2–6.7. Sediment mineral ranges are given in Table 4. Water mineral ranges are taken from U.S. Geological Survey (1994) data and Wisconsin Department of Natural Resources (1970) data (Table 4).

Discussion

Within the last 30 years, EWM has become well established in Forest Lake, and purple loosestrife has become well established in the surrounding wetlands. Neither exotic species was found during the 1968 Wisconsin Department of Natural Resources survey (1970), but EWM has now become the most dominant true aquatic macrophyte species within the northern region of Forest Lake and the fifth most abundant species within the entire lake. EWM distribution within the lake is not uniform, however; its greatest concentration was at the 2-m depth

Table 2. Abundance (A = sums of abundance scores) and relative abundance (RA) of floating-leafed and submersed species of the northern region (N), southern region (S), and whole lake (W) for Forest Lake, Fond du Lac County, Wisconsin. A_W = 0 (absence), 1 (present), 2 (abundant), or 3 (common) for each occurrence in a 0.25 m^2 area and $\%RA_W = (A/A_{Total})*100$ for 80 sample sites; A_N, A_S, $\%RA_N$ and $\%RA_S$ are calculated similarly for 40 sample sites each.

Species	A_N	$\%RA_N$	A_S	$\%RA_S$	A_W	$\%RA_W$
Ceratophyllum demersum	3	2.2	3	1.8	6	2.0
Chara sp.	25	18.7	20	12.1	45	15.1
Eleocharis acicularis	1	0.7	2	1.2	3	1.0
Myriophyllum sibericum	26	19.4	24	14.5	50	16.7
Myriophyllum spicatum	35	26.1	2	1.2	37	12.4
Najas flexilis	14	10.4	43	26.1	57	19.1
Nymphaea oderata	0	0	5	3.0	5	1.7
Polygonum amphibium	0	0	2	1.2	2	0.7
Potamogeton amplifolius	2	1.5	3	1.8	5	1.7
Potamogeton foliosus	1	0.7	0	0	1	0.3
Potamogeton gramineus	4	3.0	4	2.4	8	2.7
Potamogeton natans	0	0	3	1.8	3	1.0
Potamogeton pectinatus	1	0.7	4	2.4	5	1.7
Potamogeton pusillus	4	3.0	36	21.8	40	13.4
Potamogeton zosteriformis	3	2.2	4	2.4	7	2.3
Vallisneria americana	14	10.4	9	5.5	23	7.7
Zosterella dubia	1	0.7	1	0.6	2	0.7
Total	**134**	**100**	**165**	**100**	**299**	**100**

Table 3. Frequency (F) and relative frequency (RF) of floating-leafed and submersed species of the northern region (N), southern region (S), and whole lake (W) for Forest Lake, Fond du Lac County, WI. F_W = no. of occurrences/80 sample sites; $\%RF_W = (F/F_{Total})*100$; F_N, F_S, $\%RF_N$ and $\%RF_S$ were calculated similarly for 40 sample sites each.

Species	F_N	$\%RF_N$	F_S	$\%RF_S$	F_W	$\%RF_W$
Ceratophyllum demersum	3.8	3.4	2.5	1.9	6.3	2.6
Chara sp.	17.5	15.8	10.0	7.7	27.5	11.5
Eleocharis acicularis	1.3	1.2	1.3	1.0	2.6	1.1
Myriophyllum sibericum	17.5	15.8	16.3	12.6	33.8	14.1
Myriophyllum spicatum	23.8	21.5	2.5	1.9	26.3	11.0
Najas flexilis	13.8	12.5	33.8	26.2	47.6	19.9
Nymphaea oderata	0	0	6.3	4.9	6.3	2.6
Polygonum amphibium	0	0	2.5	1.9	2.5	1.0
Potamogeton amplifolius	2.5	2.3	3.8	2.9	6.3	2.6
Potamogeton foliosus	1.3	1.2	0	0	1.3	0.5
Potamogeton gramineus	5.0	4.5	5.0	3.9	10.0	4.2
Potamogeton natans	0	0	3.8	2.9	3.8	1.6
Potamogeton pectinatus	1.3	1.2	5.0	3.9	6.3	2.6
Potamogeton pusillus	3.8	3.4	18.8	14.6	22.6	9.4
Potamogeton zosteriformis	3.8	3.4	5.0	3.9	8.8	3.7
Vallisneria americana	13.8	12.5	11.3	8.7	25.1	10.5
Zosterella dubia	1.3	1.2	1.3	1.0	2.6	1.1
Total	**110.5**	**100**	**129.2**	**100**	**239.7**	**100**

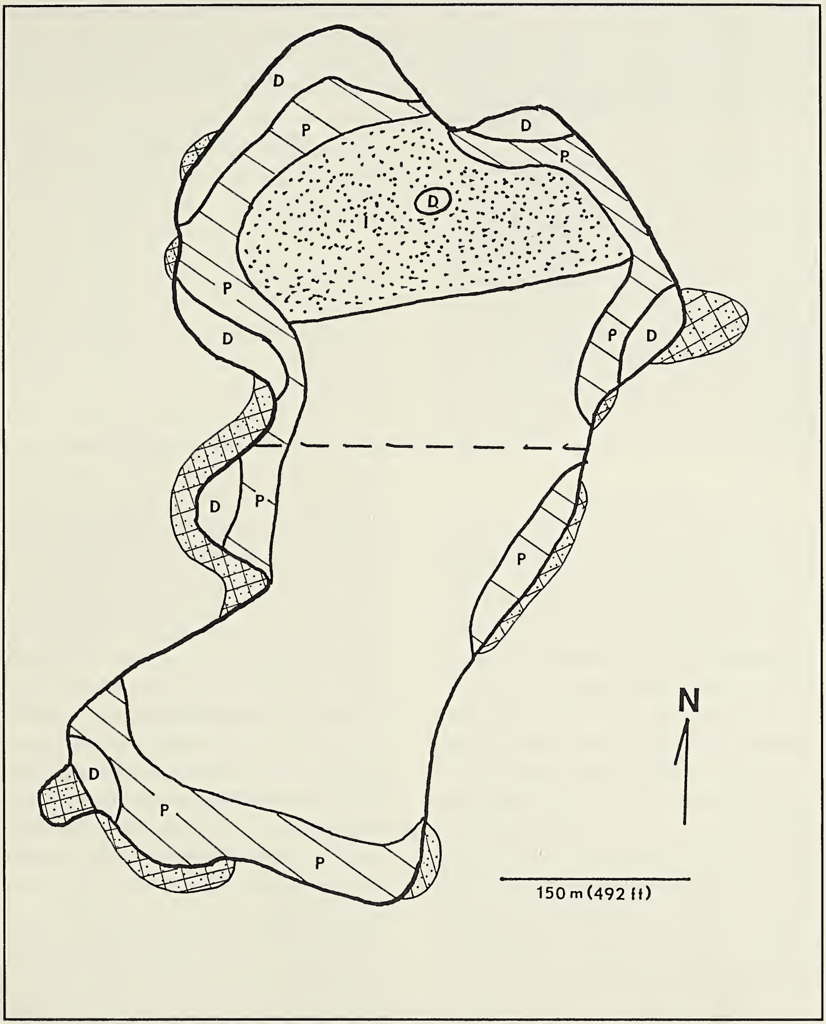


Figure 2. Distributions of EWM and purple loosestrife within and surrounding Forest Lake. Areas with dense (D) or patchy (P) stands of EWM are shown. The stippled deep water area contains patches of dense EWM stands that reach the surface later in the growing season. The cross-hatched, stippled areas identify loosestrife stands.

Table 4. Range of sediment (see collection site information in text, N = 6) and water mineral characteristics (N = 2, one shallow and one deep water sample, unless otherwise indicated; taken on May 3 [USGS 1994]) at the north end of lake; and mean water mineral characteristics (N = 1) on April 1968 (modified from WDNR 1970) of Forest Lake, Fond du Lac County, Wisconsin.

		Water, dissolved (ppm)	
Characteristic	*Sediment (ppm)*	*1994*	*1968*
Calcium	94,800 – 81,400	26	10.8
Magnesium	59,300 – 50,100	15	18.3
Iron	5,000 – 2,800	<50	0.01
Aluminum	3,800 – 2,000	—	—
Sulfur	501 – 103	4–5 (sulfate)	17.0
Potassium	468 – 128	<1	1.7
Phosphorus	247 – 155	<1 (total P; N = 8)	0.12
Sodium	231 – 173	2.4	8.7
Manganese	106 – 76	<40	—
Zinc	51 – 29	—	—
Copper	9 – 5	—	—
Boron	5 – 3	—	—

interval, which is consistent with other reports for this species (Nichols 1992, Deppe and Lathrop 1993, Lillie 1996). Purple loosestrife is restricted to shallow areas, and a visual inspection of surrounding wetlands suggests that this species warrants consideration to contain further spread.

As reported for other Wisconsin lakes (Nichols 1988), EWM was found in greatest abundance in the most disturbed areas of Forest Lake. Dense concentrations of EWM, often in pure stands, were found where the greatest number of sand beaches were located and also were growing from the shoreline to a depth of 4 m in previously dredged areas of the lake. Four sampling sites along beach areas had monotypic stands of EWM. *Chara* and *Vallisneria americana* were the only other species found in monotypic stands at one sample site each.

Changes in native aquatic plant distribution and abundance are evident within Forest Lake in the last 30 years. Several notable differences were found when comparing this report with the 1968 survey. *Potamogeton amplifolius,* once common within the northern lake region, is now much less abundant. Although *Chara* is still found along the northern shore, the thick growths of this species previously reported in the 1968 survey were not found in this survey. Within the southern region, *Potamogeton pectinatus* and *Potamogeton zosteriformis* are now found in comparatively low abundance but were previously listed as dominant species. *Najas flexilis,* while common in this report, was not mentioned in the 1968 survey. Interestingly, *Najas flexilis* has also been identified as a species that does well in disturbed areas (Nichols 1988).

While EWM is considerably less abundant in the southern half of the lake, its spread into this region has been noticed within the last several years (personal communication, C. Kendziorski). Previous research (Nichols 1990, Nichols and Buchan 1997) suggests that certain aquatic macrophytes show significant habitat associations with EWM. Three of these "indicator species" (e.g., *Najas flexilis, Myriophyllum* *sibiricum, Potamogeton gramineus)* are dominant in the southern region of Forest Lake. Fish Lake (Dane County, WI), similar to Forest Lake in aquatic macrophyte species composition, has shown a drastic increase in EWM over the last two decades (Nichols 1984, Lillie 1996). Although Fish Lake at present has shown some decline in EWM, it is still by far the most dominant species within the lake (Lillie 1996).

Physical and chemical sediment characteristics influence the distribution of rooted, submersed and floating-leafed aquatic macrophytes (Sculthorpe 1967). EWM has been shown to colonize many different sediment types, from high organic-mucky to low organic-sandy sediments (Nichols 1971, Lillie and Barko 1990, Gerber and Les 1996, Nichols and Rogers 1997). In Forest Lake, the northern shoreline has been disturbed by the development of sandy beach areas with sandy sediments to a depth of >2 m. These sandy sediments are colonized in monotypic or mixed stands by EWM, *Najas flexilis, Chara, Ceratophyllum demersum,* and *Vallisneria americana.* These species, excluding *Chara,* are described by Nichols (1988) as being tolerant of disturbance.

Determination of native and exotic plant abundance, frequency, and distribution are important for understanding plant community dynamics and for developing an aquatic plant management program aimed at slowing EWM spread. Helsel et al. (1996) have shown that when physical and chemical control techniques are used in combination, native plants can recover and reestablish after EWM eradication. However, minimizing lake disturbance and maintaining a healthy native macrophyte standing crop are probably the best preventative measures to keep exotic species from establishing or spreading within a lake. Within Forest Lake, changes in the native species assemblage may be a harbinger of EWM dominance in southern Forest Lake. The southern end of the lake shows fewer signs of disturbance; however, now that EWM has established in the northern end its spread will probably continue.

Acknowledgments

C. Kendziorski and M. Sessing assisted with field work and project development. Two anonymous referees provided many helpful suggestions for improving the original manuscript. Funding was provided through Wisconsin Department of Natural Resources, Lake Planning Aids Grant (LPL-346), and the Forest Lake Improvement Association.

Works Cited

Devine, R. 1998. *Alien invasion.* National Geographic Society, Washington, D.C. 280 pp.

Deppe, E. R., and R. C. Lathrop. 1993. Recent changes in the aquatic macrophyte community of Lake Mendota. *Transactions of the Wisconsin Academy of Science, Arts and Letters* 81:47–58.

Engel, S. 1993. Status of Eurasian watermilfoil in Wisconsin. *LakeLine* 13:10–13.

Gerber, D. T., and D. H. Les. 1996. Habitat differences among seven species of *Myriophyllum* (Haloragaceae) in Wisconsin and Michigan. *The Michigan Botanist* 35:75–86.

Gleason, H. A., and A. Cronquist. 1991. *Manual of vascular plants of northeastern United States and adjacent Canada.* 2nd edition. New York Botanical Garden, Bronx, NY. 910 pp.

Helsel, D. R., D. T. Gerber, and S. Engel. 1996. Comparing spring treatments of 2,4-D with bottom fabrics to control a new infestation of Eurasian Watermilfoil. *Journal of Aquatic Plant Management* 34:68–71.

Lillie, R. A. 1996. A quantitative survey of the floating-leafed and submersed macrophytes of Fish Lake, Dane county, Wisconsin. *Transactions of the Wisconsin Academy of Science, Arts and Letters* 84:111–25.

Lillie, R. A., and J. W. Barko. 1990. Influence of sediment and groundwater on the distribution and biomass of *Myriophyllum spicatum* L. in Devil's Lake, Wisconsin. *Journal of Freshwater Ecology* 5:417–26.

Nichols, S. A. 1971. The distribution and control of macrophyte biomass in Lake Wingra. Technical Report OWRR-B-019-WIS, University of Wisconsin-Madison, Water Resources Center. Madison, WI. 132 pp.

Nichols, S. A. 1984. Phytochemical and morphological differentiation between *Myriophyllum spicatum* L. and *Myriophyllum exalbescens* Fern. in two Wisconsin lakes. *Transactions of the Wisconsin Academy of Science, Arts and Letters* 72:153–56.

Nichols, S. A. 1988. Vegetation of Wisconsin's benchmark lakes. *Transactions of the Wisconsin Academy of Science, Arts and Letters* 76:1–9.

Nichols, S. A. 1990. Interspecific association of some Wisconsin lake plants. *Transactions of the Wisconsin Academy of Science, Arts and Letters* 78:111–28.

Nichols, S. A. 1992. Depth, substrate, and turbidity relationships of some Wisconsin lake plants. *Transactions of the Wisconsin Academy of Science, Arts and Letters* 80:97–118.

Nichols, S. A., and L. A. J. Buchan. 1997. Use of native macrophytes as indicators of suitable Eurasian watermilfoil habitat in Wisconsin lakes. *Journal of Aquatic Plant Management* 35:21–24.

Nichols, S. A., and S. J. Rogers. 1997. Within-bed distribution of *Myriophyllum spicatum* L. in Lake Onalaska, Upper Mississippi River. *Journal of Freshwater Ecology* 12:183–91.

Sculthorpe, C. D. 1967. *The biology of aquatic vascular plants.* Edward Arnold. London. 610 pp.

Titus, J. E. 1993. Submersed macrophyte vegetation and distribution within lakes: line transect sampling. *Lake and Reservoir Management* 7:155–64.

U.S. Geological Survey. 1994. Water-quality and lake-stage data for Wisconsin lakes, water year 1994.

Wisconsin Department of Natural Resources. 1970. Forest Lake, Fond Du Lac County, Wisconsin. Lake use report number MI-21. Department of Natural Resources, Madison, WI. 16 pp.

***D. Timothy Gerber** is a member of the River Studies Center and assistant professor in the Biology Department at the University of Wisconsin-La Crosse. **Address:** Department of Biology, University of Wisconsin-La Crosse, 1725 State Street, La Crosse, WI 54601.*
***Email:** gerber.dani@uwlax.edu*

Richard S. King

Evaluation of Survey Methods for the Karner Blue Butterfly on the Necedah Wildlife Management Area

Abstract *Three Karner blue butterfly (*Lycaeides melissa samuelis *Nabokov) populations were simultaneously monitored using three standard methods. Population estimates resulting from the methods were correlated with the number of butterflies counted while uniformly searching 50 x 50 m plots within the study sites. This deviates from other studies that evaluated survey methods based on correlation with mark-release-recapture surveys. A fundamental flaw of these studies is the assumption that mark-release-recapture estimates are the most accurate. Population estimates from Pollard-Yates surveys showed the highest correlation with the number of individuals found on the 50 x 50 m plots. Population estimates derived from straight-line transects provided the second best correlation followed by mark-release-recapture estimates. With data pooled by date, no significant differences between Pollard-Yates and straight-line transect derived population estimates were detected. Error estimates for mark-release-recapture surveys could be determined for only 59.5% of the population estimates. No significant differences in the variability estimates were detected among survey methods.*

Methods for estimating butterfly numbers are well established (Pollard 1977, Thomas 1983, Pollard and Yates 1993, Brown and Boyce 1998). Validation of monitoring methods has been accomplished for several species by demonstrating strong correlations between survey counts and population estimates derived from mark-release-recapture (MRR) studies (Douwes 1970, 1976; Pollard 1977; Warren 1981; Thomas 1983; Warren et al. 1986; Warren 1987). The underlying assumption of all such studies is that mark-release-recapture population estimates are the most accurate and should be the benchmark by which all other survey methods are gauged. As is the case with many Lepidoptera, MRR has been used extensively for estimating Karner blue butterfly (*Lycaeides melissa samuelis* Nabokov) populations (Schweitzer 1994). The use of MRR has raised concern because it requires many assumptions (Begon 1983) that are difficult to meet and can lead to biased estimates (Gall 1985).

Listing of the Karner blue butterfly as a federally endangered species (Clough 1992) heightened the need for reliable survey methods that are time and cost effective. Currently several methods are used to estimate Karner blue butterfly populations (Andow et al. 1994). The use of different methods in different geographic areas has made inter-site comparisons difficult. Data summary further complicates interpretation because some surveys are summarized by duration and others by transect length (Andow et al. 1994). Demonstrating Karner blue butterfly recovery requires range-wide population evaluations. Without uniform survey methods and data summary, range-wide analysis will be difficult at best. Therefore, recovery of the Karner blue butterfly is directly dependent on researchers and managers developing uniformity in survey protocol.

The goal of this project was to evaluate the accuracy and variability of three standard butterfly survey methods. The efficacy of each method was evaluated based on correlations with an independent, daily population index. Each method was further evaluated based on the spuriousness of the data it produced. The legitimacy of the methods was evaluated by exploring the assumption and limitations implicit to each.

Methods

The study was conducted during July and August 1995 on three different populations on the Necedah Wildlife Management Area in south-central Wisconsin (48°83′N, 90°10′W). All surveys, regardless of method, were conducted between 0800 and 1530. All study sites were staked with a 50 x 50 m grid system. The sites contained 130, 45, and 57 50 x 50 m plots. Each 50 x 50 m cell was searched on most days (70%) with equal effort between 20 July and August 8. The amount of survey effort was dependent on the number of surveyors, which ranged from 5 (9.1 min/plot) to 12 (22.0 min/plot). The order of cell surveys was randomized by population daily. The number of Karner blue butterflies counted while surveying each cell was recorded. The number of butterflies counted was summed for all cells within each population. Therefore, a daily population index (PI) was obtained by tallying the number of butterflies seen among 50 x 50 m cells within a population. The PI requires two assumptions: (1) the butterflies are not attracted to or repulsed by the observer and (2) butterflies counted in one cell are not counted while surveying subsequent cells. To minimize the risk of double-counting, as many as 12 surveyors were used to simultaneously survey two to four adjacent 50 x 50 m plots. By surveying adjacent plots and systematically advancing to new plots in the same direction, the risk of double counting butterflies was further reduced.

Mark-release-recapture activities were conducted on all three populations most days (70%) between 19 July and 11 August regardless of weather conditions. Butterflies were captured with standard aerial butterfly nets and given a unique three digit number with an ultra-fine point felt-tip pen. No mortalities were observed while conducting

MRR methods. Population estimates from MRR surveys (P_{mrr}) were calculated using the Jolly-Seber method with Jolly Software (Pollock et al. 1990). Mark-release-recapture requires three key assumptions: (1) the probability of capture is the same for all individuals, marked and unmarked; (2) the probability of survival is the same for all individuals, including marked individuals; (3) emigration is permanent and thus equal to death (Begon 1983).

Pollard-Yates (PY) surveys (Pollard 1977) and straight-line transect (SLT) surveys were conducted on all three populations. All PY and SLT surveys were conducted between 20 July and 15 August when rain or wind speed (> 15km/h) would not interfere. While conducting PY counts, observers walked a circular route through a subsection of the habitat patch attempting to cover all areas of high nectar/butterfly abundance. Time permitting, additional subsections were surveyed with PY transects, which resulted in more than one PY population estimate per day for some sites. SLTs ran across the entire habitat patch. The first SLT in each unit was randomly placed. Subsequent transects were added at 15 m intervals from the original transect until the habitat patch was saturated. Spacing of 15 m was used because it provided the most thorough coverage while minimizing the risk of counting the same Karner blue butterfly on subsequent transects. SLTs were permanently staked and color-coded to prevent observer deviation while traversing them. Sample size variations for SLTs resulted when all transects could not be surveyed because of logistical constraints. While conducting PY and SLT surveys, observers recorded the perpendicular distance from the transect to each butterfly. Perpendicular distances were recorded in 1/2-m intervals. While conducting PY surveys, a hand-held measuring wheel was used to measure transect length. Population estimates from the SLT and PY surveys were obtained by first determining the effective-strip-width.

Effective-strip-width is the distance from the transect that every butterfly can be assumed to be counted (Buckland et al. 1993). Effective-strip-widths were determined by fitting curves to the distribution of perpendicular distance estimates for each unit using the software "Distance" (Buckland et al. 1993). Karner blue butterflies per hectare were determined as:

$$D = \frac{n}{2^{*}esw^{*}L}$$

where n = number of Karner blue butterflies counted, esw = effective strip width, and L = transect length. Density estimates were then multiplied by the hectares in each unit to give absolute population estimates for PY (P_{PY}) and SLT (P_{slt}) surveys. When estimating abundance with PY and SLT surveys, four assumptions must be made: (1) butterflies are not double counted; (2) perpendicular distance from the transect to the butterfly is estimated accurately; (3) the probability of detecting a butterfly immediately on the transect is 100%; (4) butterflies are not attracted to or repulsed from the surveyor (Buckland et al. 1993). Assumptions 1 and 4 are shared with the PI method.

The risk of double-counting on PY transects was greatly reduced by using circular versus zig-zag routes. Much like the PI surveys, the risk of double-counting on SLT was reduced by having several surveyors simultaneously walking adjacent transects. The sessile nature of Karner blue butterflies also helps reduce the risk of double-counting on PY, SLT, and PI surveys. Although Karner blue butterflies can move several hundred meters on a weekly basis (King 1998), they move little over the course of several minutes (the time between surveys on adjacent plots or transects) (Fried 1987, Packer 1987, Lawrence and Cook 1989, Sferra et al. 1993, Welch 1993, Bidwell 1995). The effects of double-counting on either PY or SLT were further minimized by deriving population estimates from individual transects as opposed to summing the butterflies counted by day and site.

As with other butterflies (Douwes 1970, 1976; Pollard 1977; Warren 1981; Thomas 1983; Warren et al. 1986; Warren 1987), Pearson correlation analysis was used to validate the survey methods. The population estimates, P_{mrr}, P_{PY}, and P_{slt}, were correlated with the PI by population and date to determine which method provided the most accurate estimate. Therefore, accuracy was assumed to equal the precision between the population estimates and the PI. The PI was used as the benchmark because it was independent of the other methods, required the most time observing the populations, had the least assumptions and could therefore be assumed to most accurately reflect true population fluctuations. A Wilcoxon rank-sums test was used to test for differences between the P_{PY} and P_{slt} estimates where n for both was > 1. P_{mrr} could not be included in this analysis as MRR provides only one estimate per population per day. Differences in the perpendicular distance estimates between PY and SLT methods were tested with a Wilcoxon rank-sums test. The coefficients of variation for P_{mrr}, P_{PY}, and P_{slt} were measured as SE/$\bar{x}$. An ANOVA was used to test for differences in the coefficients of variation for the P_{mrr}, P_{PY}, and P_{slt} estimates. When needed to meet test assumptions, data were logarithmically transformed using SAS software. All statistics are reported as $\bar{x}$ ± SE with significance set at $P \leq 0.05$.

Results

A total of 58 and 878 Karner blue butterflies were counted on 32 PY and 492 SLT surveys respectively. The distribution of the perpendicular distance estimates for both methods approximated a half-normal distribution (Figure 1). Mean perpendicular distance for PY (1.47 ± 0.12) was slightly higher than that for SLT surveys (1.36 ± 0.07) but not significantly ($P > 0.05$). MRR surveys resulted in 1,487 marked individuals with a recapture rate of 27.8% with recaptures pooled by sex and population. Confidence intervals could be determined for only 59.5% of the P_{mrr} estimates because of small sample sizes (Table 1).

Karner blue butterfly abundance (PI) was most strongly correlated ($r = 0.90$; $p = 0.0001$; $n = 15$) with population estimates derived from the Pollard-Yates surveys (P_{PY}) (Table 1). P_{slt} provided the second best correlation ($r = 0.72$; $p = 0.0011$; $n = 17$) with PI, followed by P_{mrr} ($r = 0.66$; $p = 0.0001$; $n = 42$) (Table 1). With data pooled by date, P_{PY} and P_{slt} estimates were not significantly different. P_{mrr} had the highest mean coefficient of variance (0.57 ± 0.31) followed by P_{PY} (0.54 ± 0.09) and P_{slt} (0.50 ± 0.24) although these differences were not significant.

Of the 427 recaptures, 90.5% occurred within seven days of the original capture date (Figure 2). The mean number of days between original capture and final capture dates was 3.59 ± 0.18. One female was recaptured 19 days after her original capture, and two males were recaptured 15 days after their original capture.

Discussion

PY surveys provided the most accurate population estimate based on correlations with PI. Straight-line transect surveys pro-

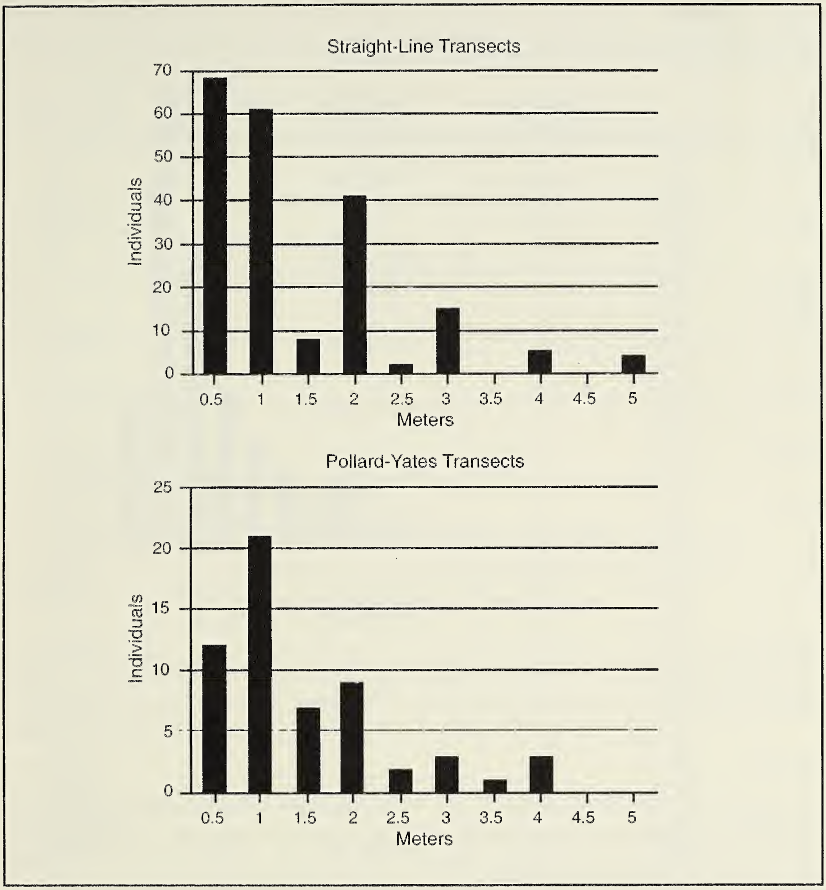


Figure 1. Distribution of perpendicular distance estimates from transect to Karner blue butterflies (*Lycaeides melissa samuelis* Nabokov) on the Necedah Wildlife Management Area, Juneau County, Wisconsin.

vided less accurate and variable estimates but the estimates were not significantly ($P \leq 0.05$) less variable. Mark-release-recapture surveys provided the least accurate population estimates. Further complicating the interpretation of P_{mrr} estimates was the lack of confidence intervals around some of those estimates. Proper testing of MRR data is precluded by the fact that only one population estimate is provided per site and day, which limits comparisons to correlation analysis. Another concern about the use of MRR with Karner blue butterflies is that individuals not only leave populations, they come back fre-

Table 1. Population estimates for three Karner blue butterfly (*Lycaeides melissa samuelis* Nabokov) populations on the Necedah Wildlife Mangagement Area, Juneau County, Wisconsin.

			Method		
Date	*Population*	*Population Index (PI)*	*Straight-line Transects (n)*	*Pollard-Yates Transects (n)*	*Mark-release-recapture*
July 20	NRYN	70	2,174± 339 (15)		195
	SRYN	11	121± 49 (12)	32	30 ± 27
	ERYN	16			16
July 21	NRYN	81			326± 108
	SRYN	10	79± 27 (32)	0	169
	ERYN	2	130± 130 (43)		2
July 22	SRYN		13± 13 (12)	96	
July 23	SRYN		0± 0 (12)	0	
July 24	NRYN	90			464± 143
	SRYN	19	40± 29 (12)	32	58± 44
	ERYN	6			6
July 25	NRYN	102			436± 97
	SRYN	28	94± 37 (12)	96	280± 244
	ERYN	15			64
July 26	NRYN	128			540± 121
	SRYN	31	27± 18 (12)	129	341± 272
	ERYN	9			24± 20
July 27	NRYN	78	1,104± 325 (15)	2,123	617± 175
	SRYN	41	134± 74 (12)	161	275± 157
	ERYN	14			35± 40
July 28	NRYN	96			922± 280
	SRYN	35	252± 63 (20)	306± 163 (3)	277± 163
	ERYN	10	309± 138 (43)	0± 0 (2)	10
July 31	NRYN	86			826± 250
	SRYN	47			212± 96
	ERYN	8			8
August 1	NRYN	71			552± 142
	SRYN	7			128± 96
	ERYN	6			36
August 2	NRYN	56			775± 248
	SRYN	68			225± 86
	ERYN	67			36
August 3	NRYN	77			493± 133
	SRYN	28	27± 18 (12)	32	491± 407
	ERYN	3			3
August 4	NRYN	96	830± 184 (15)	620	259± 98
	SRYN	32	173± 33 (20)	197± 90 (4)	193± 211
	ERYN	2	139± 72 (43)	0± 0 (2)	2
August 7	NRYN	21			778± 879
	SRYN	13	54± 36 (12)	0	52
	ERYN	1			1
August 8	NRYN	7			16
	SRYN	6	54± 30 (12)	0	6
	ERYN	0			0
August 9	SRYN		67± 24 (12)	161	
August 10	SRYN		94± 42 (12)	161	
August 11	SRYN		36± 13 (32)	73± 46 (4)	
	ERYN		0± 0 (43)		
August 15	NRYN		38± 38 (15)	100	
	SRYN		27± 18 (12)	0	

*Population estimates ± SE. Sample sizes are 1, regardless of method, unless otherwise indicated.

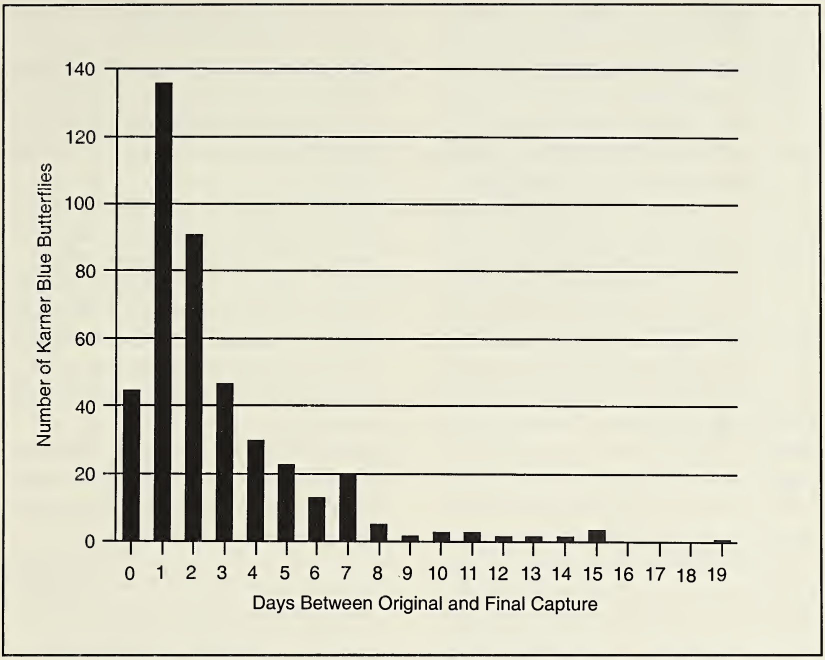


Figure 2. Days between original and final capture dates for Karner blue butterflies (*Lycaeides melissa samuelis* Nabokov) on the Necedah Wildlife Management Area, Juneau County, Wisconsin.

quently (King 1998), which is a violation of one underlying assumption of MRR methodology.

The recapture data indicates that seven-day spacing between counts on the same unit provides relative confidence (90.5%) that the same individuals are not counted on subsequent surveys. This is useful as it provides independence, which allows counts to be summed instead of averaged. The lack of significant differences between PY and SLT perpendicular distance estimates demonstrates the robustness of "Distance" methodology, which helps to validate its use for highly visible Lepidoptera like the Karner blue butterfly. Regardless of the method, population estimates employing "Distance" methodology provided more accurate results than MRR methods. More important, PY and SLT surveys provide the opportunity to independently evaluate the effectiveness and accuracy of population estimates as well as develop confidence limits around those estimates. At best, confidence limits can be established around only some MRR population estimates (< 60% during this study). Even if confidence intervals can be determined, MRR requires that they are derived internally and are therefore suspect (Manly 1971, Roff 1973).

The accuracy and reliability (variability) of PY derived estimates is encouraging for those charged with monitoring Karner blue butterfly populations. As with all endangered species, managers must be aware of the status of all Karner blue butterfly populations they manage. Monitoring dozens of populations across a broad geographic range requires a quick but dependable survey method. Of the methods tested during this study, PY counts required the least time/financial investment followed by SLT and MRR. Although clearly biased toward "optimal" habitat, PY surveys provide a quick but accurate means of monitoring Karner blue butterfly populations. This bias toward "optimal" habitat provides flexibility to reroute transects within sites as nectar sources shift throughout the flight, which is an advantage of the PY method. Data obtained from PY surveys are robust, require less time, and best describe population fluctuations. PY surveys can answer local questions about habitat management or individual population fluctuations but can also answer rangewide, recovery questions that require intersite comparisons (Thomas 1983, Pollard and Yates 1993, Swengel 1996).

Acknowledgments

I thank C. Bosely, J. Black, C. Minch, R. Burger, and J. Johnson for their work as field assistance. This study was partially funded be the National Fish and Wildlife Foundation. I thank P. Stangel of the Foundation for his assistance. Special thanks to J. Brown for comments on the manuscript and calculations of the effective strip widths. Helpful comments on this manuscript were provided by D. Andow, M. Boyce, C. Lane, C. Carnes, C. Bleser, D. Schweitzer, R. Power, A. Swengel, R. Grundel, R. Dana, and several anonymous reviewers.

Literature Cited

Andow, D. A., C. P. Lane, and R. J. Baker. 1994. Karner blue butterfly: a symbol of a vanishing landscape. University of Minnesota, Miscellaneous Publication 84–1994. 222 pp.

Begon, M. 1983. Abuses of mathematical techniques in ecology: applications of Jolly's capture-recapture method. *Oikos* 40:155–58.

Bidwell, A. 1995. Karner blue butterfly *(Lycaeides melissa samuelis)* dispersal and habitat distribution at Fort McCoy Military Reservation, Wisconsin. Masters Thesis. University of Wisconsin-Stevens Point, Stevens Point, WI. 109 pp.

Brown, J. A., and M. S. Boyce. 1998. Line transect sampling of Karner blue butterflies *(Lycaeides melissa samuelis). Environmental and Ecological Statistics* 5:81–91.

Buckland, S. T., D. R. Anderson, K. P. Burnham, and J. L. Laake. 1993. *Distance sampling: estimating abundance of biological populations.* Chapman & Hall. New York, NY.

Clough, M. W. 1992. Endangered and threatened wildlife and plants: determination of endangered status for the Karner blue butterfly. *Federal Register* 57:59236–244.

Douwes, P. 1970. Size of, gain to and loss from a population of *Heodes virgaureae* L. (Lep., Lycaenidae). *Entomologica Scandinavica* 1:263–81.

Douwes, P. 1976. An area census method for estimating butterfly population numbers. *The Journal of Research on the Lepidoptera* 15:146–52.

Fried, C. S. 1987. Dispersal of the Karner blue butterfly (*Lycaeides melissa samuelis* Nabokov) in the Albany Pine Bush. Unpublished Report. Endangered Species Unit, New York Department of Environmental Conservation.

Gall, L. F. 1985. Measuring the size of Lepidopteran populations. *The Journal of Research on the Lepidoptera* 27:97–16.

King, R. S. 1998. Dispersal of Karner blue butterflies (Lycaeides melissa samuelis Nabokov) at Necedah National Wildlife Refuge. *Transactions of the Wisconsin Academy of Sciences, Arts and Letters* 86:101–10.

Lawrence, W. S., and A. C. Cook. 1989. The status and management of Karner blue *(Lycaeides melissa samuelis)* populations in the Allegan State Game Area, Michigan. Unpublished Report. The Nature Conservancy, Michigan Field Office.

Manly, B. F. J. 1971. A simulation study of Jolly's method for analyzing capture-recapture data. *Biometrics* 27:415-424.

Packer, L. 1987. Status report on the Karner blue butterfly, *Lycaeides melissa samuelis* Nabokov, in Ontario. Committee on the Status of Endangered Wildlife in Canada. 65 pp.

Pollard, E. 1977. A method for assessing changes in the abundance of butterflies. *Biological Conservation* 12:115–34.

Pollard, E., and T. J. Yates. 1993. *Monitoring butterflies for ecology and conservation.* Chapman & Hall, London.

Pollock, K. H., J. D. Nichols, C. Brownie, and J. E. Hines. 1990. Statistical inference for capture-recapture experiments. *Wildlife Monographs* 54:1. 95 pp.

Roff, D. A. 1973. On the accuracy of some mark-recapture estimators. *Oecologia* 12:15–34.

Schweitzer, D. F. 1994. Prioritizing Karner blue butterfly habitats for protection activities. Pp. 173–84 *in* D. A. Andow, C. P. Lane, and R. J. Baker. Karner blue butterfly: a symbol of a vanishing landscape. University of Minnesota, Miscellaneous Publication 84-1994. 222 pp.

Sferra, N. J., D. N. Ewert, C. A. Clampitt, H. E. Ballard, J. M. Aguiar, and T. Darnell. 1993. Management of oak savanna and oak barrens habitat in Newaygo and Muskegon Counties, Michigan. Unpublished Report. The Nature Conservancy, Michigan Field Office.

Swengel, A. B. 1996. Effects of fire and hay management on abundance of prairie butterflies. *Biological Conservation* 76:73–85.

Thomas, J. A. 1983. A quick method of estimating butterfly numbers during surveys. *Biological Conservation* 27:195–211.

Warren, M. S. 1981. The ecology of the wood white butterfly *Leptidea sinapis* L. Ph.D. Thesis, University of Cambridge.

Warren, M. S. 1987. The ecology and conservation of the heath fritillary butterfly, Mellicta athalia. III. Population dynamics and the effects of habitat management. *Journal of Applied Ecology* 24:499–513.

Warren, M. S., E. Pollard, and T. J. Bibby. 1986. Annual and long-term changes in a population of the wood white butterfly, *Leptidea sinapis. Journal of Animal Ecology* 55:707–19.

Welch, R. J. 1993. Dispersal and colonization behavior in the Karner blue butterfly *(Lycaeides melissa samuelis)* in central Wisconsin. Unpublished Report. U.S. Fish and Wildlife Service, Green Bay Field Office.

Richard King is the staff biologist at the Necedah National Wildlife Refuge. His research currently focuses on the eastern massasauga, Karner blue butterfly, savanna ecology, and fire dynamics. Address: Necedah National Wildlife Refuge, W7996 20th Street West, Necedah, WI 54646-7531. Email: richard_s_king@fws.gov

James M. Omernik, Shannen S. Chapman,
Richard A. Lillie, and Robert T. Dumke

Ecoregions of Wisconsin

Abstract *Ecoregions are geographical areas within which the biotic and abiotic components of terrestrial and aquatic ecosystems exhibit different but relatively homogeneous patterns in comparison to that of other areas. As such these regions serve as a framework for ecosystem management in a holistic sense and allow integration of assessment and management activities across state and federal agencies that may have different responsibilities and missions for the same geographic areas. Most of the spatial frameworks of Wisconsin that are termed ecoregions or have been used for environmental management in the state were designed to address specific aspects of resource management. In a collaborative effort with various state and federal agencies, we have attempted to define a framework to meet broader ecosystem management needs that consider both the terrestrial and aquatic components as well as the human influences and associations with other ecosystem characteristics that affect management potentials for land and water resources. The "Ecoregions of Wisconsin" consist of 27 level IV regions nested within six larger level III regions that also occupy portions of adjoining states. We provide a brief description of the primary distinguishing characteristics (such as soils, vegetation, climate, geology, physiography, water quality, hydrology, and land use) within each level III and IV ecoregion, and discuss the potential applications of the ecoregion map in context of current and future directions of ecosystem management in Wisconsin.*

Ecoregions denote areas of general similarity in ecosystems and in the type, quality, and quantity of environmental resources; they are designed to serve as a spatial framework for the research, assessment, monitoring, and management of ecosystems and ecosystem components. Special purpose maps of characteristics such as plant communities, water quality, soils, and fish distributions are necessary and have long been used for dealing with specific research and management problems. Ecoregions, on the other hand, portray areas within which there is similarity in the mosaic of all biotic and abiotic components of both terrestrial and aquatic ecosystems. Recognition, identification, and delineation of these multipurpose regions are critical for structuring and implementing integrated management strategies across federal, state, tribal, and local governmental agencies that are responsible for different types of resources within the same geographical areas.

Several spatial frameworks that either are termed ecoregions or are used for environmental resource management have been developed for Wisconsin. Most, however, were designed to address specific aspects of resource management rather than ecosystem management in a holistic sense. Others were not refined or subdivided adequately to meet the needs of integrated resource assessment and management across agency and program lines. The purpose of this paper is to present a mapped framework of ecological regions designed to address these broader needs. These regions are intended to complement rather than replace the more specific ecological classifications systems, which may remain more effective for the particular subjects they were designed to address.

Historical Definition and Use of Ecoregions of Wisconsin

Although there is general agreement on the need for an ecoregion-type framework for the research, assessment, and management of environmental resources in Wisconsin, there is considerable disagreement over which framework is the most appropriate. The most popular of the several spatial frameworks that cover Wisconsin are those developed by the U.S. Department of Agriculture (USDA) Forest Service (Bailey et al. 1994, Keys et al. 1995), Albert (1995), and the U.S. Environmental Protection Agency (EPA) (Omernik 1987, 1995a; EPA 1999). The Forest Service and EPA frameworks are national or international in scope and are still undergoing development. Prior to the development of the Forest Service and EPA ecoregion maps, resource managers in Wisconsin used a number of mapping schemes to associate, describe, classify, and otherwise assemble the terrestrial and aquatic resources of Wisconsin into somewhat homogeneous groupings. These included works by Martin (1916) depicting geographical provinces, Finley's (1976) original vegetation cover map, Poff's (1970) hydro-chemical lake regions, and the map of total phosphorus in lakes in Minnesota, Wisconsin, and Michigan (Omernik et al. 1988). The more recently developed map of "natural divisions of Wisconsin" (Hole and Germain 1994) has also been used. These conceptual organizations of Wisconsin's landscape, together with many other special purpose maps (e.g., geology, soils, current vegetation, and land use), were precursors to, and were used in the compilation of, the map presented in this paper.

Titled "Regional landscape ecosystems," the mapped classification by Albert (1995) was based largely on patterns of climate, geology, physiography, and soil, as well as the "natural regions" of Hole and Germain (1994), which were heavily based on potential natural vegetation and soils. The portion of the current Forest Service's National Hierarchy of Ecological Units (Keys et al. 1995) that covers Wisconsin was derived from the work of Albert (1995) and the national classification developed by Bailey

(1976). The Forest Service classification was initiated by Bailey (1976) and was fairly consistent across the country regarding scale, level of detail, and its hierarchical approach. The revised Forest Service framework (Bailey et al. 1994, Keys et al. 1995) was compiled by different regional and/or state groups and reflects spatial inconsistencies because of the different perspectives, approaches, and backgrounds of the different individuals or groups who have conducted the work. For Wisconsin, both Albert's and the Forest Service's classifications are weighted toward terrestrial ecosystems and forest management uses. Consideration of patterns of land use and aquatic characteristics was relatively unimportant in the development of either of these classifications. This apparent lack of attention to land use and water resource characteristics is viewed by some resource managers as a weakness in these frameworks. Conversely, the inclusion of land use and water resource characteristics into the EPA framework is sometimes viewed as a bias by terrestrial resource managers. This difference in perspectives among user groups is the foundation for a continuing debate and emphasizes the need for further dialog and evolution of all frameworks.

The EPA framework, of which the map of Level III and IV Ecoregions of Wisconsin (Figure 1) is a part, is based on the belief that ecological regions can be determined by identifying areas within which there is coincidence in patterns of geographic phenomena, natural and human-related, that reflect spatial differences in ecosystems and their components. This approach also recognizes that the relative importance of each of these phenomena (which include geology, physiography, vegetation, climate, soils, land use, wildlife, and hydrology) varies from one region to another regardless of scale or hierarchical level. To avoid confusion with other meanings for different hierarchical levels of ecological regions a Roman numeral classification was adopted for the EPA maps and a North American ecological region framework of which they are a part (Commission for Environmental Cooperation [CEC] 1997). As with other similar state and regional mapping efforts, the process used to compile this new map of level III and IV ecoregions of Wisconsin was collaborative, involving numerous individuals representing several government agencies.

The major differences between this map of ecoregions of Wisconsin and those by the Forest Service and Albert lie in their methods of compilation and their intended use. Whereas the focus of the compilation of the maps by the Forest Service and Albert was on depicting regions in the terrestrial landscape that might exist in the absence of humans, the intent of this map is to show patterns of the entire ecosystem, biotic and abiotic, terrestrial and aquatic, with humans being considered as a biotic component. Until only recently, most attempts to define ecological regions did not consider patterns of human use or influence. It is now generally understood that if humans were removed from the planet the mosaic of ecosystem components would not revert to the patterns that existed in the United States before Europeans set foot on the continent or before Native Americans made their impact on the landscape. Too many plants and animals have been removed and introduced, and the land and water have been too drastically modified through activities including mining, urbanization, and channelization. Although the importance of human influence on ecosystems and their patterns is now obvious, the tendency to consider nature as if humans were not part of it seems to have been the norm. Likens (1993) commented that in spite of the fact that humans live in

Level III and IV Ecoregions of Wisconsin

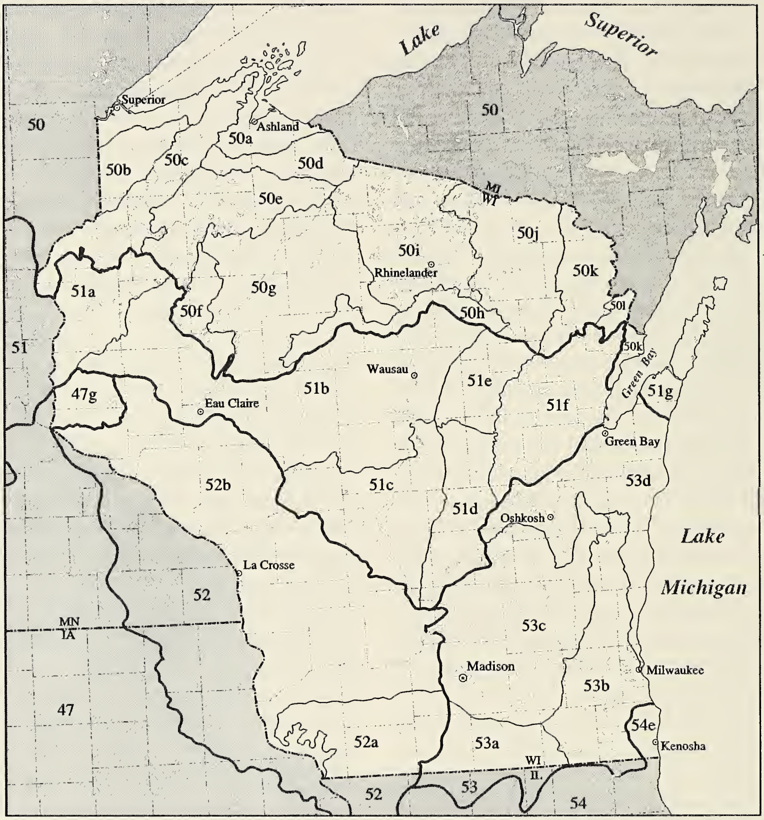


Figure 1

47 Western Corn Belt Plains
47g Prairie Pothole Region

50 Northern Lakes and Forests
50a Lake Superior Clay Plain
50b Minnesota/Wisconsin Upland Till Plain
50c St. Croix Pine Barrens
50d Ontonagon Lobe Moraines and Gogebic Iron Range
50e Chequamegon Moraine and Outwash Plain
50f Blue Hills
50g Chippewa Lobe Rocky Ground Moraines
50h Perkinstown End Moraine
50i Northern Highlands Lakes Country
50j Brule and Paint River Drumlins
50k Wisconsin/Michigan Pine and Oak Barrens
50l Menominee Ground Moraine

51 North Central Hardwood Forests
51a St. Croix Stagnation Moraines
51b Central Wisconsin Undulating Till Plain
51c Glacial Lake Wisconsin Sand Plain
51d Central Sand Ridges
51e Upper Wolf River Stagnation Moraine
51f Green Bay Till and Lacustrine Plain
51g Door Peninsula

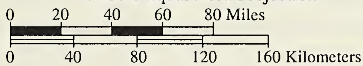
52 Driftless Area
52a Savanna Section
52b Coulee Section

53 Southeastern Wisconsin Till Plains
53a Rock River Drift Plain
53b Kettle Moraines
53c Southeastern Wisconsin Savanna and Till Plain
53d Lake Michigan Lacustrine Clay Plain

54 Central Corn Belt Plains
54e Chiwaukee Prairie Region

Level III Ecoregion
Level IV Ecoregion
State Boundary
County Boundary

Albers Equal Area Projection



Larger scale, color versions of this map can be obtained from Richard Lillie, Wisconsin DNR, Bureau of Integrated Science Services Research, 1350 Femrite Dr., Monona, WI 53716 <lillir@dnr.state.wi.us> or James Omernik, USEPA, 200 SW 35th St., Corvallis, OR 97333 <omernik@mail.cor.epa.gov>. Information on electronic coverages of the map is also available from the authors.

and among ecosystems, ecologists have avoided making detailed and rigorous analyses of the effects of human activities on ecosystems and have sought out pristine or remote areas for their study. Some have stated that, at least for environmental policy, humans should *not* be considered as a biotic component of ecosystems (Udo de Haes and Klijn 1994). However, humans have clearly had an effect on the regional capacities of ecosystems (Holling 1994). As Meeus (1995) has written, "In the course of time each culture leaves behind its own landscape."

It has been argued that the Forest Service map depicts patterns in terrestrial ecosystems and that the EPA maps, including this one of Wisconsin, reflect patterns in aquatic ecosystems, and that there is a need for separate frameworks for both types of systems. We believe that this argument is flawed for at least two reasons. First, a truly holistic approach to ecosystem management should not consider the aquatic and terrestrial ecosystems separately. "An 'ecosystem approach' recognizes that ecosystem components do not function as independent systems, rather they exist only in association with one another" (Omernik and Bailey 1997). Second, the approach used to define the EPA maps, including this one of Wisconsin, was not focused solely on aquatic systems, nor did it only consider patterns in lake density and quality in the map compilation process. Just as patterns of bedrock geology and physiography are of prime importance in defining level IV ecoregions in the Appalachians, surficial geology and soils are key components in Iowa, and elevational banding is critical in the mountains of the western United States, for parts of the country that are covered by high densities of natural lakes, such as in most of Wisconsin, patterns in lake quality are extremely helpful in revealing ecological regions. In order to define meaningful ecoregion boundaries in these types of areas it is important to recognize differences in lake density and quality with differences in many causal and reflective characteristics, including soils, surficial geology, physiography, climate, land use, and vegetation.

The Interagency Ecoregion Mapping Effort

A recent U.S. General Accounting Office (GAO) Report to Congress (GAO 1994) documented the need for agency-wide adoption of an ecosystem approach to resource management and the fact that there is no common spatial ecoregion framework to implement the approach. Although the GAO report was primarily directed toward the need for a common federal interagency framework, the report implied the need to involve state agencies as well and stated that effective ecosystem management "will require collaboration and consensus-building among federal and nonfederal parties within the larger national land and natural resource use framework" (GAO 1994). In response to the need to identify or develop a common framework of ecological regions, a National Interagency Technical Team on ecological mapping formed and was responsible for creating a Memorandum of Understanding entitled "Developing a Spatial Framework of Ecological Units of the United States." This Memorandum of Understanding was signed by the heads of all of the federal resource management agencies in 1996. Reaching the objective of the Memorandum of Understanding requires recognition of the differences in the conceptual approaches and mapping methodologies that have been used to develop the most commonly used existing ecoregion-type frameworks, including those developed by the Forest Service (Bailey et al. 1994), the EPA (Omernik 1987, 1995a), and the USDA Natural Resources Conservation Service (USDA 1981). The first task of the interagency effort is to identify ecological regions common to the three existing frameworks that also have meaning to the holistic objective to depict patterns in the mosaic of all ecosystem components, aquatic and terrestrial, as well as biotic and abiotic. These regions will be roughly at the scale of the Level III ecoregions and original Forest Service sections. While debate continues within the National Interagency Technical Team on the strengths and limitations of the different agency frameworks and the value of rule-based (quantitative) and weight-of-evidence (qualitative) approaches to defining ecoregions, the group has developed a draft map of ecological regions at this general level of detail (McMahon et al. in press).

Important to the work and final product of the interagency effort is the understanding that the common framework of ecological regions is not meant to replace many of the existing frameworks, insofar as their uses for specific applications is concerned. Mapped classifications, such as the USDA map of Major Land Resource Areas that was based on aggregations of map units from state soils maps and was originally intended to reflect patterns in soils properties as they relate to agricultural potential, should continue to be used for their specific applications. Likewise, state and regional maps that focus on terrestrial ecosystems for forest management uses will remain important for those purposes. However, for addressing ecosystem management in an integrated fashion across agencies and special interests, an ecoregional classification that reflects spatial patterns in the mosaic of all ecosystem components will be necessary.

Methods

We have defined ecoregions as areas of relative homogeneity in ecological systems and their components. Factors associated with spatial differences in the quality and quantity of ecosystem components, including soils, vegetation, climate, geology, and physiography, are relatively homogeneous within an ecoregion. The relative importance of each characteristic varies from one ecological region to another regardless of the hierarchical level. Level I and level II divide the North American continent into 15 and 51 regions, respectively (CEC 1997). At level III, the continental United States contains 103 regions (EPA 1999). Level IV is a further subdivision of the level III ecoregions. Wisconsin contains six level III (Figure 2) and twenty-seven level IV ecoregions (Figure 1). The level III descriptions contain some general characteristics of the region, emphasizing the features that make the ecoregion unique from surrounding regions. Level IV descriptions emphasize the important characteristics that make the region different from other ecoregions within the same level III ecoregion.

The approach used to compile this Wisconsin map is based on the premise that ecological regions can be identified through the analysis of the patterns of biotic and abiotic phenomena that reflect differences in ecosystem quality and integrity (Wiken 1986; Omernik, 1987, 1995a). The process of defining the ecological regions involved collaboration with local experts and began with a data collection meeting held in Madison at which time ecoregionalization methods, existing regional frameworks, and other relevant source material were discussed. Based on the approaches outlined in Omernik (1987, 1995a, 1995b) and Gallant et al. (1989, 1995) and the materials


Level I Ecoregions of the Conterminous United States
5 Northern Forests
6 Northwestern Forested Mountains
7 Marine West Coast Forests
8 Eastern Temperate Forests
9 Great Plains
10 North American Deserts
11 Mediterranean California
12 Southern Semi-Arid Highlands
13 Temperate Sierras
15 Tropical Wet Forests
Level II Ecoregions of the Mid-Western United States
5.2 Mixed Wood Shield
8.1 Mixed Wood Plains
8.2 Central Plains
8.3 Southeastern Plains
8.4 Ozark, Ouachita-Appalachian Forests
9.2 Temperate Prairies
Adapted from Ecological Regions of North America (CEC 1997).

Figure 2

and ideas provided by state and local collaborators and other experts, a draft map of level III and IV ecoregions of Wisconsin was developed and circulated among many of the attendees of the first meeting. A second meeting was then held in Central Wisconsin to receive reviewer comments on the draft map and attempt to reach consensus on boundary delineations among the collaborators.

Unlike most of the other similar state and regional efforts to map level III and IV ecoregions, consensus was not reached among those invited to collaborate or confer in this project to map ecoregions of Wisconsin. The reasons for this became clear at the review meeting when the attendees were asked for their comments, suggestions, and concerns regarding the draft map and the method used to compile it. Although 70% or more of these people were comfortable with the product and approach, the remainder were not in agreement, generally for one or more of the following reasons: (1) a concern that the "weight-of-evidence" method used to compile the map was inappropriate and that a quantitative approach should have been used instead; (2) a belief that the map represented aquatic systems and that there should be separate frameworks for terrestrial and aquatic systems; (3) a belief that there should be separate frameworks for aquatic and terrestrial systems and that the aquatic framework should be based on watersheds and/or hydrologic units (see Seaber et al. 1987); (4) a concern that the "tension line" (Curtis 1978) had not been followed in defining the regions; and (5) a concern that patterns of present or past land use should not be used as a tool in defining ecoregions.

The differences in perceptions over how to map ecological regions in Wisconsin as well as at the national level were not surprising given the general lack of agreement on the definitions of ecosystems (Gonzalez 1996) and ecosystem management (Lackey 1998), the disagreement over whether ecosystems are abstract concepts or areas with geographical borders (Rowe and Barnes 1994, Blew 1996, Marin 1997, Rowe 1997), and the history of debate over regionalization and whether quantitative or qualitative techniques are more appropriate for the task (see for example Grigg 1967 and Hart 1982). However, acceptance of the approach used to develop the map of ecological regions of Wisconsin has grown. Consensus has been reached across state and federal agencies in a growing number of states (e.g., Pater et al. 1998, Woods et al. 1999, Chapman et al. in review), and the framework is being used or is being strongly considered for use for many national resource management activities, including the development of biological criteria in surface waters (Davis et al. 1996), the development of nutrient criteria in streams (EPA 1998), and the planning, implementation, and evaluation of bird conservation (USFWS 1999).

We stress that the purpose of this paper is not to tout the advantages of one framework or approach over another, but rather to provide another step in the process of thoughtfully pursuing the debate on and advancement of the definition of ecosystems, the delineation of ecological regions, and ultimately more effective ecosystem management.

Descriptions

The naming of level III and level IV ecoregions was intended to associate place names with a key landscape characteristic descriptive or unique to the region. Consequently, the ecoregion names (and the map) serve an educational purpose by relating public perceptions to the environment, thus playing on the concept of "place" and allowing a connection to be made between ecoregions and the general public.

47. Western Corn Belt Plains

Once covered with tall-grass prairie, over 75% of the Western Corn Belt Plains is now used for cropland agriculture, and much of the remainder is in forage for livestock. A combination of nearly level to gently rolling till plains and hilly loess plains, an average annual precipitation of 63–89 cm, which occurs mainly in the growing season, and fertile, warm, moist soils make this one of the most productive areas of corn and soybeans in the world. Surface and groundwater contamination from fertilizer and pesticide applications as well as livestock concentrations are a major concern for this ecoregion.

The northeastern corner of the Western Corn Belt Plains (47) is a loess-covered till plain and extends into a small area in western Wisconsin and borders the northern boundary of the Driftless Area (52). The fertile prairie soils and gentle topography of this area contributes to more intensive agriculture than in the adjacent North Central Hardwood Forests (51) and Driftless Area (52) ecoregions.

47g. Prairie Pothole Region. The Prairie Pothole Region (47g) is characterized by smooth to undulating topography, productive prairie soils, and loess- and till-capped dolomite bedrock. The potential natural vegetation (PNV) is predominantly tall grass prairie with a gradual transition eastward to more mixed hardwoods, distinguishing 47g from the greater concentration of mixed hardwoods of both 51a to the north and 51b to the east, and the mixed prairie and oak savanna of 52b to the south.

50. Northern Lakes and Forests

The Northern Lakes and Forests (50) is an ecoregion of relatively nutrient poor glacial soils, coniferous and northern hardwoods forests, undulating till plains, morainal hills, broad lacustrine basins, and areas of extensive sandy outwash plains. Soils are formed primarily from sandy and loamy glacial drift material and generally lack the arability of those in adjacent ecoregions to the south. Ecoregion 50 also has lower annual temperatures and a frost-free period that is considerably shorter than other ecoregions in Wisconsin (NOAA 1974, Hole 1976). These conditions generally hinder agriculture; therefore, woodland and forest are the predominant land use/land cover.

The numerous lakes that dot the landscape are clearer, at a lower trophic state (mostly oligotrophic to mesotrophic with few eutrophic lakes), and less productive than those in ecoregions to the south. Streams of ecoregion 50 are mostly perennial, originating in lakes and wetlands; however, stream density is relatively low compared to ecoregions to the south. The Northern Lakes and Forests region is the only ecoregion in Wisconsin where acid sensitive lakes are found. Portions of the southern boundary of ecoregion 50 roughly correspond to the southernmost extent of lakes with alkalinity values less than 400 μeq/l (Omernik and Griffith 1986).

50a. Lake Superior Clay Plain. The Lake Superior Clay Plain (50a) is a flat to undulating lake plain and outwash lowland. The soils of 50a are generally calcareous red clays with organic deposits in swampy areas. A dearth of lakes along with a somewhat milder climate and longer growing season, due to the climate amelioration by Lake Superior, differentiates 50a from surrounding ecoregions. Land use in 50a is predominantly woodland with some limited agriculture of hay, small grains, and apples on Bayfield Peninsula, distinguishing 50a from most other level IV ecoregions in Northern Lakes and Forests (50) where the land use/ land cover is predominantly forest and woodland. Ecoregion 50a has a PNV of boreal forest (although somewhat different than boreal forests to the north), unlike the pine barrens and pine forests of 50c, the mosaic of pine and birch in 50b, and the northern mesic forest of 50e.

50b. Minnesota/Wisconsin Upland Till Plain. The Minnesota/Wisconsin Upland Till Plain (50b) is an undulating stagnation and ground moraine plain, with broad areas of hummocky, acid, loamy and sandy till and outwash. Ecoregion 50b has fewer lakes than ecoregions to the east, but a greater lake density than ecoregion 50a to the north. Extensive wetlands—in areas of poorly drained soils, peat over acid sedge and woody peat soils—are scattered throughout the ecoregion and are common in hummocky areas. The till plain of 50b supports a PNV mosaic of red and white pine, conifer swamps, and aspen/white birch/pine forests. Woodland and forest cover the majority of the ecoregion, although there is some limited agriculture with feed-grains and potatoes as the main crops. This region also has one of the lowest densities of roads in the state.

50c. St. Croix Pine Barrens. The St. Croix Pine Barrens (50c) ecoregion is characterized by mostly jack pine, concentrations of red and white pine forests and barrens, well-drained, pink sandy soils. Ecoregion 50c has a greater concentration of lakes, a higher percentage of clear lakes, and lakes with a lower trophic state than in surrounding ecoregions. The sandy soils and pine barren vegetation distinguishes ecoregion 50c from the silty lake plain and boreal forests of 50a and the till plain and more deciduous forest mosaic of 50b.

50d. Ontonagon Lobe Moraines and Gogebic Iron Range. The rolling to hilly, bedrock-controlled and collapsed moraines consisting of loamy till, much of it shallow over igneous and metamorphic rock, distinguish the Ontonagon Lobe Moraines and Gogebic Iron Range (50d) ecoregion from surrounding regions. Rock outcrops increase from very few in the southern portion of this ecoregion to abundant in the north. Likewise, the topography changes from rolling in the southern portion to hilly in the north. Perennial streams are common, and there are fewer lakes than in ecoregions to the south, but more than adjacent ecoregion 50a. The PNV of 50d is a mosaic of hemlock/sugar-maple/pine forests, swamp conifers, and cedar/hemlock forests. This represents a transition from the boreal forests of ecoregion 50a to the mix of hardwoods and conifer forests of ecoregion 50e. Historic mining of iron and copper occurred along the northern and northwestern edge of this region.

50e. Chequamegon Moraine and Outwash Plain. Irregular plains and stagnation moraines, broad areas of hummocky topography, pitted glacial outwash, numerous kettle lakes, and abundant swamps and bogs characterize the Chequamegon Moraine and Outwash Plain (50e) ecoregion. This region has more poorly developed drainage than ecoregions to the west. The soils are coarse, acid, loamy, and sandy-loam mixed—different from the pink sandy soils of ecoregion 50c and the more rocky and silty soils of ecoregion 50g.

50f. Blue Hills. The Blue Hills (50f) ecoregion is characterized by greater relief and a higher concentration of lakes than most surrounding ecoregions, and it contains lakes with generally lower lake trophic states than those of adjacent ecoregions to the east, south, and southwest. End moraines, hummocky hills and depressions, along with areas of Precambrian intrusives are common to 50f as compared to the predominantly rocky ground moraines in 50g to the east. Periodic outcrops of pink quartzite have influenced the topography of the region. Ecoregion 50f supports a PNV of hemlock/sugar maple/yellow birch, white pine and red pine forests, a transition from predominantly hemlock/sugar maple/pine forests of ecoregions in the east to sugar-maple/basswood/oak forests, oak forests, and prairie vegetation of ecoregion 51 to the west.

50g. Chippewa Lobe Rocky Ground Moraines. Much of the Chippewa Lobe Rocky Ground Moraines (50g) ecoregion is comprised of productive but rocky soils, scattered wetlands, extensive eskers and drumlins, and outwash plains. Ecoregion 50g has a considerably lower density of lakes that generally have higher trophic states than 50e, 50f, 50i, and 50h. The rocky soils of 50g are a contrast to the well-drained loamy soils in 50f and the sandy soils in 50i. Ecoregion 50g also supports a PNV mosaic of northern mesic forest (hemlock/sugar maple/yellow birch/white and red pine) and wetland vegetation (swamp conifers/white cedar/black spruce), as compared to the predominantly red and white pine forest of ecoregion 50i and the much lower hemlock component of ecoregions 50f and 50h.

50h. Perkinstown End Moraine. The Perkinstown End Moraine (50h) ecoregion is characterized by hilly to rolling collapsed moraines with outwash sand and gravel and Precambrian intrusives. Relief in this ecoregion is greater than that of the surrounding regions. The soils of 50h are coarse, loamy, and moderate to well drained, over till, in contrast to the more silty, rocky and poorly drained soils of 50g to the south. In addition, ecoregion 50h has fewer lakes than adjacent level IV ecoregions in the Northern Lakes and Forests (50) ecoregion.

50i. Northern Highlands Lakes Country. The Northern Highlands Lakes Country (50i) ecoregion is distinguished from surrounding ecoregions by pitted outwash, extensive glacial lakes (many of which are shallow), and wetlands. In contrast to other ecoregions in the Northern Lakes and Forests (50) ecoregion, Ecoregion 50i contains a much higher density of lakes of generally lower trophic state and lower alkalinity values (hence, greater sensitivity to acidification). The region has soils that are more gravelly, sandy, well to excessively drained, and developed in deep, acid drift. Ecoregion 50i supports a PNV of white and red pine forests, some pine barrens, and jack pine to the south, unlike the predominantly hardwood forests of surrounding ecoregions.

50j. Brule and Paint Rivers Drumlins. The Brule and Paint Rivers Drumlins (50j) ecoregion has extensive eskers and drumlinized ground moraines, pitted and unpitted outwash, wetlands, large glacial lakes, and a lower density of lakes than in adjacent ecoregion 50i. Lake trophic state is very low with a higher percentage of oligotrophic and mesotrophic lakes than most Level IV ecoregions in the Northern Lakes and Forests (50) ecoregion. Soils of the region range from fine to coarse, poor to well drained, and loamy and silty with extensive organic deposits, differing from the sandy, more acid soils in adjacent ecoregions. The PNV is sugar-maple/basswood forest and hemlock/sugar-maple forest, as compared to the more coniferous forests of 50i and the pine and oak barrens of 50k.

50k. Wisconsin/Michigan Pine and Oak Barrens. Irregular outwash plains and moraines, sandy and sandy-loam soils over outwash, sandy and loamy till, and peat deposits in depressions characterize the Wisconsin/Michigan Pine and Oak Barrens (50k) ecoregion. The features are a contrast to the extensive eskers and drumlins, and more loamy and silty soils of adjacent ecoregion 50j. Also, unlike the hardwood forests of ecoregion 50j to the west, 50k supports a PNV of white/red pine forests, jack pine forests, and oak forests and barrens. Land use in 50k is predominantly woodland, although some mixed agriculture is found. More frost-free days occur in 50k than in adjacent eastern ecoregions, due to the ameliorating effect of Lake Michigan and Green Bay, contributing to the greater agricultural component of the land cover/land use. In addition, 50k has more shallow bedrock than surrounding regions, with areas of exposed Precambrian basalt and granite.

50l. Menominee Ground Moraine. The Menominee Ground Moraine (50l) ecoregion is characterized by an undulating ground moraine with drumlins and swamps. The uplands consists of loamy soil over calcareous loamy till (some over dolomite); the lowland areas are muck. The region is dominantly woodland and woodland swamp, but there is a significant agricultural presence. PNV of the region is beech/sugar maple/hemlock and swamp conifer, a contrast to the white/red pine, jack pine, and oak forests of neighboring 50k.

51. North Central Hardwood Forests

The North Central Hardwoods Forests (51) ecoregion is transitional between the predominantly forested Northern Lakes and Forests (50) and the agricultural ecoregions to the south. Nearly level to rolling till plains, lacustrine basins, outwash plains, and rolling to hilly moraines comprise the physiography of this region. The land use/land cover in this ecoregion consists of a mosaic of forests, wetlands and lakes, cropland agriculture, pasture, and dairy operations. The growing season is generally longer and warmer than that of ecoregion 50 to the north, and the soils are more arable and fertile, contributing to the greater agricultural component of the land use. Lake densities are generally lower here than in the Northern Lakes and Forests, and lake trophic states tend to be higher, with higher percentages in eutrophic and hypereutrophic classes. Stream density is highly variable, with some areas having virtually no streams—in wetland and kettle terrain—to others with high densities of perennial streams.

51a. St. Croix Stagnation Moraines. The St. Croix Stagnation Moraines (51a) is a region of ground and stagnation moraines with broad irregular areas of hummocky topography. Soils are silty and loamy, with sandy loamy till commonly underlain by a substratum of acid sand and gravel glacial outwash. There are more lakes in 51a than in ecoregions to the east and south, and lake trophic states, although generally higher than in the region to the north, are lower than in the bordering ecoregion to the southeast. Land use in this region is a mix of agriculture and woodland, in contrast to the mostly woodland and forest land cover of ecoregions to the north, and the greater amounts of agriculture in ecoregions to the southeast. The PNV of 51a ranges from aspen/birch/pine forest, oak-maple forests, and sugar-maple/birch/pine forests and represents a transition from the pines of 50b to the tall grass prairie and oak forests of 47g.

51b. Central Wisconsin Undulating Till Plain. The Central Wisconsin Undulating Till Plain (51b) ecoregion has a greater percentage of agricultural land use than adjacent Ecoregion 51a. The land cover mosaic of woodland and agriculture includes large areas of cropland that produce silage corn, oats, barley, and some apples. Ecoregion 51b has fewer lakes, with higher trophic states, than adjacent level IV ecoregions in ecoregion 51. The undulating to rolling irregular plains of sandy loam till and outwash sands also distinguish this ecoregion from the stagnation moraines of ecoregion 51a to the west and the lacustrine sand plains of ecoregion 51c to the south. This ecoregion ranges from areas in the far east that are underlain with igneous metamorphic rock outcrops to areas in the west and southwest that are underlain by sandstone and shale, which also outcrops with sandstone, comprising roughly 70% of the total area. The region supports a transitional PNV mosaic of oak, hemlock/sugar maple/yellow birch, and white pine/red pine forests in the north, and more sugar maple/basswood/ oak forests to the south.

51c. Glacial Lake Wisconsin Sand Plain. Compared to adjacent ecoregions, the Glacial Lake Wisconsin Sand Plain (51c) is an area of little relief. The droughty outwash, lacustrine, and slope wash sands, sand buttes, and stream bottom and wetland soils support a PNV of jack pine/scrub-oak forests and barrens, along with sedge meadows and conifer swamps, which characterize this flat sandy lake plain. This PNV is in contrast to the predominantly white and black oak vegetation of ecoregion 51d. The region is also distinguished by its more extensive wetlands and a lack of natural lakes. Most of the existing lakes have been constructed for use in cranberry production. Land use in this region consists of woodland and agriculture with crops including mainly cranberries, strawberries, and potatoes.

51d. Central Sand Ridges. The Central Sand Ridges (51d) ecoregion has the highest density of lakes with the lowest trophic states of all level IV ecoregions in the North Central Hardwood Forests (51). Pitted glacial outwash with extensive eskers and drumlins, ice contact deposits, rolling ground moraines, and steep end moraines distinguish this region from the flat lake plain of adjacent ecoregion 51c. The dry, sandy, and loamy till soils of the region support a PNV of oak savanna (white oak, black oak, and bur oak) with areas of sedge meadows, unlike the wetland vegetation and pine or oak barrens of ecoregion 51c and the mosaic of hemlock/beech/maple forests and mixed conifers of northern ecoregion 51e.

51e. Upper Wolf River Stagnation Moraine. The Upper Wolf River Stagnation Moraine (51e) ecoregion is characterized by the hummocky ground and end moraines and pitted outwash, in contrast to the level till plains of ecoregion 51f to the east and the irregular till plain of ecoregion 51b to the west. This region supports a PNV mosaic of hemlock/beech/sugar-maple, wetland vegetation, and mixed conifers, as compared to the predominantly oak forests of 51d to the south. Land use in 51e is mixed agriculture/woodland with a larger area of intact forest than adjacent level IV ecoregions in the North Central Hardwoods Forests (51). This is due to land use practices within the Menominee Indian Reservation; more forest cover is still intact, and agricultural practices are less significant. The lake trophic state in 51e is generally higher than in 51d to the south.

51f. Green Bay Till and Lacustrine Plain. Green Bay Till and Lacustrine Plain (51f) is a transitional ecoregion characterized by wetlands, a mix of outwash and loamy recessional moraines, with many areas of outwash plains in the northwest, lake plains and ground moraines in the south, and ground moraines throughout the rest of the region. The PNV of the region represents a shift from the predominantly northern hardwoods and conifer swamps along the lake shore to the maple/basswood/oak forests and oak savanna to the south. The red sandy, loamy soils of this ecoregion are similar to some southern areas in the northern Wisconsin/Michigan Pine Barrens (50k); however, due to the generally milder climate (because of proximity to Lake Michigan), the growing season is more favorable and much of the area has been cleared of natural vegetation and replaced by agriculture.

51g. Door Peninsula. The Door Peninsula (51g) ecoregion is a lakeshore region with ground moraines. The longer growing season and shallow fertile, calcareous loamy till soils of this ecoregion support a mixed woodland/agriculture land use. Crops in this ecoregion are mostly orchard and fruit crops, including apples and cherries. The bedrock geology of 51g is shallower than other ecoregions in 51 and consists primarily of Silurian bedrock. In recent years this region has become a popular tourism area.

52. Driftless Area

The hilly uplands of the Driftless Area (52) ecoregion easily distinguish it from surrounding ecoregions. Much of the area consists of a loess-capped plateau with deeply dissected streams. Also called the Paleozoic Plateau, because there is evidence of glacial drift in this region, the glacial deposits have done little to affect the landscape compared to the subduing influences in adjacent ecoregions. Livestock and dairy farming are major land uses and have had a major impact on stream quality. In contrast to the adjacent glaciated ecoregions, the Driftless ecoregion has few lakes, most of which are reservoirs with generally high trophic states, and a stream density and flow that is generally greater than regions to the east.

52a. Savanna Section. Topography in the Savanna Section (52a) of the Driftless Area is different than the rest of the level III ecoregion because of its characteristic broad relatively level ridge tops and narrow steep sided valley bottoms. Elsewhere in the dissected Driftless Area the landform mosaic comprises relatively broad, flat valley bottoms with steep sharper crested ridges or a pattern of nearly equal amounts of flatter areas in the valley bottoms and interfluves. The soils are well drained silty loess over residuum, dolostone, limestone, or sandstone. Land use patterns in the Driftless Area also follow spatial differences in slope; hence, 52a is predominantly agriculture on the uplands and some mixed woodland/agriculture in lowland areas. The PNV of the region is a mosaic of oak forests and savannas, large prairie grassland areas, and some sugar maple/basswood/oak forests. The region is also known for past lead and zinc mining.

52b. Coulee Section. Dissected slopes and open hills with most of the gentle slope on the lowland characterize the Coulee Section (52b) ecoregion. Soils are well drained silty loess over residuum, limestone, sandstone or shale, with soils over quartzite in the Baraboo Hills area. Land use in the region is predominantly mixed agriculture/woodland, with most of the agriculture occurring on the lowlands and more level hilltops. The PNV of ecoregion 52b is a mosaic of oak forests, prairie, with larger areas of sugar maple/basswood/oak forests than in 52a.

53. Southeastern Wisconsin Till Plains

The Southeastern Wisconsin Till Plains (53) ecoregion supports a mosaic of vegetation types and represents a transition between the hardwood forests and oak savannas of the ecoregions to the west and the tall-grass prairies of the Central Corn Belt Plains (54) to the south. Like the Corn Belt Plains (54) ecoregion, land use in the Southeastern Wisconsin Till Plains (53) is mostly cropland, but the crops have historically been largely forage and feed grains to support dairy operations, rather than corn and soybeans for cash crops. The ecoregion has a higher plant hardiness value than in ecoregions to the north and west, a different mosaic of soils than western ecoregions, and flatter topography. There are fewer lakes here than in ecoregions to the north, but considerably more than in the western Driftless Area (52) and the southern Central Corn Belt Plain (47). The region also has a relatively high aquatic species diversity.

53a. Rock River Drift Plain. The Rock River Drift Plain (53a) ecoregion has numerous small creeks, a greater stream density and fewer lakes than in ecoregions to the north and east. Glaciation of this region is much older, late Pliocene-early Pleistocene, than in surrounding ecoregions. The drift mantle is thin and deeply weathered with leached soils developed from a silt-loam cap of loess over glacial drift. Steeper topography and broad outwash plains with loamy and sandy soils also characterize this region.

53b. Kettle Moraines. The Kettle Moraines (53b) ecoregion contains a higher concentration of lakes with lower trophic states than in the rest of the level III ecoregions of the Southeastern Wisconsin Till Plains (53). The soils are clayey to the east, especially along the Lake Michigan shore, and more sandy to the west, but generally less clayey than the soils in ecoregion 53d to the north. The region also contains extensive ground and end moraines and pitted outwash with belts of hilly moraines and generally has greater relief than ecoregion 53d to the northeast.

53c. Southeastern Wisconsin Savanna and Till Plain. The till plains of the Southeastern Wisconsin Savanna and Till Plain (53c) ecoregion support a mix of agriculture (cropland and dairy operations) and woodland. Crops include forage crops to support the dairy operations and a wide range of truck and specialty crops. Most of the original vegetation has been cleared with forested areas remaining only on steeper end moraines and poorly drained depressions. Irregular till plains, end moraines, kettles, and drumlins are common, and wetlands are found throughout the region, especially along end morainal ridges. PNV of this region is transitional with a mosaic of sugar maple, basswood, oak to the east, and an increasing amount of white, black, and bur oak, oak savanna, prairie, and sedge meadows toward the west.

53d. Lake Michigan Lacustrine Clay Plain. The Lake Michigan Lacustrine Clay Plain (53d) ecoregion is characterized by red calcareous clay soil, lacustrine and till deposits, and a flat plain. The topography of this ecoregion is much flatter than ecoregions to the south, and there are fewer lakes, but the lakes have generally higher trophic states than in adjacent level IV ecoregions in (50) and (51). Soils are generally silty and loamy over calcareous loamy till, with muck and loamy lacustrine soils in low-lying areas. Ecoregion 53d has prime farmland with a longer growing season and more fertile soils than surrounding ecoregions. Agriculture has a different mosaic of crops, with more fruit and vegetable crops, than that of ecoregion 53c. The PNV of this region is beech/sugar maple/basswood/red and white oak forests with a greater concentration of beech than other ecoregions in 53.

54. Central Corn Belt Plains

Prairie communities were native to the glaciated plains of the Central Corn Belt Plains, and they were a stark contrast to the hardwood forests that grew on the drift plains of ecoregions to the east. Beginning in the nineteenth century, the natural vegetation was gradually replaced by agriculture. Farms are now extensive on the dark, fertile soils of the Central Corn Belt Plains, mainly producing corn and soybeans, cattle, sheep, poultry, and especially hogs, but are not as dominant as in the drier Western Corn Belt Plains to the west. Agriculture has affected stream chemistry, turbidity, and habitat. The extent of the Central Corn Belt Plains (54) ecoregion in Wisconsin is contained within a small area in the southeastern portion of the state. Land use of the ecoregion continues to change, from exclusively agriculture to a pattern with an increasing amount of urban and industrial land.

54e. Chiwaukee Prairie Region. The Chiwaukee Prairie Region (54e) ecoregion is characterized by intensive agriculture, prairie soils, loess capped loamy till, and lacustrine deposits. The soils of ecoregion 54e are fertile and generally more productive than those of ecoregion 53 to the north and west. The PNV of the Chiwaukee Prairie Region is predominantly tall-grass prairie, in contrast to the southern mesic forest and oak savanna of the adjacent region to the north and west. Most of the natural prairie vegetation of ecoregion 54e has been replaced with cropland or urban and industrial land cover.

Applications

The ecoregion framework outlined in this paper will be particularly supportive of the more holistic approaches to natural resources conservation emerging in Wisconsin because it considers elements of the *entire* ecosystem, terrestrial and aquatic, abiotic and biotic, including humans. These contemporary approaches to environmental stewardship, collectively termed ecosystem management by some practitioners, strive to reconcile the conservation of ecological integrity and biological diversity with the availability of economic opportunities and livable communities. The overall goal is sustainable ecological, social, and economic systems. Ecoregions can provide a framework to which pertinent socio-economic and demographic information may be linked using geographic information systems.

The finding of common ground among socio-economic and ecological considerations is increasingly being undertaken through stakeholder partnerships. Participants in these endeavors generally have diverse interests, values, and technical knowledge; therefore, processes and tools— such as ecological classification systems—developed for these new management approaches should consider this circumstance. The ecoregions defined herein are intended to be broadly understandable and acceptable due to their inclusive nature. Furthermore, they are named with consideration for widespread recognition by resource managers and publics alike. Nonetheless, this ecological framework must be considered dynamic and subject to refinement with ongoing use and increased understanding in the spatial nature of ecosystems.

The Wisconsin Department of Natural Resources (WDNR) prepared a report for its resource managers in May 1995 titled "Wisconsin's Biodiversity as a Management Issue" (WDNR 1995). The report recommended (page 31) that WDNR manage at a landscape scale that involves determining both spatial and temporal scales appropriate to the problem or project and then assessing implications at larger and smaller scales. Furthermore, the WDNR biodiversity report proposed that ecoregions be determined for Wisconsin for use in developing management goals. These goals would "meet a wide variety of diverse ecological and socio-economic needs, including the conservation of biodiversity."

In response to the need to define ecoregion boundaries, in 1998 the agency initiated a project to identify Ecological Landscapes of Wisconsin (WDNR 1999). The ecological landscape units defined in the 1998-99 effort followed the USDA Forest Service's National Hierarchy Framework of Ecological Units and were designed primarily to assist regional and statewide efforts for maintaining and restoring natural communities. However, consideration was also given to broader ecosystem planning and communications applications. Ecological, social, and institutional data plus management opportunities were to be assembled for each of the 17 ecological landscape units. The Ecological Landscapes of Wisconsin map has many similarities (e.g., some boundaries lines and units are similar in position and shape) to the level III and IV ecoregion map presented in this paper, leaving the impression that the two maps are redundant. However, while both maps contain similarities, their differences reflect different origins and purposes. The Ecological Landscape map was designed by the WDNR's Land Ecosystem Management Planning Team for the exclusive purpose of defining "areas similar in ecology and management opportunities." The delineation of area boundaries on the Ecological Landscape map was influenced by a tendency to mesh the map units into the hierarchical units defined in the Forest Service's National Hierarchy mapping system. As mentioned previously, the National Hierarchy mapping was directed primarily towards forestry ecosystems and paid little consideration to land use, hydrology, and water quality, which are of critical importance to aquatic ecosystems. Recognizing the emphasis given to terrestrial ecosystems in their National Hierarchy maps, the Forest Service designed a separate framework for aquatic ecosystems (Maxwell et al. 1995).

The ecoregions described in this paper were, on the other hand, developed to facilitate ecosystem management in a more holistic sense and define regions of similar patterns in the mosaic of terrestrial, aquatic, biotic, and abiotic ecosystem components with humans being considered as part of the biota. The intent was to define "general purpose" regions to allow the various state (and federal) agencies and programs with different interests and missions to integrate their assessment, management, and reporting activities. The framework was not intended to replace narrower or special purpose frameworks or maps that may be better suited for addressing specific issues. Also, the level III and IV ecoregion framework described in this paper will augment the set of ecological landscapes by providing counterpart ecoregions that are more broadly defined and linked to the international framework—Ecological Regions of North America (CEC 1997).

The WDNR has also identified administrative areas termed Geographic Management Units (GMUs), which represent a compromise among ecoregions, watershed management units, and jurisdictional/political boundaries. These GMUs cannot serve the same ecological purposes as a strictly ecological framework but likely have advantages for working collaboratively with stakeholder partnerships. Ecoregions as planning entities tend to encourage ecological thinking, which most often must be then transferred to socio-political contexts for implementation. Effective use of these various spatial networks critically depends on the development of "cross-walking" capability using GIS technologies.

The ecoregions described in this paper

can serve research and education purposes as well as management functions. Ecoregions can provide a basis for the collection and organization of biogeophysical data such as that being contemplated under the new WDNR initiative entitled the Aquatic and Terrestrial Resources Inventory. They can also provide a framework for the development of indices of ecological integrity and other parameters that reveal the status of our landscape. Ecoregions can assist habitat suitability analyses and studies of landscape patterns that look at fragmentation and habitat corridor issues. These investigations can be helpful in designating recovery strategies for threatened and endangered species such as the timber wolf.

Ecoregions can serve an educational function by improving awareness of ecosystem spatial scales and their nested hierarchy. Ecological classification per se helps us appreciate the interconnectedness and dependency among ecosystems and also helps us learn more about the elasticity of ecological systems and their responses to natural and human-induced disturbances. Ecoregions provide a suitable context for deliberations of ecosystem opportunities and limitations plus a basis for identifying future desired conditions expressed as ecosystem goals and objectives. Ecoregion frameworks help provide an understanding of the "big picture" for local initiatives and also the converse; they should be viewed not just as an analytical tool but a tool for learning ecological relationships and concepts.

Management actions can be benefited by the use of ecoregions. The protection and preservation of sensitive areas and critical resources can employ ecoregions as a basis for examining the patterns and distributions of these elements across broad suitable landscapes to avoid actions that cause isolation effects but instead encourage connectedness. Some natural communities such as pine-oak barrens and grasslands occurred in widely distributed units in presettlement Wisconsin. An evaluation of current opportunities can benefit from an assessment of potential sites within the context of their respective ecoregions. Although grassland restoration might be considered in several ecoregions (e.g., Prairie Pothole Region, Savanna Section, Rock River Drift Plain, Kettle Moraines, Southeastern Wisconsin Savanna and Till Plain, and Chiwaukee Prairie Region) based on historic presence, an analysis of opportunities and limitations for the various ecoregions may suggest better potential for building a viable (i.e., sustainable) matrix of grasslands within one or two of these regions. This type of analysis is probably improved by the use of ecoregions that consider land use among their determining factors.

Ecoregions can help structure water resource assessment and management programs in Wisconsin. Watersheds, as landscape units, are generally well understood by various publics and are often used as the basis for water resource programs. Watersheds are critical as research units because they help identify areas of influence on water quality relative to a particular point. However, watersheds seldom correspond to areas within which there is similarity in the factors that cause or reflect differences in the quality and quantity of water (Omernik and Bailey 1997, Griffith et al. 1999). In contrast, ecological regions define areas of similarity in mosaics of these factors and hence depict areas of reduced variability in capacities, potentials, and responses to land management activities. A more refined analysis of the characteristics associated with spatial differences in water quality is yielded by consideration of ecological regions within and across watershed boundaries. Here again the incorporation of land use as a component of this ecological classification system is important to its use in exploring non-point source water quality issues, developing reference site data, defining biogeophysical criteria, and setting goals for watersheds, especially larger units such as the Wisconsin and Mississippi River basins.

In 1999, the Forest Service undertook a reassessment of "roadless areas" and road building in national forests. The protection of roadless areas can impact water quality, biological diversity, forest health, and recreational opportunities. Concerns were raised on how management of the Nicolet-Chequamegon Forest in Wisconsin might be altered by the assessment. The Forest was evaluated under a similar study (RARE—Roadless Area Review and Evaluation) in the 1970s (U.S. Forest Service 1979). A contemporary assessment of opportunities for designation of roadless areas or similar management units such as wilderness or natural areas could involve a look at the size and distribution of potential sites across various ownerships by ecoregions.

We believe that the level III and IV ecoregion map presented herein is the most integrated ecological framework developed for Wisconsin. It is nested within an international system and has excellent potential for structuring environmental monitoring and management activities. Because of its widespread development and comprehensive nature, the framework is particularly suited to multidisciplinary, interagency work. The map can enhance collaborative ecosystem research, monitoring, planning, and management. It can also provide a foundation for conducting bioassessments, establishing environmental standards, and reporting such as the 305(b) Wisconsin Water Quality Assessment Report to Congress (a requirement of the Federal Clean Water Act) and the State of the Natural Resources (an annual report produced by the WDNR to the citizens of Wisconsin.) Clearly, this ecoregion framework has many potential applications, but they will not be realized unless the map is added to the tool kit of Wisconsin resource managers and used along with other tools to meet the challenges of contemporary management of natural resources.

Acknowledgments

We wish to acknowledge the many individuals who provided materials and ideas that were used to distinguish the ecoregions and delineate their boundaries. Particularly deserving of mention is Dave Hvizdak. Jim Addis should be recognized for his help in initiating the project and providing partial support. We thank Darrell Zastrow, Gerald Bartelt, Joe Kovach, Dave Hvizdak, and Gordon Matzke for their critical comments of earlier drafts of the manuscript. Partial support was also provided by the U.S. Environmental Protection Agency Region V REMAP program. The Wisconsin Department of Natural Resources provided additional funding.

Literature Cited

Albert, D.A. 1995. Regional landscape ecosystems of Michigan, Minnesota, and Wisconsin: a working map and classification (fourth revision: July 1994). General Technical Report NC-178. U.S. Department of Agriculture, Forest Service, St. Paul, Minnesota. 250 pp.

Bailey, R.G. 1976. Ecoregions of the United States. Map (scale 1:7,500,000). U.S. Department of Agriculture, Forest Service, Ogden, Utah.

Bailey, R.G., P.E. Avers, T. King, and W.H. McNab, eds. 1994. Ecoregions and subregions of the United States (map - scale 1:7,500,000). (Supplementary table of map unit descriptions compiled and edited by W.H. McNab and R.G. Bailey.) U.S. Department of Agriculture, Forest Service, Washington D.C.

Blew, R.D. 1996. On the definition of ecosystems. *Bulletin of the Ecological Society of America* 77:171-73.

Chapman, S.S., J.M. Omernik, J.A. Freeouf, D.J. Huggins, J.R. McCauley, C.C. Freeman, G. Steinaur, R. Angenlo, and R. Schlepp. In review. Ecoregions of Nebraska and Kansas. (Map poster). U.S. Geological Survey, Reston, Virginia.

Commission for Environmental Cooperation (CEC). 1997. Ecological regions of North America. Commission for Environmental Cooperation, Montreal, Quebec, Canada. 71 pp.

Curtis, J.T. 1978. *The vegetation of Wisconsin — an ordination of plant communities.* The University of Wisconsin Press, Madison. 657 pp.

Davis, W.S., B.D. Snyder, J.B. Stribling, and C. Stoughton. 1996. Summary of biological assessment programs for streams and wadeable rivers. EPA 230-R-96-007. U.S. Environmental Protection Agency, Office of Policy, Planning, and Evaluation, Washington, D.C.

Finley, R.W. 1976. Original vegetation cover of Wisconsin. Map (scale 1:500,000) and accompanying text. North Central Forest Experiment Station, U.S. Department of Agriculture, Forest Service, St. Paul, Minnesota.

Gallant, A.L., E.F. Binninan, J.M. Omernik, and M.B. Shasby. 1995. Ecoregions of Alaska. Map (scale 1:5,000,000). U.S. Geological Survey Professional Paper 1567. U.S. Government Printing Office, Washington, D.C. 73 pp.

Gallant, A.L., T.R. Whittier, D.P. Larsen, J.M. Omernik, and R.M. Hughes. 1989. Regionalization as a tool for managing environmental resources. EPA/600/3-89/060. U.S. Environmental Protection Agency, Corvallis, Oregon. 152 pp.

Gonzalez, O.J. 1996. Formulating an ecosystem approach to environmental protection. *Environmental Management* 20:597-605.

Griffith. G.E., J.M. Omernik, and A.J. Woods. 1999. Ecoregions, watersheds, basins, and HUCs: how state and federal agencies frame water quality. *Journal of Soil and Water Conservation* 54(4):666-77.

Grigg, D.B. 1967. Regions, models, and classes. Pp. 461-509 *in* R.J. Chorley and P. Hagget, eds. *Models in Geography.* Methuen and Co., London.

Hart, J.F. 1982. The highest form of the geographer's art. *Annals of the Association of American Geographers* 72:1-29.

Hole, F.D. 1976. *Soils of Wisconsin.* Map (scale 1:710,000). The University of Wisconsin Press, Madison, Wisconsin. 233 pp.

Hole, F.D., and C.E. Germain. 1994. Natural divisions of Wisconsin. Map (scale 1:1,000,000) and accompanying text. Wisconsin Department of Natural Resources, Madison, Wisconsin.

Holling, C.S. 1994. An ecologist view of the Malthusian conflict. Pp. 79-104 *in* K. Lindahl-Kiessling and H. Landberg, eds. *Population, Economic Development, and Environment.* Oxford University Press, New York. 312 pp.

Keys, J.E. Jr., C.A. Carpenter, S.L. Hooks, F.G. Koeneg, W.H. McNab, W.E. Russell, and M.L. Smith. 1995. Ecological units of the eastern United States — first approximation. Map (scale 1:3,500,000). Technical Publication R8-TP 21. U.S. Department of Agriculture, Forest Service, Atlanta, Georgia.

Lackey, R.T. 1998. Seven pillars of ecosystem management. *Landscape and Urban Planning* 40:21-30.

Likens, G.E. 1993. Preface. *In* M.J. McDonnell and T.A. Picket, eds. *Humans as components of ecosystems: the ecology of subtle human effects and populated areas.* Springer-Verlag, New York.

Marin, V.H. 1997. General system theory and the ecological concept. *Bulletin of the Ecological Society of America* 77:102-04.

Martin, L. 1916. The physical geography of Wisconsin. Wisconsin Geological and Natural History Survey Bulletin No. 36. Education Series No. 4. 3817 Mineral Point Road, Madison, WI 53705-5100. 549 pp.

Maxwell, J.R., C.J. Edwards. M.E. Jensen, S.J. Paustian, H. Parrot, and D.M. Hill. 1995. A hierarchical framework of aquatic ecological units in North America (Nearctic zone). General Technical Report NC-176. United States Department of Agriculture, Forest Service, North Central Forest Experiment Station, St. Paul, Minnesota. 72 pp.

McMahon, G., S.M. Gregonis, S.W. Waltman, J.M. Omernik, T.D. Thorson, J.A. Freeouf, A.H. Rorick, and J.E. Keys. In press. Developing a spatial framework of common ecological regions for the conterminous United States. *Environmental Management.*

Meeus, J.H.A. 1995. Pan-European landscapes. *Landscape and Urban Planning* 3:57-79.

Omernik, J.M. 1987. Ecoregions of the conterminous United States. Map (scale 1:7,500,000). *Annals of the Association of American Geographers* 77:118-25.

Omernik, J.M. 1995a. Ecoregions: a spatial framework for environmental management. Pp. 49-62 *in* W. Davis and T. Simon, eds. *Biological assessment and criteria: tools for water resource planning and decision making.* Lewis Publishers, Boca Raton, Florida.

Omernik, J.M. 1995b. Ecoregions: a spatial framework for managing ecosystems. *The George Wright Forum* 12(1):35-50.

Omernik, J.M., C.M. Rohm, S.E. Clarke, and D.P. Larsen. 1988. Summer total phosphorus in lakes: a map of Minnesota, Wisconsin, and Michigan. Map (scale 2,500,000). *Environmental Management* 12:815-25.

Omernik, J.M., and R.G. Bailey. 1997. Distinguishing between watersheds and ecoregions. *Journal of the American Water Resources Association* 33(5):935-49.

Pater, D.E., S.A. Bryce, T.D. Thorson, J. Kagen, C. Chappell, J.M. Omernik, S.H. Azevedo, and A.J. Woods. 1998. Ecoregions of western Washington and Oregon. (Map poster). U.S. Geological Survey, Reston, Virginia.

Poff, R.J. 1970. The chemical composition of Wisconsin lake waters: a basis for water quality studies. Wisconsin Department of Natural Resources, Division of Fish, Game, and Enforcement, Bureau of Fish Management, Management Report No. 30. Publication #300-19. P.O. Box 7924, Madison, Wisconsin. 26 pp.

Rowe, J.S. 1997. Defining the ecosystem. *Bulletin of the Ecological Society of America* 78:95-97.

Rowe, J.S., and B.V. Barnes. 1994. Geo-ecosystems and bio-ecosystems. *Bulletin of the Ecological Society of America* 75:40-41.

Seaber, P.R., F.P. Kapinos, and G.L. Knapp. 1987. Hydrologic unit maps. U.S. Geological Survey Water-Supply Paper 2294. United States Department of the Interior, Geological Survey, Denver, Colorado. 63 pp.

Udo de Haes, H.A. and F. Klijn. 1994. Environmental policy and ecosystem classification. *In* F. Klijn, ed. *Ecosystem classification for environmental management.* Kluwer Academic Publishers, AH Dordrecht, The Netherlands. 293 pp.

U.S. Department of Agriculture (USDA). 1981. Land resource regions and major land resource areas of the United States. Map (scale 1:7,500,000). Agriculture Handbook 296. U.S. Government Printing Office, Washington, D.C. 156 pp.

U.S. Environmental Protection Agency (EPA). 1998. National strategy for the development of regional nutrient criteria. EPA 822-R-98-002. U.S. Environmental Protection Agency, Office of Water, Washington, D.C.

U.S. Environmental Protection Agency. 1999. Level III ecoregions of the continental United States (revision of Omernik 1987). U.S. Environmental Protection Agency, National Health and Environmental Effects Research Laboratory, Western Ecology Division, Corvallis, Oregon.

U.S. Fish and Wildlife Service (USFWS). 1999. A proposed framework for delineating ecologically-based planning, implementation, and evaluation units for cooperative bird conservation in the U.S. U.S. Fish and Wildlife Service, North American Waterfowl and Wetlands Office, Arlington, Virginia. 9 pp. plus appendix.

U.S. Forest Service. 1979. Roadless and undeveloped area evaluation II, RARE II, final environmental statement, January 1979. Washington, D.C, U.S. Government Printing Office Publication No. 650-771 with map.

U.S. General Accounting Office (GAO). 1994. Ecosystem management: additional actions needed to adequately test a promising approach. GAO/RCED-94-111. U.S. General Accounting Office, Washington, D.C. 87 pp.

U.S. National Oceanic and Atmospheric Administration (NOAA). 1974. *Climates of the States; a practical reference containing basic climatological data of the United States.* Vol. 1, *Eastern States, plus Puerto Rico and the U.S. Virgin Islands.* Water Information Center, Port Washington, New York. 975 pp.

Wiken, E. 1986. Terrestrial ecozones of Canada: Ottawa, Environment Canada. Ecological Land Classification Series no. 19, 26 pp.

Wisconsin Department of Natural Resources (WDNR). 1995. Wisconsin's biodiversity as a management issue. Bureau of Research Information and Publication Team. WDNR Pub-RS-915-95. 240 pp.

Wisconsin Department of Natural Resources. 1999. Ecological landscapes of Wisconsin. WDNR Land Ecosystem Management Planning Team. 101 S Webster Street, Madison, WI 53707.

Woods, A.J., J.M. Omernik, J.A. Nesser, J, Sheldon, and A.H. Azevedo. 1999. Ecoregions of Montana (color poster with map, descriptive text, summary tables, and photographs) U.S. Geological Survey, Reston, Virginia.

Wisconsin Map Sources

Albert, D.A. 1995. Regional landscape ecosystems of Michigan, Minnesota, and Wisconsin: a working map and classification (fourth revision: July 1994). General Technical Report NC-178. U.S. Department of Agriculture, Forest Service, St. Paul, Minnesota. 250 pp.

Anderson, J.R. 1970. Major land uses. Map (scale 1:7,500,000). Pp. 158-59 *in The national atlas of the United States of America.* Revised from a map by F.J. Marschner. U.S. Department of the Interior, U.S. Geological Survey, Washington, D.C.

Bailey, R.G. 1976. Ecoregions of the United States. Map (scale 1:7,500,000). U.S. Department of Agriculture, Forest Service, Ogden, Utah.

Bailey, R.G., P.E. Avers, T. King, and W.H. McNab, eds. 1994. Ecoregions and subregions of the United States. Map (scale 1:7,500,000) (supplementary table of map unit descriptions compiled and edited by W.H. McNab and R.G. Bailey). U.S. Department of Agriculture, Forest Service, Washington D.C.

Barnes, C.P., and F.J. Marschner. 1933. Natural land-use areas of the United States. Map (scale: 1:4,000,000). U.S. Department of Agriculture.

Black, R.F. 1974. *Geology of Ice Age: national scientific reserve of Wisconsin.* Library of Congress, Washington D.C. 234 pp.

Clayton, L., J.W. Attig, D.M. Mickelson, and M.D. Johnson. 1991. Glaciation of Wisconsin. Education serial no. 36. Wisconsin Geological and Natural History Survey, Madison, Wisconsin. 4 pp.

Curtis, J.T. 1978. *The vegetation of Wisconsin — an ordination of plant communities.* The University of Wisconsin Press, Madison, Wisconsin. 657 pp.

Eyre, F.H., ed. 1980. Forest cover types of the

United States and Canada. Map (scale 1:7,500,000). Society of American Foresters, Washington, D.C. 148 pp.

Fago, D. 1992. Distribution and relative abundance of fishes in Wisconsin. VIII Summary Report. Technical Bulletin No. 175, Wisconsin Department of Natural Resources, Madison, Wisconsin. 378 pp.

Finley, R.W. 1976. Original vegetation cover of Wisconsin. Map (scale 1:500,000). U.S. Department of Agriculture, Forest Service, St. Paul, Minnesota.

Fritz, T.O. 1975. Mineral resources, mining, and land-use planning in Wisconsin. Information circular no. 26. University of Wisconsin-Extension, Geological and Natural History Survey, Madison, Wisconsin. 61 pp.

Griffith, G.E., J.M. Omernik, T.F. Wilton, and S.M. Pierson. 1994. Ecoregions and subregions of Iowa: a framework for water quality assessment and management. *Journal of Iowa Academy of Science* 101:5-13.

Hadley, D.W., and J.H. Pelham. 1976. Glacial deposits of Wisconsin- sand and gravel resources potential. Map (scale 1:500,000). Wisconsin Geologic and Natural History Survey, Madison, Wisconsin.

Hammond, E.H. 1970. Classes of land surface form. Map (scale 1:7,500,000). Pp. 62-63 *in The national atlas of the United States of America.* U.S. Department of the Interior, U.S. Geological Survey, Washington, D.C.

Hole, F.D., and C.E. Germain. 1994. Natural divisions of Wisconsin. Map (scale 1:1,000,000) and accompanying text. Wisconsin Department of Natural Resources, Madison, Wisconsin.

Hole, F.D. 1976. *Soils of Wisconsin.* Map (scale 1:710,000). The University of Wisconsin Press, Madison, Wisconsin. 233 pp.

Kammerer, P.A. Jr. 1981. Ground water quality atlas of Wisconsin: information circular no. 39. U.S. Department of the Interior, U.S. Geological Survey. 37 pp.

Keys, J.E. Jr., C.A. Carpenter, S.L. Hooks, F.G. Koenig, W.H. McNab, W.E. Russell, and M.L. Smith. 1995. Ecological units of the eastern United States — first approximation. Map (scale 1:3,500,000). Technical Publication R8-TP 21. U.S. Department of Agriculture, Forest Service, Atlanta, Georgia.

Kline, V.M., and G.C. Cottam. 1979. Vegetation response to climate and fire in the Driftless Area of Wisconsin. *Ecology* 60:861-68.

Kuchler, A.W. 1970. Potential natural vegetation. Map (scale 1:7,500,000). Pp. 89-91 *in The national atlas of the United States of America.* U.S. Department of the Interior, U.S. Geological Survey, Washington, D.C.

Kuchler, A.W. 1964. Potential natural vegetation of the conterminous United States (map and manual). Map (scale 1:3,168,000). American Geographic Society Special Publication 36.

Kurta, Allen. 1994. *Mammals of the Great Lakes region.* The University of Michigan Press, Ann Arbor, Michigan. 376 pp.

Loveland, T.R., J.W. Merchant, J.F. Brown, D.O. Ohlen, B.C. Reed, P. Olson, and J. Huchinson. 1995. Seasonal land-cover regions of the United States. Map supplement. *Annals of the Association of American Geographers* 85(2):339-35.

Lyons, John. 1989. Correspondence between the distribution of fish assemblages in Wisconsin streams and Omernik's ecoregions. *American Midland Naturalist* 122:163-82.

Lyons, John. 1996. Patterns in the species composition of fish assemblages among Wisconsin streams. *Environmental Biology of Fishes* 45:329-41.

Martin, Lawrence. 1974. *The physical geography of Wisconsin.* The University of Wisconsin Press, Madison, Wisconsin. 608 pp.

Mudrey, M.G., B.A. Brown, and J.K. Greenberg. 1982. Bedrock geologic map of Wisconsin. Map (scale 1:1,000,000). University of Wisconsin-Extension, Geological and Natural History Survey.

Omernik, J.M. 1987. Ecoregions of the conterminous United States. Map (scale 1:7,500,0000). *Annals of the Association of American Geographers* 77:118-25.

Omernik, J.M. 1995a. Ecoregions: a spatial framework for environmental management. Pp. 49-62 *in* W.S. Davis and T.P. Simon, eds. *Biological assessment and criteria: tools for water resource planning and decision making.* Lewis Publishers, Boca Raton, Florida.

Omernik, J.M. and R.G. Bailey. 1997. Distinguishing between watersheds and ecoregions. *Journal of the American Water Resources Association* 33:935-49.

Omernik, J.M., and A.L. Gallant. 1988. Ecoregions of the Upper Midwest States: EPA/600/3-88/037. U.S. Environmental Protection Agency, Corvallis, Oregon, 56 pp.

Omernik, J.M., and G.E. Griffith. 1986. Total alkalinity of surface waters: a map of the Upper Midwest region of the United States. Map (scale 1:2,500,000). *Environmental Management* 10:829-39.

Omernik, J.M., D.P. Larsen, C.M. Rohm, and S.E. Clarke. 1988. Summer total phosphorus in lakes in Minnesota, Wisconsin, and Michigan. Map (scale 1:2,500,000). *Environmental Management* 12:815-25.

Omernik, J.M., C.M. Rohm, R.A. Lillie, and N. Mesner. 1991. The usefulness of natural regions for lake management: an analysis of variation among lakes in northwestern Wisconsin, U.S.A. *Environmental Management* 15:281-93.

Ostrum, M.E. 1981. Bedrock geology of Wisconsin. Map (scale 1:500,000). Wisconsin Geologic and Natural History Survey, University of Wisconsin, Madison, Wisconsin.

Paull, R.K., and R.A. Paull. 1980. *Field guide — Wisconsin and Upper Michigan.* K/H Geological Field Guide Series. Library of Congress, Washington D.C. 260 pp.

Richmond, G.M., and D.S. Fullerton, eds. 1984. Quaternary geologic map of Lake Superior, 4° x 6° Quadrangle. (W.R. Farrand, D.M.. Mickelson, W.R Cowan, and J.E. Goebel, compilers). Map (scale 1:1,000,000). U.S. Geological Survey Miscellaneous Investigations series. Map I-1420 (NL-16).

Richmond, G.M., and D.S. Fullerton, eds. 1983. Quaternary geologic map of Chicago, 4° x 6° Quadrangle. (J.A. Lineback, N.K. Bluer, D.M Mickelson, W.R. Farrand, and R.P. Goldthwait,compilers). Map (scale 1:1,000,000). U.S. Geological Survey Miscellaneous Investigations series Map I-1420 (NK-16).

Richmond, G.M., and D.S. Fullerton, eds. 1983. Quaternary geologic map of Minneapolis, 4° x 6° Quadrangle. (J.E. Goebel, D.M. Mickelson, W.R Farrand, L. Clayton, A. Cahow, H.C. Hobbs, and M.S. Walton Jr., compilers). Map (scale 1:1,000,000). U.S. Geological Survey Miscellaneous Investigations series Map I-1420 (NL-15).

Richmond, G.M., D.S. Fullerton, and A.C. Christiansen. 1991. Quaternary geologic map of Des Moines, 4° x 6° Quadrangle. (G.R. Hallberg, J.A. Lineback, D.M. Mickelson, J.C. Knox, J.E Goebel, H.C. Hobbs, J.W. Whitfield, R.A. Ward, J.D. Boellstorf, J.B Swinehart, and V.H. Dreeszen, compilers). Map (scale 1:1,000,000). U.S. Geological Survey Miscellaneous Investigations series Map I-1420 (NK-15).

Robertson, D.M., and D.A. Saad. 1995. Environmental factors used to subdivide the western Lake Michigan drainages into relatively homogeneous units for water-quality site selection. Fact Sheet FS-220-95. U.S. Department of the Interior, U.S. Geological Survey, Madison, Wisconsin.

State Planning Office. 1974. Generalized land cover interpreted from ERTS-1 satellite imagery, map 7. Map (scale 1:500,000). Wisconsin Department of Administration and the Institute for Environmental Studies, University of Wisconsin, Madison, Wisconsin.

Trotta, L.C., and R.D. Cotter. 1973. Depth to bedrock in Wisconsin. Map (scale 1:1,000,000). University of Wisconsin Extension, Geological and Natural History Survey in cooperation with the U.S. Geological Survey, Madison, Wisconsin.

U.S. Department of Agriculture. 1987. Wisconsin crops from planting to harvest 1977-86, and Wisconsin weather. Publication no. 220-87. U.S. Department of Agriculture, National Agricultural Statistics Service, Wisconsin Agricultural Statistics Service, Madison, Wisconsin.

U.S. Department of Agriculture, Natural Resources Conservation Service (formerly the Soil Conservation Service). Various county soil surveys of Wisconsin.

U.S. Department of Agriculture, Natural Resources Conservation Service. 1996. Draft — Ecological framework region 10 (Minnesota, Iowa, and Wisconsin): major land resource concepts — STATSGO vs. MLRA. Map (scale 1:1,000,000). U.S. Department of Agriculture, Natural Resources Conservation Service, National Soil Survey Center in cooperation with CALMIT-University of Nebraska, Lincoln, Nebraska.

U.S. Department of Agriculture. 1983. Wisconsin major forest types. Map (scale 1:1,000,000). U.S. Department of Agriculture, Forest Service, St. Paul, Minnesota.

U.S. Department of Agriculture. 1981. Land resource regions and major land resource areas of the United States. Map (scale 1:7,500,000). Agriculture Handbook 296. U.S. Department of Agriculture, Soil Conservation Service, U. S. Government Printing Office, Washington D.C. 156 pp.

U.S. Department of the Interior. 1974. Hydrologic unit map — State of Wisconsin. Map (scale 1:500,000). U.S. Department of the Interior, Geological Survey, prepared in cooperation with the U.S. Water Resources Council, Washington D.C.

U.S. Department of the Interior. 1976. Mineral and water resources of Wisconsin. U.S. Department of the Interior, U.S. Geological Survey, Wisconsin Geological and Natural History Survey, U. S. Government Printing Office, Washington D.C. 185 pp.

U.S. Department of the Interior, Geological Survey. Topographic sheets of Wisconsin [various maps]. Map (scale 1:250,000).

U.S. Environmental Protection Agency. 1999. Level III ecoregions of the continental United States (revision of Omernik, 1987). U.S. Environmental Protection Agency, National Health and Environmental Effects Research Laboratory, Western Ecology Division, Corvallis, Oregon.

U.S. National Oceanic and Atmospheric Administration. 1974. *Climates of the States; a practical reference containing basic climatological data of the United States.* Vol. 1, *Eastern States, plus Puerto Rico and the U.S. Virgin Islands.* Water Information Center, Port Washington, New York. 975 pp.

Vankat, J.L. 1979. *The natural vegetation of North America: an introduction.* John Wiley & Sons, New York. 261 pp.

Wisconsin Department of Natural Resources. 1997. Draft: Land type associations (LTA's) for northern Wisconsin. Map (scale 1:550,000). Madison, Wisconsin.

Wisconsin Geological and Natural History Survey. 1976. Glacial deposits of Wisconsin: sand and gravel resource potential. Map (scale 1:500,000). Wisconsin Geological and Natural History Survey, University of Wisconsin-Extension, and the State Planning Office, Wisconsin Department of Administration, Madison, Wisconsin.

Wisconsin Geological and Natural History Survey. 1989. Groundwater contamination susceptibility in Wisconsin. Map (scale 1:500,000). Wisconsin Geological and Natural History Survey, University of Wisconsin-Extension, Madison, Wisconsin.

Wisconsin Geological and Natural History Survey. Various page size (8"x 10") maps (scale approx. 1:2,730,000). Wisconsin Geological and Natural History Survey, University of Wisconsin-Extension, Madison, Wisconsin.

———. 1968. Aeolian silt and sand deposits of Wisconsin.

———. 1996. Bedrock geology of Wisconsin.

———. 1986. General land use/land cover.

———. 1989. Groundwater contamination susceptibility in Wisconsin.

———. 1964. Glacial deposits of Wisconsin.

———. 1995. Hydric soils in Wisconsin (STATSGO data).

———. 1979. Major land use.

———. 1990. Plant hardiness zone map: Wisconsin.

———. 1995. Potential gravel source areas: Wisconsin (STATSGO data).

———. 1996. Potential prime farmland in Wisconsin (STATSGO data).

———. 1983. Thickness of unconsolidated material in Wisconsin.

James M. Omernik is a geographer with the U.S. Environmental Protection Agency. His work has included the design and development of national and regional maps of nutrient concentrations in streams, total alkalinity of surface waters, total phosphorus regions for lakes, and ecological regions. Address: USEPA, 200 SW 35th St., Corvallis, OR 97333. E-mail: omernik@mail.cor.epa.gov

Shannen S. Chapman is a geographer with Dynamac Corporation, a contractor with the USEPA. Her current research focuses on ecoregion delineation and mapping, and she has worked on ecoregion refinement for the states of Wisconsin, Kansas, Nebraska, and Missouri. Address: Dynamac Corporation, USEPA Environmental Research Laboratory, 200 SW 35th St., Corvallis, OR 97333. E-mail: chapman@mail.cor.epa.gov

Richard A. Lillie is a research biologist with the Wisconsin Department of Natural Resources, Bureau of Integrated Science Services, Ecological Inventory and Monitoring Section, Monona. Address: 1350 Femrite Drive, Monona, WI 53716. E-mail: lillir@mail01.dnr.state.wi.us

Robert T. Dumke (Retired) was with the Wisconsin Department of Natural Resources, Office of the Secretary, Madison, during the time this project was conducted. He was formerly the Director, Bureau of Research (now Bureau of Integrated Science Services). Former Address: 101 S. Webster St., Madison, WI 53707 (Retired). Current Address: Box 688, Three Lakes, WI 54562.

Cathleen Palmini

Across the Unknown Waters to Wisconsin: The Migration Narratives of Four Women Settlers

"When i [sic*] looked into the water and see the little waves that receded back from the boat it seemed that every one was bearing me away from all my friends forever."

—*Orpha Bushnell Ranney, letter of September 1847*

"Sick still. Took nothing the last two days except a little brandy and Laudnum. . . . A fair wind, a great swell on the sea. Ship rolling tremendously."

—*Isabella Mckinnon, diary entry of April 15, 1852*

"All of us, including the sailors thought that this was the end, for we could feel the ship sinking lower and lower. . . . The yelling, the noise, and the panic was terrible."

—*Emilie Schramm Crusius, memoir of 1854 trans-Atlantic voyage*

"What inexpressible joy and relief did I experience when I set my feet on terra firma."

—*Racheline S. Wood, letter of December 1, 1838*

The words of ordinary women in a period of upheaval chronicle homesickness, seasickness, shipwreck, and joy at setting their feet again on firm ground. Compelling glimpses into individual women's lives in the mid-1800s, these words are more compelling for their rarity—few Wisconsin women's writings from the settlement period are accessible which describe the voyage across the Atlantic Ocean and through the Great Lakes to Wisconsin. Held in archives or remaining with family members, the sometimes brief or fragmentary diaries,

*Writings have been transcribed as found with no editorial corrections.

letters, and memoirs of common women have often been viewed as historically insignificant and remain unpublished. The memorable writings of four women of this period, describing travel by water to Wisconsin, humanize the broad sweep of Wisconsin history by focusing on personal accounts of voyages. What does one write when the immediate future is unknown, when the only certainty is what one has left behind? These women express in four unique, feminine voices not only daily experiences while sailing or steaming toward Wisconsin but feelings and attitudes about their lives during this transition.

Who were these women? Isabella Mckinnon, quiet and uncomplaining, crossed the Atlantic in a sailing ship in 1852 and wrote each day in a diary ending with her arrival in Otsego, Wisconsin. In 1854, adventurous, seemingly ever-hungry Emilie Schramm and her mother traveled by steamship from Germany bound for Sauk City. Racheline S. Wood, self-assured but lonely, chronicled in letters her difficult travels of 1838, through the Erie Canal and through the Great Lakes by steamship settling in Plattville. Orpha Bushnell Ranney, although the least-educated, expressed clearly in letters of 1847 her loneliness for loved ones left behind, as she and her husband undertook Great Lakes travel to reach Sun Prairie.

Across the Atlantic

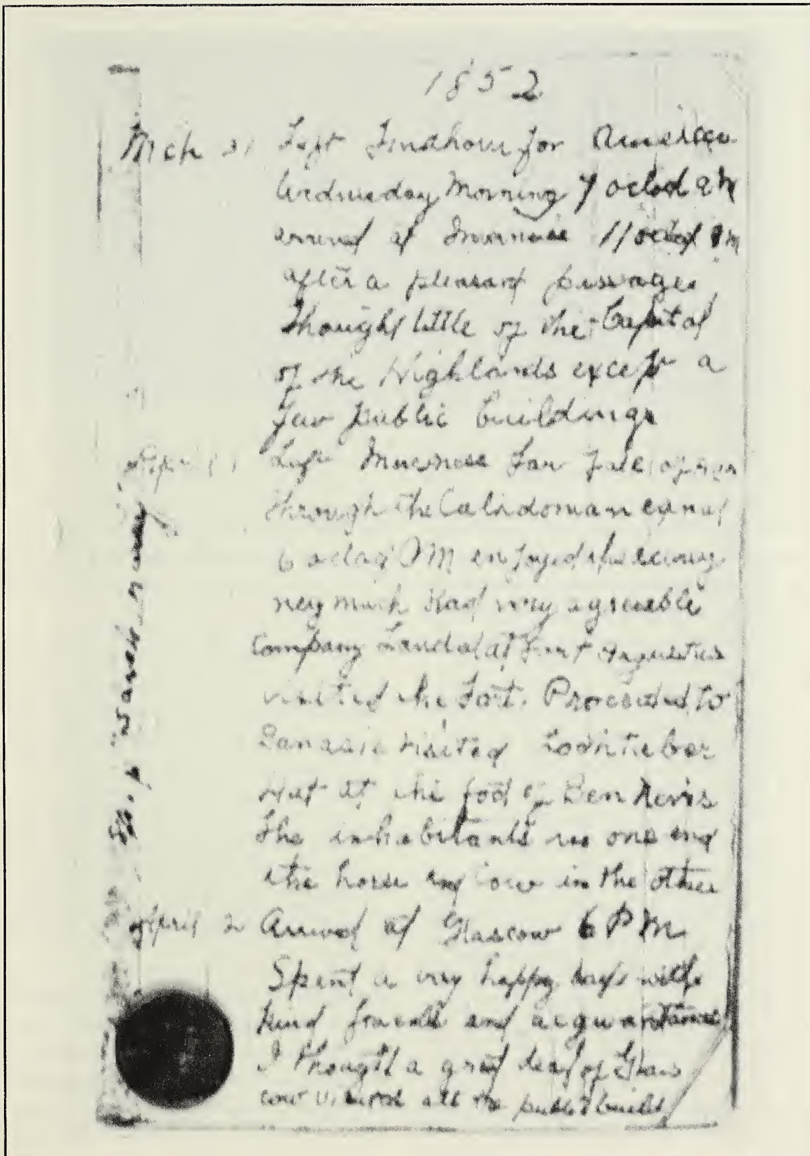
To merely state that the population of Wisconsin grew from 30,945 to 775,881 between 1840 and 1860 is to belie the drama as well as the tedium of the actual journeys of settlers (Smith 466). Immigrants who had crossed the Atlantic by sailing ship or steamer during this period made up approximately half the population of Wisconsin in 1860 (Current 78). The diary of Isabella Mckinnon, written aboard a sailing ship, and the memoir of Emilie Schramm Crusius, describing a steamship voyage, are first-person descriptions of trans-Atlantic immigration to Wisconsin.

Isabella Mckinnon

Nineteen-year-old Isabella Mckinnon, after leaving her village of Findhorn, Scotland, boarded the sailing ship "Sarah Mary" on April 9, 1852, bound for America. In her small four-by-six inch leather journal, Isabella recorded in pencil the notable happenings of each day until June 4, 1852, when she reached her destination—Otsego, Wisconsin. Written in sentence fragments most often without subjects, her diary never reveals whether she made the trip alone or with her family. Isabella's account is notable for her succinctness and calm in describing a voyage that included days of discomfort and dangerous storms as well as days of becalmed seas when the ship made no progress.

The average length of travel to America by sail was six weeks, depending on whether the wind was fair and whether the captain and crew were skilled. Isabella's trip took eight weeks, and she probably traveled as a steerage passenger rather than a higher-paying cabin passenger. The steerage passenger lived in the long 'tween decks—the space between the main deck open to the weather and the lower deck below it. The rows of bunks built there, usually in two tiers, were temporary for the east to west journey. For the trip from America back east, the 'tween decks often carried lumber—a cargo commonly considered more valuable than the steerage passenger (Greenhill 16–17).

Isabella's record did not dwell on the living conditions but briefly described activity on board. Her first entry after boarding the "Sarah Mary" was typical as she matter-of-factly stated "Captain Brown delivered a lec-



1852

Mch 31 Left [illegible] for America
Wednesday morning 7 oclock AM
arrived at Inverness 11 oclock PM
after a pleasant passage
thought little of the capital
of the Highlands except a
few public buildings
April 1 Left Inverness [illegible]
through the Calidonian canal
6 oclock PM enjoyed the scenery
very much Had very agreeable
company Landed at Fort Augustus
visited the Fort. Proceeded to
Banavie visited [illegible]
Hut at the foot of Ben Nevis
The inhabitants in one end
the horse and cow in the other
April 2 Arrived at Glascow 6 PM
Spent a very happy days with
kind friends and acquaintances
I thought a great deal of Glas
cow visited all the public build

Diary of Isabella Mckinnen. State Historical Society of Wisconsin Archives.

ture on board to the passengers from John 6." They remained in the Bay of Greenoch for one day for inspections:

> Passengers examined by the Doctor and Government Inspector. Eight of the passengers rejected. The sugar condemned by the Government Inspector. Superior [sugar] returned. Left the Bay of Greenoch at 5:00 o'clock P.M. Wind unfavorable. Towed out to Sea by a steam tug. One of the passengers a woman, got drunk and disorderly and was put in irons for sometime.

On April 11, she recorded the first of many Sundays, the observance of Sabbath being important enough to her always to merit comment. Of one Sunday, she wrote: "Public worship on the quarter deck. A good attendance, very impressive on the mighty deep." This Sabbath she called unprofitable because the ship was becalmed. To pass the day, the Captain distributed tracts to the passengers, and Isabella spent the greater part of the day reading. The following day the rules of the ship were read.

> April 12: A committee of the passengers formed to keep order and observe cleanliness, one of the rules, to rise at 7:00 A.M. To be in bed at 10:00 P.M. to be rigidly enforced. A fine day, wind favorable. Took the last look of Scotlands hills at 10:00 o'clock A.M. A little sick, soon got better, employed the day in sewing, crocheting and reading. An alarm of fire, nothing serious. A fair wind, all sails set. Going at the rate of 8 knots an hour. A dance, to the music of the Bagpipes, Fiddle and Tambarine, got up amongst the passengers. A beautiful night. On deck all the evening.

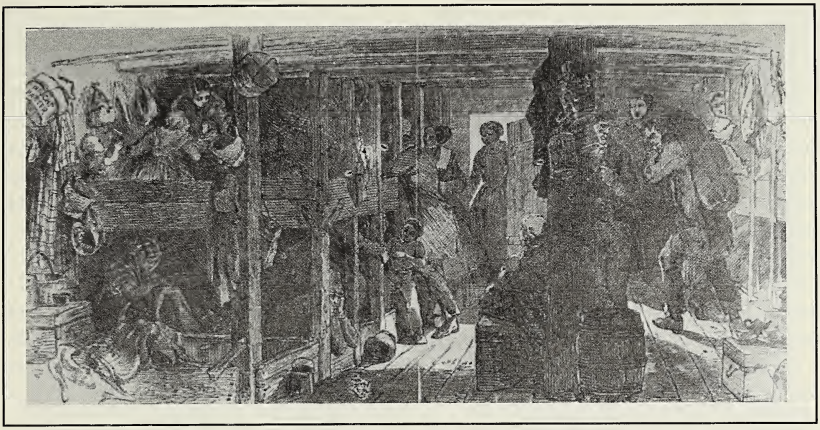
And so Isabella was on her way, and her diary revealed that she did not complain and she did not dramatize happenings. Unused to the motion of the ship, many passengers on sailing ships were seasick as the ship rolled and pitched and tossed. Isabella was seasick for several days and wrote only "A strong fair wind. Sick all day." and the next day "Still continuing a fair wind. Very sick." On the sixth day out, she was still seasick and mentioned the remedy she was trying: "Sick still. Took nothing the last two days except a little brandy and Laudnum." Later that day she reported:

> Went on the quarter deck at 12:00 o'clock. Was much refreshed with the fresh air. A fair wind, a great swell on the sea. Ship going at the rate of 8 1/2 knots an hour. Ship rolling tremendously. Every one more afraid than another. Passed a wreck in the morning.

That seemed to be the end of her seasickness, and she turned to brief descriptions of daily activities. The weather and sailing conditions always merited comment, and during an April storm she did not display her usual calm:

> April 20: A very fine day, calm. The Atlantic like a loch. The wind rose at 3:00 p.m. A strong breeze with rain at 7:00 P.M. Ship going a good rate. On deck at 9:00 o'clock, looking rather stormy. Stayed on the deck an hour with very interesting company.
>
> April 21: Very stormy all day. High wind with showers of rain and hail, continued very severe all night. Thought we would never see morning. Water rushing into the steerage.
>
> April 22: Storm somewhat abated, wind contrary.

After this initial storm, even severe weather did not cause her to make worried remarks about their safety. The days seemed to drag on and Isabella's writing dwindled to two or three phrases each day. Noteworthy were two days when fights broke out and the men involved were put in irons for an hour. Passing ships also broke the monotony.



Steerage passengers. *Illustrated London News,* May 5, 1851.

On May 7, about four weeks out, she experienced an event worth recording in more detail:

> Seven ships in sight, fishing for Cod. Passed close by one. Some one with the life boat went and brought some cod, part of which Captain Brown distributed to the passengers gratis. The deck very much resembled a fish market. Every one crowding to get their share. Wind somewhat favorable. 16 miles from Sable Island. 400 from New York.

The passengers' enthusiasm probably reflects the poor quality or at least the sameness of the food provided on board. The food provided for cabin passengers on many sailing ships was adequate to mediocre, and for steerage passengers some ships provided only meager rations with the passengers being expected to cook their own (Greenhill 17).

After several days of misty weather, Long Island, "a very welcome sight," came into view on May 17, and Isabella's daily writing increased. Her first views of America were described with a good-humored tone:

> The tug came along side at 12:00 0'clock. Coming up the River was the finest sight I ever saw. The scenery exceeded everything I have seen. Off Staten Island at 2:00 o'clock. A very pretty place. The doctor came aboard. The passengers all on deck and examined in less than five minutes. The Doctor said he had never examined a more healthy good looking set of passengers. Arrived opposite New York at 3:30 o'clock P.M. The first thing I got belonging to America was a New Testament, which a gentleman came aboard and kindly presented to the passengers. A very amusing sight to see friends meeting friends.

True to form, Isabella did not say who met her. She noted that New York was a very fine city and then detailed her methods of travel across the country. She traveled up the Hudson River and took the Erie Railway for 500 miles to Dunkirk, New York. She took lodging there in a house kept by "very fine people" but was "very much disappointed with the look of the country."

The steamer "Niagara" took her up Lake Erie to Cleveland, a city which she found impressive: "A very fine place and beautiful buildings. Far surpassing any I have yet seen in America. Streets so wide and trees growing on each side." Continuing to Detroit by the steamer "Detroit," Isabella arrived on a Sunday morning in time to visit a Roman Catholic Church. She appreciated the very large, fine building but not the "very strange ceremonies." After staying only a few minutes, she found a Methodist Episcopal Church more to her liking: "Very clean, never saw a more respectable looking congregation."

Continuing on to Chicago by railroad, she found that cholera was spreading in the town. On May 29 she took the "Arctic Steamer" to Milwaukee of which she wrote, "Apparently a fine place." She took lodging in the Wisconsin House, walked around the town, and visited the Congregational Plymouth Church and an "English Church."

On June 1, 1852 she left Milwaukee for Otsego, a distance of 80 miles. Traveling half way the first day, she stayed overnight at "a tavern by the way." Her last three diary entries took her through stormy weather to Otsego:

> June 2nd - Passed through Watertown in the forenoon. A very nice little place. Arrived at Lowell a small village and stayed all night. An awful night of thunder and lightining. Never saw anything like it before. The sky all in a blaze for two hours.
>
> June 3rd - Left Lowell early in the morning and were detained in Columbus by a thunder storm. A nice little place. Proceeded to Otsego and were overtaken by another thunder storm and heavy rain. Were obliged to remain all night in the "Prairie House" about 5 miles from Otsego.
>
> June 4th - Arrived all safe at Otsego in good health not without a good deal of fatigue on the 4th of June, 1852.

There, Isabella Mckinnon ended her diary with no mention of whom she might have joined in Otsego or her reasons for this destination. Isabella's detached written reaction to the trip, although not the difficulty of the ocean passage itself, is in stark contrast to Emilie Schramm Crusius's descriptive and good-humored memoir of her trans-Atlantic voyage on a steamship.

Emilie Schramm Crusius

In 1854, the unmarried Emilie Schramm and her mother crossed from Neckargartach, Germany, to Philadelphia on the maiden voyage of the screw steamship "City of Philadelphia." During this mid-1800s period, when sailing ships were being replaced by steamships for emigrant travel, the conditions for passengers did not improve immediately. However, the traveling time was cut from six weeks on a sailing ship to about ten days on a steamer, meaning a shorter time to endure the hardships and the tedium. Cabin passage on some liners became lush, but ship owners remained disinterested in the conditions for steerage passengers until William Inman began in 1850 providing ships on which emigrants in steerage could travel in relative comfort. His liners were built to accommodate emigrants, not to transport timber, mail, or other freight (Armstrong 34–35). Emilie and her mother were fortunate that the "City of Philadelphia" was an Inman steamer, because although they had paid for cabin passage, they were assigned bunks in the steerage section because of the large number of passengers.

From the beginning of her account, Emilie wrote as if the trip were an adventure. At age 28, Emilie took charge of the arrangements, and, by comparison, her mother seemed timid and scolding and always expecting the worst. Beginning with the steamboat trip down the Rhine River to

Emigrants. *Illustrated London News,* May 10, 1851.

Rotterdam, Emilie wrote with a great deal of descriptive detail and expressed an appreciation for any kindness shown her and her mother:

> On Thursday we boarded the steamer, "Victoria," and traveled down the Rhine, admiring the beautiful scenery, the many romantic ancient castles, and the high bluffs on either shore, covered with rows upon rows of fruitful vineyards. On board we found a rather boisterous group, but we always discovered some nice people with whom we could chat. We were traveling second class, but for some unknown reason the steward allowed us to occupy two beautifully upholstered easy chairs in a cabin with large gold-framed mirrors on the walls and beautiful rugs on the floor. I had never seen such regal splendor.

Emilie tended her seasick mother on the steamer and also recorded that her mother became ill after drinking the water in Rotterdam. Because milk soup was all her mother wanted to eat, Emilie sought out fresh milk and, when she could find it, cooked milk soup for her mother.

On the night before departure for Philadelphia, they waited with other travelers in the Emigrants' Hotel, and that evening a dance kept them awake most of the night: "We both wept to think of such levity and irresponsible behavior on the last night on terra firma. So many were very drunk in spite of having to start on the long perilous journey the next day." In boarding the tender that was to take them to the "City of Philadelphia," they faced trouble with their baggage:

> All passengers had to carry their own luggage. We were really in a bad situation. I tried to take some of our belongings to the tender, but there was such a crowd of passengers who pushed and crowded so persistently that it was impossible to make any headway, much less to go back after mother. I was beside myself; called to her and finally she came, hardly able to drag the remaining luggage with her. Just as she set foot on the boat it raised anchor. To this day I can't understand how we two helpless women overcame every obstacle as well as we did!

While her mother was again seasick, Emilie couldn't get enough to eat. Although the soup was too peppery, the smoked meat smelly, and the coffee served with molasses, she enjoyed the excellent potatoes and delicious white bread so unlike what she had eaten in Germany. Emilie soon made friends with Marie Siegel, another young adult traveling with her mother, and the two became friendly with the steward who "showered us with favors whenever possible." Emilie reported: "I really had no complaint, and so, just like pretty blond Marie, I was always in a happy mood. She and I were among the few who weren't seasick, spending most of our time on deck, healthy and gay as the fish."

This carefree passage to America was interrupted when the ship rammed a cliff near Newfoundland. Near midnight a terrific crash was followed by a furious rolling of the ship.

> All of us, including the sailors thought that this was the end, for we could feel the ship sinking lower and lower. . . . The yelling, the noise, and the panic was terrible. . . . The men who slept on the level below us tumbled out of their beds and immediately found themselves standing in a foot of water. Trying to save what they could, they grabbed the next best thing and rushed up the stairway. When they reached us, —but what was that? There the fellow stood, wearing nothing but a long white shirt and a high silk hat! We all screamed with hysterical laughter, but soon again soberly realized our perilous plight. Everyone was terrified; mother prayed fervently and I—I went to get something to eat. I recalled the story of Robinson Crusoe who was shipwrecked on a deserted island and learned to fend for himself without the help of the barest necessities. Of course, mother scolded me for thinking of food at a time like this when we stood so close to eternity.

By pumping out the engine room, the crew was able to back the ship onto a sandbar. The passengers were ordered to one side of the ship to counter-balance the tilt of the ship which continued to sink. Rockets were sent up, a little cask containing the names of the passengers and the crew thrown into the sea, and the lifeboats lowered. Amid terrific crowding and pushing, Emilie, holding her mother's hand and the zwieback and honey cakes from Germany, stepped down into a lifeboat. They were taken to a nearby island where the men made a big bonfire out of driftwood.

The next few days the crew rowed back to the ship several times and retrieved luggage and food. Their baggage was not recovered, and Emilie theorized that their cases had "probably plunged into the ocean through the great hole in the hull when we struck the rock." On the third day they heard a startling blast of a cannon from a ship that was to transport them to the city of St. John on the Canadian coast. When their turn came:

> We scrambled on to the little steamer, but it didn't leave until ten o'clock that night! Never, as long as I live, will I forget the awful nightmare of that trip. Frenzied, hysterical screams of "Fire! Fire!" suddenly awakened us out of

> a deep sleep. Poor mother, wringing her hands and weeping, kept lamenting, "We've escaped death by drowning, and now we'll be burned to death!" the fire at last brought under control and after a seemingly endless night we landed, exhausted, at St. John at 5 a.m.

Those people who were shipwrecked lodged with families in St. John for nearly a month, and Emilie was amused when "a mass was said for all of us poor victims of shipwrecks." Her proud mother refused offers of financial assistance as well as gifts including used clothing from a Protestant bishop, so Emilie sewed garments for them. She seemed happy in their cozy host home, appreciated the food, attended a church service at which they couldn't understand the sermon but enjoyed the music, and turned down social invitations because they lacked suitable dresses. However, they continued to be concerned by the high stormy seas and the reports of steamers sinking.

On a stormy October day they departed for Boston, but couldn't land there:

> We were supposed to disembark at Boston, but imagine our surprise when we passed it by, why we weren't told; but some of the passengers said it would have been impossible to land in Boston Harbor. This is a rough voyage, very stormy, with a dark, forbidding sea, and our boat, a small steamer, rocks and pitches like a cork on the angry waves. Poor mother has lost all hope thinking the good Lord has forsaken us now.

But eventually the strong wind subsided, and they entered Philadelphia harbor on a calm, placid sea.

Emilie and her mother settled with her brother in Sauk City, where Emilie became a school teacher and married Louis Crusius in 1860. While her travel narrative brims with youthful enthusiasm and optimism, her summation of her life written in a second memoir is heavily sad. She lost all but three of the nine children she bore. At age 73 she wrote:

> I was blessed with a sunny nature and really would have enjoyed life, had not misfortune after misfortune continually hunted me down. While my children were small I was so happy with them and it was my then carefree outlook which my dear husband so loved in me; but the tragic loss of one dear little one after the other threatened to break me down both mentally and physically. . . . It truly is a miracle I'm still alive; I must be a pretty tough weed. My one wish is just to be near my dear children.

Through the Great Lakes

While Emilie's travel memoir does not detail her methods of travel to Wisconsin, she may have joined the tens of thousands in this mid-1800s period who crossed the Great Lakes to settle in Wisconsin. Often beginning with a trip down the Erie Canal, approximately half of all trans-America migrants to Wisconsin during this period made part of their journey by steamboat through the Great Lakes. Steamers advertised regular schedules, speedy trips, and luxurious accommodations, but travel by Great Lakes steamer was not without mishaps. Seasickness among passengers was common as were accidents involving piers, ice, rocks, and other vessels. Larger steamers were especially prone to hang up on sandbars and beaches during low water or storms. Fires on board were sometimes deadly: the steamship "Niagara," taken by Isabella Mckinnon, was destroyed by fire in 1856 at a loss of over 60 lives (Jenson 212). Some passengers described their trips through the Great Lakes as more harrowing than crossing the Atlantic Ocean.

Racheline S. Wood

In 1838, Racheline S. Wood experienced an eventful trip west through the Great Lakes which included the rescue of passengers after their steamboat hung up on a reef of rocks. Her letters of 1837 to 1840 chronicle Racheline's travels from Vermont to Platteville, Wisconsin, where she settled. Each letter was addressed to her sister Maryann Wood, Enosburgh, Vermont, a place Racheline called home.

Racheline's letters show a degree of education and lofty language not found in the first two travel accounts. At times she projected the sense that she was above the station of many of her fellow travelers, and in frequent comparisons between the east and other areas through which she traveled, she left no doubt that New England was superior in most respects.

In a letter of December 1, 1838, Racheline described the highlights of her journey through the Erie Canal and Great Lakes and her loneliness. The previous distance that divided her from her sister in Vermont seemed short in comparison: "now hundreds of miles with the broad lakes roll between us." But although she and her sister were divided in body, Racheline said their spirits might converse through letters, and she began with the story of her journey. After deciding in mid-August 1838 to leave "dear New England for the far west," she traveled by private conveyance for three days to Troy, New York.

Her spirits fell as they entered New York state: "we rumbled along over those try patience roads gasping at the lofty eminences which rose on either side of us threatening to shut out the light of day." Having previously mentioned "the sterile fields, the frowning heights, the miserable huts" they passed in their travels, she became more cheerful as they came to an area of "highly luxuriant and fruitful fields" which extended all the way to Troy.

Arriving in Troy, she "spent there about three hours running up and down the city most delightfully, called at multitudes of stores and milliners shops and at 5 o'clock was glad to get on board of a canal boat bound for Buffalo on which I remained a week." Her summary of Troy was this:

> Yet with all the pride and advantages of the Yorkers I think New England has whereof to boast not only in morals but in the tidiness and good taste of their establishments. Their buildings are constructed very different from ours with much less good taste and with a general appearance of slackness.

Racheline's "brief sketch of our first nights repose" on the Erie Canal boat included a characterization of her fellow travelers as all grades and ages from the "poor to the man of honour, little babes of 3 weeks, squalling young ones of 1-2-3 years." The sleeping arrangements proved less than satisfactory. Near nine o'clock hammocks were swung to accommodate about half the passengers. In the small room appropriated to the ladies, she selected a place to sleep:

> The middle birth in the middle range was fairly laid there and congratulating myself in having found the best birth when crash went the one above me and down it fell. I sprang to evade it, which going down went mine with the one beneath. Such a racket, the ladies room called forth the simpathies of the gentlemen whose room resounded with mirth when ascertaining the cause of disturbance.

They picked up their berths and made beds on the floor, but she reported that she didn't get a wink of sleep with the "noise of the crew on the deck and the fussing of the rolling of babies upon my feet." During the day, she wrote, they were privileged to get out on the tow path and walk a mile or more.

Leaving the canal, Racheline joined the estimated 5,000 travelers who in a single day in 1838 steamed from Buffalo through the Great Lakes for the west (Channing 267). Racheline reduced the steamboat trip through Lake Erie to only a single line: "Thursday I took the steamboat at Buffalo had a pleasant ride to Detroit where we stopped some hours." After changing boats the passengers continued the journey through Lake Huron and into Lake Michigan, but Sunday morning their boat ran up on a reef of rocks opposite Beaver Island in the straits of Mackinac: "a punishment it would seem for travelling on the sabbath but I must do so or lose my company." The passengers were thrown from their berths as the first sign of disaster, and all attempts to free the boat failed. They waited "near 40 long, wearisome, trying hours" hoping for a boat to come and take them to shore which was about two miles away.

On Tuesday with the waters rising, freight was thrown overboard and the 400 passengers were taken to shore in a small boat:

> In haste we prepared to leave what had seemed our grave, and although the waves were so high as to hide the small boat from view when within but a few rods of our deserted home I never enjoyed a ride better. What inexpressible joy and relief did I experience when I set my feet on terra firma.

After the boat landed with difficulty still some distance from shore, Racheline was carried ashore on a gentleman's shoulders and the passengers took refuge in the fort. In a note written in the margin she regretted she did not have space to better describe "the thousands of Indians which I saw at Michaelimack in their bark canoes their tents which were placed along the Lake almost as far as the eye could reach."

Late in the afternoon enough freight had been thrown overboard so that their ship floated, and it was moored about six miles further out. On Wednesday the passengers were returned to board, and they continued to Chicago having been on the lakes "near a fortnight." "Carelessness was considered the cause of the disaster; as the boat was at least six miles out of its right course when she struck." Thus she ended her travel narrative but her marginal writing included a plea for a long and detailed letter from her sister. Her loneliness was clear in this marginal note:

> I seem to be clear out of the world. I cannot even realize how far I am from you and every relative on earth. When musing on what intervenes between me and those dearer than all resides on earth my heart sickens within me. I dash the thought away as poison.

In a final letter from Platteville, Wisconsin, dated March 10, 1840, Racheline urged her sister Mary to come and live with her and take up a teaching position. Racheline had planned a select school for girls, number limited to 20 and pay of $4 a quarter. She would not be taking the post because she was to be married:

> About a year since, I became acquainted with a Mr. Bass. . . . A strictly moral person, a member of the total abstinence society and is reputed to be worth. . . some thousands exclusive of all debts. I think it more than probable you will not like him but if I do no matter for your opinion.

After giving Mary traveling advice and asking her to bring a dozen good used silver teaspoons and a pair of sugar tongs, Racheline concluded: "I would like to have you live constantly with me." No further letters are available to indicate what Mary thought of these plans and whether she moved to Plattville.

Orpha Bushnell Ranney

Also urging her family to move to Wisconsin, Orpha Bushnell Ranney's letters provided details on farming in Wisconsin as well as a description of her trip west. As a new bride of 21, she traveled with her husband from New York State in September, 1847, settling first near Sun Prairie. In the first of her letters written over a period of 50 years to her sister in Connecticut, Orpha described her trip by canal boat through the Erie Canal and then by steamboat through the Great Lakes.

Of the four women in this article, Orpha appears the least educated. Her writing, with its lack of punctuation and capitalization (except for names), was not unusual for women's writing of the time. Her letters continued line after line with no sentence breaks and sometimes incorrect grammar and spelling. The spidery script penmanship of the period filled every inch of the paper.

Most letter-writers of this time used a standard 10"x15" sheet of paper which was folded once to provide three writing pages and one blank side. The written-on sides were folded inside the blank side until a 3"x 5" clean surface remained for the address. The folds were then sealed with wax. Orpha not only filled the three sides of her paper in the usual fashion but also filled all the margins as well by writing in them sideways. From the tone of her letters, and many others from this period, this practice of using every bit of space spoke not only of the frugality of the writer but the desire and urgency to use every opportunity to communicate with loved-ones left behind.

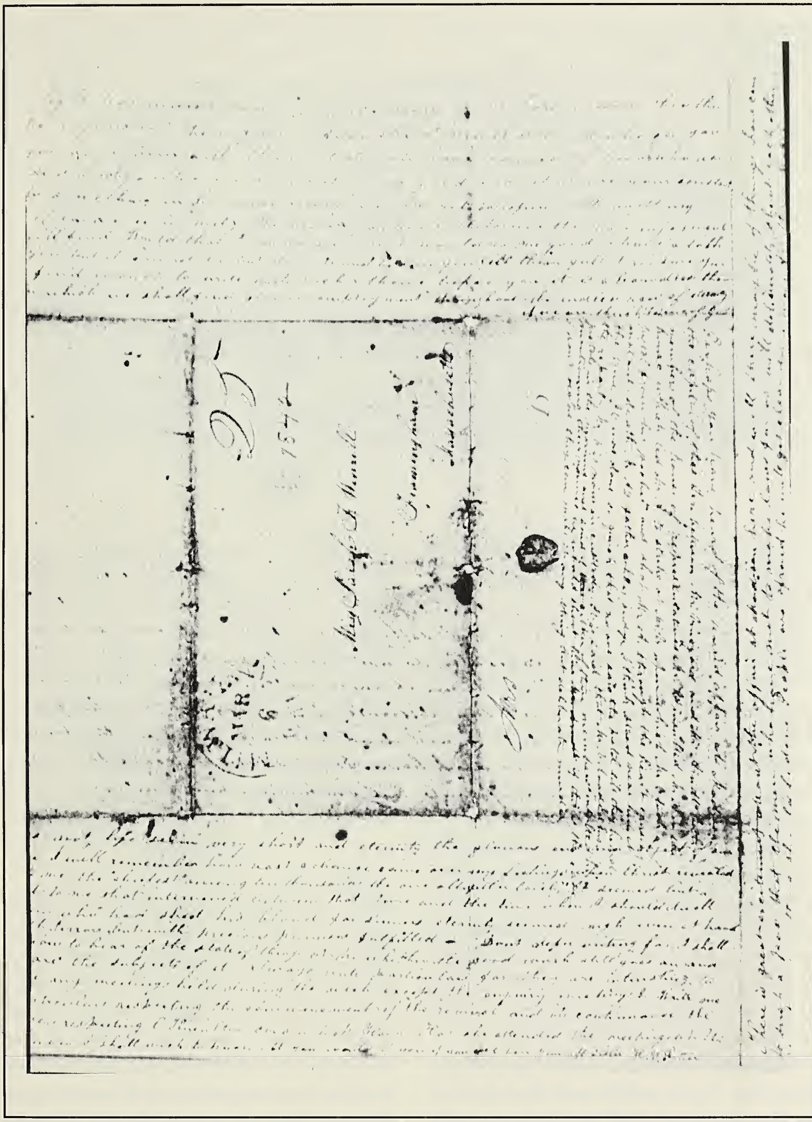
In her letter of September, 1847, Orpha seemed alternately engaged in the new experiences of the "long and tedious journey" and saddened by leaving family and friends.

> it was very pleasant on the canal i see a great many pleasant places and things and those that were interesting but when i looked back and thought of what i was leaving and where i was going it spoilt it all when i looked in to the water and see the little waves that receded back from the boat it seemed that every one was bearing me away from all my friends forever

Although lacking in education, Orpha's writing clearly conveyed her feelings of loneliness as well as her amazement and sometimes fear during some of the trip's happenings. She wrote that she loved to travel and "see so many things which you know are new to me." Orpha, probably from a lower social stratum than Racheline Wood, did not expect special favors and appreciated any that came her way. Describing the journey from Buffalo by steamboat through the Great Lakes, she wrote:

> we took Cabin passage had a room to ourselves which was pleasanter than to be obliged to stay with the rest of the passengers all the while if you want to see a table set in style and vituals cooked in style of all sorts and descriptions you must travel on board a steamboat there is a great deal to be learnt you are waited on in style if you take a Cabin passage you are as big as any of them

However, on the third day the weather became stormy, and Orpha became seasick as did her husband Edward: "the third the lake was rough enough the white caps rolled the boat rocked and tumbled we staggered about like a pack of drunkards i was as sick as death." She also feared that the boat would sink in the storm: "every time the boat stirred it seemed as if we should all sink to the bottom she would rock and twist



Letter of 1842. State Historical Society of Wisconsin Archives.

about and i thought she would all fall to pieces O how i wished i was on land."

The water remained rough for the remainder of the trip, and Orpha reported that the crossing took eight days rather than the general four days when the weather was good. One night the steamer struck a sandbar, and it took the crew most of the night to free it. On a second stormy night the boat was anchored on a sandbar behind an island, perhaps to evade the windy weather. In the process the engine was damaged: "when they were on the sand bar they strained there engine so that they could not keep up against head winds at all when the wind was ahead they had to stop I was afraid the old boiler would burst I was sick all the rest of the way."

Although her letter did not contain specifics on the route traveled, she wrote "we stopt at Cannada and at Mackinaw" where the passengers had some trout. She was impressed by an Indian camp probably on the north shore passing through the straits of Mackinac: "there was between two and three hundred Indians there boats and wigwams were scattered all along the shore they had on there blankets and their wampum and tassels on there heads they looked curious enough."

The travel portion of her letter ended with a visit ashore at one of their stops: "i went in and see the glass works how curious and the salt works it does not seem as if man could ever learn so much." So despite the stormy weather and seasickness, Orpha seemed to retain her sense of amazement at the things she was seeing on the trip.

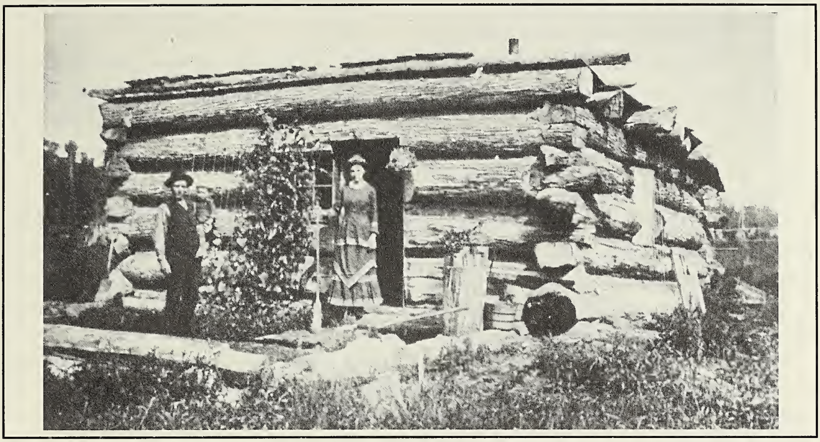
From later letters and a short memoir, we know that Orpha and Edward Ranney lived the first winter of 1847 in Wisconsin with his brother and that their first child was born in January and died that September. The Ranneys' story was not one of successful Wisconsin settlers who easily put down roots. The family farmed only a short time in Wisconsin, moved back east to New York and then Connecticut. They returned to a Wisconsin log house and farming in Dane County in 1852. By the time they moved to Dunn County in 1855, first living in a shanty, Orpha had given birth to six children, five living. Edward soon built a house and, within weeks of moving in, Orpha gave birth to her seventh child who lived only minutes. After living for six years "on the prairie," Edward sold out, invested in timber, and moved the family to Cedar Falls, Dunn County. While her writings indicated that Edward was the decision-maker, Orpha wrote matter-of-factly about all these moves and followed no matter how harsh the conditions.

Edward's health failed and he died "of consumption" in May 1867. Their ninth child was born three months later. Orpha and the children stayed to farm—raising crops and hogs, cattle, and hens. The family got along pretty well, according to Orpha, and she continued to write her sister from Cedar Falls, Dunn County, Wisconsin, the last letter dated August 28, 1898 (Orpha was 74).

Conclusion

Each of these women wrote a highly personal account of her migration to Wisconsin, and each writing provides both glimpses of what happened on the journey as well as how each woman felt and reacted. These accounts vary from brief and detached to detailed and humorous and are expressed in styles from very educated to bordering on illiterate. Each trip was unique, but the sense of voyaging into the unknown was universal.

These narratives make clear that there were no uneventful voyages in route to Wis-



Wisconsin family. Wisconsin Visual Materials Archive.

consin. Because of storms, accidents, and shipwreck, each of these four women feared for her safety and her life during her travels. Every voyager bound for Wisconsin may not have experienced such life-threatening events, but all had to cope with unfamiliar and often harsh conditions on board and throughout their travels. While caught up in the rigors of the trip, travelers were also painfully aware of the distance between them and loved ones left behind. For most immigrants there would be no going back.

It is not surprising that these women voiced complaints and fears, described loneliness and bouts with seasickness. It is surprising that their writing and outlook is not more negative. They just as readily wrote with humor and matter-of-fact acceptance and expressed appreciation for kindnesses received and amazement at new sights and experiences. Their writings contain a mix of beautiful as well as bleak scenery, unease at unfamiliar types of fellow travelers and pleasure with new companions, strange food relished or found unpalatable, luxurious cabins as well as difficult sleeping accommodations, events that were amusing and fearful events that nearly led to a watery grave. They recorded their travels to Wisconsin with a keen eye, and amazingly their complaints were not in proportion to the conditions and events they endured during their trips.

Although Emilie describes herself and her mother as "we two helpless women," this characterization clearly does not hold for any of these women. They each accomplished their trips across unknown waters, the Atlantic and the Great Lakes, with a combination of resilience, sturdiness, and courage—qualities that stood them in good stead when they reached Wisconsin.

Literature Cited

Armstrong, Warren. *Atlantic Highway.* New York: John Day, 1962.

Channing, Edward. *The Story of the Great Lakes.* New York: Macmillan, 1910.

Crusius, Emilie Schramm. Memoirs, 1900. Ms. MAD 4/14/SC 1354. State Historical Society of Wisconsin Archives, Madison.

Current, Richard N. *History of Wisconsin, Volume II.* Madison: State Historical Society of Wisconsin, 1976.

Greenhill, Basil. *Travelling by Sea in the Nineteenth Century.* London: Black, 1972.

Jensen, John Odin. History and Archeology of the Great Lakes Steamer Niagara. *Wisconsin Magazine of History* 82 (1999): 198–230.

Mckinnon, Isabella. Diary, 1852. Ms. MAD 4/14/File 1852 March 1852. State Historical Society of Wisconsin Archives, Madison.

Ranney, Orpha Bushnell. Papers, 1847–1898. Ms. Stout SC 118. State Historical Society of Wisconsin Archives, Madison.

Smith, Alice E. *History of Wisconsin, Volume I.* Madison: State Historical Society of Wisconsin, 1973.

Wood, Racheline S. Letters, 1837–1842. Ms. MAD 4/14/File 1837 July 14. State Historical Society of Wisconsin Archives, Madison.

Cathleen Palmini *is an associate professor at University of Wisconsin-Stevens Point, where she serves as Wisconsin Documents and Reference Librarian. She has studied the private writings of midwestern pioneer women for the last ten years.* ***Address:*** *University Library, University of Wisconsin-Stevens Point, Stevens Point, WI 54481.* ***Email:*** *cpalmini@uwsp.edu*

James L. Theler

Animal Remains from Native American Archaeological Sites in Western Wisconsin

Since the 1950s archaeological teams have worked at excavating ancient Native American living sites in western Wisconsin to learn how the ancestors of modern American Indians lived and how their way of life changed over time. Included among the rich harvest of archaeological materials recovered from excavated sites are a large number of shells and bones from the animals that provided animal protein for the region's Native Americans prior to the arrival of Europeans. In addition, remains of small vertebrates recovered occasionally during archaeological work provide a glimpse of animals that were not used for food but were simply part of the local environment.

This summary has been compiled for people interested in documenting which species of animals were present in the western Wisconsin area of the Upper Mississippi Valley during the five thousand years prior to European arrival. The 190 species listed here were recovered as bones and shells from 32 Native American living sites, the majority of which are located in western Wisconsin (see Table 1 and Figure 1). Because they have passed through a series of "human filters," these archaeological faunal assemblages do not constitute statistically representative samples of local animal populations at the time the sites were occupied. First, these species were selectively chosen by ancient peoples for their suitability as food, clothing, and tool stock. Second, the archaeological recovery process itself can be selective for both the size and the type of faunal material recovered. Third, the existing archaeological faunal assemblages have been analyzed by people with varying levels of expertise. Nonetheless, these faunal remains provide a wealth of information on

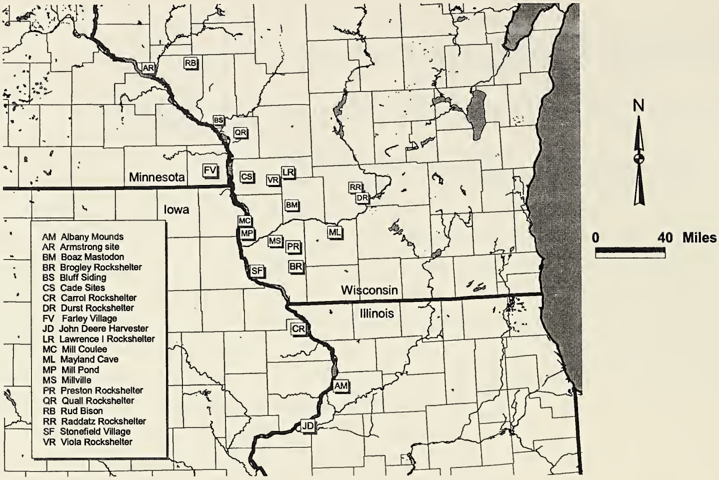


Figure 1. Archaic and woodland sites and selected Oneota sites outside of the La Crosse locality.

the animals used by Native Americans and also serve as a general index for the species once present in the region. Because of their particular relevance I have included a small number of archaeological sites outside western Wisconsin, including the John Deere Harvester site, Albany Mounds, Carroll Rockshelter, and the Farley Village (see Table 1 and Figure 1).

Methods and Materials

Most faunal remains recovered from archaeological sites are discarded food residue deposited with other debris as trash or refuse. At open-air living sites, archaeologists find much of this refuse in pits that the residents dug into the ground and used for storing agricultural produce or other products. When a pit fell into disuse, it was sometimes filled with camp refuse. Archaeologists can usually detect these pits by the dark staining that permeates the soil when organic material decays.

Protective rock overhangs, or rockshelters, were commonly used for human habitation and often contain animal remains in great abundance. These remains are sometimes found in refuse pits but are most abundant in middens that accumulated on the surface as trash repeatedly deposited in the same location. The rockshelters of western Wisconsin appear to have been commonly occupied during the cooler months of the year. The occupants tended to concentrate their living areas at the front of the shelter and toss unwanted materials, including animal bones, to the rear. Open middens or individual discarded bones were often scavenged by domestic dogs and wild

Table 1. List of archaeological sites with identified animal remains.

Abbreviation	*Site Name*	*Site Number*	*Location*	*References*
Oneota Sites				
PC	Pammel Creek	47Lc61	La Crosse Co., WI	Theler 1989, Arzigian et al. 1989
VV	Valley View	47Lc34	La Crosse Co., WI	Stevenson 1994
GU	Gundersen	47Lc394	La Crosse Co., WI	Theler 1994a, Arzigian et al. 1994
MV	Midway Village	47Lc19	La Crosse Co., WI	Scott 1994, Gibbon 1970, Theler 1994b
NS	North Shore	47Lc185	La Crosse Co., WI	Theler 1994b
JB	Jim Braun	47Lc59	La Crosse Co., WI	Theler 1994b
TS	Tremaine	47Lc95	La Crosse Co., WI	Styles and White 1993, Theler 1994b
SR	State Road Coulee	47Lc176	La Crosse Co., WI	Theler 1994b, Anderson et al. 1995
LC	Long Coulee	47Lc333	La Crosse Co., WI	Theler 1990
KS	Krause	47Lc41	La Crosse Co., WI	Theler n.d. a
SL	Sand Lake	47Lc44	La Crosse Co., WI	Theler 1985
OT	OT	47Lc262	La Crosse Co., WI	Styles and White 1993
FS	Filler	47Lc149	La Crosse Co., WI	Styles and White 1993, Penman and Yerkes 1992
AR	Armstrong	47Pe12	Pepin Co., WI	Savage 1978
FV	Farley Village	21Hu2	Houston Co., MN	Theler 1994b
Woodland and Archaic Sites				
CR	Carrol Rockshelter	13Db486	Dubuque Co., Ia	Collins et al. 1997
QR	Quall Rockshelter	47Lc84	La Crosse Co., WI	Theler n.d. b
VR	Viola Rockshelter	47Ve640	Vernon Co., WI	Theler n.d. c
CS	Cade sites	47Ve631, 643, 644	Vernon Co., WI	Theler et al. n.d.
MS	Millville	47Gt53	Grant Co., WI	Pillaert 1969, Theler 1983
SF	Stonefield Village	47Gt1	Grant Co., WI	Theler 1983
PR	Preston Rockshelter	47Gt157	Grant Co., WI	Theler 1987a
RR	Raddatz Rockshelter	47Sk5	Sauk Co., WI	Parmalee 1959
DR	Durst Rockshelter	47Sk2	Sauk Co., WI	Parmalee 1960
BR	Brogley Rockshelter	47Gt156	Grant Co., WI	Theler 1987b
MP	Mill Pond	47Cr186	Crawford Co., WI	Theler 1987a
MC	Mill Coulee	47Cr100	Crawford Co., WI	Theler 1987c
LR	Lawrence I Rockshelter	47Ve154	Vernon Co., WI	Berwick 1975
ML	Mayland Cave	47Ia38	Iowa Co., WI	Storck 1972
BS	Bluff Siding	47Bf45	Buffalo Co., WI	Theler 1981
JD	John Deere Harvester	11RI337	Rock Island Co., Il	Van Dyke et al. 1980
AM	Albany Mounds	11Wt1	Whiteside Co., Il	Klippel 1977, Benchley et al. 1977
Other Sites Mentioned in Text				
RB	Rud Bison		Buffalo Co., WI	Theler et al. 1994
BM	Boaz Mastodon		Richland Co., WI	Palmer and Stoltman 1976

animals, causing loss of the least resilient portions of the bone assemblage and damage to surviving bone.

Native Americans harvested huge quantities of freshwater mussels in portions of the Upper Mississippi River Valley, especially in the vicinity of the Rock Island Rapids in Illinois and Prairie du Chien in Wisconsin. At these locations, Native Americans made seasonal mussel harvests over many hundreds of years. The resulting discarded shells built up to create large shell middens that blanket portions of these areas.

Recovery and Identification of Animal Remains

During the past fifty years, as archaeologists have become interested in understanding the contents of living sites, they have generally used some type of screening device to separate artifacts and animal remains from the excavated soil. An archaeological screen is an open-topped box with wood sides and a metal screen attached as the bottom. Screen mesh sizes have varied depending on the excavators' objectives. Some excavators in the past used screen with a 1/2-inch mesh, but today the minimum standard is 1/4-inch mesh. Since the 1970s many archaeologists have employed finer screens with a mesh size of 1/16 inch or less to recover both animal and carbonized plant remains. The recovery method is a critical factor in the types and frequencies of animal species recovered. Few fish or small mammal remains are recovered with 1/2- or 1/4-inch screen.

Another critical factor is how the animal remains are identified. The remains analyzed by J. Theler as cited in this summary were identified through direct comparisons of the archaeological specimens to modern specimens of known species. Collections of "synoptic" reference skeletons and shells used in these analyses are housed at the University of Wisconsin–La Crosse and at the Zoology Museum at the University of Wisconsin–Madison. A number of experts have provided identifications for specimens that were difficult to identify because of a lack of reference material and/or expertise.

Archaeological specimens for which species identification was ambiguous are not included in the tables accompanying this summary, although they are listed in the original reports. Most faunal analysts note ambiguous identifications by the use of "cf.," which indicates that a specimen "compares favorably" but cannot be definitely assigned to the species. Mallards, for example, are often cited as "mallard (?) cf. *Anas platyrhynchos*" or "probable mallard, *Anas* cf. *A. platyrhynchos*" because most mallard bones are difficult or impossible to distinguish from those of the black duck *(Anas rubripes).* Many archaeological sites of the Upper Mississippi region document the presence of "cf." mallard, but these identifications are not included in this summary, causing mallards to appear rather uncommon in the tables. The taxonomic nomenclature used in this summary for mammals follows Hazard (1982), except for elk (see Thomas and Toweill 1982). Birds follow Robbins (1991), amphibians and reptiles are after Vogt (1981), fish are after Becker (1983), crawfishes are after Page (1985), and mollusks follow Turgeon et al. (1988).

Animal Remains Excluded from This Summary

Bone, antler, or shell of many animal species were commonly used as raw material for making tools and ornaments. Bone tools, even if identifiable to species, were not included in this summary because the materials were often collected or retained in a very different way from animal products used for food. Certain skeletal elements, such as antlers dropped by elk and deer in mid-winter, appear to have been collected and saved for future conversion into tools (Theler 1989). During certain periods in pre-European times, bones and shells of some species seem to have been traded as raw materials for tool manufacture.

One example of tool stock are the shoulder blades (scapulae) of bison, used for the manufacture of agricultural hoes. The latest prehistoric people in the La Crosse area were the Oneota, agriculturalists who grew domestic plant crops in the region between A.D. 1250 and A.D. 1650 (Figure 2).

The most common large Oneota artifact is the bison scapula hoe, with nearly one hundred specimens recovered at local sites. Unworked, non-scapula bison bones, however, are very rare at all sites in the La Crosse area, indicating that living bison were uncommon locally. The most likely source of Oneota bison scapulae was the region west of the Mississippi River in Iowa and Minnesota.

This summary does not give the number of recovered bones for each animal species or the number of individual animals, although that information is usually available in the cited reports. There is evidence that many groups deboned large mammals at the kill location, retaining only selected bones to be used as tool stock, or left smaller bones on the hide to aid in carrying the meat/hide bundle back to the camp or village (Perkins and Daly 1968; Skinner 1923:142). Elk and white-tailed deer seem to have been consistently deboned in the field during the later prehistoric period (Theler 1989:223, 1994a:40-41).

Two other types of remains are also omitted from this summary. The first are animal remains occasionally found as possible ritual items placed with human burials. The second are faunal materials that represent long-distance trade, such as marine shell *(Marginella apicina)* beads recovered at the Overhead and Sand Lake sites and a single unworked American alligator *(Alligator mississipiensis)* tooth from the State Road Coulee site (see Anderson et al. 1995).

Pre-European Native American Cultures and Time Units

Four archaeological cultural/time units are used in this summary. They represent a simplified version of the subdivisions of the pre-European human prehistory of the region. The best archaeological evidence indicates that the first people to enter the Upper Mississippi River Valley, the Paleo-Indians, arrived about 12,000 years ago. They were the peoples who hunted mammoths *(Mammuthus)* and mastodon(t) *(Mammut americanum)* in North America. Not included in the present summary are the remains of animals associated with the last Ice Age or Pleistocene period, which ended about 11,000 years ago. At the Boaz mastodon site in Richland County, Wisconsin, mastodon remains appear to be associated with a spear point, suggesting PaleoIndian-mastodon contact (Palmer and Stoltman 1976). Animal remains associated with the early portion of the current postglacial (Holocene) period, but without human association, are not included in the tables. One such early Holocene paleontological site is the Rud Bison site (Theler et al. 1994), which produced several partial skeletons of the extinct bison *(Bison occidentalis)* in Buffalo County, Wisconsin.

Following the Pleistocene, the descendants of the PaleoIndians settled into the region. These Archaic groups followed an annual subsistence cycle of hunting and gathering wild resources. They did not make pottery containers or build earthen mounds

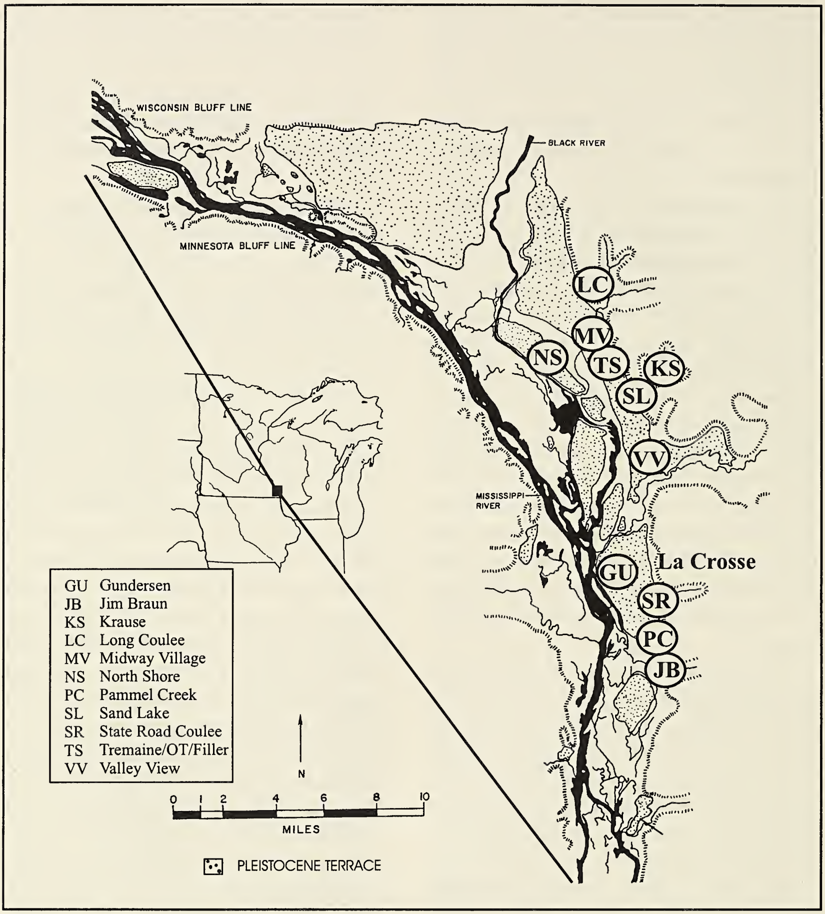


Figure 2. Oneota sites at the La Crosse locality.

to cover their dead. The Archaic period lasted from about 11,000 to 2,000 years ago. The subsequent Woodland peoples (2,000 to 800 years ago) are characterized by the use of pottery vessels and constructed burial mounds. In the later part of the Woodland period, there is evidence for the use of the bow and arrow, the building of effigy mounds, and adaptation to domestic plant cultivation. The final pre-European residents of western Wisconsin, the Oneota, lived in the area between 800 and 400 years ago. These village agriculturalists raised corn, beans, squash, and tobacco. They harvested local game during the summer and seasonally hunted bison and other large game west of the Mississippi River. In early historic times the La Crosse area Oneota are believed to be people known as the Ioway Indians.

Results

Mammals

There are 44 species of mammals represented at the 32 archaeological sites covered in this summary (Table 2). Those interested in the distribution of Late Quaternary mammals recovered from archaeological or paleontological contexts in North America are referred to Faunmap (Faunmap Working Group 1994). The human remains listed in Table 2 do not represent burials, but rather isolated bones or teeth that are occasionally found during excavations of habitation areas.

It is clear that the most economically important animal utilized by pre-European groups was the white-tailed deer *(Odocoileus virginianus).* The remains of this species are especially numerous at Archaic and Woodland fall-winter occupations in western Wisconsin rockshelters. The occupation zones in these rockshelters often contain thousands of deer bones, broken open for extraction of the fat-rich marrow. The fall-winter white-tailed deer provided a perfect package, in both size and quality, of meat, fat, and hide (Gramly 1977). While not nearly as abundant as deer, bones of elk *(Cervus canadensis)* are present at most sites. These bones are usually from the hoof. Presumably, they were left on the hide to help transport the hide/meat bundle, while most of the skeleton was left at the kill location.

The situation for bison *(Bison bison)* is similar to that for elk, though found at fewer sites. The few unmodified bison bones at Oneota sites on the La Crosse terrace are mostly hoof bones (phalanges). Bison remains are almost unknown at sites in Wisconsin's Driftless area, with an exception in the Archaic component at Preston Rockshelter in Grant County. At the Carroll Rock Shelter, a Late Woodland site in Dubuque County, Iowa, a different pattern is represented with bison apparently taken close to the occupation area and the meat with some associated bone returned to the site (Collins et al. 1997).

The remains of black bear *(Ursus americanus)* are widely but thinly represented, particularly at La Crosse area Oneota sites. Most of these remains are mandible/maxilla sections and bones associated with leg extremities (e.g., metacarpals, metatarsals, and phalanges), presumably bones left on the skin. The presence of bear skull parts seems to relate to an interest in acquiring the animals' large canine teeth.

Mustelids, the members of the weasel family, are rare at all sites and often are represented only by skull parts (mandibles or crania). River otter *(Lutra canadensis)* and mink *(Mustela vison)* remains are found at many Oneota sites in the La Crosse area. It is possible that the particular elements represented relate to special or ritual use of these animals (Parmalee 1959b:89, 1963:67, Plate 2; Skinner 1925:150-51, Plates 25-26; 1926:248, Plate 41; Theler 1989, 1994:42-43).

Other mammals of some importance are the muskrat and beaver. The remains of both riparian species were widespread at regional sites. At La Crosse area Oneota sites, beaver are represented largely by skull parts. Numerous lower jaws (mandibles) of beaver have been found with the incisors carefully removed. This pattern is believed to be related to the use of beaver incisors as woodworking tools (Theler 1989, 1994).

In pre-European times, the dog was the only domestic animal in the Upper Mississippi River Valley. Domestic dogs were

Table 2. Mammals.

Common Name	*Scientific Name*	*Oneota*	*Woodland*	*Archaic*
Opossum	*Didelphis virginiana*		QR/PR	
Masked Shrew	*Sorex cinereus*	FV		
Short-tailed Shrew	*Blarina brevicauda*	VV/SR/FV	VR/CR	PR/RR
Prairie Mole	*Scalopus aquaticus*	PC/VV/FV/SR/ SL/MV	QR/MS/PR/CR	PR/RR
Big Brown Bat	*Eptesicus fuscus*			RR
Eastern Cottontail	*Sylvilagus floridanus*	VV/SR	QR/VR/PR/DR/ML	PR/RR/DR
Eastern Chipmunk	*Tamias striatus*	VV/MV/FV	QR/VR/MS/PR/ DR/MC	CS/PR/ RR/DR
Woodchuck	*Marmota monax*	VV/MV	QR/VR/MS/PR/ DR/MP/ML	PR/RR/DR
Thirteen-lined Ground Squirrel	*Spermophilus tridecemlineatus*	PC/VV/FV/KS/OT	QR/PR/AM	PR
Gray Squirrel	*Sciurus carolinensis*	VV	VR/MS/PR/DR/ML	PR/RR/DR
Fox Squirrel	*Sciurus niger*	VV		
Red Squirrel	*Tamiasciurus hudsonicus*		QR/AM	PR/RR
Flying Squirrel	*Glaucomys volans*		QR/PR	PR/RR
Plains Pocket Gopher	*Geomys bursarius*	VV/GU/MV/FV/ SR/SL/OT/AR	QR/VR/CS	
Beaver	*Castor canadensis*	PC/GU/MV/JB/ SR/FV/KS/SL/ OT/FS/AR	QR/VR/CS/MS/ PR/DR/MP//ML/ AM/CR	PR/RR/DR
Deer Mouse	*Peromyscus maniculatus*	PC/KS		
White-footed Mouse	*Peromyscus leucopus*		CS	
Meadow Vole	*Microtus pennsylvanicus*	PC/FV/KS/SL/FS	CS	
Prairie Vole	*Microtus ochrogaster*	KS/SL	CS	CS
Southern Bog Lemming	*Synaptomys cooperi*		CS	RR
Muskrat	*Ondatra zibethicus*	PC/VV/GU/MV/ TS/SR/FV/KS/ SL/OT/AR/FS	QR/VR/CS/MS/ PR/DR/MP/ML/AM	CS/PR/ RR/DR
Meadow Jumping Mouse	*Zapus hudsonius*	KS		
Porcupine	*Erethizon dorsatum*	VV	VR	
Domestic Dog	*Canis familiaris*	PC/GU/MV/ KS/OT	MS	
Coyote	*Canis latrans*		DR	DR
Wolf	*Canis lupus*	PC	QR/MP	PR/RR/LR
Red Fox	*Vulpes vulpes*		DR/AM	
Grey Fox	*Urocyon cinereoargenteus*		PR/AM	
Black Bear	*Ursus americanus*	PC/VV/GU/MV/ JB/TS/FV/SE/ KS/SL/AR	DR/ML	LR
Raccoon	*Procyon lotor*	PC/VV/GU/JB/ FV/KS/SL/MV	ML/AM/QR/VR/ MS/PR/DR/MP/MC	CS/PR/ RR/DR
Pine Marten	*Martes americana*	MV		RR
Fisher	*Martes pennanti*		QR/PR/DR	RR/DR
Long-tailed Weasel	*Mustela frenata*		PR	PR/RR

Table 2, continued.

Common Name	*Scientific Name*	*Oneota*	*Woodland*	*Archaic*
Mink	*Mustela vison*	PC/VV/GU/ SR/SL/AR	MS/DR	
Badger	*Taxidea taxus*	VV/FV/SR	QR/MS	
Striped Skunk	*Mephitis mephitis*	OT	QR/PR	PR
River Otter	*Lutra canadensis*	PC/VV/GU/ SR/SL/FS	MS/PR/DR	
Mountain Lion	*Felis concolor*			RR/LR
Bobcat	*Lynx rufus*	GU	MS/AM	RR
American Elk	*Cervus canadensis*	AR/PC/VV/GU/ MV/JB/TS/FV/ SR/KS/SL/OT	JD/BS/VR/CS/ MS/PR/DR/MP/AM	CS/PR/ RR/DR
White-tailed Deer	*Odocoileus virginianus*	OT/FS/AR/PC/ VV/GU/MV/NS/ JB/TS/SR/FV/ KS/SL	MC/LR/ML/AM/ JD/QR/VR/CS/ MS/PR/DR/MP	LR/ML/ CS/PR/ RR/DR
Moose	*Alces alces*	FV		
Bison	*Bison bison*	PC/VV/MV/JB/ SR/KS/OT/AR	CR	PR
Human	*Homo sapiens*	PC/MV/TS/SR/ KS/SL/OT/AR	QR/CS/PR	

associated with Native peoples throughout most of North America over the past 10,000 years. Dogs were important in Native societies as pack animals (Henderson 1994), assistants in the hunt, village alarm systems, disposers of unused food, and sometimes a food resource (Snyder 1991). Dog remains have been found at a number of archaeological sites where they appear to have been used as a food. A complete set of four discarded lower leg extremities (paws) was found adjacent to a refuse pit at the Pammel Creek site (Theler 1989:181, Figure 5.3), and another set was found in pit fill at the Krause site. Two dog skulls were recovered in a refuse-filled pit at the OT site (O'Gorman 1989). Intentional dog burials appear to be rare at Woodland or Oneota sites in the Upper Mississippi River Valley. One dog burial was found in a conical mound at the Raisbeck Mound group in Grant County, Wisconsin, by W. C. McKern in 1932 (Rowe 1956:41).

Birds

In all, 51 species of birds are represented in the 32 faunal assemblages (Table 3). As noted in the Methods and Material section, bones with uncertain identifications were excluded from the table.

The most widely represented bird species is the wild turkey *(Meleagris gallopavo).* In southwestern Wisconsin, turkey remains are represented by a range of skeletal elements. They are fairly abundant at both Archaic and Woodland sites south of a line from Green Bay to Prairie du Chien that marks the species' distribution before European contact (Schorger 1942, 1966: Figure 6). Ten La Crosse area Oneota sites have produced turkey remains. These bones are primarily those from the wing tips (carpometacarpus, phalanges, and digits) that support the stout primary feathers. Primary feathers are the best choice for arrow fletching, according to Schorger (1966:361-62) and Loran Cade, a Wisconsin primitive archery

Table 3. Birds.

Common Name	*Scientific Name*	*Oneota*	*Woodland*	*Archaic*
Common Loon	*Gavia immer*	VV/AR		
Great Egret	*Casmerodius albus*	SL		
American Bittern	*Botaurus lentiginosus*	SR/AR		
Tundra Swan	*Cygnus columbianus*		AM	PR
Trumpeter Swan	*Cygnus buccinator*	MV/SL/AR	AM	
Canada Goose	*Branta canadensis*	PC/VV/MV/SR/ KS/FS/AR	QR/MS/DR/PR/AM	RR
Woodduck	*Aix sponsa*	PC/VV/GU/MV	AM	RR
Green-winged Teal	*Anas crecca*	GU/AR	QR/ML	
Blue-winged Teal	*Anas discors*	MV	MS	
Mallard	*Anas platyrhynchos*	MV/SR	MS/DR/ML/AM	RR
Northern Pintail	*Anas acuta*		AM	PR
Northern Shoveler	*Anas clypeata*	VV		
Gadwall	*Anas strepera*		PR	
Redhead	*Aythya americana*	VV	MS	
Ring-necked Duck	*Aythya collaris*	VV	ML	
Common Goldeneye	*Bucephala clangula*		ML	
Bufflehead	*Bucephala albeola*	GU/AR	CR	
Common Merganser	*Mergus merganser*	PC	MS/AM/CR	
Hooded Merganser	*Lophodytes cucullatus*	VV/AR		
Turkey Vulture	*Cathartes aura*			RR
Northern Harrier	*Circus cyaneus*	SL		
American Kestrel	*Falco sparverius*			PR
Merlin	*Falco columbarius*	VV		
Peregrine Falcon	*Falco peregrinus*	FS		
Red-tailed Hawk	*Buteo jamaicensis*	AR	PR	RR/PR
Bald Eagle	*Haliaeetus leucocephalus*		VR	
Red-shouldered Hawk	*Buteo lineatus*		DR	
Ruffed Grouse	*Bonasa umbellus*		DR/ML/PR	RR/DR/PR
Greater Prairie Chicken	*Tympanuchus cupido*	MV	PR	PR
Wild Turkey	*Meleagris gallopavo*	PC/VV/GU/MV/ TS/SR/FV/SL/ OT/FS	VR/MS/DR/ML/ PR/AM/CR	PR/CS/ RR/DR/LR
Virginia Rail	*Rallus limicola*	AR		
Common Moorhen	*Gullinula chloropus*	AR		
Sora	*Porzana carolina*	VV/GU/MV		RR
American Coot	*Fulica americana*	GU/TS/SR/ KS/AR	PR/AM	RR
Sandhill Crane	*Grus canadensis*	PC/VV/SR/FS/AR		
Upland Sandpiper	*Bartramia longicauda*	VV		
Passenger Pigeon	*Ectopistes migratorius*	VV/FV/SR/MV	VR/DR/PR	RR/PR
Sharp-tailed Grouse	*Tympanuchus phasianellus*		QR/MS/DR/ML/PR	RR/DR/PR
Eastern Screech-owl	*Otus asio*	VV	PR	RR
Great Horned Owl	*Bubo virginianus*	VV/SR		

Table 3, continued.

Common Name	*Scientific Name*	*Oneota*	*Woodland*	*Archaic*
Barred Owl	*Strix varia*	VV		RR
Belted Kingfisher	*Ceryle alcyon*	VV		
Red-headed Woodpecker	*Melanerpes erythrocephalus*	PC/SR		RR
Northern Flicker	*Colaptes auratus*	VV/GU	PR	
Blue Jay	*Cyanocitta cristata*	AR		RR
American Crow	*Corvus brachyrhynchos*	VV	AM	RR
Common Raven	*Corvus corax*	VV		
Red-bellied Woodpecker	*Melanerpes carolinus*		VR	
American Robin	*Turdus migratorius*		PR	PR
Red-winged Blackbird	*Agelaius phoeniceus*	PC/GU/MV/TS/ FV/KS/SL	VR	RR
Northern Cardinal	*Cardinalis cardinalis*			RR

enthusiast (personal communication, 1993). This distribution of bones seems to indicate that turkey wing tips, with the primary feathers attached, were saved during seasonal travel or hunts or perhaps traded into the La Crosse area during the Oneota occupation.

Waterfowl are present at many sites, with Canada geese and dabbling ducks being most common. Canada geese are the most widespread, with both bones and eggshell having been recovered. According to an analysis of bone size and eggshell structure (Speth 1987), the Canada geese harvested in the La Crosse area were the "giant race" *(Branta canadensis maxima).* Mallards *(Anas platyrhynchos)* and wood ducks *(Aix sponsa)* have been found at several sites. The presence of eggshell and medullary bone (Rick 1975) in some elements indicates spring harvest of waterfowl eggs and nesting birds. The trumpeter swan *(Cygnus buccinator)* is represented at three La Crosse area Oneota sites.

A wide range of raptorial birds (e.g., hawks, owls) as well as crows and ravens show up in small numbers at archaeological sites. It is well known that Native American peoples often assigned ritual significance to certain bird species (Skinner 1923, 1925:89; Wilson 1928). Although not included in the tables, two burial sites of the Upper Mississippi River Valley contain interesting bird remains. A "headdress" found with a human burial in a Sauk County, Wisconsin, mound included the remains of two bird skulls and portions of four wing bones from the common raven (*Corvus corax,* see Wittry 1962). At the Flynn site, a protohistoric Oneota cemetery uncovered during road construction in Allamakee County, Iowa, a raven skull was also associated with a human burial (Bray 1961).

Smaller species of perching birds (Passeriforms) are rare or absent in the faunal assemblages from sites of all time periods. The single exception is the red-winged blackbird *(Agelaius phoeniceus),* represented at seven Oneota sites in the La Crosse area. The bones of this species are sometimes found charred, indicating their probable use as food. Red-winged blackbirds are a noted agricultural pest and would have been a common summer resident near Oneota villages and cornfields.

Fishes

There are 35 species of fish represented at the 32 archaeological sites (Table 4). The most widespread species is the freshwater drum *(Aplodinotus grunniens),* and the most common fish are the catfishes, particularly the black bullhead *(Ictalurus melas).* Many fish species, including northern pike *(Esox lucius)* and members of the sucker family (Catostomidae), were taken during spawning periods. Others (gar, bowfin, and bullheads) were taken during the summer months by seining or trapping in shallow backwaters along the Mississippi River. The thick, durable rhombic scales of gar (Lepisosteidae) are present at most sites along the Mississippi River, but well-preserved skull bones are necessary to separate the longnose gar *(Lepisosteus osseus)* from the shortnose gar *(Lepisosteus platostomus).* The exterior surface of gar scales often exhibit evidence of being burned or scorched, an indication that entire fish may have been roasted in their armor-like scale covering.

Exceptionally large flathead catfish *(Pylodictis olivaris)* of 50 pounds or more and large channel catfish *(Ictalurus punctatus)* are present at many Woodland and Oneota sites adjacent to the Mississippi River. These catfish were probably harvested from their nest sites during the mid-summer. There is no indication based on estimated size or species distribution that gill nets were used or swift waters fished. For example, juvenile individuals of the flathead and channel catfish that are typically associated with relatively swift water are almost unknown from the late prehistoric sites of the Upper Mississippi River.

Amphibians

The bones of frogs, toads, or salamanders are occasionally found by use of fine-screen recovery techniques at archaeological sites. In most cases these remains appear to be part of the natural rain of small-scale fauna preserved at some sites, rather than a regular part of the human diet. Four amphibian species are represented at the sites considered here (Table 5).

Two occurrences of amphibians are worthy of mention. The skeletal remains of nine leopard frogs *(Rana pipiens)* were found in the bottom of a refuse-filled pit at the Tremaine site, an Oneota site on the La Crosse terrace. It is unclear whether these individuals represent a natural inclusion or were brought to the site as food items. The rock fill at the base of the pit lay directly on the bones of these frogs.

Also of interest are the skeletal remains of at least three tiger salamanders *(Ambystoma tigrinum)* recovered from pit fill at the Krause site, an Oneota habitation area on the La Crosse terrace. The zone of pit fill that contained the salamander bones also produced over 14,000 bones representing more than 400 individual fish (mostly small black bullheads) of 16 species. Thrown into this mix were crawfish remains, the bones of a coot *(Fulica americana),* and the paws of a dog. This deposit is thought to largely represent a seining episode in a backwater habitat. The occurrence of the tiger salamander is of interest given the historic absence of the species in the unglaciated Driftless Area of southwestern Wisconsin, except for one historic report (Vogt 1981:45).

Reptiles

The remains of turtles occur at many of the 32 archaeological sites considered, with nine species represented (Table 5). They are typically represented by segments of the upper and lower shells (the carapace and plastron). Turtle remains appear most frequently at the open-air Woodland and Oneota sites found adjacent to the Mississippi River and its wetlands.

Table 4. Fishes.

Common Name	*Scientific Name*	*Oneota*	*Woodland*	*Archaic*
Lake Sturgeon	*Acipenser fulvescens*	PC/VV/MV/FS		
Shovelnose Sturgeon	*Scaphirhynchus platorynchus*	PC		
Paddlefish	*Polyodon spathula*	SL		
Shortnose Gar	*Lepisosteus platostomus*	PC/MV		
Longnose Gar	*Lepisosteus osseus*	PC/MV	MS	
Bowfin	*Amia calva*	PC/VV/GU/MV/NS/JB/TS/SR/KS/SL/OT/FS	QR/MS/MP/MC	CS
Northern Pike	*Esox lucius*	PC/GU/SR/KS/OT/FS		
Bigmouth Buffalo	*Ictiobus cyprinellus*	PC/VV/SR		
Smallmouth Buffalo	*Ictiobus bubalus*	VV/SL	MC	
Quillback	*Carpiodes cyprinus*	VV/OT		
River Carpsucker	*Carpiodes carpio*	VV		
Black Redhorse	*Moxostoma duquesnei*	PC/KS		
Golden Redhorse	*Moxostoma erythrurum*	PC/VV/KS/SL	VR/MC	
Silver Redhorse	*Moxostoma anisurum*	PC		
Shorthead Redhorse	*Moxostoma macrolepidotum*	PC/VV/MV/TS/FV/SL/FS	QR/VR	
River Redhorse	*Moxostoma carinatum*	VV/KS		
Northern Hog Sucker	*Hypentelium nigricans*	OT		
White Sucker	*Catostomus commersoni*	PC/VV/FV/SR/OT		
Black Bullhead	*Ictalurus melas*	PC/VV/GU/MV/NS/TS/KS/SL/OT/FS	PR	
Brown Bullhead	*Ictalurus nebulosus*	PC/VV/MV/NS/TS/KS/SL/OT		
Yellow Bullhead	*Ictalurus natalis*	PC/VV/MV/NS/TS/KS/SL/OT/FS		
Channel Catfish	*Ictalurus punctatus*	PC/VV/GU/MV/JB/TS/FV/SR/KS/SL/OT/FS	VR/PR/MP	
Tadpole Madtom	*Noturus gyrinus*	PC/KS		
Flathead Catfish	*Pylodictis olivaris*	PC/VV/MV/JB/SR/SL/OT	MP/MC	
Smallmouth Bass	*Micropterus dolomieui*	VV/GU		
Largemouth Bass	*Micropterus salmoides*	PC/MV/RB/SL	MP/MC	
Green Sunfish	*Lepomis cyanellus*	VV/GU		
Pumpkinseed	*Lepomis gibbosus*	PC/VV/KS/SL		
Bluegill	*Lepomis macrochirus*	VV/MV/KS		
Rock Bass	*Ambloplites rupestris*	VV/MV/FV/ST		
White Crappie	*Pomoxis annularis*	VV/KS		
Black Crappie	*Pomoxis nigromaculatus*	PC/VV/MV		
Walleye	*Stizostedion vitreum*	PC/VV/GU/KS/FS		
Yellow Perch	*Perca flavescens*	PC/VV/GU/MV/FV/SR/SL	QR/MS	
Freshwater Drum	*Aplodinotus grunniens*	PC/VV/GU/MV/NS/JB/TS/SR/FV/KS/SL/OT/FS/JD	QR/MP/MC	CS

Table 5. Amphibians, reptiles and crawfish.

Common Name	*Scientific Name*	*Oneota*	*Woodland*	*Archaic*
Amphibians				
Eastern Tiger Salamander	*Ambystoma tigrinum*	KS		
American Toad	*Bufo americanus*	SR/KS		
Northern Leopard Frog	*Rana pipiens*	MV/TS/SR/KS	VR	
Green Frog	*Rana clamitans*	MV		
Reptiles				
Snapping Turtle	*Chelydra serpentina*	AR/JD/PC/VV/ GU/MV/NS/SR/ KS/SL/OT/FS	QR/VR/MS/ DR/AM	RR/DR
Stinkpot Turtle	*Sternotherus odoratus*		MP	
Wood Turtle	*Clemmys insculpta*		VR	
Blanding's Turtle	*Emydoidea blandingi*	TS/SR/AR	MS/DR/MP	RR/DR
Ornate Box Turtle	*Terrapene ornata*		PR/DR/AM	RR/DR
Painted Turtle	*Chrysemys picta*	PC/VV/GU/MV/ JB/SR/OT/AR	QR/VR/MS/ PR/AM	RR
Map Turtle	*Graptemys geographica*	PC/VV/MV/ SR/OT	QR	
False Map Turtle	*Graptemys pseudogeographica*	PC/GU		
Softshell Turtle	*Trionyx*	JD/PC/GU/MV/ JB/TS/SR/KS/ SL/OT/FS	QR/MS/DR/ MP/AM	
Bullsnake	*Pituophis melanoleucus*	PC/GU/MV	QR/VR	
Garter Snake	*Thamnophis radix*	KS		
Timber Rattlesnake	*Crotalus horridus*		QR/VR	
Eastern Hognose Snake	*Heterodon platyrhinos*	SR		
Fox Snake	*Elaphe vulpina*	SR	VR	
Crayfish				
Papershell Crayfish	*Orconectes immunis*	PC		
Northern Crayfish	*Orconectes virilis*	PC		
Devil Crayfish	*Cambarus diogenes*	PC		
White River Crayfish	*Procambarus acutus*	KS		

The most widespread turtle remains are those of the snapping turtle *(Chelydra serpentina)*. Although the remains are present on many sites, only one or two individuals are represented in most of the site assemblages. Scorching on the exterior of many shell fragments indicates that when captured (perhaps during spring egg-laying on dry land), turtles were cooked in their shell. The softshell turtle *(Trionyx)* is also widespread, but few individuals are represented. The softshell turtle is easy to identify to the genus level by the distinctly sculptured exterior surface of its shell, but it is difficult to distinguish between the two species (*Trionyx spiniferus* and *Trionyx muticus*) found in the

Upper Mississippi Valley. Therefore, the tables include this common taxon only at the genus level. The ornate box turtle *(Terrapene ornata)* has been recovered at archaeological sites (e.g., Preston Rockshelter in Grant County) adjacent to this species' historically known range on the sand terraces along the lower Wisconsin River (Vogt 1981:99-100). The box turtle is absent from the archaeological sites at the Prairie du Chien and La Crosse terraces. A variety of other turtles show up infrequently. The Blanding's turtle *(Emydoidea blandingi)* has been found at a few sites, and its deeply cupped upper shell was sometimes modified for use as a container.

The vertebrae of five species of snakes have been recovered. Snakes are believed to be part of a natural accumulation of smaller vertebrates that can become incorporated into archaeological site deposits. There is no indication that snakes were harvested for any reason by Native Americans of the Upper Mississippi River Valley. The late prehistoric Oneota sites of the La Crosse terrace do show several occurrences of the bullsnake *(Pituophis melanoleucus)*. The bullsnake's presence is not surprising given that many La Crosse terrace Oneota sites contain bones and burrows of the Plains pocket gopher *(Geomys bursarius)*, a common prey species of the bullsnake.

Crayfish

Crayfish remains have been recovered from refuse-filled pits at the Krause and Pammel Creek sites, both Oneota villages (Table 5). At Pammel Creek, hundreds of burned crawfish carapace (shell) fragments occurred in ash zones that also produced red-winged blackbird bones and carbonized wild rice *(Zizania aquatica)* grains (see Arzigian et al. 1989). These three food items may have been harvested during the mid-summer period at a single floodplain habitat.

Freshwater Mussels

There are 39 species of freshwater mussels represented at the 32 archaeological sites (Table 6). Many Native peoples of the Upper Mississippi River Valley harvested large numbers of freshwater mussels as a seasonal food source. One Woodland period shell midden near Prairie du Chien, Wisconsin, is estimated to contain more than a million shells, the result of many seasons of use (Theler 1987a). Although mussels were used primarily as food, their shells were sometimes converted into tools (Theler 1991, 1994) and crushed into the tempering agent used in Oneota shell-tempered pottery (Theler 1990). In a few cases, attractive shells such as the elephant-ear *(Elliptio crassidens)* were buried with the dead (see Mead 1979:164).

While the shells of large, heavy mussels such as the washboard *(Megalonaias nervosa)* were sometimes traded or carried over some distance (Theler 1991:324-25), most shells were evidently discarded adjacent to the body of water in which they were harvested. These shells accumulated to form middens or were used as fill for storage pits that had fallen into disuse. The archaeological record of freshwater mussel distribution provides a unique view of the geographic distribution of these animals prior to European disruption of the native aquatic ecosystem. A case in point is the assemblage of mussels from the Brogley Rockshelter, located along the Platte River in Grant County, Wisconsin. Brogley Rockshelter produced thousands of individual shells of more than 20 mussel species (Theler 1987b). This site is an important example because it demonstrates the rich freshwater mussel fauna that occupied the interior small streams of western Wisconsin's Driftless Area prior to European settlement. The two most abundant species at Brogley were the spike *(Elliptio*

Table 6. Freshwater mussels.

Common Name	*Scientific Name*	*Oneota*	*Woodland*	*Archaic*
Cylindrical Papershell	*Anodontoides ferussacianus*		QR/PR	PR/BR
Giant Floater	*Anodonta grandis*	PC/VV/GU/MV/NS/SR/SL/FS	QR/VR/PR/BR	PR/BR
Squawfoot	*Strophitus undulatus*	VV/SR/FV	QR/VR/DR/MP/BR/BS	BR
Elktoe	*Alasmidonta marginata*	PC/GU/MV/AR	VR/MS/BR/JD	BR
Slippershell Mussel	*Alasmidonta viridis*		BR	BR
Rock-Pocketbook	*Arcidens confragosus*	NS	MC	
White Heelsplitter	*Lasmigona complanata*	PC/VV/GU/SR/SL/AR	BS/QR/PR/DR/MP/AM/BR/JD	
Fluted-Shell	*Lasmigona costata*	GU/AR	QR/VR/MS/DR/MP/BR/BS	BR
Creek Heelsplitter	*Lasmigona compressa*	FV	BR	BR
Washboard	*Megalonaias nervosa*	VV	MS/BR/JD	BR
Pistolgrip	*Tritogonia verrucosa*	PC/VV/GU/MV/SR/SL/FS	MS/SF/MP/MC/JD/BS	
Maple Leaf	*Quadrula quadrula*	PC/VV/GU/MV/NS/LC	MS/MP/MC/JD/BS	
Winged Maple Leaf	*Quadrula fragosa*	GU/MV	MP/MC/BS	
Monkeyface	*Quadrula metanevra*	PC/VV/GU/NS/JB/LC/SR/FS/AR	MS/SF/MC/AM/JD/CR	RR
Wartyback	*Quadrula nodulata*		MP/MC/JD	
Pimpleback	*Quadrula pustulosa pustulosa*	PC/VV/GU/MV/NS/JB/LC/SR/SL/FS	MS/SF/MP/MC/AM/JD/BS/CR	
Threeridge	*Amblema plicata*	PC/VV/GU/MV/NS/JB/SR/LC/SR/SL/FS/AR	QR/MS/SF/PR/DR/MP/MC/AM/BR/JD/BS	DR/BR
Ebonyshell	*Fusconaia ebena*	PC/VV/GU/MV/NS/JB/SR/LC/SL/FS	QR/MS/SF/MD/MC/AM/BR/JD/CR	
Wabash Pigtoe	*Fusconaia flava*	PC/VV/GU/MV/NS/JB/SR/LC/SL/FS/AR	MS/SF/MP/MC/AM/BR/JD/BS	BR
Purple Wartyback	*Cyclonaias tuberculata*	JB/LC	SF/DR/MP/MC/AM/JD	
Sheepnose	*Plethobasus cyphyus*	VV/GU/NS/LC/SR	MS/SF/DR/MP/MC/AM/JD	RR
Round Pigtoe	*Pleurobema coccineum*	PC//VV/GU/MV/NS/JB/LC/SR/FS/AR	MS/SF/MP/MC/JD/BS	
Elephant-ear	*Elliptio crassidens*		QR/SF/MP/MC/AM/JD/CR	
Spike	*Ellipio dilatata*	PC/GU/JB/AR	QR/VR/MS/PR/DR/MP/MC/AM/BR/JD/BS	BR/PR/RR/DR
Threehorn Wartyback	*Obliquaria reflexa*	PC/VV/MV/NS/SL/FS	SF/MP/MC/JD	
Mucket	*Actinonaias ligamentina*	PC/VV/MV/JB/SR/FS	QR/MS/SF/DR/MP/MC/AM/BR/JD/CR	RR/DR/BR

Table 6, continued.

Common Name	*Scientific Name*	*Oneota*	*Woodland*	*Archaic*
Butterfly	*Ellipsaria lineolata*	PC/VV/GU/MV/NS	SF/MP/MC/AM/JD/CR	
Hickorynut	*Obovaria olivaria*	PC/VV/GU/MV/NS/LC/SR	MS/SF/MP/MC/AM/JD	
Deertoe	*Truncilla truncata*	VV/MV/NS/JB/LC	MP/MC/JD	
Fragile Papershell	*Leptodea fragilis*	PC/VV/GU/MV/NS		
Pink Heelsplitter	*Potamilus alatus*	PC/VV/GU/MV/SR/SL/FS/AR	QR/MS/PR/DR/BR/JD/BS	PR/DR/BR
Pink Papershell	*Potamilus ohiensis*	VV	MP	
Black Sandshell	*Ligumia recta*	PC/SL/AR	QR/MS/MP/MC/BR/JD/BS/CR	RR
Ellipse	*Venustaconcha ellipsiformis*		VR/BR	BR
Rainbow	*Villosa iris*			BR
Yellow Sandshell	*Lampsilis teres*	FS	MS/SF/MC/AM	
Fatmucket	*Lampsilis siliquoidea*	PC/VV/GU/MV/NS/SR/SL/AR	QR/VR/MS/SF/PR/DR/MP/BR/BS	PR/RR/BR
Higgins Eye	*Lampsilis higginsi*	VV/LC	SF/MP/MC	
Plain Pocketbook	*Lampsilis cardium*	PC/VV/GU/MV/SR	QR/MS/SF/PR/DR/MP/MR/AM/BR/JD/BS	PR/RR/DR/BR

dilatata) and the ellipse *(Venustaconcha ellipsiformis).* These species, along with an array of other small-stream mussel taxa (e.g., *Alasmidonta viridis, Lasmigona compressa,* and *Villosa iris iris*) are unknown in the region today and illustrate the importance of the archaeological record for producing well-dated assemblages to aid in an accurate biogeography.

Summary and Conclusions

The pre-European peoples of western Wisconsin occupied a region rich in animal resources. These people followed an annual round to harvest subsistence resources. This round involved a schedule of movement to place people at the best location during the season most advantageous for taking favored plants and animals. By 7000 years ago, Archaic peoples of the region harvested deer during the fall and winter as a major food resource along with many other animal species. The spring-summer resource base of Archaic peoples is not known.

During Woodland times, human groups were engaged in an annual fall-winter harvest of deer and elk as their primary source of meat and skins for leather. Cool season camps were generally positioned in the game rich valleys of the dissected uplands, often many miles from larger river valleys. The largest number of deer seem to have been taken in the fall of the year when these animals are in prime condition. Animal bones were broken open at these fall-winter camps in a process to extract the nutrient- and fat-rich marrow. This marrow was perhaps mixed with dried (jerked) meat and sometimes berries to produce a sausage-type product known in the early historic period as pemmican, which could be kept for a year or more and often served as a winter food resource.

During the summer months, many Woodland groups were concentrated along the margins of larger waterways to harvest fish, freshwater mussels, turtles, waterfowl, and riparian mammals. At many locations summer camps were strategically positioned near beds of mussels and floodplain lakes seasonally replenished with fish. In the mid- to late summer as water levels dropped, nets were apparently be used to harvest fish. In addition to netting in backwaters, fish appear to have been taken while spawning in the spring and early summer months.

It is not until the end of the Late Woodland period at about A.D. 900-1000 that the peoples of western Wisconsin become involved in horticulture by tending small garden plots planted in corn. The adoption of gardening did not occur until the seasonal round of wild food harvest became difficult under the stress of increased population density. This prevented effective cool season movement as the dissected uplands became occupied by some Woodland peoples on a year-round basis.

At the end of prehistory we see the development of the Oneota, who represent a distinct cultural tradition. The Oneota were the first to practice corn agriculture using field systems, rather than the hypothesized Woodland garden plots. In addition to cultivated plants, the Oneota made extensive use of fish, mussels, waterfowl, and mammals during their summer residence at farming villages. During the cool season, most of the Oneota along the Mississippi are believed to have traveled west to hunt bison, deer, and elk, as well as trade with neighboring peoples.

Domestic dogs were kept by the Archaic, Woodland, and Oneota peoples of Wisconsin. Dogs were the only domestic animal found in pre-European Wisconsin. They served many functions in these Native American societies that included carrying burdens during annual movements and acting as an alarm system when intruders approached encampments. Dogs also ate animal and vegetable products that were not eaten by people. In times of special need, or for certain ceremonies, dog would be eaten. Dogs served as storage on-the-paw to convert and store protein until needed by humans.

Acknowledgments

I would like to thank the scientists who provided identifications or confirmed identifications on a number of specimens. Bobcat and certain black bear bones from the Gundersen site were identified by Dr. Danny Walker and Matthew Glenn Hill at the University of Wyoming, Laramie. The fragment of antler from Farley Village tentatively identified as moose was confirmed based on a direct comparison of antler surface sculpture conducted by Dr. Orrin C. Shane at the Science Museum of Minnesota, St. Paul, Minnesota. The small mammal jaws/teeth reported by Theler from Farley Village, Pammel Creek, Krause, Sand Lake, and the Cade sites were identified by Dr. Holmes A. Semken, Jr., of the Department of Geology, University of Iowa, Iowa City, Iowa. Several of the uncommon species of birds from the Sand Lake site were identified by Dr. Paul W. Parmalee of the Frank H. McClung Museum, University of Tennessee. Dr. J. Alan Holman at Michigan State University identified certain amphibian and reptile remains, including the tiger salamander bones recovered at the Krause site. Dr. David A. Stansbery of the Museum of Zoology, Ohio State University, offered comments on my early analysis of freshwater mussel shells recovered from the Prairie du Chien shell middens.

My colleagues Constance M. Arzigian and Robert F. Boszhardt at the Mississippi Valley Archaeology Center, University of Wisconsin–La Crosse, provided valuable comments on this report. I would like to thank Ms. Tricia Duyfhuizen, Managing Editor of the *Transactions,* for her editorial assistance. Katherine Stevenson generously provided her editorial skills in the preparation of this manuscript. Edward Brush is thanked for preparing the tables. Jean Dowiasch is thanked for preparing the maps used in this report. I would like to thank Dr. Jeffery A. Behm and one anonymous reviewer for their insightful comments on this paper. Finally, I would like to express my thanks to Mr. John Dobrovolny, Regional Historian with the Upper Mississippi River Wildlife Refuge of the U.S. Fish and Wildlife Service for the support to prepare portions of the report.

Literature Cited

Arzigian, Constance M., Robert F. Boszhardt, James L. Theler, Roland L Rodell, and Michael J. Scott. 1989. Human adaptation in the Upper Mississippi Valley: a study of the Pammel Creek Oneota Site (47LC61) La Crosse, Wisconsin. *The Wisconsin Archeologist* 70(1-2):1-281.

Anderson, Adrian, Allan Westover, Terrance J. Martin, Mathew L. Murray, Susan M. T. Myster, Barbara O'Connell, and L. Anthony Zalucha. 1995. The State Road Coulee site: 47LC176. *The Wisconsin Archeologist* 76(1-2):48-230.

Becker, George C. 1983. *The fishes of Wisconsin.* The University of Wisconsin Press, Madison.

Benchley, Elizabeth, Michael Gregg, and Mark J. Dudzik. 1977. Recent investigations at Albany Mounds Whiteside County, Illinois. Circular No. 2. Illinois Archaeological Survey.

Berwick, David E. 1975. Analysis of vertebrae fauna of Lawrence I Rockshelter (Ve-154), Vernon County, Wisconsin. M.A. Thesis, Department of Anthropology, University of Wisconsin–Madison.

Bray, Robert T. 1961. The Flynn Cemetery: an Orr Focus Oneota burial site in Allamakee County. *Journal of the Iowa Archeological Society* 10(4):15-25.

Collins, James M., Richard W. Slaughter, David L. Asch, K. Kris Hirst, and John L. Cordell. 1997. A brief evaluation of the Carroll Rock Shelter, Dubuque County, Iowa. *Journal of the Iowa Archeological Society* 44:84-101.

Gramly, Richard M. 1977. Deerskins and hunting territories: competition for a scarce resource in the northeastern woodlands. *American Antiquity* 42(4):601-05.

Gibbon, Guy E. 1970. The Midway Village Site: An Orr Phase Oneota Site in the Upper Mississippi River Valley. *The Wisconsin Archeologist* 51(3):79-162.

Faunmap Working Group. Co-directors and principal authors, Russell W. Graham and Ernest L. Lundelius, Jr.; compilers, Mary Ann Graham, Ralph F. Stearley, and Erich K. Schroeder. 1994. Faunmap: a database documenting late quaternary distributions of mammal species in the United States. Scientific Papers 25(1 and 2). Illinois State Museum, Springfield.

Hazard, Evan B. 1982. *The mammals of Minnesota.* University of Minnesota Press, Minneapolis.

Henderson, Norman. 1994. Replicating dog travois travel on the Northern Plains. *Plains Anthropologist* 39(148): 125-44.

Klippel, Walter E. 1977. Appendix A. Pelecypods from the Albany site. Pp. 93-97 *in* Benchley, E., M. Gregg, and M. J. Dudzik. Recent investigations at Albany Mounds Whiteside County, Illinois. Circular No. 2. Illinois Archaeological Survey.

Mead, Barbara. 1979. The Rehbein I Site (47-

Ri-81): a multicomponent site in Southwestern Wisconsin. *The Wisconsin Archeologist* 60(2):91-182.

O'Gorman, Jodie A. 1989. The OT Site (47-Lc-262) 1987 archaeological excavation: preliminary report. Archaeological Report 15. Wisconsin Department of Transportation, Madison.

Page, Lawrence M. 1985. The crawfishes and shrimps (Decapoda) of Illinois. Illinois Natural History Survey Bulletin 35, Article 4:355-448.

Palmer, Harris A., and James B. Stoltman. 1976. The Boaz mastodon: a possible association of man and mastodon in Wisconsin. *Midcontinental Journal of Archaeology* 1:163-77.

Parmalee, Paul W. 1959a. Animal remains from the Raddatz Rockshelter, SK5, Wisconsin. *The Wisconsin Archeologist* 40(2):83-90.

Parmalee, Paul W. 1959b. Use of mammalian skulls and mandibles by prehistoric Indians of Illinois. *Transactions of the Illinois Academy of Science* 52:85-95.

Parmalee, Paul W. 1960. Animal remains from the Durst Rockshelter, Sauk County, Wisconsin. *The Wisconsin Archeologist* 41(1):11-17.

Parmalee, Paul W. 1963. Vertebrate remains from the Bell Site, Winnebago County, Wisconsin. *The Wisconsin Archeologist* 44(1):58-69.

Penman, John T., and Richard W. Yerkes. 1992. Vertebrate remains from the Filler Site, a late prehistoric occupation in La Crosse County, Wisconsin. *The Wisconsin Archeologist* 73(3-4):199-236.

Perkins, Dexter, Jr., and Patricia Daly. 1968. A hunters village in Neolithic Turkey. *Scientific American* 219(5):96-106.

Pillaert, E. Elizabeth. 1969. Faunal remains from the Millville Site (47-Gt-56), Grant County, Wisconsin. *The Wisconsin Archeologist* 50(2):93-108.

Rick, Ann M. 1975. Bird medullary bone: a seasonal dating technique for faunal analysts. *Canadian Archaeological Association Bulletin* 7:183-90.

Robbins, C. Richard, R. M. Bailey, C. E. Bond, J. R. Brooker, E. A. Lachner, R. H. Lea, and W. B. Scott. 1980. *A list of common and scientific names of fishes from the United States and Canada.* Fourth Edition. Special Publication No. 12. American Fisheries Society.

Robbins, Samuel D. 1991. *Wisconsin birdlife: population & distribution • past & present.* The University of Wisconsin Press, Madison.

Rowe, Chandler W. 1956 The Effigy Mound Culture of Wisconsin. Milwaukee Public Museum. Publications in Anthropology. Number 3. Milwaukee.

Savage, Howard. 1978. Armstrong: faunal analysis. *The Wisconsin Archeologist* 59(1):118-45.

Schorger, A. W. 1942. The wild turkey in early Wisconsin. *Wilson Bulletin* 54:173-82.

Schorger, A. W. 1966. *The wild turkey: its history and domestication.* University of Oklahoma Press, Norman.

Scott. Michael J. 1989. Pammel Creek Site fish scale analysis. *The Wisconsin Archeologist* 70(1-2):243-50.

Scott. Michael J. 1994. Faunal remains from the Midway Village Site. *The Wisconsin Archeologist* 75(3-4):393-421.

Skinner, Alanson. 1923. Observations on the ethnology of the Sauk Indians. *Bulletin of the Public Museum of the City of Milwaukee* 5(1):1-57.

Skinner, Alanson. 1925. Observation on the ethnology of the Sauk Indians, Part III, notes on material culture. *Bulletin of the Public Museum of the City of Milwaukee* 5(3):119-80.

Skinner, Alanson. 1926. Ethnology of the Ioway Indians. *Bulletin of the Public Museum of the City of Milwaukee* 5(4):181-354.

Snyder, Lynn M. 1991. Barking mutton: ethnohistoric, ethnographic, archaeological, and nutritional evidence pertaining to the dog as a Native American food resource on the plains. Pp. 359-78 *in* Purdue, J. R., W. E. Klippel, and B. W. Styles. *Beamers, bobwhites,* *and blue-Points: tributes to the career of Paul W. Parmalee.* Scientific Papers Volume 23. Illinois State Museum, Springfield.

Speth, Janet M. 1987. Seasonal implications of giant Canada goose remains from Oneota Sites in Wisconsin. *The Wisconsin Archeologist* 68(2):155-61.

Stevenson, Katherine. 1994. Chronological and settlement aspects of the Valley View Site (47Lc34). *The Wisconsin Archeologist* 75(3-4):237-94.

Storck, Peter L. 1972. The archaeology of Mayland Cave. Ph.D. Dissertation, Department of Anthropology, University of Wisconsin–Madison.

Styles, Bonnie L., and Karli White. 1993. Analysis of faunal remains. Pp. 99-115 *in The OT Site (47Lc262). Vol. 1, The Tremaine Site Complex: Oneota Occupation in the La Crosse Locality, Wisconsin.* Archaeological Research Series No. 1. State Historical Society of Wisconsin, Madison.

Theler, James L. 1981. Faunal remains from Bluff Siding (47-Bf-45), Buffalo County, Wisconsin. *The Wisconsin Archeologist* 62(1):34-44.

Theler, James L. 1983. Woodland tradition economic strategies: animal resource utilization in southwestern Wisconsin and northeastern Iowa. Ph.D. Dissertation, Department of Anthropology, University of Wisconsin–Madison. University Microfilms, Ann Arbor, Michigan.

Theler, James L. 1985. Faunal analysis. *In* Sasso, Robert, Robert Boszhardt, James Knox, James Theler, Katherine Stevenson, James Gallagher, and Cynthia Styles-Hanson. Prehistoric ridged field agriculture in the Mississippi Valley. Reports of Investigations No. 38. Mississippi Valley Archaeology Center, University of Wisconsin-La Crosse.

Theler, James L. 1987a. Woodland tradition economic strategies: animal resource utilization in southwestern Wisconsin and northeastern Iowa. Report 17. Office of the State Archaeologist, University of Iowa, Iowa City.

Theler, James L. 1987b. The prehistoric freshwater mussels from Brogley Rockshelter in southwestern Wisconsin. *American Malacological Bulletin* 5(2):165-71.

Theler, James L. 1987c. Prehistoric freshwater mussel assemblages of the Mississippi River in southwestern Wisconsin. *The Nautilus* 101(3):143-50.

Theler, James L. 1989. The Pammel Creek Site faunal remains. Pp. 157-241 *in* Arzigian, C. M., R. F. Boszhardt, J. L. Theler, R. L. Rodell, and M. J. Scott. Human adaptation in the Upper Mississippi Valley: a study of the Pammel Creek Oneota site (47LC61) La Crosse, Wisconsin. *The Wisconsin Archeologist* 70(1-2):1-281.

Theler, James L. 1990. A possible Oneota freshwater mussel cache intended for ceramic tempering material. *Journal of the Iowa Archeological Society* 37:1-3.

Theler, James L. 1991. Aboriginal Utilization of Freshwater Mussels at the Aztalan Site, Wisconsin. Pp. 315-32 *in* Purdue, J. R., W. E. Klippel, and B. W. Styles. *Beamers, bobwhites, and blue-Points: tributes to the career of Paul W. Parmalee.* Scientific Papers 23. Illinois State Museum, Springfield.

Theler, James L. 1994a. Animal Remains: The Gundersen Site: An Oneota Village and Cemetery in La Crosse, Wisconsin. Pp. 38-53 and Appendix B *in* Arzigian, C. A., R. F. Boszhardt, H. P. Halverson, and J. Theler. *Journal of the Iowa Archeological Society* 41:3-75.

Theler, James L. 1994b. Oneota faunal remains from seven sites in the La Crosse, Wisconsin Area. *The Wisconsin Archeologist* 75(3-4):343-92.

Theler, James L. n.d.a. Faunal remains from the Krause Site (47Lc41), La Crosse County, Wisconsin. Unpublished faunal list housed at the University of Wisconsin La Crosse.

Theler, James L. n.d.b. Faunal remains from the

Quall Rockshelter (47Lc84), La Crosse County, Wisconsin. Unpublished faunal list housed at the University of Wisconsin–La Crosse.

Theler, James L. n.d.c. Faunal remains from the Viola Rockshelter (47Ve640), Vernon County, Wisconsin. Unpublished faunal list housed at the University of Wisconsin–La Crosse.

Theler, James L. n.d. Faunal remains from the Cade Sites (47Ve631, 643, and 644), Vernon County, Wisconsin. *In* Theler, James L., Loren Cade, Dan Garrigan, Eric Pfaff, Jennifer Phillips, Erin Richardson, Sarah Van Galder, Scott Welch, and Heather Woolley. Bad Axe River archaeology: research at prehistoric sites in a small stream valley in Western Wisconsin's Driftless Area. Unpublished manuscript on file at the Department of Sociology and Archaeology, University of Wisconsin-La Crosse.

Theler, James L., Robert F. Boszhardt, Dean G. Wilder, and Matthew Glenn Hill. 1994. The Rud Bison Site: a *Bison Bison Occidentalis* locale in western Wisconsin. *Current Research in the Pleistocene* (11):98-99.

Thomas, Jack W., and Dale Toweill. 1982. *Elk of North America: ecology and management.* Stackpole Books, Harrisburg, Pennsylvania.

Turgeon, Donna D., A. E. Bogan, E. V. Coan, W. K. Emerson, W. G. Lyons, W. L. Pratt, C. F. E. Roper, A. Scheltema, F. G. Thompson, and D. J. Williams. 1988. *Common and scientific names of aquatic invertebrates from the United States and Canada: mollusks.* Special Publication 16. American Fisheries Society.

Van Dyke, Allen, David F. Overstreet, and James L. Theler. 1980. Archaeological recovery at 11-Ri-337, an early middle Woodland shell midden in East Moline, Illinois. *The Wisconsin Archeologist* 61(2):125-256.

Vogt, Richard L. 1981. *Natural history of amphibians and reptiles of Wisconsin.* Milwaukee Public Museum, Milwaukee.

Wilson, Gilbert L. 1928. Hidatsa eagle trapping. *Anthropological Papers* 30, pt. 4:99-245. American Museum of Natural History, New York.

Wittry, Warren L. 1962. A raven headdress from Sauk County, Wisconsin. *The Wisconsin Archeologist* 43(4):87-94.

James Theler is a professor of archaeology at the University of Wisconsin-La Crosse. His archaeological research has focused on the subsistence and settlement patterns of Native American peoples of western Wisconsin prior to the arrival of Europeans. Address: Department of Sociology and Archaeology, University of Wisconsin-La Crosse, La Crosse, Wisconsin 54601.
Email: theler.jame@uwlax.edu

Wisconsin Academy of Sciences, Arts and Letters

Wisconsin Academy of Sciences, Arts and Letters
1922 University Avenue
Madison, Wisconsin 53705

ISSN 0084-0505

Telephone (608) 263-1692

Of Frankenfoods and Golden Rice

Risks, Rewards, and Realities of Genetically Modified Foods

TRANSACTIONS Volume 89, 2001

Edited by Frederick H. Buttel and Robert M. Goodman

Wisconsin Academy of Sciences, Arts and Letters
Since 1870, supporting thought, culture, and the exchange of ideas

Of Frankenfoods and Golden Rice
Risks, Rewards, and Realities of Genetically Modified Foods

Transactions Volume 89, 2001

Edited by

Frederick H. Buttel, Ph.D.
Professor and Chair, Department of Rural Sociology
University of Wisconsin–Madison

and

Robert M. Goodman, Ph.D.
Professor of Plant Pathology
University of Wisconsin–Madison

Wisconsin Academy of Sciences, Arts and Letters
Since 1870, supporting thought, culture, and the exchange of ideas

Managing Editors

Joan Fischer
Michael Goodman

About the Wisconsin Academy

The Wisconsin Academy of Sciences, Arts and Letters is an independent, nonprofit membership organization founded in 1870 to gather, share, and act upon knowledge in the sciences, arts, and letters for the benefit of the people of Wisconsin. Everyone is welcome to join. Programs include an art gallery featuring a different Wisconsin artist every month; a quarterly magazine about Wisconsin thought and culture (the *Wisconsin Academy Review*); the Wisconsin Idea at the Academy, which brings together people from diverse fields to examine public policy issues; and public forums on topics of current interest. Our annual journal *Transactions,* which has been published since 1872, this year reflects content of our Fall Forum 2000 on genetically modified foods.

ISSN 0084-0505

Wisconsin Academy of Sciences, Arts and Letters
1922 University Avenue
Madison, Wisconsin 53705
www.wisconsinacademy.org
Tel. 608/263-1692
e-mail: contact@wisconsinacademy.org

Contents

From the Wisconsin Academy

Michael Goodman
Fall Forum Director
Wisconsin Academy of Sciences, Arts and Letters

"No one in biotech will want to speak at a public forum. They're hoping that the whole issue will just go away." I heard this sentiment often in the early days of planning for the Wisconsin Academy's Fall Forum 2000, "Genetically Modified Food: Risks, Rewards, & Realities," which was held in Madison in November of that year. As it turned out, that sentiment was stating things far too simply.

When I met with scientists and others working in the biotechnology realm, I learned that many indeed were interested in letting others know their thoughts and motivations. Among those standing on the "other side" of the issue—people who oppose production of genetically modified foods—there were some who wanted to denounce the entire science, but many more who were interested in searching for common ground. And then there were those people—specifically, farmers—who felt they were being left out of the discussion altogether. It became clear that there was a tremendous opportunity to initiate an open discussion on this very contentious issue.

The Wisconsin Academy's mission to further knowledge required us to bring in as many points of view as possible (and believe me, there are many more than the ones I portrayed above). Our goal was to craft a discussion that would allow those involved and those in attendance not only to learn some basics and hear the disagreements, but also to hear where those in opposition could find common ground. Forum planners and advisors—a diverse group that included scientists, educators, farmers, historians, writers, and ethicists—came up with a structure that brought a wide range of experts, views, and content to the one-day discussion (see appendix for the forum agenda). You can see the basics of the format we chose in the content of this volume of *Transactions*. Much of the content for this book came from the forum. Presenters generously rewrote, adapted, and updated their talks for this collection.

These articles represent a wide range of thoughts on the subject of biotechnology and agriculture. Topics touch upon economics and international trade, farming and storage, world hunger, history, and ethics. The introduction to this book by our guest editors Frederick Buttel and Robert Goodman, who also served as forum planners, does a wonderful job giving the reader a thorough background on the subject of genetically modified food as well as outlining the range of authors and subjects in this volume. Our special thanks to them for their expertise and hard work in putting together this volume of *Transactions*.

I believe that this mix of topics and viewpoints is greater than the sum of its parts. Forum attendees were given the opportunity to have some of their opinions questioned and to discover the many shades of gray that exist when talking about such complicated issues. I am sure that some people left with the same opinions they had on arrival. But I know that many others changed their views, maybe not enough to make them join the "other side," but enough to leave them thinking about these issues with new insights and more information at their disposal. I am certain this collection of essays will offer readers that same opportunity. And that is the Wisconsin Academy at its best.

Major conference support for the Fall Forum 2000 was made possible through a grant from The Evjue Foundation, Inc., the charitable arm of *The Capital Times*.

Fall Forum 2000 Planning Committee

Deborah Blum
Professor, School of Journalism and Mass Communication,
University of Wisconsin–Madison

Frederick H. Buttel
Chair, Department of Rural Sociology,
University of Wisconsin–Madison

Terry Devitt
Science Editor, Office of News and Public Affairs,
University of Wisconsin–Madison

Michael Goodman
Fall Forum Director and Associate Director of Programs,
Wisconsin Academy of Sciences, Arts and Letters

Robert M. Goodman
Professor of Plant Pathology,
University of Wisconsin–Madison

Paul Hayes
Science Writer,
Wisconsin Academy Fellow

Karl Nichols
Research Scientist,
Third Wave Technologies

Louise Robbins
Historian of Science

Robert Streiffer
Professor of Ethics, Medical School and Department of Philosophy,
University of Wisconsin–Madison

Craig Trumbo
Professor of Life Sciences Communications,
University of Wisconsin–Madison

Tom Zinnen
Biotechnology Education,
University of Wisconsin–Madison Biotechnology Center

Introduction to the Scientific, Political, and Ethical Dialogue on Genetically Modified Organisms

Frederick H. Buttel and Robert M. Goodman

The genetically modified organism (GMO) controversy in the United States is in one sense a very particular phenomenon; yet in another sense it is an entirely predictable occurrence in the early twenty-first-century development of the agricultural and food system.[1] In the latter sense, it is deeply rooted in U.S. regulatory politics of the 1980s and corporate decisions of the early 1990s. In the 1980s, a laissez-faire regulatory environment coincided with new technologies and new investment emerging from the private sector that resulted in prototype GMO and GM food products (Flavr Savr tomatoes and virus-, herbicide-, and insect-resistant crops). These new products were "shoehorned" into existing regulations at the EPA, the USDA, or both, with only grudging overview from the FDA. Ironically, what regulatory oversight these early products received was demanded by industry.

[1]Accordingly, genetically modified (GM) foods are those that contain ingredients from GMO crop varieties, though there remains debate as to whether there should or should not be a statistical definition (regarding "tolerance" of the maximum permissible amounts of one or another GM ingredient) in defining what are and are not GM foods. Also, as we will note, the definition—even the usage—of GMO is subject to debate. We actually prefer the terminology "genetically engineered crop."

In the 1980s and 1990s, several major chemical companies experimented with their reinvention as "life sciences" companies. These companies, which emerged as the commercial proponents of GMO crops, made a fateful decision—to reject labeling of their products and largely withdraw from early initiatives to educate a public whose nascent skepticism had failed to ignite in response to Jeremy Rifkin and various environmental groups. They also ignored the early signs from Europe of a controversy in the making.

By early 1999, agricultural biotechnology in the United States was clearly on a roll with considerable momentum. As of the 1998 growing season about 36 percent of U.S. soybean acreage, 20 percent of U.S. cotton acreage, and 22 percent of U.S. corn acreage was devoted to genetically engineered varieties, and about 60 percent of Canadian canola acreage was devoted to genetically engineered varieties (James 1998). The adoption rates for U.S. GMO soybeans, corn, and cotton from 1995 to 1998 and for Canadian canola arguably represented the most rapid adoption curve of any new agricultural technology in world history. The controversy over recombinant bovine somatotropin (rBST; also known as recombinant bovine growth hormone, or rBGH), which had heretofore been the United States's most contested new biotechnology product, had largely blown over by early 1999, and in retrospect nothing that might have been learned about corporate approaches to public concerns over technologies provided to farmers was in fact learned.

By April 1999, the European Union (EU) had approved three *Bacillus thuringiensis* (Bt) corn varieties and one herbicide-tolerant corn variety, and at least six additional Bt and herbicide-resistant crop varieties (and two "stacked" [both Bt and herbicide-resistant] varieties) were under EU regulatory review. In early 1999, the World Trade Organization (WTO), which included a number of provisions on intellectual property, nontariff barriers to trade, and the harmonization of national standards of food regulations that were favorable to commercial biotechnology, had been in effect for nearly four years and appeared to be becoming increasingly well institutionalized. WTO rules seemed to obligate the EU countries to not only approve these new agricultural input products but also to accept imports of GM grains and oilseeds product.

By the summer of 1999, however, there was a transnational eruption of social conflict over GMOs. The EU began to restrict imports of GM corn and soybeans and initiated what at this writing remains a de facto moratorium on approval of new GM input products. The Seattle protests at the 1999 WTO ministerial meeting were galvanized to a significant degree around consensus among environmental, labor, consumer, sustainable agriculture, development-assistance, and human rights groups that there should be resistance against GM foods and, most importantly, against WTO rules that limit the ability of nations and consumers to choose not to consume GM food ingredients. In 2000, the resistance to GM foods spread to a number of other nations and regions, including especially Japan, Korea, Thailand, Australia, and India. In early 2000 there was so much uncertainty about securing markets for GM corn and soybean products that many U.S. farmers stopped using them, or continued to do so with great apprehension. Bt corn use in the U.S., for example, has declined during each of the past two growing seasons.

One of the points that came out at the Wisconsin Academy conference "Genetically Modified Food: Risks, Rewards, and Realities" is that there is little agreement on what the notion of "GMO" (and thus of "GM food") means. Before proceeding further we want to be clear about what we mean by GMOs. Some observers—including, interestingly enough, many of the most active proponents and opponents of molecular biological technologies used in agriculture—tend to see GMOs as being synonymous with "agricultural biotechnology." Biotechnology is a very broad term that encompasses a suite of conventional methods—including tissue culture—as well as newer techniques based on molecular biology used for enhanced management of plant-breeding programs and in diagnosis of diseases and stresses that reduce crop production. These biotechnology methods are not what the GMO controversy is about. Rather, the focus of the controversy is on crop varieties and the foods derived therefrom that have been developed with the use of genetic engineering. By genetic engineering is meant the construction of genes engineered from recombinant DNA made in the laboratory and introduced into the chromosomes of a crop plant. Such genes, collectively called transgenes, when expressed in the recipient plant impart a new trait or property on the plant.

Today, GMO crop plants contain single-gene (or a small number of) transgenes that impart two major types of traits: There are the Bt crops (chiefly corn, cotton, and potatoes) that as a result of expression of a gene taken from the soil bacterium *Bacillus thuringiensis* are resistant to insect pests, and herbicide-resistant (HR) crops (chiefly soybeans, corn, and canola) engineered using bacterial or modified plant genes. Virus-resistant crops also fall within our definition of GMOs, since they involve one or a few transgenes that code for proteins that affect input traits. Interestingly, virus-resistant crops have not been particularly controversial. In part, this is because virus-resistant crops were not adopted rapidly and have not been the commercial blockbuster products that Bt cotton and corn and HR soybeans have been. It is also the case that most environmental and related organizations see virus-resistant crops as being environmentally benign, if not somewhat positive.

The fact that during mid- to late 1999 there emerged very rapidly a considerable controversy over GMOs was in some sense not surprising. This controversy is in many respects a fairly typical aspect of agricultural research and development in the United States and elsewhere. Agricultural science is no longer undertaken in a relative vacuum of interest and concern by most farmers, consumers, and citizens groups, as was the case until about the early 1970s. The dominant institutions of agricultural research and development—especially the land-grant universities and affiliated system of agricultural experiment stations, the Agricultural Research Service of the U.S. Department of Agriculture, and multinational seed-chemical-biotechnology companies—have quite definite sets of supporters and detractors among the American public. Though the reasons for this support and dissent vary, the system's supporters believe that the research and development trajectories that are under way are either clearly proven or highly promising and portend a more sound future of expanded productivity and output, increased food quality, and greater food security. Detractors worry that the agro-food system is being shaped according to a corporate agribusiness agenda, that the new technologies that are being developed are environmentally unsustainable and detrimental to the future of family farming, and that GMOs are likely to contribute little to global food security. The relative lull in what had become a fairly standard 1980s and 1990s debate over a range of agro-science issues was more the exception than the rule. Since that time, however, there has been a steady—if not always newsworthy or publicly visible—struggle within and between countries over GMOs.

But while it has become commonplace that agricultural research and new agricultural technologies are subject to debate and controversy, in certain ways the GMO controversy differs from those of previous decades (such as the controversies over Alar use on apples, antibiotic use in livestock, and factory methods of livestock farming). First, the GMO controversy was unique in that it was essentially induced by international trade and by the WTO's rules governing trade. European resistance to GMOs was spearheaded by the realization by European people, European nations, and the EU that adherence to WTO rules would result in a widespread presence of GM foods in the European food supply. Thus, the GMO controversy was set in motion by WTO rules and European reactions to these trade rules. Not surprisingly, concern about GMOs would ultimately prove to be one of the major factors that catalyzed the ongoing antiglobalization movement (though GMO concerns now play a very minor role in this movement).

A second distinctive aspect of the GMO controversy is closely related to the first: this controversy is a global one. Clearly, every Organization for Economic Cooperation and Development (OECD) country must deal with a range of GMO policy issues—regulatory issues, intellectual property issues, agro-food trade policy, and so on. But the GMO controversy does not end there. The GMO controversy has become a North-South and international development controversy. As Borlaug and Ruttan suggest in their articles on biotechnology and the prospects for food-production increases in the developing world, the voices of the contending parties are perhaps most shrill when they discuss whether GMOs—or biotechnology more generally—will be positive for the developing world.

Much of the North-South GMO debate has centered on the "golden rice" issue. GMO proponents tout the potentials of golden rice—a transgenic rice containing one daffodil gene and two bacterial genes that together code for an increased level of provitamin A—for its being able to reduce the incidence of night blindness and other disorders that lead vitamin A deficiency to be associated with elevated rates of mortality, especially childhood mortality. GMO opponents, however, suggest that golden rice is little more than a "rhetorical technology."[2] Golden rice, they say, will probably never

[2]The term "rhetorical technology" was used by Michael Pollan in his widely circulated March 4, 2001, *New York Times Magazine* article on the golden rice debate entitled "The Great Yellow Hype."

be deployed in a widespread manner, since it is covered by dozens of patents, many of which are likely to involve claims on new rice varietal products that will make them impractical to commercialize. Further, they suggest that golden rice is a wrongheaded solution to the problem of poverty and homogenization of the food supply. Poor rural people do not need golden rice as much as they need social arrangements that enable them to diversify their production systems and to have access to balanced diets containing sufficient vitamin A. There is also legitimate concern about acceptance of this odd-looking rice by the world's poorest.

A final way in which the GMO controversy has been distinctive is in the degree to which agricultural scientists have been mobilized to support one or the other side of the issue. A good many molecular biology researchers in the agricultural sciences have banded together under the organizational banner of the AgBioWorld Web site (http://www.agbioworld.org/) created by Tuskegee University molecular biology researcher C. K. Prakash. AgBioWorld has obtained the endorsement of more than 3,000 agricultural scientists around the world and is the leading nonprofit group supporting the use of biotechnology and molecular biology in agriculture. Importantly, AgBioWorld's home page touts golden rice technology. AgBioWorld's mobilization of agricultural scientists against those who criticize the technology (e.g., Pat Roy Mooney, who is also mentioned on the home page of this Web site) is one of the largest and most impressive instances of agricultural researchers banding together to defend this cluster of new technologies. Note, though, that while the cadre of agricultural scientists who support GMOs is very substantial and represents the majority of researchers, a smaller but still impressive-sized group of agricultural scientists and other biologists (especially ecologists) has expressed significant concerns about GMO technology. The skeptical minority of agricultural and ecological scientists is concerned that the methods and regulatory procedures for determining the environmental risks of these technologies are inadequate, and that these technologies may already be exhibiting major environmental (as well as socioeconomic) problems such as weed resistance to herbicides, genetic drift to wild and weedy relatives, and insect resistance to Bt. In addition, there are a good many other scientists whose views about GMOs are ambivalent; they recognize the importance of molecular tools in agricultural research and see some advantages to GMOs, but they also recognize that the current generation of GMO products has shortcomings and that public opposition to GMOs carries the risk of souring the public on agricultural research as a whole. In general, then, there has never before been a sociotechnical issue in agriculture that has so divided citizens, agricultural scientists, and countries as this one.

The Conference Papers and the Key Issues Regarding GMOs and GM Foods

The papers in this special issue of *Transactions* represent a variety of views and touch on a wide-ranging set of issues relating to GMOs. The first paper, by Dan Charles, is based on Charles's research and writing of *Lords of the Harvest: Biotech, Big Money, and the Future of Food* (Perseus, 2001). In his book, Charles provides an overview of the development of the agricultural biotechnology industry and of the GMO controversy. Charles, a former reporter for National Public Radio, is not a biologist, historian, or social scientist but rather a storyteller. In his contribution to this volume, he draws on his upbringing and subsequent family experiences in agriculture to capture in stories the disconnect that often is found between the thinking and actions of corporate scientists and their leaders on the one hand and the realities of agriculture on the other. He also raises the specter of a "double standard" of society's interest in agriculture. To go along with the question "Where do the realities of GMO crops end and the myths begin?", Charles also asks, "Where do the myths of traditional agriculture end and the realities begin?"

The next two papers illustrate the main dimensions of the GMO debate. One of these papers, by the renowned plant breeder and geneticist Norman Borlaug and reprinted from *Plant Physiology*, is a spirited advocacy of biotechnology in general and contemporary GMO products in particular. Norman Borlaug was for about two decades the principal wheat breeder at CIMMYT (the Spanish acronym for International Center for the Improvement of Maize and Wheat, located outside Mexico City), and for his efforts in introducing Green Revolution wheat to South Asia he received the Nobel Peace Prize in 1970. The wheat Green Revolution in India, Bangladesh, and Pakistan, along with the introduction of Green Revolution rice varieties from the International Rice Research Institute into the region in the 1970s, is credited with saving millions of lives of persons who would otherwise have perished due to the direct and indirect results of malnutrition. Borlaug's scientific and political stature has provided him with a unique vantage point and platform from which to assess the new trajectory of agro-food research and development.

Borlaug stresses that ultimately the focal issues in evaluating the matter of biotechnology and the future of world agriculture are the relative safety of GM crops for humans and the environment, and the fact that the future food security status of the majority of the world—the peasants and urban dwellers of low-income countries—depend on pursuing biotechnological research with dispatch. Borlaug stresses that GM crop varieties do not differ in any significant ways from conventional or nontransgenic ones, and that the new GMOs are as safe as—and in some ways superior to—conventional varieties on human health and ecological grounds. But Borlaug's most direct comments come on the topic of the role that biotechnological research and GMO technology will need to play in winning the race against population in the developing world, and on the related topic of the environmental and other activist groups that he sees as impeding the pursuit of food production innovations needed by the poor.

In contrast to Borlaug's confidence in biotechnology and his conviction that the future well-being of billions of the world's poorest depend on aggressive development of these new technologies, Frederick Kirschenmann, director of the Leopold Center for Sustainable Agriculture at Iowa State University, raises a number of pointed concerns about GMOs and biotechnology. GMO technology, according to Kirschenmann, is rooted in an ideology of biological determinism, which sees agricultural problems and their necessary solutions primarily in genetic terms, and in terms of "quick fixes." Not only does this ideology tend to lead to de-emphasis on ecological and social risks; in addition, Kirschenmann argues, biological determinism tends to crowd out promising alternatives such as agroecological approaches that employ, rather than suppress, biological and habitat diversity.

Jeffrey Burkhardt, a professor of agriculture and natural resource ethics in the

Institute of Food and Agricultural Sciences at the University of Florida, begins his article by noting that as important and widely discussed as the scientific and legal-political dimensions of GMOs have become, the GMO issue should ultimately be seen as being an ethical one—whether GMOs and GM foods are ultimately morally and ethically acceptable. Burkhardt stresses, however, that the matter of ethical acceptability of GMOs and GM crops is a complex matter in that there are several extant "ethical paradigms"—consequentialist ethics, the ethics of autonomy and consent, and the ethics of virtue and tradition—that bring very different ethical considerations to bear on GMO issues. In addition, ethical acceptability of GM inputs and food products depends on the kind of GM product being considered. Various GM products, for example, involve major variations in environmental, social-distributional, and productivity consequences.

Borlaug, Kirschenmann, and Burkhardt all make frequent reference to the issue of whether GMOs and GM foods are critical to economic development and food security in the low-income countries of the South. Vernon Ruttan, Regents Professor Emeritus of Economics and Agricultural and Applied Economics at the University of Minnesota and the former head of agricultural economics at the International Rice Research Institute during the early years of the Green Revolution, addresses this issue in a provocative and somewhat unexpected way. As amply illustrated by Borlaug's article, it has become fairly typical that those persons who were involved in the early stages of the Green Revolution tend to support GMOs, and biotechnology research and development more generally, because of biotechnology's promise in generating sustained agricultural productivity improvement in developing countries. Ruttan states how important it will be to achieve new trajectories of productivity and output improvement in agriculture in the South. He suggests, however, that it remains an open question as to whether GMO-type technology will have sufficient potential to remove the current physiological constraints to yield increase that are now becoming manifest in crop agriculture across the developing world.

International aspects of the GMO food controversy receive two further treatments from very different perspectives. Lori P. Knowles brings the perspective of one who has studied contemporary trade negotiations and the related international political issues; she places the GMO issues in this context and in particular focuses on their relationship to the politics of biodiversity issues. Agriculture's history is one of international exchange of biological materials; no country in the world, in the North or the South, depends for its agriculture primarily on its native species but instead relies on species introduced over centuries of international trade, and more recently through intentional collection and distribution of germ plasm. Richard Manning has traveled the world in recent years reporting on crop improvement research being carried out in developing countries, from Brazil, Chile, China, and India to Ethiopia, Uganda, and Zimbabwe. In an article based on his recent book, *Food's Frontier: The Next Green Revolution* (North Point Press, 2000), Manning contrasts the debate over GMO technologies in the developed countries to the issues of local empowerment of developing-country citizens to make their own decisions about appropriate technologies as they strive to address the critical need, for example, for improved pest resistance in a grain legume, chickpea, which is an important source of protein in the diets of many of the poor in India.

While the implications of GMOs and GM foods for international development are among the most potent social and ethical issues in evaluating these new technologies, the articles by Bradford Barham, Lydia Zepeda, John Petty, and Carl Gulbrandsen and Howard Bremer suggest that there are crucial domestic policy dimensions of GMOs. Barham argues that in some respects GMO technology has similarities to that of rBST in the dairy sector. Both technologies are seemingly scale neutral because the input product can be purchased in either small or large lots and can be used on farms ranging from very small to very large. At the same time, available data on both technologies suggest that they are much more applicable to large-farm operations, suggesting the likelihood that GMOs as well as other agricultural biotechnology products will benefit larger farmers over smaller ones.

Zepeda examines the second crucial domestic policy issue relating to GMOs, that of labeling for international—and possibly domestic—markets. Zepeda suggests that strong rationales exist for GMO labeling for both domestic and international markets. Survey data from American consumers show very strong public support for labeling, and GMO labeling for international markets would serve to help maintain

U.S. market access in Europe and Asia and to diffuse trade conflicts between the United States and its major trading partners. These factors, plus the reality that labeling is already widespread in many other countries, suggest that GMO labeling is the appropriate direction to follow. The fact that GMO labeling is not actively being considered in the United States indicates the range of powerful interests that are opposed to labeling.

John Petty's paper illustrates one of the reasons that GM food labeling has its critics and opponents. Petty, Executive Director of the Wisconsin Agri-Service Association, a trade association of the state's feed, grain, and seed managers and owners, notes that GM food labeling would entail a number of costs for consumers and farmers as well as the grain and food-manufacturing industries. In addition to the costs of labeling, Petty stresses that it will be impossible to ensure that there will be no "adventitious presence" of GMO grain; tolerances for GMO-free grains will need to be established, and the smaller the tolerance, the more expense will be incurred in labeling.

A significant subtext in the broader consideration of biotechnologies in agriculture has been the issue of ownership of intellectual property. In 1980 in its landmark 5–4 *Diamond v. Chakrabarty* decision, the U.S. Supreme Court made it possible to lay claim to patents covering living things, including genes. Subsequent interpretations of this ruling have extended to patenting of crop varieties, particularly in the United States. A further development in this recent history has been the growth of patent seeking by public institutions, such as universities and agencies of the U.S. government itself. Carl Gulbrandsen and Howard Bremer describe some of the history behind these trends, with particular focus on the Bayh-Dole Act of 1980 as subsequently amended. Their article places the history of Bayh-Dole in the context of the much longer history of the Wisconsin Alumni Research Foundation, one of the pioneering institutions for protecting intellectual property arising from publicly funded research.

Conclusion

The Wisconsin Academy conference, entitled "Genetically Modified Food: Risks, Rewards, and Realities," was extraordinarily exciting and informative. A good many people came to the conference with fairly definite ideas about genetically engineered crop varieties and GM foods, but regardless of their previous commitments on the issues at hand, most of the approximately 250 people in attendance found they learned a great deal. The articles in this special issue include several of the major addresses given at the conference, but dozens of other contributions were lively, informative, and well received.

It is telling that despite the particular points of view expressed in the articles on GM food issues, three aspects of these issues—ethical responsibilities, the emergence of new paradigms, and global relevance and impacts—were repeatedly touched on by the authors. All of our authors see that the GMO/GM foods issue must ultimately be addressed or resolved on ethical grounds, or on grounds of the public good, even though the authors have varying views about how ethical and public good considerations should be weighed. The authors also see the GMO/GM foods issue in paradigmatic terms—that the way we debate, address, and resolve these issues will cast the die for decades to come in terms of how we approach food and agriculture. Finally, while the U.S. government and its social groups will address GMO/GM foods policy issues in terms of domestic considerations, these issues are by their nature global. What we do here in the United States and how we do so will shape the future of food security across most of the nations of the world. The nature of GMO/GM foods issues is that we cannot approach them solely in terms of group or national interests, since the welfare of much of the rest of the world depends on the quality of the judgments we will make during the first decade of this new millennium.

Frederick H. Buttel (Guest Editor, Transactions*) is professor and chair, Department of Rural Sociology, and professor of Environmental Studies at the University of Wisconsin–Madison. He is also associate director of the Program on Agricultural Technology Studies at UW–Madison after having served as its director from 1992-1998, and an affiliated professor in the Development Studies Program and a senior fellow at the Center on World Affairs and the Global Economy (WAGE). Buttel has had a longstanding interest in environmental sociology, rural sociology, and the sociology of the environmental and agricultural sciences. He was elected a fellow of the American Association for the Advancement of Science (AAAS) in 1987, and is past president of the Rural Sociological Society, past president of the Agriculture,*

Food, and Human Values Society, and a former chair of the Section on Environment and Technology of the American Sociological Association. He is currently president of the Environment and Society Research Committee (RC 24) of the International Sociological Association (1998-2002).

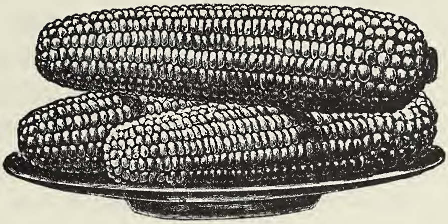
Robert M. Goodman (Guest Editor, Transactions*) is a professor in the departments of Plant Pathology and Environmental Studies, and chair of the Undergraduate Program in Molecular Biology, at the University of Wisconsin–Madison. He chairs the oversight committee for the McKnight Foundation's Collaborative Crop Research Program and is a member of the Board of Trustees of the Centro Internacional de Meijoramiento de Maiz y Trigo (CIMMYT). He serves on the Boards of Directors of two genomics companies and of the Cornell Research Foundation, and was formerly executive vice president for research and development at Calgene, Inc. Prior to his years at Calgene, Goodman was on the faculty of the Department of Plant Pathology and the International Soybean Program (INTSOY) at the University of Illinois at Urbana–Champaign. Goodman was the first to prove the viral cause of a widespread group of devastating tropical plant diseases and to show that the genomes of the viruses involved were tiny circular molecules of DNA, which are still among the smallest known viruses. Since moving to Wisconsin in 1991, Goodman's research has turned to basic studies on microbial diversity in natural environments. He is currently writing a book and developing a new course on microbial symbiosis.*

Reference

James, C. A. 1998. *Global Review of Commercialized Transgenic Crops: 1998.* No. 9-98. Ithaca, N.Y.: International Service for the Acquisition of Ag Biotech Applications.

Telling the Story

Daniel Charles



Reprinted with permission from *Lords of the Harvest: Biotech, Big Money, and the Future of Food* by Daniel Charles (Perseus Publishing, 2001).

I am a storyteller by profession and with conviction. I'm convinced that stories stay with us longer than any collection of miscellaneous facts. They help us make some sense of the world. When I began working on a book about genetically engineered crops, I imagined that storytellers got a special exemption from being drafted into the battles raging over them. I thought I could stroll unimpeded among the bristling barricades, and I tried to persuade everyone I met that I posed no threat to anyone. *I just want to tell this story.*

They still didn't trust me. Below the surface of almost every conversation, evident in opaque expressions, in hesitations and vague answers, lurked uncertainty. *Friend or foe?* Later, as I struggled to carve a narrative out of masses of information, I decided that the people I'd been interviewing had been right all along. Storytellers were not onlookers in this battle; we were, if anything, its grand strategists. The dispute over genetic engineering involves facts, to be sure. But its parties disagree far more passionately over the *story.* They quarrel over the nature of the characters, over the plot, and over the editing. They also feud over the unknowable: the ending.

Among the anecdotes and tales that occupy our minds, a few are embedded so deeply that they shape the way we perceive the world. Those stories—sometimes we call them myths—create cavities within our brains, shaped to accept any similar narratives. Facts and experiences stick with us—they strike a chord, to use a common phrase—if they slip into these preformed contours. And as it happens, the tale of genetically engineered plants fits some of the most cherished spaces that our minds possess.

It is, for instance, a tale of progress, of discovery and creativity, solving problems and expanding the boundaries of human possibility. It follows outlines carved out by the Wright brothers, and Alexander Graham Bell, and Jonas Salk with his vaccine for polio. It's Gregor Mendel, planting peas in the garden of his monastery more than a century ago and discovering the patterns of human inheritance. These stories form part of the professional ideology of scientists, each of whom dreams of finding his or her role in this grand tale. And it is a powerful myth that shapes many people's understanding of genetically engineered food. (When I interviewed people recently at Cereon, Monsanto's genomics subsidiary, I met them in a small room with a revealing name: the Copernicus Room.)

Others think of the story of Bill Gates, or the Internet. It's a tale of new technology that will destroy old businesses and build new ones; it's also a dream of great wealth. I was talking to a financial analyst the other day about agricultural biotechnology. He said, "It's like—and this sound crazy—but it's like if you got plunked down fifty years ago in the orchards of places like Sunnyvale, and Palo Alto." This, of course, is the place known today as Silicon Valley.

A countervailing myth flows like an undertow beneath the triumphal story of progress, undermining it. It's the story of unpredictable, threatening technology unleashed upon an unsuspecting world through human folly: Pandora opening her box; Rachel Carson's account of DDT in *Silent Spring*; nuclear power and Chernobyl. In the words of a passionate opponent of biotechnology in New Zealand: "Today, the smug status of genetic engineering eerily recalls that period in the early 1960s when nuclear reactors were 'commercialized' on the basis of enthusiasts' claims of understanding and control. . . . Alongside airy dismissals of the dangers, the promised benefits are wildly exaggerated."

Several layers deeper, almost buried in our collective unconscious, lie other stories, ancient ones from the Mediterranean cradle of civilization, warning against the temptation to overstep humanity's rightful bounds. In the Garden of Eden, the serpent tempts Eve: You can eat the fruit of this tree. *You will be like God.* Just a few pages further on, God contemplates humanity's attempts to build a tower that will reach to heaven, and confounds its hubris in a confusion of languages. Centuries later, Mary Shelley repeats the warning in her story of Dr. Frankenstein and his fateful, doomed monster. Echoes of these tales resound in the anti-biotechnology proclamation of Charles, Prince of Wales, from the summer of 1998: "This kind of genetic modification takes mankind into realms that belong to God, and to God alone."

It's pointless to argue over which one of these versions of the agricultural biotechnology story is true. They all hold some truth. They all are, in the same measure, false, because they aren't really about agricultural biotechnology at all. They are, literally, preconceptions. They allow us to recognize important things about the world, but they also blind us to reality, when that reality doesn't fit such preset patterns.

I'd like to tell a few stories as well. These aren't grand, mythic stories like the ones I just mentioned. Those you might call stories with a capital S. These are small stories, the kind you might tell about your slightly crazy uncle. The good thing about them is that they really are about genetically engineered food, as opposed to something else. And they do, I think, offer some food for thought. So we'll just see if these stories are powerful enough to stick in your minds.

Twenty years ago a man named David Padwa went to see the famous financier George Soros. Padwa was one of the earliest visionaries of agricultural biotechnology. He was a precocious child of New York City; he'd made a fortune in the computer business, then he'd wandered the world and ended up in Santa Fe. He'd also acquired some small seed companies. And when he heard about the first breakthroughs in gene splicing, a light bulb turned on in his head. My seeds, he said to himself, are really packages of DNA. We now can manipulate that DNA, create new genetic packages, and sell them for lots of money.

This was 1981; biotechnology was hot in the investment community. And Padwa tried to tap some of that money. He went to see Soros and presented his vision for a revolution in agriculture.

When Padwa was done, Soros said, "I'm not going to give you any money. Two reasons. I don't like businesses where you only get to sell your product once a year, and I don't like businesses in which anything you could possibly do can be overwhelmed by the weather."

When David Padwa told me this story he laughed and said, "Two very good reasons!" The point of this story is: Agriculture is different. Selling genetically altered plants is different from selling chemicals, and it's different from selling pharmaceuticals. And from the point of view of biotech companies, agriculture is different in extremely annoying ways.

I'll quote one former executive from the company Calgene: "I love agricultural biotechnology . . . except for the fact that it involves agriculture." This, in fact, could be the epitaph on Calgene's tomb.

Some of you may remember Calgene. In the early 1990s, it was the first company to sell a genetically engineered plant: the Flavr Savr™ tomato. Calgene's scientists had figured out how to shut down a particular gene within the plant. As a result, the tomato didn't go soft as fast as a conventional tomato; it had a longer shelf life. And Calgene told the world that this genetic alteration was so powerful, it would allow the company to take over a big chunk of the fresh tomato business. They were going to sell a billion dollars' worth of tomatoes each year.

Then Calgene ran into agriculture. The first problem was that somehow they didn't quite get around to breeding their new gene into all the different varieties of tomatoes that might grow well in different parts of California, Florida, and Mexico. When they finally got some tomato breeders working on the problem, there was almost no time left.

This is my favorite part of the story. One of the company's young executives went to see the tomato breeder and told her that she needed to have the breeding done in a year. The breeder was doing her work as fast as she possibly could, but a tomato plant will grow only so fast. "It's not possible," she said.

"But you've *got to,*" said the man from the business side of the company. "Listen! Money is no object! Anything you need to speed it up, we can get it!"

The plant breeder, getting exasperated, replied, "It can't be done! There are biological limits!"

The division of Calgene that was producing the Flavr Savr™ was seriously devoted to new ideas in management. People there talked a lot about teamwork and communication and synergy. "Come on!" said the man from Calgene to the breeder. "Think outside the box!"

To make a short story even shorter, the tomato flopped in the field. Yields were terrible. Disease claimed much of the crop in Florida. And many of the tomatoes weren't hard enough to withstand shipping and handling; they turned into tomato puree en route.

With a bit of time, Calgene managed to iron out many of those problems, but they still were losing money. And then came the final, fatal insult. Calgene's products were buried in a flood of tomatoes from Mexico—a product of traditional breeding called the Long Shelf Life tomato. It was a beautifully ripe-looking, red, hard tomato; it didn't taste that great, but at least visually, it *delivered* what Calgene had promised. Tomato prices fell through the floor, and Calgene's project was finally dead. It was a triumph of old technology over new technology.

A few years later, Monsanto came along, with a couple of genes that really did make a big enough difference that farmers would be willing to pay extra for them: *Bacillus thuringiensis* (Bt), and Roundup resistance genes. Monsanto's leaders really did believe the Silicon Valley story. Their company, they said, would be the Microsoft of agriculture. It would deliver the software, in this case the genes. It would license those genes to seed companies, which owned the hardware—the seed.

But once again, *agriculture is different*. Monsanto ran into the complexity of the seed business. Seed lives in this twilight zone of capitalism—somewhere between a real product, like a car, and a free gift of nature, like the air. (Hybrid corn is a special case: it's more like a product, because it's complicated to create hybrid seed, and farmers can't usually do that on their own.) Companies in the soybean or wheat seed business were selling something that they couldn't really control. Farmers could take part of the harvest and use it for seed the next year. Other seed companies could take any new variety and start using it as breeding material. As a result, seed companies had never been able to charge a huge amount for an improved product. But Monsanto wanted huge amounts of money for its genes— huge amounts at least by the standards of the seed industry.

This led to two things: Monsanto came up with ways to impose new rules on the seed trade; it used patents and contracts to ban the saving of seed and to set the prices that farmers were charged for the use of Monsanto's genes. And as time went on, Monsanto became convinced that the only way to earn what it wanted was to own substantial chunks of the seed industry. So Monsanto went out and spent $8 billion to buy seed companies. (One of the acquisitions was blocked, so the final total was closer to $5 billion.)

It was a more fateful decision, I think, than anyone inside the company realized at the time. Some risks the company's executives had considered. They understood the financial impact. They thought about potential antitrust problems. But they did not comprehend the emotional impact of those decisions on a community of people who object to turning biology into commodities.

Seeds are different. They are products, but they represent the bounty of the earth and the mysterious nature of life. For twenty years, a committed band of activists had been predicting that patents on life would bring forth monopolists of life. Monsanto, because of the manner in which it had entered the seed business, had become exactly the corporate monster that these activists had long predicted. And one of the most gifted of these activists, Pat Mooney, stood at a pay phone on a chilly streetcorner in Victoria, British Columbia, listening to one of his colleagues describe a new technology that would render the offspring of a harvest sterile. It was a biological tool that would prevent the saving and replanting of a farmer's harvest. Monsanto was about to buy the seed company that owned this technology. And Pat Mooney said, "Let's call it Terminator!" The Terminator gene, as millions of people around the world came to call it, symbolized everything that people felt was wrong and perverse about biotechnology in agriculture.

There is a moral to these stories. It's the second point I'm trying to make. People who are trying to introduce products of biotechnology into agriculture would do well to remember some old-fashioned virtues: modesty and patience. Modesty in one's claims regarding the technology, and patience when it comes to trying to extract profits from it. Calgene couldn't afford to be modest and patient with its tomato and was punished by the market. Monsanto wasn't willing to be modest and patient and reaped a whirlwind of public opposition. If a company can't afford to be modest and patient in this business, well, maybe it shouldn't be in the business in the first place.

The tale of agricultural biotechnology is one of new wine in old wineskins, of new technology emerging within a traditional industry unwilling to change its practices. It is a story of double standards, as the public demanded strict assurances from genetic engineering while taking a relatively laissez-faire approach to traditional agriculture. Indeed, if the standards governing genetic engineering were applied to the rest of agriculture, much food production would have to be shut down.

Forget chemical factories and toxic waste dumps—the single most environmentally destructive human activity on the planet is agriculture. Clearing and plowing land in order to grow crops (even following organic methods) amounts to an ecological disaster visited annually upon at least a quarter of the planet's land surface.

Nor are the products of traditional agriculture uniformly safe to eat. Food from some plants, such as peanuts, causes allergic reactions among hundreds of thousands of people. Other grains, including wheat and corn, contain small amounts of extremely toxic and carcinogenic compounds that result from certain plant diseases. Yet the public, for the most part, smiles indulgently. As the hapless George Banks says of fox hunting in *Mary Poppins*, "Well, I don't mind *that* so much. It's tradition!"

Except for the use of technology invented since World War II—primarily pesticides—agriculture is largely unregulated. Farmers can plant what they want on their land. They can plow right up to the edges of creeks, causing soil erosion; they can overdose their land with fertilizer or agricultural chemicals, placing nearby streams or groundwater at risk. They can plant the same crops year after year, depleting the soil of nutrients and risking infestations of destructive pests or epidemics of plant disease. Farmers *shouldn't* do any of this; it's not in their economic self-interest, and most don't. But none of it is illegal.

Plant breeders, for their part, are free to introduce genes into crops from any of the plant's closely related species without worrying about reactions from either government regulators or consumers. Some years ago, a soybean breeder located wild relatives of the soybean in Australia that appeared to be immune to one of the major pests afflicting soybeans in the United States, a worm called the cyst nematode. He took pollen from these plants, fertilized conventional soybeans, and managed to recover fertile offspring of this union that also were immune to the pest. The trait was then bred into standard soybean varieties, ready for planting by any American farmer. These varieties were products of the laboratory, not of nature. No one, in this case, even knows what genes make the plant immune to the cyst nematode, or why. No one needs to know. They are subject to no regulatory review.

Neither are so-called STS soybeans, which can tolerate sprays of an herbicide called Synchrony. These plants were created by soaking soybeans in chemicals, inducing random mutations in soybean DNA. Because the mutation was created *within* the cell, and not spliced in from an outside source, it faced no government review.

The supporters of biotechnology speak constantly and with great irritation about the higher standards applied to genetically engineered crops. It would be more logical (and therefore more correct, they believe) to apply the same standard across all crops.

But *which* standard? Consider the unspeakable: that all of agriculture deserves the same scrutiny applied to genetically engineered crops. Perhaps, when plant breeders create STS soybeans, or a variety of wheat that resists the predations of the Hessian fly, they shouldn't simply be allowed to start selling such seeds to farmers. Perhaps they should be required to find out what genes produce this trait and whether these varieties might cause any unwanted effects either to the ecosystem or to human health.

If farmers are required to limit their plantings of Bt corn or cotton for the good of the ecosystem (as indeed they should be), why not go further? Why not compel (or induce, through cash incentives) farmers to do other things that would produce even more substantial environmental benefits, such as allow more of their land to revert to grasslands or wooded areas?

Plant breeders, and most farmers, will be outraged at such suggestions. They will point out that the burden of such initiatives will fall most heavily on the smallest seed companies and on farmers already teetering on the edge of financial oblivion. Others will point out that efforts to subsidize better (but less efficient) agricultural practices might be incompatible with free trade in agricultural products.

That's all true. Those are good reasons for proceeding cautiously and patiently, alert to the social and economic consequences of our actions. But they aren't reasons for turning a blind eye toward the environmental effects of traditional agriculture.

Finally, there is the most pernicious aspect of the double standard affecting agriculture and biotechnology: the double standard of knowledge and passion. This double standard needs to be abolished first. If genetic engineering is fascinating, or even ominous, then plowing, sowing, reaping, or breeding cannot be mundane.

So let genetic engineering be a window into things that ultimately are more important. Let us begin to learn where the myth of agriculture ends and reality begins. Let's try to understand why farmers do what they do to so much of Earth's surface. And if we care about the health of the planet, particularly the part of it devoted to agriculture, perhaps we'll be willing to pay for what we value, either through direct purchases of food or through taxes. In the best of worlds, we might be able to create forms of agriculture that are good for all of the world's inhabitants.

Daniel Charles is author of the book, Lords of the Harvest: Biotech, Big Money, and the Future of Food *(Perseus Publishing, 2001), from which this chapter was reprinted. He has been a reporter for National Public Radio and* New Scientist *magazine.*

Ending World Hunger: The Promise of Biotechnology and the Threat of Antiscience Zealotry

Norman E. Borlaug

During the twentieth century, conventional breeding produced a vast number of varieties and hybrids that contributed immensely to higher grain yield, stability of harvests, and farm income. Despite the successes of the Green Revolution, the battle to ensure food security for hundreds of millions of miserably poor people is far from won. Mushrooming populations, changing demographics, and inadequate poverty-intervention programs have eroded many of the gains of the Green Revolution. This is not to say that the Green Revolution is over. Increases in crop management productivity can be made all along the line: in tillage, water use, fertilization, weed and pest control, and harvesting. However, for the genetic improvement of food crops to continue at a pace sufficient to meet the needs of the 8.3 billion people projected to be on this planet at the end of the quarter century, both conventional technology and biotechnology are needed.

What Can We Expect from Biotechnology?

The majority of agricultural scientists, including myself, anticipate great benefits from biotechnology in the coming decades to help meet our future needs for food and fiber. The commercial adoption by farmers of transgenic crops has been one of the most rapid cases of technology diffusion in the history of agriculture. Between 1996 and 1999, the area planted commercially with transgenic crops has increased from 1.7 to 39.9 million hectares (James 1999). In the last twenty years, biotechnology has developed invaluable new scientific methodologies and products, which need active financial and organizational support to bring them to fruition. So far, biotechnology has had the greatest impact in medicine and public health. However, a number of fascinating developments are approaching commercial applications in agriculture.

Transgenic varieties and hybrids of cotton, maize, and potatoes, containing genes from *Bacillus thuringiensis* that effectively control a number of serious insect pests, are now being successfully introduced commercially in the United States. The use of such varieties will greatly reduce the need for insecticides. Considerable progress also has been made in the development of transgenic plants of cotton, maize, oilseed rape, soybeans, sugar beet, and wheat, with tolerance to a number of herbicides. The development of these plants could lead to a reduction in overall herbicide use through more specific interventions and dosages. Not only will this development lower production costs, but it also has important environmental advantages.

Good progress has been made in developing cereal varieties with greater tolerance for soil alkalinity, free aluminum, and iron toxicities. These varieties will help to ameliorate the soil degradation problems that have developed in many existing irrigation systems. These varieties will also allow agriculture to succeed in acidic soil areas, thus adding more arable land to the global production base. Greater tolerance of abiotic extremes, such as drought, heat, and cold, will benefit irrigated areas in several ways. We will be able to achieve more crop per drop by designing plants with reduced water requirements and adopting between-crop/water-management systems. Recombinant DNA techniques can speed up the development process.

There are also hopeful signs that we will be able to improve fertilizer-use efficiency by genetically engineering wheat and other crops to have high levels of Glu (glutamine) dehydrogenase. Transgenic wheats with high Glu dehydrogenase, for example, yielded up to 29 percent more crop with the same amount of fertilizer than did the normal crop (Smil 1999).

Transgenic plants that can control viral and fungal diseases are not nearly as developed. Nevertheless, there are some promising examples of specific virus coat genes in transgenic varieties of potatoes and rice that confer considerable protection. Other promising genes for disease resistance are being incorporated into other crop species through transgenic manipulations.

I would like to share one dream that I hope scientists will achieve in the not-too-distant future. Rice is the only cereal that has immunity to the *Puccinia sp.* of rust. Imagine the benefits if the genes for rust immunity in rice could be transferred into wheat, barley, oats, maize, millet, and sorghum. The world could finally be free of the scourge of the rusts, which have led to so many famines over human history.

The power of genetic engineering to improve the nutritional quality of our food crop species is also immense. Scientists have long had an interest in improving maize protein quality. More than seventy years ago, researchers determined the importance of certain amino acids for nutrition. More than fifty years ago, scientists began a search for a maize kernel that had higher levels of Lys (lysine) and Trp (tryptophan), two essential amino acids that are normally deficient in maize. Thirty-six years ago, scientists at Purdue University (West Lafayette, Ind.) discovered a floury maize grain from the South American Andean highlands carrying the opaque-2 gene that had much higher levels of Lys and Trp. But as is all too often the case in plant breeding, a highly desirable trait turned out to be closely associated with several undesirable ones. The dull, chalky, soft opaque-2 maize kernels yielded 15 to 20 percent less grain weight than normal maize grain. However, scientists from the International Maize and Wheat Improvement Center (near Mexico City) who were working with opaque-2 maize observed little islands of translucent starch in some opaque-2 endosperms. Using conventional breeding methodologies supported by rapid chemical analysis of large numbers of samples, the scientists were able to slowly accumulate modifier genes to convert the original soft opaque-2 endosperm into vitreous, hard-endosperm types. This conversion took nearly twenty years. Had genetic engineering techniques been available then, the genes that controlled high Lys and Trp could have been inserted into high-yielding hard-endosperm phenotypes. Thus, through the use of genetic engineering tools, instead of a thirty-five-year gestation period, quality protein maize could have been available to improve human and animal nutrition twenty years earlier. This is the power of the new science.

Scientists from the Swiss Federal Institute of Technology (Zurich) and the International Rice Research Institute (Los Baños, the Philippines) have recently succeeded in transferring genes into "golden rice" to increase the quantities of vitamin A, iron, and other micronutrients. This work could eventually have profound impact for millions of people with deficiencies of vitamin A and iron, causes of blindness and anemia, respectively.

Because most of the genetic engineering research is being done by the private sector, which patents its inventions, agricultural policy makers must face a potentially serious problem. How will these resource-poor farmers of the world be able to gain access to the products of biotechnology research? How long, and under what terms, should patents be granted for bioengineered products? Furthermore, the high cost of biotechnology research is leading to a rapid consolidation in the ownership of agricultural life science companies. Is this consolidation desirable? These issues are matters for serious consideration by national, regional, and global governmental organizations.

National governments need to be prepared to work with and benefit from the new breakthroughs in biotechnology. First and foremost, governments must establish regulatory frameworks to guide the testing and use of genetically modified crops. These rules and regulations should be reasonable in terms of risk aversion and implementation costs. Science must not be hobbled by excessively restrictive regulations. Because much of the biotechnology research is under way in the private sector, the issue of intellectual property rights must be addressed and accorded adequate safeguards by national governments.

Standing Up to the Antiscience Crowd

The world has or will soon have the agricultural technology available to feed the 8.3 billion people anticipated in the next quarter of a century. The more pertinent question today is whether farmers and ranchers will be permitted to use that technology. Extremists in the environmental movement, largely from rich nations or the privileged strata of society in poor nations, seem to be doing everything they can to stop scientific progress in its tracks. It is sad that some scientists, many of whom should or do know better, have also jumped on the extremist environmental bandwagon in search of research funds. When scientists align themselves with antiscience political movements or lend their names to unscientific propositions, what are we to think? Is it any wonder that science is losing its constituency? We must be on guard against politically opportunistic pseudoscientists like the late Trofim D. Lysenko, whose bizarre ideas and vicious persecution of his detractors contributed greatly to the collapse of the former USSR.

We all owe a debt of gratitude to the environmental movement that has taken place over the past forty years. This movement has led to legislation to improve air and water quality, protect wildlife, control the disposal of toxic wastes, protect the soils, and reduce the loss of biodiversity. It is ironic, therefore, that the platform of the antibiotechnology extremists, if it were to be adopted, would have grievous consequences for both the environment and humanity. I often ask the critics of modern agricultural technology: What would the world have been like without the technological advances that have occurred? For those who profess a concern for protecting the environment, consider the positive impact resulting from the application of science-based technology. Had 1961 average world cereal yields (1,531 kilograms per hectare) still prevailed, nearly 850 million hectares of additional land of the same quality would have been needed to equal the 1999 cereal harvest (2.06 billion gross metric tons). It is obvious that such a surplus of land was not available, and certainly not in populous Asia. Moreover, even if it were available, think of the soil erosion and the loss of forests, grasslands, and wildlife that would have resulted had we tried to produce these larger harvests with the older, low-input technology! Nevertheless, the antibiotechnology zealots continue to wage their campaigns of propaganda and vandalism.

One particularly egregious example of antibiotechnology propaganda came to my attention during a recent field tour to Africa. An article in the *Independent* newspaper from London, entitled "America Finds Ready Market for Genetically Modified

Food: The Hungry" (Walsh 2000), is accompanied by a ghastly photograph depicting a man near death from starvation, lying next to food sacks. The caption below reads, "Sudanese man collapsing as he waits for food from the UN World Food Program."

The article's author, Declan Walsh, writing from Nairobi, implies that there is a conspiracy between the U.S. government and the World Food Program (WFP) to dump unsafe, genetically modified American crops into the one remaining unquestioning market: emergency aid for the world's starving and displaced. I, for one, take heartfelt umbrage against this insult to the WFP, whose workers and collaborators helped feed 86 million people in eighty-two countries in 1999. The employees of the WFP are among the world's unsung heroes, who struggle against the clock and under exceedingly difficult conditions to save people from famine. Their achievements, dedication, and bravery deserve our highest respect and praise.

In his article, Walsh quotes several critics of the use of genetically modified food in Africa. Elfrieda Pschorn-Strauss, from the South African organization Biowatch, says, "The US does not need to grow nor donate genetically modified crops. To donate untested food and seed to Africa is not an act of kindness but an attempt to lure Africa into further dependence on foreign aid." Dr. Tewolde Gebre Egziabher of Ethiopia states, "Countries in the grip of a crisis are unlikely to have leverage to say, 'This crop is contaminated; we're not taking it.' They should not be faced with a dilemma between allowing a million people to starve to death and allowing their genetic pool to be polluted." Neither of these individuals offers any credible scientific evidence to back their false assertions concerning the safety of genetically modified foods. The WFP accepts only food donations that fully meet the safety standards in the donor country. In the United States, genetically modified foods are judged to be safe by the Department of Agriculture, the Food and Drug Administration, and the Environmental Protection Agency and thus they are acceptable to the WFP. That the EU has placed a two-year moratorium on genetically modified imports says little per se about food safety, but rather it says more about consumer concerns, largely the result of unsubstantiated scare mongering done by opponents of genetic engineering.

Let's consider the underlying thrust of Walsh's article that genetically modified food is unnatural and unsafe. Genetically modified organisms and genetically modified foods are imprecise terms that refer to the use of transgenic crops (i.e., those grown from seeds that contain the genes of different species). The fact is that genetic modification started long before humankind began altering crops by artificial selection. Mother Nature did it, and often in a big way. For example, the wheat groups we rely on for much of our food supply are the result of unusual (but natural) crosses between different species of grasses. Today's bread wheat is the result of the hybridization of three different plant genomes, each containing a set of seven chromosomes, and thus could easily be classified as transgenic. Maize is another crop that is the product of transgenic hybridization (probably of teosinte and Tripsacum). Neolithic humans domesticated virtually all of our food and livestock species over a relatively short period 10,000 to 15,000 years ago. Several hundred generations of farmer descendents were subsequently responsible for making enormous genetic modifications in all of our major crop and animal species. To see how far the evolutionary changes have come, one needs only to look at the 5,000-year-old fossilized corn cobs found in the caves of Tehuacan in Mexico, which are about one-tenth the size of modern maize varieties. Thanks to the development of science over the past 150 years, we now have the insights into plant genetics and breeding to do purposefully what Mother Nature did herself in the past by chance.

Genetic modification of crops is not some kind of witchcraft; rather, it is the progressive harnessing of the forces of nature to the benefit of feeding the human race. The genetic engineering of plants at the molecular level is just another step in humankind's deepening scientific journey into living genomes. Genetic engineering is not a replacement of conventional breeding but rather a complementary research tool to identify desirable genes from remotely related taxonomic groups and transfer these genes more quickly and precisely into high-yield, high-quality crop varieties. To date, there has been no credible scientific evidence to suggest that the ingestion of transgenic products is injurious to human health or the environment. Scientists have debated the possible benefits of transgenic products versus the risks society is willing to take. Certainly, zero risk is unrealistic and probably unattainable. Scientific advances always involve some risk that unintended outcomes could occur. So far, the most prestigious national academies of science, and now even the Vatican, have come out in support of genetic engineering to improve the quantity, quality, and availability of food supplies. The more important matters of concern by civil societies should be equity issues related to genetic ownership, control, and access to transgenic agricultural products.

One of the great challenges facing society in the twenty-first century will be a renewal and broadening of scientific education at all age levels that keeps pace with the times. Nowhere is it more important for knowledge to confront fear born of ignorance than in the production of food, still the basic human activity. In particular, we need to close the biological science knowledge gap in the affluent societies now thoroughly urban and removed from any tangible relationship to the land. The needless confrontation of consumers against the use of transgenic crop technology in Europe and elsewhere might have been avoided had more people received a better education about genetic diversity and variation. Privileged societies have the luxury of adopting a very low risk position on the genetically modified crop issue, even if this action later turns out to be unnecessary. But the vast majority of humankind, including the hungry victims of wars, natural disasters, and economic crises who are served by the WFP, does not have such a luxury. I agree with Mr. Walsh when he speculates that esoteric arguments about the genetic makeup of a bag of grain mean little to those for whom food aid is a matter of life or death. He should take this thought more deeply to heart.

We cannot turn back the clock on agriculture and use only methods that were developed to feed a much smaller population. It took some 10,000 years to expand food production to the current level of about five billion tons per year. By 2025, we will have to nearly double current production again. This increase cannot be accomplished unless farmers across the world have access to current high-yielding crop production methods as well as new biotechnological breakthroughs that can increase the yields, dependability, and nutritional quality of our basic food crops. We need to bring common sense into the debate on agricultural science and technology, and the sooner the better!

Conclusion

Thirty years ago, in my acceptance speech for the Nobel Peace Prize, I said that the Green Revolution had won a temporary success in man's war against hunger, which if fully implemented could provide sufficient food for humankind through the end of the twentieth century. But I warned that unless the frightening power of human reproduction was curbed, the success of the Green Revolution would be only ephemeral.

I now say that the world has the technology that is either available or well advanced in the research pipeline to feed a population of ten billion people. The more pertinent question today is: Will farmers and ranchers will be permitted to use this new technology?

Extreme environmental elitists seem to be doing everything they can to derail scientific progress. Small, well-financed, vociferous, and antiscience groups are threatening the development and application of new technology, whether it is developed from biotechnology or more conventional methods of agricultural science.

I agree fully with a petition written by Professor C. S. Prakash of Tuskegee University, and now signed by several thousand scientists worldwide, in support of agricultural biotechnology, which states that no food products, whether produced with recombinant DNA techniques or more traditional methods, are totally without risk. The risks posed by foods are a function of the biological characteristics of those foods and the specific genes that have been used, not of the processes employed in their development.

The affluent nations can afford to adopt elitist positions and pay more for food produced by the so-called natural methods; the one billion chronically poor and hungry people of this world cannot. New technology will be their salvation, freeing them from obsolete, low-yielding, and more costly production technology.

Most certainly, agricultural scientists and leaders have a moral obligation to warn the political, educational, and religious leaders about the magnitude and seriousness of the arable land, food, and population problems that lie ahead, even with breakthroughs in biotechnology. If we fail to do so, then we will be negligent in our duty and inadvertently may be contributing to the pending chaos of incalculable millions of deaths by starvation. But we must also speak unequivocally and convincingly to policy makers that global food insecurity will not disappear without new technol-ogy; to ignore this reality will make future solutions all the more difficult to achieve.

Norman E. Borlaug was awarded the Nobel Peace Prize in 1970 for launching the "Green Revolution," which helped Pakistan, India, and a number of other countries *improve their food production, and for his lifelong work in helping feed the hungry. Borlaug, who grew up on his family's farm in rural Iowa and attended a one-room schoolhouse, was awarded his doctorate in plant pathology in 1942 by the University of Minnesota. He served at the Rockefeller Foundation as the scientist in charge of wheat improvement under the Cooperative Mexican Agricultural Program. With the establishment of the International Maize and Wheat Improvement Center (CIMMYT) in Mexico in 1964, he assumed leadership of the Wheat Program, a position he held until his official retirement in 1979. He now leads the Sasakawa–Global 2000 agriculture program (SG 2000), a joint venture between the Sasakawa Africa Association and The Carter Center's Global 2000 program. SG 2000 works with more than 600,000 small-scale farmers in eleven sub-Saharan African countries. For more information, see the Norman Borlaug Heritage Foundation at www.normanborlaug.org*

References

James, C. 1999. *Global Review of Commercialized Transgenic Crops: 1999.* International Service for the Acquisition of Agri-biotechnology Applications Briefs No.12. Preview. Ithaca, N.Y.: International Service for the Acquisition of Agri-biotechnology Applications.

Smil, V. 1999. "Long-Range Perspectives on Inorganic Fertilizers in Global Agriculture." Travis P. Hignett Memorial Lecture, International Fertilizer Development Center, Muscle Shoals, Ala.

Walsh, D. 2000. "America Finds Ready Market for Genetically Modified Food: The Hungry." *Independent* [London], March 30.

Questioning Biotechnology's Claims and Imagining Alternatives

Frederick Kirschenmann

. . . [humans] are only fellow-voyagers with other creatures in the odyssey of evolution. This . . . should have given us, by this time, a sense of kinship with fellow-creatures; a wish to live and let live; a sense of wonder over the magnitude and duration of the biotic enterprise.

—Aldo Leopold

The controversy surrounding the use of transgenic technology appears to be based largely on different assessments of the merits of that technology. Proponents argue that genetic manipulation will help us feed the world, cure diseases, and solve many other problems facing the human species. Opponents argue that the projected benefits are overblown and that the technology poses many risks that have not been adequately assessed.

But these quarrels inevitably lead us into circular arguments. We won't know, *for sure*, whether genetic engineering will feed the world until we try it, and if it doesn't, it will be too late—developing other options for enabling the world to feed itself will have been ignored. We won't know, *for sure*, if transgenic organisms will create ecological havoc until we release them, and if they do, it will be too late—we won't be able to put the genie back into the bottle. In the meantime, we continue to limit our debate to our assessment of the technology's potential risks or benefits, relying on our personal or collective judgments about the technology's efficacy or on our biases about the technology's capabilities.

It seems more fruitful to look at some of the underlying assumptions that lead us to our conclusions about the technology's promises and problems. If the assumptions are faulty, a strong likelihood exists that the conclusions may be unreliable as well. The fact that many of these assumptions are found wanting leads us to the second topic of this paper: an examination of alternatives to biotechnology.

Prevailing Ideology

The first questions we might consider are these: What is the ideology that informs modern science, and is that ideology sound? Richard Lewontin, the prominent geneticist at Harvard University, argues persuasively that our modern optimism regarding the ability to solve many of our social, medical, and agricultural problems with transgenic technologies is based on an ideology that he calls "biological determinism." This is an ideology that, he says,

> ... makes the atom or individual the causal source of all the properties of larger collections. It prescribes a way of studying the world, which is to cut it up into the individual bits. It breaks the world down into independent autonomous domains, the internal and the external. Causes are either internal or external, and there is no mutual dependency between them.
>
> For biology, this world-view has resulted in a particular picture of organisms and their total life activity. Living beings are seen as being determined by internal factors, the genes. (Lewontin 1991, 13)

But Lewontin (1991) argues that this ideology completely ignores the actual relationship that exists between organisms and their environments. He suggests that there are actually four rules of "the real relationship between organisms and their environment" (87):

1. "Environments do not exist in the absence of organisms, but are constructed by them out of bits and pieces of the external world" (87).
2. "The environment of organisms is constantly being remade during the life of those living beings" (87).
3. "Fluctuations in the world matter only as organisms transform them" (90).
4. "The very physical nature of the environment as it is relevant to organisms is determined by the organisms themselves" (91).

Lewontin's rules of biology remind us that organisms are not the isolated entities that we assume they are when we fantasize about feeding the world by manipulating a few genes in a few plants or animals, or healing debilitating diseases by adjusting a few defective genes. Each individual within a species is a "unique consequence of both genes and the developmental environment in a constant interaction" (Lewontin 1991, 26). Such interactions remind us that all problems and threats to our well-being are finally a combination of molecular specification and the unique interactions among genes, organisms, and environment. "It is a fundamental principle of developmental genetics," writes Lewontin, "that every organism is the outcome of a unique interaction between genes and environmental sequences modulated by random chances of cell growth and division, and that all these together finally produce an organism. Moreover, an organism changes throughout its life" (27).

The notion that gene technology can, by itself, solve problems when those problems are, at least in part, derived from social and environmental interactions illustrates a faith in technological fixes that is not corroborated by experience. For example, it has always been something of a mystery to me how we can claim that we will be able to "feed the world" of expanding future populations by producing more food with biotechnology when we are presently failing to feed more than 800 million malnourished people in an era of overproduction (Sen, 1981, 1984; Leisinger, 2000).

Molecular World as Ecosystem

A second underlying question we might ask is this: Is it possible to do "just one thing" at the molecular level? Ecologists have demonstrated that it is *not* possible to do "just one thing" in the ecosystems in which we live. Even when we have made good-faith efforts to improve the resilience of our ecological homes, we have often miscalculated the extent to which, and the manner in which, species within ecosystems are interdependent.

Ecologist Yvonne Baskin provides a chilling example. In an effort to boost the numbers of salmon that swim upstream from Montana's Flathead Lake to spawn in Glacier National Park's McDonald Creek, state fisheries officials stocked the upstream portions of the watershed with exotic opossum shrimp to provide extra food for the salmon. Extra salmon, they believed, would, in turn, provide more food for eagles, bears, gulls, mallards, goldeneyes, coyotes, minks, otters, and many other species that feed on the salmon and their eggs.

But, as Baskin (1997) notes, "The plan overlooked an important bit of natural history of both shrimp and fish" (41). The salmon, it seems, feed on zooplankton near the surface during the day while the shrimp spend the day near the bottom, pretty much out of reach of the fish. "At night the shrimp migrate upwards to feed on zooplankton themselves—the same zooplankton, unfortunately, that serve as the chief food for [the salmon]" (41). Consequently, "Rather than supplying a new food resource for the [salmon], humans had unwittingly introduced a competitor" (41). As a result, writes Baskin,

> . . . zooplankton quickly declined, especially populations of daphnia, or water fleas, which are a favored food of both the [salmon] and the shrimp. Within just a few years, the [salmon] population in the lake had collapsed, too. One hundred kilometers upstream in McDonald Creek, the disappearance of the spawning [salmon] eliminated a food resource that had once fortified eagles for their winter migration and fattened bears for hibernation. It also brought to an end a wildlife spectacle that had boosted off-season tourism revenues for the park and neighboring communities. (Baskin 1997, 42)

In less than nine years, the population of 100,000 salmon was reduced to 50. If our judgment is this bad, are we really ready to begin modifying the genome?

There is every reason to believe that the same ecosystems dynamics that are at work on the organism level are also at work on the molecular level. In fact, Robert Service revealed in a 1997 *Science* magazine article that the use of "gene-typing techniques that directly sample and compare gene sequences from different organisms" (1740) for the first time reveals just how diverse and interconnected the world of single-celled microbes is. He reports that "a pinch of soil can contain 1 billion microbes or more" and describes the world of microbes as a "thimble-sized rainforest" (1740). Moreover, he concedes that describing the "ecological structure" of this biodiversity is "virtually impossible" (1740).

Such observations, made possible by sophisticated analyses of DNA, would tend to confirm Richard Lewontin's suggestion that the *ecosystem* metaphor is much more appropriate for biotechnology than the software "operating systems" metaphor that the biotech industry prefers.[1] "You can always intervene and change something in it," says Lewontin, "but there's no way of knowing what all the downstream effects will be or how it might affect the environment. We have such a miserably poor understanding of how the organism develops from its DNA that I would be surprised if we *don't* get one rude shock after another" (quoted in Pollan 1998, 49).

This is not to suggest that all genetic engineering should be banned. All species, after all, do modify their environments. In fact, as we have seen, Lewontin argues that the environment is constructed by living organisms out of the bits and pieces of the external world available to them. In other words, the environment wouldn't even exist if it were not for organisms modifying it. But it does suggest that if we continue to ignore the ecological dimensions of our modifications, as we seem to regularly do with genetic engineering, we are likely to experience many unpleasant surprises.

The awareness that ecosystems dynamics are at work at the molecular level suggests that we need to proceed more cautiously than most molecular biologists have

[1]Evelyn Fox Keller in *The Century of the Gene* (Cambridge, Mass.: Harvard University Press, 2000) argues that given the dynamic, ecosystem nature of the genetic world, the major lesson we are likely to learn from our further research in genetics is "humility."

done thus far. And it means that we need to pay attention to fundamental ecological principles in the process of our modifications. We can no longer blithely continue to assume that our proposed modifications are "safe" simply because we have convinced ourselves that

- genetic engineering is no different from ordinary sexual reproduction,
- nature will always keep all populations in balance,
- transgenic organisms will always be ecologically competent, or
- because the host has been domesticated, it is so genetically debilitated that the transgenic organism will not pose an ecological problem.

None of these assumptions will serve us well.

It is prudent to remember here that not all of our natural selection modifications have been problem-free. For example, Phil Regal, professor in the college of biological sciences at the University of Minnesota, reminds us that domesticated bees "became a spreading menace when the genes of African bees were added to their populations" (Regal 1994, 12). Regal has provided us with a good set of ecological principles for assessing the risk of releasing transgenic organisms based on his extensive studies of patterns and mechanisms of adaptation to natural environments in plants and animals.

The Basis for Assessing Risk

There is a third underlying question we might ask ourselves: What is an appropriate basis for evaluating a decision to release a transgenic organism into the environment?

In a cogent essay published in the November 1994 issue of *BioScience* magazine, Mario Giampietro, at that time a visiting associate professor at Cornell University, evaluated the bases on which we might determine whether or not it is "good" to release a transgenic organism into the environment. He suggested that such a decision must be analyzed on at least three different levels—the individual, the social, and the biospherical (Giampietro 1994).

At the individual level we would ask whether a transgenic organism would be beneficial to individuals—to the company that develops it, to the individual who will use it, to the organism that has been altered. At this level it is relatively easy to quantify risks and benefits. It is also the level at which most industries want to make decisions.

At the social level things begin to get more complicated. Here we need to determine if the release of the transgenic organism will contribute to the overall well-being and stability of society. At this level we need to ascertain if the release of a particular organism will contribute to the economic welfare of the community in which it is released and whether it poses unacceptable health risks to human populations.

At the biospheric level we begin to encounter a wide range of issues that are extremely difficult to assess through conventional risk/benefit analysis. The overarching complexity of ecological systems makes it impossible to quantify outcomes, but we should at least acknowledge the complexity and the questions it raises.

> Since every organism is part of a very complex, well-orchestrated ecosystem that has evolved over several millennia it is virtually impossible to assess, in advance, how changes in an organism may change the ecology in which that organism exists. How do these changes affect energy flows? How do they affect oscillations in predator-prey relationships over many life cycles? Do they increase the possibility of one species taking over, as non-native species have done when introduced into new ecologies? (Kirschenmann and Raffensperger 1995, 6)

Giampietro suggests that our decisions regarding transgenic organisms are made mostly at the individual level, with occasional passing reference to the social level. We rarely make them on the biospheric level. He reminds us that if we are interested in sustainability, then we need to give primary attention to the biospheric level.

Giampietro's analysis implores us to be clear about which problems we are trying to solve with transgenic organisms. For example, if we are concerned only about making more food immediately available to help feed a growing population, we might well decide to support the development of genetically engineered organisms that promise to improve yield (the individual level). If, on the other hand, we are concerned about the social inequities and the political structures that prevent people from gaining access to food despite adequate production (the social level), or if we are concerned about the size of the ecological footprint that increased populations of overconsuming humans leave on the planet, causing a degradation of the environment and loss of the ecosystem services on which food production depends (the biospheric level), then we might be led to approach the problem of hunger from a different perspective.

If Giampietro's analysis helps us to be clearer about the problem we are actually trying to solve, his proposal might help us realize, for example, that current applications of biotechnology in agriculture are primarily designed to solve the problems of monoculture farming—specializing production systems by reducing them to one or two species of crops or animals within a bioregion.

Most biotechnology applications in crop production seem to be designed to prop up monocultures and the industrial food system they serve. But as every biologist and every farmer surely knows by now, monocultures are inherently unstable and fraught with pest problems. This is because monocultures are fundamentally at odds with nature. Nature is diverse and complex. All organisms in nature have learned to adapt to biodiversity. Nature, accordingly, will always find ways to overcome the specialization and simplification of monocultures. A recent study on the benefits of biodiversity published by the Council for Agricultural Science and Technology concludes that "the development and increased use of high-diversity cropping systems, which currently are greatly underutilized, could substantially contribute to agricultural productivity, sustainability, and stability" (Council for Agricultural Science and Technology 1999, 1). On what basis do we convince ourselves that molecular biology will be any more successful at solving monoculture's inherent weaknesses than toxic chemicals have been?

Ethical Issues

The aforementioned issues, of course, force us to ask yet another question: What is the ethical basis for making decisions with respect to transgenic organisms? This is a particularly difficult question to answer in that our culture, going all the way back to the seventeenth century, has insisted on separating facts from values. Values, accordingly, have been relegated to the realm of personal opinion and private faith. Ethics and values have nothing to do with science and facts. That perspective has left us with few disciplined tools for making ethical decisions as a society. The technologies of our new generation, however, are rapidly propelling us into a world in which we no longer have the luxury of relegating ethics to the arena of private and personal choice.

In his thought-provoking paper published in the April 2000 issue of *Wired* magazine, Bill Joy, cofounder and chief scientist of Sun Microsystems, helps us to understand why this is so. Our new-generation technologies—robotics, genetic engineering, and nanotechnology—not only are self-replicating, but they also have the power to radically change the physical world and run the risk of doing "substantial damage in the physical world" (Joy 2000, 240). Moreover, while they have the potential to "significantly extend our average life span and improve the quality of our lives," they lead "to an accumulation of great power and, concomitantly, great danger" (242).

Joy proceeds to spell out what is different about the dangers of twenty-first-century technologies compared with the dangers of those of the twentieth century.

> Certainly the technologies underlying the weapons of mass destruction ... —nuclear, biological, and chemical . . . —were powerful, and the weapons an enormous threat. But building nuclear weapons required, at least for a time, access to both rare—indeed, effectively unavailable—raw material and highly protected information: biological and chemical weapons programs also tended to require large-scale activities.
>
> The 21st century technologies—genetics, nanotechnology, and robotics . . . —are so powerful that they can spawn whole new classes of accidents and abuses. Most dangerously, for the first time, these accidents and abuses are widely within the reach of individuals or small groups. They will not require large facilities or rare raw materials. Knowledge alone will enable the use of them. Thus we have the possibility not just of weapons of mass destruction but of knowledge-enabled mass destruction . . . , this destructiveness hugely amplified by the power of self-replication.
>
> I think it is no exaggeration to say we are on the cusp of the further perfection of extreme evil . . . (Joy 2000, 242)

It may be important to remind ourselves that this is not the ranting of an end-of-the-world fanatic who foresees Armageddon at every turn. This is someone who has been at the forefront of developing the very technologies that he feels now put us in a situation where we simply no longer have the luxury of ignoring difficult ethical issues.

In the December 1997 issue of *Harper's* magazine, David Shenk reaches similar conclusions about the decisions that society will impose as a result of the new choices that will be available to us. He describes these choices as "the burden of knowing, the burden of choosing" (Shenk 1997, 39). He imagines his daughter, twenty years from now, pregnant with her first child. Her doctor informs her that the karyotype and the computer analysis indicate that the fetus is carrying a genetic marker for severe manic depression. Will she abort?

According to Shenk, that question is only the beginning of a long list of ethical decisions we will be forced to make, including what kind of children we will decide to bring forth into the world. And what happens if a "pop-genetics culture" emerges that leads millions of people to choose identical offspring—another monoculture with all of its attendant deficiencies?

Shenk, like Joy, ultimately finds us wrestling with the issues of control and freedom. Are we going to allow these powerful technologies to be available to anyone who wants them, or are we going to control who uses them and for what purpose—and if so, who will be the ones to control them? If we allow them to be freely available, Joy argues, they will inevitably fall into the hands of people who will use them for evil, evil that can destroy the world as we know it. Likewise, Shenk argues that free markets and consumer choice would become even more dominant forces in society than they already are, and the prospect of individuals or elite groups of individuals buying genetic advantages for themselves "might well spell the end" to "egalitarian harmony" (Shenk 1997, 45). The faith we have had in the notion that we *all* have to be considered equal at some fundamental level in order to sustain a peaceful, just, and functional society may evaporate.

For farmers who have worked hard to develop and supply markets for crops that do not contain genetically modified organisms (GMO), there is another, more immediate ethical problem. As transgenic crops spread throughout the landscape, it is becoming increasingly difficult for farmers to produce GMO-free crops.

Mary-Howell Martens recently completed research that explores the difficulty farmers are having with the production of non-GMO crops. She discovered that virtually all of the 2000 non-GMO corn crop produced in the Midwest that has been tested revealed GMO contamination at an average level of 0.25 percent (Martens 2001).

David Vetter, a veteran organic grower and processor near Marquette, Nebraska, had managed to keep his open-pollinated organic corn free of GMO contamination since he started developing the variety twelve years ago. But when he finished harvest in November he had his 2000 crop tested and found GMO contamination. Careful management and selective breeding enabled Vetter to develop an open-pollinated variety of corn that produces a quality comparable to that of standard hybrid varieties—making it a valuable product. Quality open-pollinated varieties not only save on input costs, but Vetter's customers prefer them as well. In addition to the extra costs involved in managing his corn to prevent pollen drift, Vetter now also has to absorb the additional cost of testing all of his corn. Further, now that the corn has traces of GMO contamination, Dave will label his corn to reflect the contamination—something he feels he must ethically do, but also something he is certain will cost him some of his customers (Vetter 2000, personal communication).

Seed companies that sell GMO-free seed are now pushing for higher GMO residue tolerances of GMO contamination so they can still market their seed as GMO-free. Vetter believes this is an indication that the more often such seed is planted, the higher the contamination levels will climb. That prospect, plus the expectation that many additional GMO crop varieties will be introduced into the environment, suggests that farmers in the United States will soon be unable to produce any GMO-free, and therefore any "organic," crops at all.

Small farms everywhere are finding that the development of specialty markets is critical to their survival. The market Vetter has developed for his corn is a very high value specialty market that took him twenty years to develop. If he must finally sell his certified organic corn on the conventional market because his customers reject it, the price differential will be equal to his annual farm income, approximately $17,000 on forty acres.

Who pays for David Vetter's loss?

Imagining Alternatives to Biotechnology

Most proponents of agricultural biotechnology argue that although some risks may be involved in using this technology, we have no alternative but to forge ahead. Given the exploding growth of the world's human population, it is the only way to avoid calamity. A recent essay by Klaus Leisinger (Leisinger 2000), executive director of the Novartis Foundation for Sustainable Development and professor of sociology at the University of Basel, serves as a good example of this position. Leisenger paints the usual picture. The global population will grow another 50 percent by the year 2050—three billion additional people. Most of that population growth will take place in the developing world. And much of it will take place in urban centers since urbanization will soar. By 2030, 57 percent of the population of developing countries will live in cities. And, he says, "People living in cities are not able to feed themselves through subsistence food production in the same way that people living in rural areas do" (2).

This will have a cascadelike effect. Exploding populations living in urban areas of poor nations where the people do not have the opportunity to feed themselves (urban gardens and urban fringe farms notwithstanding) will require that we begin producing higher yields. Because the eating patterns of urban people are substantially different from those of rural people, we will also have to produce different food. Urban people eat more high-value foods, more animal proteins, and more vegetables. That means that there will be a diversion of cereals from food to feed and the need to produce even more grain because of the loss of protein involved in the conversion of plant food to meat. Leisinger doesn't tell us why this shift from rural to urban must *necessarily* take place. We do know that the industrialization of agriculture in the industrial world has had the related social cost of pushing farmers off their land by increasing farm size. But the necessity of doing this to achieve production goals is not self-evident. In fact, many studies show that midsized farms are more efficient producers than megafarms (Peterson 1997; Strange 1988).

Leisinger goes on to argue that this higher productivity (which, in his view, can be achieved only with biotechnology) will also have positive ecological effects. "If average annual per hectare productivity increases just 1 percent, the world will have to bring more than 300 million hectares of new land into agriculture by 2050 to meet expected demand. But a productivity increase of 1.5 percent could double output without using any additional cropland" (Leisinger 2000, 2–3). Failure to achieve that productivity through biotechnology will necessitate bringing fragile lands and wilderness areas into agricultural production, with all of the attendant ecological devastation. There is no mention of the land that will be taken out of production due to urban sprawl if Leisinger's scenario comes to pass, or the potential for increased production through successful urban farming ventures such as the urban gardens in Cuba, where 50,000 tons of food are now produced annually inside the city of Havana—without the aid of genetic engineering.

Nor does Leisinger mention the potential for increasing food availability by decreasing waste. In the United States it is estimated that 25 to 40 percent of the food produced in agricultural fields is lost due to waste and spoilage between field and table. Nor does he mention the potential of increasing yields by improving soil quality—the most effective way to further increase yields, according to the National Academy of Sciences (National Research Council 1993). Nor does Leisinger tell us how people crammed into urban centers, living on annual incomes of less than $400, are going to be able to buy the food produced with biotechnology. He suggests that as the economies of developing nations grow, people will eat higher on the food chain. But he fails to mention the fact that as economies grow, the "absolute gap between rich and poor ... increase[s]" (Korten 1995, 48).

To his credit, Leisinger *does* call attention to the additional problems associated with maintaining current levels of productivity, such as declining water resources, declining soil quality, unforeseen climate changes, and poor governance—issues that biotechnology proponents often overlook. He fails to mention, however, that most of these problems were caused by the industrial farming methods that he wants to perpetuate. He also fails to acknowledge that food security is often most radically affected by two consequences of modern industrial agriculture: the pest infestations that occur because of the lack of biodiversity and genetic variability that is integral to modern industrial farming practices, and the failure to initiate land reforms that could put land into the hands of local farmers who can produce food for local populations.

Nevertheless, Leisinger believes that agricultural biotechnology is the linchpin to solving the food security problem associated with global population explosion. His contention, however, is rarely based on concrete field data. Mostly it is based on conjecture and analogy. He cites a World Bank panel's *prediction* that rice yields in Asia could increase by 10 or 20 percent with biotechnology. He compares the *future* potential of biotechnology with the past yield increases achieved with Green Revolution technologies.

Yet he does not mention the downsides of the Green Revolution technologies—the same waterlogging and salinization of soils, depletion of water resources, and environmental contamination that he feels we must now address with biotechnology in order to achieve adequate yields. He also fails to report that while rice yields increased with Green Revolution technologies, other food sources were depleted, such as the fruit previously grown on trees surrounding rice paddies and the fish previously produced within rice paddies. Both were destroyed by the pesticide inputs required to make the Green Revolution technologies perform. Neither does he mention that in many developing countries farmers are abandoning the Green Revolution technologies in favor of integrated pest management (IPM) and other less invasive agroecological practices, and in many instances they are now experiencing higher yields with less costly inputs.

To his credit, Leisinger acknowledges that we should judge genetic engineering "in the context of a wider technological pluralism" (Leisinger 2000, 11). Biotechnology, he argues, should be used only if it proves "superior to other technologies with regard to cost-effectiveness" (11).

Fair enough. But cost-effectiveness has to include the potential ecological and social costs. And here, I think, is where Leisinger's analysis, as well as the analyses of many other proponents of agricultural biotechnology, fails to give us a sufficiently thorough perspective. Above all, it does not give adequate attention to alternatives for achieving the goals of providing adequate food and fiber within a robust economy, a healthy ecology, and vibrant communities.

Assessing Risk

If we include the social and ecological costs in our assessment of the cost-effectiveness of agricultural biotechnology, we have to begin with the question of risk. Most proponents (and Leisinger is no exception) want to dismiss the problem of risk by claiming that "sound science" has already settled the matter. Leisinger argues, for example, that "there is a scientific consensus" establishing that there is "no conceptual distinction" between biotechnology and classical methods, and that the same laws govern both methods (Leisinger 2000, 11). That presumably provides prima facie evidence that there is no significant risk.

That assumption leads him to the conclusion that anyone who introduces the specter of "speculative risks" into the debate is doing so *deliberately* in an "attempt to stir up controversy" (12). He goes on to imply that the debate over risk finally boils down to uninformed "laypersons" on one side, who operate out of "*Angst*" and "feelings," and Nobel laureates in biochemistry and molecular biology on the other, who have the "irrefutable facts presented by scientists" (17).

One almost doesn't know where to begin here. One would have thought that the discoveries of quantum mechanics had laid to rest, once and for all, the flawed notion that science can establish anything as an "irrefutable fact." Quantum physicists demonstrated that the world is a world of *probability*, not *predictability* (Pagels 1982). Risks, therefore, can never be assessed with any kind of certainty.

Furthermore, science doesn't operate on the basis of "irrefutable facts." It operates on the basis of a consensus of the scientific community. That consensus is arrived at as a result of the peer review of data over long periods of time. And the consensus is *always* subject to review. Whenever scientists discover new data, or look at old data from a new perspective, old conclusions can give way to radical new ones, establishing a new consensus—and therefore a new "objective" truth. It is the scientific community's own failure, from time to time, to honor this reality, and therefore the necessary tentativeness of its conclusions, that gives rise to public distrust of science. Jim Davidson, research dean at the University of Florida, stated the matter with poignant clarity, with respect to agricultural science, as early as 1989.

> The distrust on the part of non-agricultural groups is well justified. With the publication of Rachel Carson's book entitled *Silent Spring*, we, in agriculture, loudly and in unison stated that pesticides did not contaminate the environment—we now admit that they do. When confronted with the pres-

> ence of nitrates in groundwater we responded that it was not possible for nitrates from commercial fertilizer to reach groundwater in excess of 10 parts per million under normal productive agricultural systems—we now admit they do. When questioned about the presence of pesticides in food and food quality, we assured the public that if a pesticide was applied in compliance with the label, agricultural products would be free of pesticides—we now admit they're not. (Quoted in Pesek 1990)

To this list, one can add scientists' assurances that there was no link between mad cow disease and Creutzfeldt-Jakob disease, between organophosphates and pesticide poisoning, and between the release of chlorofluorocarbons (CFCs) and the hole in the ozone. One can also add the assurances of scientists that nuclear energy was safe and would be "too cheap to meter" and that thalidomide was a safe drug. Proponents of biotechnology always seem to leave these examples out when they compare opponents of biotechnology to the technophobes who were opposed to railroads and the Model T (Anderson 2000; Leisinger 2000).

The problem here is not with the intelligence of scientists. If that were the case, the solution would be simple—just get smarter scientists. The problem is that scientists sometimes fall into the trap of making universal claims based on insular data. We simply cannot make accurate predictions about how a technology will perform in the world of interconnected and interdependent relationships of living systems based on isolated data collected in laboratories. In the world of social and ecological relationships there will simply always be surprises—and the surprises will be vastly magnified when we introduce technologies into ecosystems with which they did not evolve. And finding out the "truth" about how these technologies will behave in that complex, interdependent world usually takes a lot of time and careful monitoring. It took us forty years to discover that CFCs were blowing a hole in the ozone.

Thoughtful scientists and conservationists have, in fact, suggested some "laws of technology" based on these ecological observations. Stephen Schneider suggests, "The bigger the technological solution, the greater the chance of extensive, unforeseen side effects and, thus, the greater the number of lives ultimately at risk" (Schneider

1976, 14). And Aldo Leopold proclaimed, "The greater the rapidity of human-induced changes, the more likely they are to destabilize the complex systems of nature" (Leopold 1949, 220).

So when Professor Leisinger wants to assure us that agricultural biotechnology does not pose any significant risk, that it is "not very different" from what we have done in the past, and that the only reason there is so much opposition is that "highly sophisticated activists are easily able to mislead a scientifically uneducated public" (Leisinger 2000, 15), we can perhaps be forgiven if we simply disagree.

Bill Joy, cofounder and chief scientist of Sun Microsystems, also disagrees. Joy suggests that our new generation of technologies—robotics, genetic engineering, and nanotechnology—do "pose a different threat than the technologies that have come before" since they "share a dangerous amplifying factor: They can self-replicate" (Joy 2000, 240). Joy, who has been at the forefront of developing these technologies and is a consummate student of the science of those technologies, hardly fits Leisinger's description of a "sophisticated activist" intent on misleading an "uneducated public."

I believe we will be better served if we follow the advice of ecologists who have carefully observed the workings of nature rather than the advice of Leisinger, who seems to have observed only the tantalizing promises of a largely untested technology. Ecologists warn that "the level of uncertainty in our understanding of ecological processes suggests that it would be prudent to avoid courses of action that involve possibly dramatic and irreversible consequences and, instead, to wait for better information" (Daily et al. 2000, 395).

The Wrong Paradigm

But concerns about the potential risks embedded in this technology are not the only reason that we should look for alternatives. Perhaps the more basic reason to search for alternatives is that the present application of biotechnology in agriculture conforms to the same paradigm that has failed us in chemical technology.

The central problem is brilliantly articulated by Joe Lewis and his colleagues in a brief perspective paper published by the National Academy of Sciences (Lewis et al. 1997). Lewis is a researcher with the Agricultural Research Service's Insect Biology and

Population Management Research Laboratory in Tifton, Georgia. His research has focused on pest-management problems in agriculture. Lewis argues that the principal problem with industrial pest management is that we are operating out of a paradigm that he calls "therapeutic intervention." That approach attempts to solve pest problems by applying a "direct external counterforce" against the problem. In other words, we attack the problem of a pest within a complicated, interconnected system by intervening in that system with an external force geared simply to eradicate the pest. Though that approach has succeeded in killing some target pests, it has not solved the problem of crop losses due to pests. Some studies, in fact, indicate that crop losses have actually *increased* with the continued intensification of pesticide applications (Lewis et al. 1997).

This therapeutic intervention approach is now being widely questioned, not only in agriculture but also in medicine, social systems, and business management. The reason this approach is being abandoned is that we now generally recognize that using a counterforce from outside the system to solve a problem that is intrinsic to the system exacerbates rather than solves the problem.

In his work on systems dynamics, Peter Senge helps us understand why this is so. He warns that applying externally imposed solutions at the expense of analyzing and understanding the functions of the system usually leads to *creating* the problem we are trying to solve. The reason, he suggests, is that "the long-term, most insidious consequences of applying non-systemic solutions is increased need for more and more of the solution" (Senge 1990, 61).

Industrial pest management is simply a classic example of this principle at work. Trying to solve a pest problem by applying a pesticide kills not only some of the target pest but also nontarget predators that previously kept other pests in check. In addition, it creates resistant varieties of the target pest, making the original pest even more difficult to manage.

To date, the application of biotechnology has largely followed this same interventionist paradigm and therefore is likely to experience the same problems. Instead of using the technology to better understand how systems work and perhaps using it as one tool within a whole-systems approach, we use the technology to intervene in the system to "fix" the problem. Genetically inserting *Bacillus thuringiensis* (Bt) into the corn plant to control the corn borer is a poignant example. Virtually all entomologists agree that the corn borer will develop resistance to Bt; it is simply a question of when. And if the study reported in *Science* magazine is correct in its assessment that genes encoding resistance to Bt in the European corn borer are *dominant* rather than *recessive* as previously thought, then the high dose/refuge strategy[2] that farmers have been told to use to postpone resistance is likely to have little effect (Huang et al. 1999).

Furthermore, if we apply Professor Leisinger's cost-effectiveness screen, then planting Bt corn to control corn borer turns out *not* to be a very good choice. Peer-reviewed data now suggest that yield losses due to corn borer infestations have to exceed 10 to 15 bushels an acre before Bt corn becomes less costly than other options. And that does not take into account the yield loss the farmer will experience from planting the 20 percent of his crop to conventional corn not *protected with insecticides*, which farmers are supposed to plant to slow down resistance (Sears and Schaafsma 1999).

The Alternatives

As it turns out, alternatives often exist to the "quick-fix" applications of biotechnology. Managing corn rootworm serves as an example. Corn rootworm has become one of the most difficult pests for corn farmers to manage. The University of Illinois's Michael Gray, one of the leading entomologists in the country studying this pest, reports that Western corn rootworm has not only become resistant to most of the insecticides used against it, but it also has evolved resistance to cultural practices such as crop rotation. So here it would seem we have a perfect candidate for a transgenic Bt variety to control a problem for which there are no alternatives (Gray 2000).

But Gray is not so sure. First, from the cost-effectiveness perspective, he calculates that farmers will invest more than $400 million annually in technology fees alone to prevent an economic loss estimated at $650 million annually. So at best, farmers can

[2]The high dose/refuge strategy is the practice of inserting high doses of Bt into the transgenic plants to obtain maximum kill and simultaneously requiring that farmers plant at least 20 percent of their crop to conventional, non-transgenic varieties on which no pesticides at all are used to serve as a breeding ground for insects unaffected by Bt.

expect less than a one-dollar return for each dollar invested, and that assumes that losses due to pest infestation in the refuge acres will be minimized.

But there are other problems. The long-term cost to the environment, and eventually to the farmer, could be significant. Some scientists believe a strong likelihood exists that Bt corn for rootworm control could harm beneficial insects, such as the pest-eating ladybird beetle. They also worry that the toxins may not break down in the soil and therefore may harm vital soil organisms, which could affect yields. There is also concern that this technology may quickly lead to the development and spread of Bt-resistant rootworms because the rootworms will feed on the endotoxins of the transgenic plants twice during a growing season, first as larvae on the roots and then as adults on the pollen and foliage. Gray believes that apart from careful IPM monitoring and careful selection of fields in which the transgenic varieties would be planted, resistance is assured (Ferber 2000).

But even in this case there may be an alternative scenario. A trio of researchers with the Agricultural Research Service at the University of Missouri have developed corn lines with *native-plant* resistance to corn rootworms. The selection process used to develop new varieties from these native plant sources produces resistance with multiple proteins. Transgenic varieties, on the other hand, depend on only one protein. Rootworms, accordingly, will likely develop resistance to the transgenic varieties rather quickly, while the multiple-protein varieties could be effective much longer. Interestingly, Bruce Hibbard, one of the researchers working with the native plant varieties, says that they "aren't necessarily trying to eradicate corn rootworms completely" but desire simply to hold "rootworm damage below the economic threshold" (Ritchie 2000, 14). Hibbard's comment suggests an effort to understand why the rootworm is a pest and find ways to alter the system so that it will no longer be a pest rather than introducing an external counterforce to eradicate it.

This raises an important question. If we were to put as much effort and research funding into ecological approaches for solving production problems as we are currently expending in the engineering approach, what solutions would we find? Conversely, if we begin by telling ourselves that there are no alternatives to engineering external controls, we guarantee that the ecological approaches won't be explored.

Leisinger suggests the possibility of increasing rice yields by 10 or 20 percent with biotechnology. But *Science* magazine reported on a research project conducted in China recently in which two varieties of traditional rice that are locally adapted were companion planted. Farmers experienced an 18 percent overall yield increase and did not need to use a fungicide ("Variety Spices Up Chinese Rice Yields," 2000). Mae-Wan Ho, head of the bioelectrodynamics laboratory at Open University in the United Kingdom, reports that a Japanese farmer has developed a method of producing rice, which he calls the Aigamo method, that increases rice yields 20 to 50 percent in the first year. The method involves putting about 200 ducklings into each hectare of rice paddy. The ducks, it seems, eat insects and snails that attack rice plants; eat weed seeds and seedlings; and oxygenate the water, which encourages the roots of rice plants to grow. And the mechanical stimulation of their paddling makes for sturdier rice plants. Using this method, the farmer's two-hectare farm annually produces "seven tonnes of rice, 300 ducks, 4,000 ducklings and enough vegetables to supply 100 people" (Ho 1999, 339). Observers believe that the Aigamo method, which is now being adopted in many developing countries, has the potential to make Japan—which currently imports 80 percent of its food—food self-sufficient again.[3]

The type of agriculture the Aigamo method represents has the potential to bring about other positive effects. Agriculture that is based on such wonderful complexities cannot be readily managed in large-scale monocultures. And because the method promises to be extremely productive, it suggests the possibility of supporting more people on the land with smaller-scale, highly productive farms. That poses the possibility of a different kind of future. A system that supports more people on the land may slow down, or even reverse, the migration to megacities. Could it therefore be possible that the rest of the scenario Leisinger predicts, which follows from the continued trend toward urbanization, might also not come to pass?

---

[3]Brian Halweil (2001) provides another example of an alternative to transgenic crops. He reports that farmers in East Africa have managed to successfully control the Striga weed by planting leguminous trees prior to planting corn. He argues this may be a more useful technology than herbicide-resistant corn because the corn and the herbicide would be too expensive for African farmers. "Biotech, African Corn and the Vampire Weed," *World Watch* magazine, September/October 2001. Volume 14, Number 5 (pp. 26-31).

There are other examples of alternative approaches to food security that do not include the use of biotechnology. The Land Institute in Salina, Kansas, has been developing perennial polycultures from wild grasses that could reduce soil erosion, use water more efficiently, and reduce planting and tillage costs (Land Institute 2000). John Jevons, world renowned for his "double digging"[4] method, has experienced phenomenal yield increases in vegetable production (Madden and Chaplowe 1997). Richard Manning, after studying the various sites where the McKnight Foundation is conducting pioneering research in developing countries, concludes that we will never be successful in our efforts to feed the world if we do not take the complexity and diversity of local cultures and local ecologies into consideration (Manning 2000). After careful observation, Manning concludes that genetic engineering may be a limited tool that can be used effectively in these whole-systems approaches to food production in an expanding human population, but it will not be the solution.

Manning's concluding remarks are instructive for us.

> The genetic engineering business is going to get all the headlines, but these simple matters [attending to the needs of local cultures and local ecologies] are potentially far more earth-shaking. What must happen, and to a degree is happening, in agriculture is also an information revolution. If there was a key mistake of the Green Revolution, it was in simplifying a system that is by its very nature complex.
>
> Farming is not just growing food. It is not simply a tool we use to feed however many beings our social structure generates. The way we grow food determines our structure, makes our megacities, makes us who we are. Agriculture is culture, at bottom about the integrity of individual lives. Those lives gain their integrity and value when they are deeply embedded in a rich environment of information. This is about growing good food, but more important, it is about making good lives. We will fail if we attend to the former without considering the latter. (Manning 2000, 218)

---

[4]Double digging is a method of cultivation that loosens the soil at both the topsoil and subsoil levels.

Conclusion

What is our prevailing scientific ideology, and how does it affect the assessment of these new technologies? Do we recognize ecosystems dynamics at the molecular level, and will we incorporate the potential consequences of ecosystems functions in our assessment of the potential ramifications of the release of transgenic organisms? Will we be clear about the level at which we are attempting to solve a problem and properly assess the risk at the individual, the societal, and the biospheric levels? What are the ethical implications of the new technologies, and how do we begin making sound ethical choices in the wake of an ethically challenged society? These are all questions we need to ponder if we are going to make sound decisions as we enter the new era of our new-generation technologies.

Our current fascination with new-generation technologies may be distracting us from recognizing at least two important human failures. The first is our tendency to believe that we can solve all our problems without nature. In Iowa we now have a cow named Bessie that will shortly give birth to a gaur, an oxlike Asian bovine mammal. It will be the world's first cloned endangered species, and the experiment is being executed to help save the species from extinction.

Columnist Ellen Goodman suggests that this may be a necessary thing to do, but it raises a number of questions when one looks at the problem from a whole-systems perspective. How is it that we are willing to expend this extraordinary effort to save one species while we seem oblivious to the fact that we continue to destroy the habitat of hundreds of others? What does it mean to save a species from extinction when its habitat has been destroyed? Do we think that the baby guar can live on an Iowa farm, raised by an Iowa cow, and still be a gaur (Goodman 2000)?[5]

Proponents of biotechnology often seem to be oblivious to the context in which the technology is released—all the complex, interdependent relationships of organisms within a species and of species within their environments. Biotechnology is never simply a matter of "just adding another gene to what we have already been doing," as Monsanto Science Fellow and Agronomist John Kaufmann put it recently at a biotech

[5]The gaur was born on January 8, 2001, and died eighteen hours after birth.

conference.[6] Stuart Newman, professor of cell biology and anatomy at New York Medical College, says, "There is an incorrect, but prevalent notion, that genes are modular entities with a one-to-one correspondence between function and a gene" (Newman 2000, 27).

An article that appeared in the *New York Times* science section in July 1994 provides one example of the complex relationships that have evolved in nature. The article points out that researchers have discovered "a chemical laxative in the cherry-sized fruit of a Costa Rican shrub. The drug appears to act on the bowels of the birds, to the plants' and not the birds' advantage" (Yoon 1994, 1). Though we have known that fruits contain laxatives, this is the first evidence that "the biological effect of these tasty treats is the result of chemical manipulation in which animals are drugged into transporting and dropping the precious seeds quickly" (1). In other words, plants have evolved a complex mechanism that enables them to control the rate of passage of a seed through birds to give the plants the best opportunity to propagate themselves. We simply have to take such contexts into account as we contemplate changing the world with powerful, self-replicating technologies.

Everyone agrees that biotechnology has the ability to make dramatic changes in nature. If that were not true, then the argument that it has the potential to dramatically increase productivity would be hollow. But if powerful technologies have the potential to radically change components of such complex relationships, thereby potentially upsetting delicate interactions that have evolved over millennia, shouldn't it inspire caution?

Bill Joy reminds us of a second human failure that we also must ponder as we develop new technologies. He writes that we almost never pause to try to "understand the consequences of our innovations while we are in the rapture of discovery and innovation" (Joy 2000, 243).

Frederick Kirschenmann is the director of the Leopold Center for Sustainable Agriculture at Iowa State University. He is also the president of Kirschenmann

[6] Comment made by Dr. Kaufmann during a panel presentation at the Wisconsin Academy of Sciences, Arts and Letters conference on genetically modified foods in Madison, Wisc., November 3–4, 2000.

Family Farms, a certified organic farm in Windsor, North Dakota. He earned degrees from Yankton College in South Dakota, from the Hartford Theological Seminary in Connecticut, and a Ph.D. from the University of Chicago.

References

Anderson, Barb Baylor. 2000. "21st Century Model T." *Agri-Marketing*, July/August, 74–76.

Baskin, Yvonne. 1997. *The Work of Nature.* Washington, D.C.: Island.

Council for Agricultural Science and Technology. 1999. "Benefits of Biodiversity." Council for Agricultural Science and Technology Task Force Report no. 133, February. Ames, Iowa: Council for Agricultural Science and Technology.

Daily, Gretchen C., Tore Soderqvist, Sara Aniyar, Kenneth Arrow, Partha Dasgupta, Paul R. Erlich, Carl Folke, AnnMari Jansson, Bengt-Owe Jansson, Niles Kautsky, Simon Levin, Jane Lubshenco, Karl-Goran maler, David Simpson, Davaid Starrett, Dave Tilman, and Brian Walker. 2000. "The Value of Nature and the Nature of Value." *Science*, July 21, 395–96.

Ferber, Dan. 2000. "New Corn Plant Draws Fire From GM Food Opponents." *Science*, February 25, 1390–91.

Giampietro, Mario. 1994. "Sustainability and Technological Development in Agriculture: A Critical Appraisal of Genetic Engineering." *BioScience* 44:677–90.

Goodman, Ellen. 2000. "Cloning of Endangered Species Isn't a Parlor Trick." *Des Moines Register*, October 18, 15A.

Gray, Michael. 2000. "Proscriptive Use of Transgenic Hybrids for Corn Rootworms: An Ominous Cloud on the Horizon?" *Proceedings of the Crop Protection Technology Conference.* University of Illinois, Urbana-Champaign, January Paper presented at a conference at the University of Illinois. (Available from Frederick Kirschenmann; contact at leopold1@iastate.edu)

Ho, Mae-Wan. 1999. "One Bird—Ten Thousand Treasures." *The Ecologist*, October, 339.

Huang, F., L. L. Buschman, R. A. Higgins, and W. H McGaughey. 1999. "Inheritance of Resistance to Bacillus Thuringiensis Toxin (Dipel ES) in the European Corn Borer." *Science* 284:965–67.

Joy, Bill. 2000. "Why the Future Doesn't Need Us." *Wired*, April, 238–62.

Kirschenmann, Frederick, and Carolyn Raffensperger. 1995. "Genetic Engineering and Sustainability: Rethinking the Environmental and Agricultural Issues." Unpublished paper. (Available from Frederick Kirschenmann; contact at leopold1@iastate.edu)

Korten, David. 1995. *When Corporations Rule the World*. West Hartford, Conn.: Kumarian.

Land Institute. 2000. *Land Report* (quarterly newsletter). No. 67, Summer. Salina, Kan.: Land Institute.

Leisinger, Klaus M. 2000. "The 'Political Economy' of Agricultural Biotechnology for the Developing World." Unpublished paper. (Available from Frederick Kirschenmann; contact at leopold1@iastate.edu)

Leopold, Aldo. 1949. *A Sand County Almanac*. London: Oxford University Press.

Lewis, W. J., J. C. van Lenteren, Sharad C. Phatak, and J. H. Tumlinson. 1997. "A Total System Approach to Sustainable Pest Management." *Proceedings of the National Academy of Sciences* 94:12243–48.

Lewontin, R. C. 1991. *Biology as Ideology*. Concord, Ontario: House of Anansi.

Madden, J. Patrick, and Scott G. Chaplowe, eds. 1997. *For All Generations*. Glendale, Calif.: OM.

Manning, Richard. 2000. *Food's Frontier: The Next Green Revolution*. New York: North Point.

Martens, Mary-Howell. 2001. "Strategies to Reduce GM Contamination on Organic Farms." To be published in *Acres* USA. E-mail communication.

National Research Council. 1993. *Soil and Water Quality*. Washington, D.C.: National Academy Press.

Newman, Stuart. 2000. "Epigenetics vs. Genetic Determinism." *In Made Not Born*, ed. Casey Walker, 27–45. San Francisco: Sierra Club.

Pagels, Heinz R. 1982. *The Cosmic Code*. New York: Penguin.

Pesek, John. 1990. "Research Findings on Alternative Methods: Based on the NRC Report on Alternative Agriculture." Unpublished manuscript, presented at

Northwest Farm Managers Association, February 26, 1990. (Available from Frederick Kirschenmann; contact at leopold1@iastate.edu)

Peterson, Willis L. 1997. "Are Large Farms More Efficient?" Staff Paper P97-2, Department of Applied Economics, University of Minnesota, Minneapolis, January.

Pollan, Michael. 1998. "Playing God in the Garden." *New York Times Magazine*, October 25, 44–49.

Regal, P. J. 1994. "Scientific Principles for Ecologically Based Risk Assessment of Transgenic Organisms." *Molecular Ecology* 3:5–13.

Ritchie, Jim. 2000. "Corn Hybrids with non-GMO Resistance … Zap Rootworms the Natural Way." *Soybean Digest*, October, 14–15. (http://www.industryclick.com/magazinearticle.asp?magazineid=20&releaseid=2314&magazinearticleid=3647&siteid=5)

Schneider, Stephen. 1976. *The Genesis Strategy*. New York: Plenum.

Sears, M., and A. S. Schaafsma. 1999. "Responsible Deployment of Bt Corn Technology in Ontario." Canadian Food Inspection Agency, Plant Health and Production Division, Plant Biosafety Office, http://www.inspection.gc.ca/english/plaveg/pbo/btcormai2e.shtml

Sen, Amartya. 1981. *Poverty and Famines: An Essay on Entitlement and Deprivation*. Oxford: Clarendon Press.

Sen, Amartya. 1984. *Resources, Values and Development*. Cambridge, Mass.: Harvard University Press.

Senge, Peter M. 1990. *The Fifth Discipline*. New York: Doubleday.

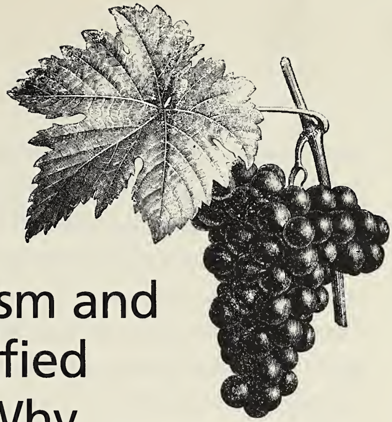
Service, Robert. 1997. "Microbiologists Explore Life's Rich, Hidden Kingdoms." *Science*, March 21, 1740.

Shenk, David. 1997. "Biocapitalism: What Price the Genetic Revolution?" *Harper's*, December, 37–45.

Strange, Marty. 1988. *Family Farming*. Lincoln: University of Nebraska Press.

"Variety Spices up Chinese Rice Yields." 2000. *Science*, August 18, 1122.

Yoon, Carol Kaesuk. 1994. "Scientists Find a Plant That Dupes Birds Into Spreading Its Seeds." *New York Times*, July 12, 1–4.



The Genetically Modified Organism and Genetically Modified Foods Debates: Why Ethics Matters

Jeffrey Burkhardt

Genetically modified organisms (GMOs) and genetically modified (GM) foods have become subjects of considerable public debate. The controversies are the result of differing views concerning the products of "the new biotechnology"—recombinant DNA (rDNA) technology, to be precise. rDNA technology has allowed scientists to move genes across species' boundaries, to create traits in plants, animals, and microorganisms that could never be accomplished using traditional crossbreeding techniques. For example, genes from cold-water fish can be inserted into tomato plants to make them more tolerant to colder weather. The reality of transgenic technology has caused some people to raise questions about the nature and consequences of GMOs. For example, do GM foods differ in any relevant ways from non-GM foods? Are any differences significant as to how they will affect human health or the environment? How strictly are GMOs being tested? Who oversees the regulation and registration process? These are scientific and legal-political issues, and they are being discussed everywhere from grocery stores to the halls of Congress.

As important as these kinds of issues are in the GMOs/GM foods debates, other controversies have arisen regarding the *ethics* of GMOs and GM foods. People differ in their judgments about whether producing and using GMOs are morally correct things to do. The issue is whether GMOs and GM foods are morally and ethically acceptable. If they are ethically acceptable, then there is nothing wrong about producing, using, or consuming them. If they are not acceptable, people should stop producing them; or at least those people who find them unacceptable should be able to avoid them. Clearly, some people think GMOs and GM foods are ethically acceptable, whereas others do not. The point of this essay is to explain why the deeper ethical-philosophical reasons underlying the GMO debates are so important. If we are to resolve ethical (as opposed to scientific) controversies associated with GMOs and GM foods, a key step is to acknowledge differences in basic values and then debate the matter in terms of these deeper commitments and concerns.

Components of Acceptability

Judgments about ethical acceptability depend on answering several preliminary questions. Although there are people who for philosophical or religious reasons reject transgenic technology whatever its applications, it is still important to recognize that differences exist among the products of biotechnology. The first question regarding acceptability should be, "What GMO are we talking about?"

What Product?

Different products have different ethical dimensions. For example, bovine growth hormone (recombinant bovine somatotropin, or rBST), an early GM product, was designed to increase the efficiency of milk production by getting cows to produce more milk without increasing their feed intake. People who have written on the ethical acceptability of rBST have called attention to its possible negative effects on cows, potential impact on human health, and economic effects on small-scale dairy operations (see, e.g., Comstock 1989). In contrast, Roundup-Ready® crops, such as soybeans and cotton, were designed to permit a farmer to spray a herbicide on his or her field, killing weeds but not affecting the Roundup-Ready® crops at all. Analysts have written on the potential cost savings resulting from farmers not having to till weeds or use numerous herbicides to kill the different sorts of weeds that invade the field. Others have pointed out the potential human health risks and, again, economic effects on small farms (Lappé and Bailey 1998). *Bacillus thuringiensis* (Bt) corn is yet another example. Bt corn was engineered to produce a substance in the plant that is toxic to insect pests. The product was designed to reduce the need for spraying insecticides; however, people have claimed—in fact, it was a major controversy in the Corn Belt—that the pollen from Bt crops kills monarch butterfly larvae that consume it, a significant environmental impact (Environmental News Service 1999). Finally (though the list of GMOs and GM foods is much longer than provided in these examples), so-called "golden rice" is a transgenic product with greatly enhanced beta carotene (vitamin A–producing) content, intended to provide a more nutritious food staple for people in Third World rice-consuming countries where vitamin A deficiency is a serious problem—a cause of blindness in children. Although this GM product is several years away from the market, it has been discussed in terms of both its major health benefits as well as its potentially prohibitive cost to poor people (Burkhardt 2001).

The point concerning each of these examples is that, in part, the ethical acceptability or lack of it depends on the kind of GMO or GM food we are addressing: What are its features? What are its intended consequences?

What Context?

A second set of concerns that bear on ethical acceptability is the context in which the analysis or argument is set. Part of what has made the GMO and GM foods debates difficult for some people to understand is that individuals frequently talk past each other, as one party focuses on a set of issues in one context that are different from the issues and context that concern another party. For instance, much of the scientific community has tended to focus on the role of the new biotechnology in contributing to food quantity, quality, and affordability, whereas others have focused on contexts such as human (animal) health, environmental safety, issues concerning social justice or fairness, or different implications of GM technology for the developed versus the developing world. Certainly, each of these general areas of concern is important in the ethical appraisal of GMOs and GM foods. By focusing primarily or even exclusively on one area, however, parties involved in the debates or controversies tend to ignore other relevant issues or considerations that appear in a different context. For example, when scientists limit the context of their ethical appraisal of GMOs and GM foods to the context of producing enough affordable food ("feeding the world"), they bypass other legitimate issues such as whether peasant farmers in a developing nation may be put at a disadvantage because they are unable to afford to employ the newest bioengineered crop variety. Similarly, those who limit their vision regarding rBST to effects on animals may have missed important points about the need for increased dairy productivity in poor areas of the world. Attention needs to be paid to all of the relevant contexts in which a judgment about the ethical acceptability of GMOs and GM foods can (and should) be made.

What Ethical Paradigm?

Focusing on particular products and their contexts provides the target for judging ethical acceptability. An ethical paradigm provides the criteria for making judgments. An ethical paradigm is a basic, general philosophy about what things count as right or wrong, and why. The paradigm contains basic value judgments about what is most important for people to do, or how they should be treated, or overall how we should live. In essence, the paradigm establishes the lens through which people view the world, providing a substantive standard for unequivocally deciding whether actions, policies, or, in this case, a set of products and processes are ethically correct. In the following section the three major paradigms identified by philosophers of ethics are discussed. These are (1) consequentialism, (2) autonomy/consent ethics, and (3) virtue/tradition ethics. Each of these implies a set of ethical judgments about food and agriculture generally, which in turn entails a judgment about the ethical acceptability of GMOs and GM foods.

In our daily lives, we seem to make ethical judgments on the basis of all three paradigms. Sometimes we decide as if we are consequentialists, sometimes as if we hold to autonomy/consent ethics, and sometimes as if we are virtue/tradition based. However, in our public acts—voting, expressing opinions in community forums, talking with friends or colleagues—we tend to fall into one of the camps. We become *more* consequentialist, *more* autonomy/consent oriented, or *more* virtue/tradition focused. Regardless of an individual's own moral or ethical code, these ethical paradigms provide criteria for judging how we collectively ought to act, how we societally ought to judge right and wrong, and how we ought to direct public policy. In the public debates over GMOs and GM foods, the three ethical paradigms discussed here are routinely invoked as reasons why we should do something regarding GMOs. Scientists, farmers, consumer activists, environmentalists, animal welfarists, concerned citizens, and so on—the parties to the debate—express these ethical perspectives in clear and forceful ways. Just as it is worth paying attention to differences among products and contexts, it is worth attending to differences among ethical paradigms or basic ethical philosophy. It may not make the disagreements go away, but we will be clearer about where we all stand.

Three Ethical Paradigms

Consequentialist Ethics

For many people, the question "Is X ethically right?," where X stands for an action, policy, or, in the present case, the production and use of a technology, is best answered by answering a different question: "Does (will) X produce good consequences (outcomes, effects, etc.)?" If the answer to this latter question is yes, then we have an obligation to do X, or at least it is permissible (acceptable) to do X. If the answer is no, then it is ethically or morally wrong to do or allow X. The question here is, what counts as a *good* consequence?

Despite general agreement among consequentialists that we ought to promote good consequences or outcomes, there is no universal assent as to what those might be. Numerous candidates have been offered: we ought to satisfy the wants and needs of the greatest number of people; we ought to promote the greatest amount of material, spiritual, intellectual, and emotional happiness as possible; we ought to maximize material benefits and minimize costs; and so forth. Some have placed an economic value on the definition of "good," yielding what we commonly call the benefit-cost approach: try to achieve the greatest net financial benefit as a result of our actions or policies. Not everyone agrees with the financial interpretation of consequentialist ethics, but some version of a "satisfied wants and preferences" criterion has come to dominate the consequentialist paradigm's calculus of right and wrong. Indeed, the long-standing slogan of consequentialist ethics, that "the greatest good of the greatest number" is what determines ethical acceptability or ethical obligations, has come to be understood as what satisfies most people's preferences and desires. Personal health and security (and hence financial stability) are undoubtedly part of what most people want, so that consequentialist ethics also requires actions or policies that help achieve those goods. Most who subscribe to the consquentialist ethical paradigm believe that with enough foresight and care in reasoning, we can find the ethically right solution to any problem we may face (see Slote 1985).

Ethics of Autonomy/Consent

Those who subscribe to the ethics of autonomy/consent approach the matter of right and wrong in a very different fashion. Ethical rightness or acceptability depends on whether an action, practice, or policy respects or protects the individual person as he or she acts on his or her judgments about morality. The assumption, initially, is that people are generally rational and are mature enough to make judgments about what is right and wrong. People are *entitled* to make their own judgments. This is what autonomy means—self-determination. There is a long history, within the paradigm, of discussion about what it is that makes individual human beings deserving of personal sovereignty or autonomy, and how respecting and protecting autonomy should be translated into practical ethical rules or duties. One line of thought views this as a matter of respecting people's *rights*, that is, legitimate claims people have that others do or do not act toward them in particular ways. For many contemporary autonomy/consent ethicists, the idea of individual rights is further refined: anything anyone might do that affects other people, potentially infringing on rights or limiting self-determination, requires the consent of those affected. Without prior consent, actions that affect people are ethically unacceptable, indeed, ethically wrong.

It is instructive to note here that those who subscribe to the ethics of autonomy/consent demand that actions be consented to, even if, on some consequentialist calculation, those actions would benefit people. For example, it might be shown that putting chemicals in the public water supply kills bacteria that could harm people; hence, adding the chemical achieves a public good. Even so, the autonomy/consent paradigm requires that people be given the opportunity to agree with or object to the action and, at the extreme, be provided with an alternative water source if they disagree. For those accustomed to the consequentialist or benefit-cost approach, this demand may seem stubborn or unreasonable. Nevertheless, it is based on the principle that each individual person is entitled to decide how to live his or her life; others may not interfere without each individual's prior agreement (see Rippe 2000).

Ethics of Virtue/Tradition

A third basic ethical paradigm defines ethical rightness in terms of whether an action, practice, or policy promotes or is consistent with a set of virtues, usually set by a particular ethical or moral tradition. Virtues are ideal character traits or states of being that are thought to be definitive of the ethical life. For example, honesty, integrity, piety, and fairness are virtues under this definition. So are self-actualization, harmony with human nature, and life in accordance with Nature. These are in turn defined by the community within which one lives or by which he or she defines himself or herself. Honesty may mean complete openness and candor ("tell all") in one community's view; it may be simple truthfulness ("don't lie") in another's. Life in accordance with Nature may mean not killing animals in one community, and humane killing for consumption in another. The key is that the community and its tradition define what it understands to be the "excellences of character" that constitute the good life, the ethical life. It is incumbent on others not to endanger the so-defined way of life or act in ways that prevent people from virtuous actions (Crisp and Slote 1997).

An important aspect of this is that there may be certain elements of a community's tradition that seem at odds with what the majority believe, or even what is in the majority's best interests. Indeed, there may be occasions where the greatest good for the greatest number appears to require violation of a tradition or limitation on the practice of particular virtues. For example, the demands of an ethically justifiable war require drafting religious pacifists into military service. All this attests to is the fact that the virtue/tradition paradigm, like the autonomy/consent paradigm, can stand in decided opposition to what consequentialist ethics deems ethically acceptable or even obligatory. There may also be cases where preservation of a community's way of life seems to require violation of a person's autonomy. Literature and films are filled with examples of people torn between self-determination and the demands of their religious or cultural tradition.

The preceding discussion of ethical paradigms is far too brief to do justice to the complexity of these positions. I refer the interested reader to Blackburn (2001) for a more thorough discussion of the major differences among, and subtle nuances within, each of the paradigms or ethical orientations. The point is to recognize, in advance of any discussion of food and agricultural GMOs, that these are long-standing ethical perspectives that have informed ethical debate on matters from slavery to abortion. How they apply to the GMO and GM foods controversies remains an interesting and critical aspect of these disagreements.

Ethics and Agricultural Biotechnology

The ethical acceptability of agricultural GMOs, whatever paradigm the issue is approached from, in part depends on judgments about the ethical acceptability of major features of the food and agricultural system. For example, the judgment that pesticide-reducing GMOs are ethically acceptable depends on a more basic judgment about the unacceptability of pesticide use. In fact, debates about the ethics of certain agricultural practices predate current controversies about GMOs and GM foods. Each of the paradigms entails judgments about agriculture and the food system, and arguments or positions regarding biotechnology are based on those judgments.

The Consequentialist Perspective on Agricultural Biotech

Consequentialists subscribe to the view that actions, policies, practices, and technologies ought to promote people's happiness, defined as satisfied wants or preferences. The question is whether agriculture does this, and the answer is usually that it does. Historically, agricultural policy in the United States has been guided by a set of clearly consequentialist goals: (1) produce enough food to feed a growing and nonrural population (sufficient *quantity*), (2) produce food that is safe and nutritionally adequate (good *quality*), and (3) ensure that food is generally affordable for consumers while also ensuring that farmers receive profits from their work sufficient to keep them in business (adequate *price*). I refer to these goals collectively as the *QQP* formula, which in turn provides a consequentialist justification for actions or technologies needed to maintain QQP. Those actions and technologies help to guarantee as far as possible that the greatest good of the greatest number is achieved. People's wants and preferences for available, safe, and affordable food are satisfied.

Most observers agree that the key to achieving QQP is *efficiency* in agricultural production. This means getting the most output from the least inputs, or in standard farming terms, productivity and yields. Growers want to keep costs down while maintaining high quality and high quantity. Historically, most successful farm technology, from hybrid seed to chemicals to high-tech machines, has been adopted with productivity and yield in mind. It is not surprising, then, that farmers and policy makers concerned with efficiency, and ultimately with QQP, should want technologies continually improved so as to achieve even greater productivity and yield—all the time maintaining safe, affordable food. This is where agricultural biotechnology enters the picture.

The so-called "first generation"[1] of GM technology was designed to help farmers achieve greater degrees of efficiency. Roundup-Ready® crops were intended to reduce the need for costly herbicides while maintaining or improving yield. Bt crops were designed to reduce the need to spray pesticides, and rBST's purpose was to increase milk yields without increased feed costs. To the extent that each of these GM products and any others intended for increased efficiency achieve their desired results, they logically must receive a judgment of approval in terms of QQP. Generally speaking, a consequentialist appraisal of the ethical acceptability of these GM products results in a straightforward endorsement. If GMOs and GM foods contribute to the satisfaction of people's wants and preferences, they are ethically justifiable—perhaps even ethically required (Burkhardt 2001).

Currently, most ethical discourse about GMOs has been couched in consquentialist terms. At issue have been questions about whether current or foreseeable GM

---

[1] Please refer to end notes for all notes in this article.

products will satisfy the "greatest good for the greatest number" criterion. Though the answer is usually yes, occasionally there have been concerns that some things that people want other than QQP, for example, environmental protection, are not being provided by GMO and GM food technology, and in fact, GMOs may endanger these "other goods." The controversy over Bt corn and monarch butterflies is a case in point. People want butterflies protected at the same time they want inexpensively produced, available, safe food. Similarly, some consequentialists have raised issues about long-term consequences of GMOs: Will our children's health be placed at risk by the use of GM technology? What about future people's wants and preferences? Are they being placed at risk?

Despite these kinds of questions, by and large the consequentialist position has been that with enough foresight and a careful calculation of benefits and costs, we can find the ethically correct solution to any problem we may face. This implies vigilance in risk assessments and inclusion of food and environmental safety concerns in appraisals of acceptability. Once we commit to satisfying wants and preferences, however, we have to at least implicitly endorse those technologies that help us achieve that end. For the vast majority of consequentialists, GM technology, in agriculture as in medicine, in principle and nearly always in practice is ethically acceptable.

Autonomy/Consent and Food/Agricultural Biotech

The autonomy/consent paradigm begins with the axiom that self-determination implies that people have inviolable rights, which establishes the ethical demand that people be given a choice concerning how they want to act and be treated. Foremost among these rights is the right not to be harmed or placed at risk against one's will. Certainly, an individual can choose to accept some risks: people freely choose to drive cars, fly in airplanes, engage in sports such as football, invest in the stock market—all activities with some degree of risk associated with them. As long as a person's choice to engage in one of these activities is not coerced and does not harm others or place other people at risk, these are ethically acceptable acts. When a person drives drunk, plays sports recklessly, or puts all the family savings into a stock of questionable value, acceptability starts to evaporate: the individual is risking or harming others. This is ethically wrong.

Autonomy/consent ethicists may not concern themselves with the overall goals of the agricultural/food system, as do consequentialists, but proponents of free choice and the right not to be harmed occasionally agree with some consequentialists in posing this question: Is our food safe? The food system, they maintain, is far from transparent. Most consumers know nothing of farm production techniques, transportation and processing systems, even packaging and marketing activities. Yet most consumers want to know that when they purchase foods from the grocery store or at a restaurant, the food will not harm them. In fact, under this ethical orientation, people have a right to purchase items that will not place them unknowingly at risk. This puts the ethical burden on everyone in the chain from farm gate to food store to ensure that food is free from harmful contaminants and as safe as can reasonably be expected. And it is also part of the legal (and I would add ethical) mandate of certain agencies of the U.S. Department of Agriculture and the Environmental Protection Agency, the U.S. Food and Drug Administration, and state and local public health agencies. Autonomy/consent demands that people not be placed at risk against their wills; lack of transparency in the food system makes the obligation of government agencies to ensure safety a strong one.

For the autonomy/consent perspective, the issue of GM foods arises in part because of the lack of transparency of the food system to consumers, but also because at least in the United States, the regulatory agencies made a decision that, in effect, exempted most GM foodstuffs from any special testing regarding safety. USDA, EPA, and FDA agreed that the process of modifying soybeans, for example, was irrelevant to the safety of the soybeans themselves. That is, if a soybean is submitted for approval by EPA or FDA, it does not matter if it was modified through conventional plant-breeding techniques or with the use of rDNA technology (FDA 2000). Some consumer activist groups saw this as an attempt to smuggle GM crops into the food supply, even though, they argued, there had not been any long-term studies concerning the safety (particularly regarding allergenicity) of GM-derived crops. Even if GM foods are safe under current government guidelines, over the long term, consumers may be being placed at risk against their wills.

An even more fundamental point of the autonomy/consent proponents is this: whatever reasons a person might have to want to avoid GMOs and GM foods, he or she has the right to be able to avoid them. Some people may have reservations about government and industry claims regarding the safety of GM foods. Some may object to the specific kinds of commodities that are being genetically engineered, for example, corn and rice, staples in poor nations. And some may have deeper religious objections to GMOs and GM foods—concerns about scientists "playing God." Whatever the reason, autonomy/consent ethics demands that people have the choice to avoid these products. Hence, autonomy/consent proponents have been the strongest supporters of some form of labeling of GM foods. Mandatory labeling is now the rule in other parts of the world, notably, the European Union (EU), and various pieces of legislation have been put forth in the U.S. Congress and in state legislatures requiring some form of labeling. How this will play out in the United States remains to be seen. The point is that labeling receives its strongest philosophical and ethical justification in terms of the ethics of autonomy/consent.

One further dimension of the autonomy/consent perspective on GMOs deserves attention. This has to do with farmers' choices. Even before the enactment of the EU labeling legislation, there were concerns among some farm groups that non-GM crop seed would become less and less available. Because farmers make their planting decisions on the basis of expected markets (among other things), and with the possibility that markets for GM grains would shrink significantly (boycotts in the EU), some farmers desired to plant non-GM varieties. The way the seed industry is structured, however—with a very small number of large corporations, all heavily invested in GM crop technology, controlling a large portion of the seed market—questions have been raised as to whether corporations will continue to supply non-GM seed.

For affected farmers, this is also a matter of autonomy/consent. Some small-farm activists maintain that the actions of the commercial seed industry giants deliberately harm smaller operations, especially those in developing nations (Rural Advancement Foundation International 1999). Whether or not that is true, it has primarily been larger commercial farm operations in the United States (and commodity associations such as the American Corn Growers Association [ACGA]) who have voiced concern about choices and alternatives. Despite costs and other practical constraints, government agencies and seed industry giants are exploring ways to "segregate" and "identity preserve" GM and non-GM seed as a way of accommodating farmers' needs and the demands of the global market.

Many people who take a consequentialist view on these matters believe that the autonomy/consent issues that are raised are not so much a matter of biotechnology as a matter of power and control: consumers and farmers want greater control over the choices available to them in their respective arenas. Consequentialists liken the GMO controversy to the issue of organic foods: organics tended to be produced for local markets by smaller-sized producers, so that a choice for organic was really a rejection of large-scale corporate agriculture and the multinational seed/chemical inputs corporations. Though there may be some truth in these claims, they do not undermine the essential claims of the autonomy/consent approach to the ethical acceptability of GMOs, GM foods, and GM crop seed. People have the ethical right to choose what they consume and purchase, which implies that they be allowed both to *know* what they are consuming and to avoid or reject it if they so desire.

Ethics of Virtue/Tradition and Food/Agricultural Biotech

Several versions of virtue/tradition ethics have been offered in connection with the appraisal of agriculture generally and food/agricultural biotechnology in particular. These include the positions taken by Roman Catholics and some fundamentalist Protestant denominations in the United States (see Warner 2000), and rural and farm groups in other nations, again notably the EU. Though each position has its unique features, these usually negative appraisals of GMOs and GM foods tend to reflect more general traditions within virtue/tradition ethics, *agrarian* ethical philosophy, and, for lack of a better term, what I call *naturism*. These are somewhat different approaches to assessing ethical acceptability in general, so they will be discussed separately.

Agrarianism is the philosophy that views agriculture as more than a business or economic sector in society: agriculture is a "way of life." What this means is that agriculture has a unique and ethically special set of contexts, practices, and virtues that are inherent in its nature. The practice of bringing forth sustenance from the soil in the face of nature's unpredictability requires that the farmer be patient, strong, and self-reliant and respectful of natural processes. It also requires that the farmer work in harmony with others in the community, since only through mutual respect and reciprocity can many of the tasks of farming, or living in a rural community, be accomplished. Agrarianism sees the traditional family farm as a place where real human values and virtues can be practiced, instilled in the next generation, and hence preserved. Participation in and psychological and ethical "ownership" of an *agricultural* community is among the most important virtues or values people can embrace (Berry 1977).

Whatever challenges or threatens traditional farm virtues and rural communities is regarded as ethically suspect if not plain unacceptable. For this reason, agrarians have long been critics of government policies, business decisions, and technology-development agendas that have tended to undermine farming as a way of life. For example, agrarians claim that U.S. government policies have tended to favor larger, corporate, heavily "industrialized" farms that are (assumed to be) better able to deliver QQP to a predominantly urban/suburban population. Nonfarm interests (e.g., multinational petrochemical corporations) have increasingly purchased large blocks of farmland and have destroyed many rural communities as farming transformed from a family-based, labor-intensive, community-oriented enterprise to a mechanical/chemical production system. Researchers in both industry and in agricultural colleges and universities have limited their attention to efficiency and productivity in the development of technologies for agriculture. With the exception of farm protest groups and some academics, respect for traditional family farms and rural communities is rarely found outside those rural communities that have managed to hang on despite the accelerating trends toward large agri*business*.

Given the basic ethical position of agrarians toward modern agriculture, it should come as no surprise that most agrarians find GM technology to be ethically unacceptable. As noted earlier, food/agricultural GMOs are usually designed and intended for businesslike efficient production. They are not designed to enhance the quality of life for farm families or their communities. In this regard, agrarians echo many of the concerns voiced by proponents of autonomy/consent ethics: farmers are systematically being robbed of the ability to choose. In this case, however, it is not only that they may not be able to resist the technology—they may not be able to preserve their values and ways of life (Burkhardt 2000).

By far the strongest expression of the agrarian rejection of modern agriculture and GM technology has come from smaller-sized, traditional farm communities in Europe and from peasant farm activists in developing nations in Africa, Latin America, East Asia, and India. In Europe, the concern is that GM technology will favor larger farms, make traditional agriculture less competitive, and drive small farms out of business. Alternatively, GM technology may make foodstuffs cheaper, allowing foreign- (read: U.S.-) produced foods to replace domestic products, again, forcing traditional farmers out of business. In either case, a valued way of life is threatened.

In the developing world, the agrarian critique of GMOs reflects a view that even if traditional family-style agriculture is not threatened initially, decreased availability of non-GM crop seed (again as a result of the concentration of ownership in the seed industry) may mean peasant farmers would be forced to use GM seed. This may be costly, and it may force farmers to get big or get out. More importantly, it threatens traditional ways of life, including the use of indigenous crops and growing practices.

In the United States and Canada, where most people are so far removed (physically and psychologically) from agriculture, the agrarian position and critique of the ethical acceptability of GMOs and GM foods has not received much attention. In the late 1980s and early 1990s the agrarian critique of bovine growth hormone (rBST) did surface in Wisconsin, Minnesota, Missouri, and a few dairy farm–rich areas in New England. After that controversy faded from public awareness, agrarianism itself faded from public view.

The second version of a virtue/tradition ethics to be considered here is what I call naturism. This view has also been endorsed in part by members of religious denominations in their exhortations that scientists engaged in GM research and development should not be "playing God." In its more general and secular interpretation, this view simply argues that we should not be engaging in *transgenic* technology—crossing species boundaries. *Nature,* understood as an integrated system of beings and processes, should not be treated this way: GM technology is ethically unacceptable.

Appealing to nature in this way can occasionally seem fuzzy-headed or mystical, but there is actually a rational basis for this perspective. The term nature is a placeholder for a complex set of relationships among species of plants and animals, what we call an ecosystem. Though ecosystemic interactions are not all beneficial to every participant in the system—some things die, some things prey on others, some things mutate into others—the process of evolution produces, at any given point in time, an equilibrium. This is not to say that the system becomes static, rather, that each species functions in such a way that makes the system work as it does. In effect, each species contributes to the ecosystem's operations.

The problem with GM technology is that by transferring genetic material across species boundaries, one transfers physical traits from the donor to the recipient. These are not always (nor are they usually intended to be) traits that would appear in the recipient species through natural evolutionary processes or even through deliberate intraspecies crossbreeding. According to naturism, trans-species transfers of genetic material can upset the operation of ecosystems. At the very least, we do not know enough about, nor can we control enough of, complex ecosystems to be sure that the GMO will not cause irreparable damage. Perhaps even life as we know it—including human life—may be threatened.

For naturists, once we recognize the delicate balancing processes that constitute ecosystems or nature, we must see that human beings have no right to manipulate species or processes in this way. At root, people have an ethical responsibility to try to avoid disruption of deep ecological processes. Obviously, nearly everything people do "interferes with nature," and much of this is necessary for people to live their lives. However, the position taken by naturists is that GM technology is an arbitrary and capricious attempt to manipulate life at the deepest level.

The specific virtues and tradition implied by the naturist perspective are not as well defined as within agrarianism and some other virtue/tradition ethical orientations. Considerable philosophical work is under way to try to articulate what naturism practically implies (Callicott 1999). One thing naturists agree on is that genetic engineering is ethically unacceptable.

In sum, then, virtue/tradition ethics defines ethical acceptability in terms of consistency with some deeply held values and virtues, whether they relate to farming as a way of life, to life in accord with nature, or to following God's plan and will. Not all virtue/tradition ethical perspectives will necessarily reject GMOs or biotechnology overall. However, both in the United States and around the world, variations on this ethical paradigm have generally rejected GMOs and GM food. The depth of convictions among adherents to virtue/tradition ethics, as well as the force of reasoned arguments stemming from these convictions, have contributed to the seriousness and intensity of public debates and have occasionally fueled violent political action against GMOs and GM foods.

Concluding Remarks

It has not been the intention here to argue in favor of any of the ethical paradigms or approaches to evaluating the ethical acceptability of GMOs and GM foods. Rather, the point has been to illustrate the importance of each of these three ethical paradigms in the GMO debates. In many respects, both autonomy/consent and virtue/tradition ethics have been marginal to public debate, though perhaps autonomy/consent less so than virtue/tradition ethics. While somewhat marginal, these orientations should not be marginal*ized.*

Indeed, public debate about GMOs and GM foods over the past decade-plus has been dominated by considerations of risk, costs, and benefits of these products of the new biotechnology. Because these products and technologies are logically and institutionally linked to an important social and economic force in the global community—agriculture—it is hardly surprising and initially justifiable that the economic dimensions be primary. Potential implications for the environment and for people's health demanded that environmental and food safety be factored into the assessment of ethical acceptability. Still, these concerns were defined in terms of economic costs and benefits.

In the 1990s, however, consumer activist groups began to push an agenda of autonomy/consent regarding GM foods. In some cases this opened the debate to a different set of ethical concerns, indeed, a different way to think about the ethics of GMOs. So-called "civil society organizations" (CSOs) such as the Rural Advancement Foundation International and Farm Aid began to push agendas stressing protections for small farms and the rural way of life. Environmentalist groups encouraged considerations of intrinsic value in natural systems and places. Each perspective introduced ethical considerations that had been absent from the public arena.

Whatever one may believe about the soundness of the arguments presented by political actors opposed to GMOs, these critics have provided a valuable service to all of us concerned about agriculture and food as well as technology. The three ethical paradigms presented here predate and are independent of any critics' (or proponents') use of them in public discourse and debate. Professional philosophers and ethicists wrote about issues in agriculture and agricultural biotechnology years before these issues became matters of widespread public controversy.[2] Nevertheless, the fact is that autonomy/consent and virtue/tradition ethics were forced into the public consciousness by activist critics. Activists have refused to limit ethical discussion to consequentialist issues—costs, benefits, risks. In so doing, they have forced policy makers and concerned citizens to recognize that we differ in what we believe is right or wrong about GMOs, but more importantly, why we differ.

As is true regarding many public issues with ethical dimensions or with deep, conflicting underlying ethical judgments, the solution to the GMO controversies may ultimately come down to political-economic decisions. Lawmakers may decide in favor of labeling as a way of appeasing constituents. Policy makers in USDA, EPA, or FDA may decide that any additional or different kinds of tests for GMOs would be too costly and establish inefficient barriers to marketing these products. The president of the United States may direct the secretary of the Department of Agriculture to press ahead with a "more biotech is better" research agenda to try to capture the world market for GMOs, GM foods, and GM crops. Regardless of the reasons that laws and policies ultimately are made, ethics still matters. Recognizing—and respecting—the rationality of opposing basic ethical beliefs and a different ethical paradigm is an important step in understanding the debates. Those who disagree with us are not always uninformed or irrational; sometimes they just subscribe to a different ethical paradigm.

Jeffrey Burkhardt, Ph.D., is Professor of Agriculture and Natural Resource Ethics and Professor of Food and Resource Economics in the Institute of Food and Agricultural Sciences (IFAS) of the University of Florida, Gainesville. He is author of two books and numerous professional articles on ethics of food and agricultural biotechnology and has lectured widely in the United States and Europe on this topic.

He teaches courses on agriculture and natural resource ethics and coordinates the University of Florida/IFAS teaching, research, and extension program in this area.

Notes

1. Observers have characterized the products of GM technology in terms of the general kinds of goals or properties associated with them. The so-called "first generation" has been targeted at agronomic goals—productivity and yield, reduced chemical inputs, and the like. The "second generation" is supposed to provide benefits more directly to consumers, such as better flavor, longer shelf life, improved nutrition content, and so forth. The "third generation," still a long way from reality, would include novel uses of agricultural products, for example, building materials from plant fibers (not wood) and oils, alternative energy sources, and single foods (e.g., corn) with all the vitamins, minerals, and proteins necessary for a wholly nutritious diet.

2. Berry (1977) alluded to the development of agricultural biotechnology and offered an agrarian critique as early as 1977, although the agricultural biotechnology research and development effort was still in a prenatal stage at the time. It was not until after the 1980 *Diamond v. Chakrabarty* U.S. Supreme Court decision, allowing patents on "novel life forms" produced through rDNA techniques, that the agricultural biotechnology industry began in earnest. Among the earliest ethical treatments of food and agricultural biotechnology are Thompson (1984), Doyle (1985), and Burkhardt (1986). There is now a considerable ethical/philosophical literature on GMOs and GM foods; I refer the reader to the extensive bibliography in Thompson (1998).

References

Berry, W. 1977. *The Unsettling of America.* San Francisco: Sierra Club.

Blackburn, S. 2001. *Being Good: An Introduction to Ethics.* Oxford, UK: Oxford University Press.

Burkhardt, J. 1986. "Biotechnology, Ethics, and the Structure of Agriculture." *Agriculture and Human Values* 4:2.

Burkhardt, J. 2000. "Agricultural Biotechnology, Ethics, Family Farms, and Industrialization." In *Encyclopedia of Ethical, Legal, and Policy Issues in Biotechnology,* edited by T. Murray and M. Mehlman. New York: Wiley.

Burkhardt, J. 2001. "Agricultural Biotechnology and the Future Benefits Argument." *Journal of Agricultural and Environmental Ethics* 14:2.

Callicott, J. B. 1999. *Beyond the Land Ethics: Essays in Environmental Philosophy.* Albany: State University of New York Press.

Comstock, G. 1989. "The Case Against BGH." *Agriculture and Human Values* 5:1.

Crisp, R., and M. Slote, eds. 1997. *Virtue Ethics.* Oxford, UK: Oxford University Press.

Doyle, J. 1985. *Altered Harvest: Agriculture, Genetics and the Future of the World's Food Supply.* New York: Viking.

Environmental News Service. 1999. "bT Corn Deadly to Buterflies" (May). http://www.lycos.ens.com/

Food and Drug Administration. 2000. *Use of Standards in Substantial Equivalence Determination.* Washington, D.C.: U.S. Government Printing Office.

Lappé, M., and B. Bailey. 1998. *Against the Grain.* Monroe, Maine: Common Courage Press.

Rippe, K. P. 2000. "Novel Foods and Consumer Rights: Concerning Food Policy in a Liberal State." *Journal of Agricultural and Environmental Ethics* 14:1.

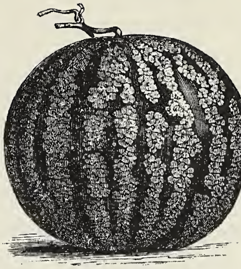
Rural Advancement Foundation International. 1999. "Traitor Technology: How Suicide Seeds Work/Where They Are Being Patented." *RAFI Communique* (January 30). http://www.rafi.org

Slote, M. 1985. *Common-Sense Morality and Consequentialism.* Boston: Routledge.

Thompson, P. B. 1984. "Agricultural Biotechnology and the Rhetoric of Risk." *Environmental Professional* 9:3.

Thompson, P. B. 1998. *Food Biotechnology in Ethical Perspective.* London: Blackie Academic.

Warner, K. D. 2000. *Questioning the Promise: Critical Reflections on Agricultural Biotechnology from the Perspective of Catholic Teaching* (March). Des Moines, Iowa: National Catholic Rural Life Commission.



Biotechnology and Agriculture: A Skeptical Perspective

Vernon W. Ruttan

Reprinted with permission from *AgBioForum,* Vol. 2, No. 1, Winter 1999.

A combination of population and income growth will almost double the demand for food and other agricultural commodities over the next half century. Advances in crop productivity during the twentieth century have largely been based on the application of Mendelian genetics. If farmers are to respond effectively to the demands that will be placed on them over the next half century, research in molecular biology and biotechnology will have to be directed to removing the physiological constraints that are the source of present crop yield ceilings.

Since the beginning of the industrial revolution, a series of strategic or general-purpose technologies have served as the primary vehicles for technical change across broad industrial sectors. In the nineteenth century the steam engine was the dominant general-purpose technology. In the early twentieth century the electric generator and the internal combustion engine became pervasive sources of technical change. By the third quarter of the twentieth century, the computer and the semiconductor had assumed that role across both the manufacturing and service industries. It is not an exaggeration to suggest that biotechnology is poised to become the most important new general-purpose technology of the first half of the twenty-first century.

A consistent feature of these general-purpose technologies has been a long period between their initial emergence and their measurable impact (David 1990). The steam engine underwent a century of modification and improvement before its widespread adoption in industry and transport. It was half a century from the time electric power was first introduced until it became a measurable source of growth in industrial productivity. Controversy about the impact of computers on productivity continued into the 1990s. It is not yet possible to demonstrate measurable impact of biotechnology on either human health or agriculture in terms of broad indicators for health (such as infant mortality or life expectancy) or agriculture (such as output per hectare or per worker).

The argument I make in this paper is that the advances in crop productivity experienced during the twentieth century were made possible primarily by the application of the principles of Mendelian genetics to crop improvement. Biotechnology is poised to become an important source of productivity growth in agriculture during the first half of the twenty-first century. But the advances in the new biotechnology achieved thus far have not yet raised yield ceilings beyond the levels achieved using the older methods. Nor do they promise to do so in the near future.

The Mendelian Revolution

Before the beginning of the twentieth century almost all increases in crop production were achieved by expanding the area cultivated. Selection by farmers led to the development of landraces suited to particular agroclimatic environments. But grain yields, even in favorable environments, rarely averaged above 2.0 metric tons per hectare (30 bushels per acre). Efforts to improve yields through farmers' seed selection and improved cultivation practices had relatively modest impact on yield prior to the application of the principles of Mendelian genetics to crop improvement. In the United States, for example, maize yields remained essentially unchanged, at below 30 bushels per acre, until the 1930s. Not until the introduction of hybrids was the corn yield ceiling broken (Duvick 1996; Mosher 1962).

Similar yield increases have occurred in other crops. These increases occurred first in the United States, Western Europe, and Japan. Since the early 1970s, dramatic yield increases, heralded as the Green Revolution, have occurred in many developing countries, primarily in Asia and Latin America. By the 1990s, several countries in Africa were beginning to experience substantial gains in maize and rice yields (Eicher 1995).

Yield Constraints

By the early 1990s, however, concern was growing that yields of a number of important cereal crops, such as maize and rice, might again be approaching yield ceilings. In the Philippines, rice yields in maximum yield trials at the International Rice Research Institute had not risen since the early 1980s (Pingali, Moya, and Velasco 1990). In the United States, maize yields that had been rising at an arithmetically linear rate of approximately 2.0 bushels per year appeared to be following a logarithmic path. Two bushels per year is a much lower percentage rate of increase when maize yield stands at 130 bushels per acre than when it was 30 bushels per acre.

The issue of whether crop yields are approaching a yield plateau has become increasingly controversial. In an exceedingly careful review and assessment of yield trends for eleven crops in the United States, Reilly and Fuglie found that an arithmetically linear trend model provided the best fit for five crops while an exponential model provided the best fit for another five—"but none of the differences between the two models are statistically significant" (Reilly and Fuglie 1998, 280).

Efforts have been made to partition the sources of yield increases among genetic improvements, technical inputs (fertilizer, pesticides, irrigation), and management. I find many of these approaches conceptually flawed.[1] Genetic improvements have been specifically directed to enabling yield response to technical inputs and management. For example, changes in plant architecture such as short stature and more erect leaves have been designed to increase plant populations per unit area and to enhance fertilizer response. The combined effect has been to substantially raise yield per acre or per hectare.

It is hard to escape a conclusion, drawing on the basic crop science literature,

---

[1]In the mid-1990s, Donald N. Duvick of Pioneer Hybrid International conducted a series of very careful experiments to determine the relative contribution of increases in maize yields due to breeding. His results suggest that plant breeding contributed about 60 percent of the yield increases between 1935 and 1975. Duvick has also suggested in correspondence (February 13, 1999) that by the mid-1990s in the United States and other developed countries, the relative contribution of plant breeding is probably higher than in the period he studied because there are fewer increments to yield being realized from more effective weed control or higher levels of nitrogen fertilizer application. Duvick also reminded me that advances in crop yield from plant breeding has been due at least as much to the tacit knowledge of experienced breeders as from the application of the principles of Mendelian genetics.

that advances in the yields of the major food and feed grains are approaching physiological limits that are not very far above the yields obtained by the better farmers in favorable areas, or at experiment station maximum yield trials (Cassman 1998; Sinclair 1998). If present yield ceilings are to be broken, it seems apparent that improvements in photosynthetic efficiency, particularly the capture of solar radiation and reduction of water loss through transpiration, will be required. Even researchers working at the frontiers of plant physiology are not optimistic about the rate of progress that will be realized in enhancing crop metabolism (Cassman 1998; Mann 1999; Sinclair 1998).

The Biotechnology Revolution

The impact of advances in biotechnology on crop yields has come much more slowly than the authors of press releases announcing the biotechnology breakthrough of the week anticipated in the early 1980s (Ruttan 2001). The development of in vitro tissue and cell culture techniques, which were occurring in parallel with monoclonal antibody and rDNA techniques, would make possible the regeneration of whole plants from a single cell or a small piece of tissue. It was anticipated that the next series of advances would be in plant protection through introduction or manipulation of genes that confer resistance to pests and pathogens. Many leading participants in the development of the new biotechnologies expected that these advances would lead to measurable increases in crop yields by the early 1990s (Sundquist, Menz, and Neumeyer 1982).

Though the early projections were overly enthusiastic, significant applications were beginning to occur by the mid-1990s. The first commercially successful virus-resistant crop, a virus-resistant tobacco, was introduced in China in the early 1990s. The Calgene Flavr Savr™ tomato, the first genetically altered whole food product to be commercially marketed, was introduced (unsuccessfully) in 1994. Important progress was made in transgenic approaches to the development of herbicide resistance, insect resistance, and pest and pathogen resistance in a number of crops. DNA marker technology was being employed to locate important chromosomal regions affecting a given trait in order to track and manipulate desirable gene linkages with greater speed and precision. By the 1998 crop year, almost 110 million acres (44 million hectares) had been planted worldwide to transgenic crops, primarily herbicide or virus-resistant soybeans, maize, tobacco, and cotton (table 1).

Table 1. Global Area of Transgenic Crops in 1999 and 2000 by Crop and by Trait

	1999		2000		1999–2000	
	Hectares planted (in millions)	Area planted (%)	Hectares planted (in millions)	Area planted (%)	Hectares increase (in millions)	Percent increase (1999/2000)
Crop						
Soybean	21.6	54	25.8	58	+4.2	19
Corn	11.1	28	10.3	23	-0.8	-7
Cotton	3.7	9	5.3	12	+1.6	43
Canola	3.4	9	2.8	7	-0.6	-18
Potato	<0.1	<1	<0.1	<1	<0.1	N/A
Total	39.9	100	44.2	100	4.3	+11
Trait						
Herbicide tolerance	28.1	71	32.7	74	+4.6	+16
Insect resistance	8.9	22	8.3	19	-0.6	-2
Bt/Herbicide tolerance	2.9	7	3.2	7	+0.3	+10
Other traits	<0.1	<1	<0.1	<1	<0.1	N/A
Total	39.9	100	44.2	100	+4.3	11

Source: Review: *Global Review of Commercialized Transgenetic Crops* (ISAAA Briefs No. 21-2000) by Clive James, 2000.

The important point that needs to be made, however, is that the biotechnology products presently on the market are almost entirely designed to enable producers to achieve yields that are closer to present yield ceilings rather than to lift yield ceilings.[2] When I

[2]Control of insect pests of cotton, primarily tobacco budworm, cotton bollworm, and pink bollworm, represents one of the most dramatic, and clearly positive, results of the introduction of a transgenic crop. The introduction of the *Bacillus* microorganism into cotton has resulted in a dramatic reduction in the use of insecticides while substantially enhancing cotton yields (Flack-Zepeda, Traxler, and Nelson 2000). The effect was, however, not to enhance the genetic potential of the cotton plant but rather to enable the plant to come closer to realizing its genetic potential in the field.

asked the research director of a major commercial seed company when he might expect to see a line in table 1 for higher biological potential, his response was, "I don't know. There is a lot of hype out there." One reason for the cautious response is that attention is shifting away from yield to a second-generation emphasis on quality traits.

More Generations

Even as we move into the initial years of the first generation of agricultural biotechnologies, second- and third-generation technologies are being enthusiastically heralded (Kishore and Shewmaker 1998). The objective of the second generation, now being explored at the laboratory level, is to create value downstream from production. A high-oil maize, recently introduced by DuPont, though not strictly a biotechnology product, is often referred to as an example. Efforts are being directed to develop cereals fortified with the critical essential amino acids such as lysine, methionine, threonine, and tryptophan for use in animal feed rations and in consumer products. It is also anticipated that oilseeds will be modified to enhance protein quality and their content of fat that is free of trans fatty acids (Kalaitzandonakes 1998).

A third generation of biotechnologies, directed to the development of plants as nutrient factories to supply food, feed, and fiber, is also anticipated. High-carotene fruits, vegetables, and oils designed to reduce vitamin A deficiency is one example. In the longer run it is anticipated that biotechnology will revolutionize crop production and utilization technology. Processed feed and food will be grown in fermentation vats using biotechnology-engineered microorganisms and generic biomass feedstocks (J. Reilly, personal communication, January 25, 1999; Rogoff and Rawlins 1987).

In a fit of what can only be characterized as irrational exuberance, some biotechnology publicists have proclaimed that the benefits of new value-added grain production systems will be shared equitably among producers, the biotechnology and food industries, and consumers. In addition, these systems will eliminate the historic cycles of price and profit instability associated with traditional commodity market instability (Freiberg 1998). It is not too difficult to hear echoes of the hype of the early 1980s when the first-generation biotechnologies were still in the laboratory.

Some Concerns

I am concerned that more intensive research efforts are not being devoted to attempts to break the physiological constraints that will limit future increases in crop yields. These constraints will impinge most severely on yield gains in those areas that have already achieved the highest yields. It is possible that advances in fundamental knowledge in areas such as functional genomics, for example, might provide a scientific foundation for a new round of rapid yield increases. This would, in turn, enhance the profitability of private-sector allocation of research resources to yield improvement. But it would appear exceedingly rash to predict that these advances will leave any measurable impact on production within the next several decades (Duvick 1996).

I am concerned that many developing countries have not yet acquired the research and development capacity necessary to enable their farmers to realize the potential yield gains from crop-improvement efforts. In most developing countries, yields are still so far below existing biological ceilings that substantial gains can be realized from a strategy emphasizing traditional crop breeding combined with higher levels of technical inputs, better soil and crop management, and first-generation biotechnology crop-protection technology. Because the fastest rates of growth in demand, arising out of population and income growth, will occur in the poorest countries, it is doubly important that these countries acquire the capacity to sustain substantial agricultural research efforts.

I am also concerned about the economic and scientific viability of public-sector agriculturally oriented research in developed countries. Since 1980, the resources available to the federal government (USDA) agricultural research system have remained essentially unchanged in real terms. Public support for the state agricultural experiment stations (from federal and state sources) has barely kept up with inflation.[3] The eco-

[3]The Department of Plant and Microbial Biology at the University of California–Berkeley has recently entered into an arrangement to sell its "research product" to Novartis (Wein 1999). A number of similar relationships had been developed between private universities (Harvard, Massachusetts Institute of Technology, and Washington University) and large pharmaceutical companies in the early 1980s. The Berkeley arrangement is controversial, primarily because it is the first time a major public university has entered into such a close arrangement.

nomic viability of private-sector research requires that it be directed to the development of proprietary products. It is important for the scientific and technical viability of private-sector agricultural research that the capacity of public-sector institutions to conduct basic and generic research be not only maintained but enhanced as well.

Vernon W. Ruttan is a Regents' Professor Emeritus in the Departments of Economics and Applied Economics and an Adjunct Professor in the Hubert H. Humphrey Institute of Public Affairs at the University of Minnesota. He has served as a staff member of the President's Council of Economic Advisors (1961-63) and as President of the Agricultural Development Council (1973-78). Ruttan's research has been in the field of agricultural development, resource economics, and research policy. He is the author of numerous books and is currently writing Social Science Knowledge and Economic Development, *to be published by the University of Michigan Press, 2002. Ruttan has been elected a fellow of the American Agricultural Economics Association (1974); American Academy of Arts and Sciences (1976); the American Association for the Advancement of Science (1986); and to membership in the National Academy of Sciences (1990).*

References

Cassman, K. 1998. "Ecological Intensification of Cereal Production Systems: The Challenge of Increasing Crop Yield Potential and Precision Agriculture." In *Plants and People: Is There Time?* Proceedings of a National Academy of Sciences Colloquium, Irvine, California, December 5–6, 1998. (Retrieved January 31, 1999, from the World Wide Web, http://www.lsc.psu.edu/nas/colloquium.html)

David, P. A. 1990. "Computer and Dynamo: A Historical Perspective on the Modern Productivity Paradox." *American Economic Review* 80:355–61.

Duvick, D. N. 1996. "Plant Breeding, an Evolutionary Concept." *Crop Science* 36:359–548.

Eicher, C. K. 1995. "Zimbabwe's Maize-Based Green Revolution: Preconditions for Replication." *World Development* 23:805–18.

Flack-Zepeda, J. B., G. Traxler, and R. G. Nelson. 2000. "Supplies Distribution from the Introduction of a Biotechnology Innovation." *American Journal of Agricultural Economics* 82:360–69.

Freiberg, B. 1998. “Will Biotechnology Bring Prosperity to Rural America?” *AgBio Forum* 1(2):76–77. (Retrieved January 1, 1999, from World Wide Web, http://www.agbioforum.missouri.edu)

Kalaitzandonakes, N. 1998. “Biotechnology and Identity-Preserved Supply Chains: A Look at the Future of Crop Production and Marketing.” *Choices* (Fourth Quarter), 15–18.

Kishore, G. M., and Shewmaker, C. 1998. “Biotechnology: Enhancing Human Nutrition in Developing and Developed Worlds.” *In Plants and Population: Is There Time?* Proceedings of a National Academy of Sciences Colloquium, Irvine, Calif., December 5–6, 1998. (Retrieved January 31, 1999, from the World Wide Web: http://www.lsc.psu/nas/colloquium.html)

Mann, C. G. 1999. “Genetic Engineers Aim to Soup Up Crop Photosynthesis.” *Science* 283:314–16.

Mosher, M. L. 1962. *Early Iowa Corn Yield Tests and Related Later Programs.* Ames: Iowa State University Press.

Pingali, P. L., P. F. Moya, and L. E. Velasco. 1990. “The Post–Green Revolution Blues in Asian Rice Production: The Diminished Gap Between Experiment Station and Farmer Yields.” Social Science Paper 90-01. Manila, Philippines: International Rice Research Institute.

Reilly, J. M., and K. O. Fuglie. 1998. “Future Yield Growth in Field Crops: What Evidence Exists.” *Soil and Tillage Research* 47:275–90.

Rogoff, M., and S. L. Rawlins. 1987. “Food Security: A Technological Alternative.” *BioScience* 37:800–807.

Ruttan, V. W. 2001. *Technology, Growth and Development: An Induced Innovation Perspective*. New York: Oxford University Press.

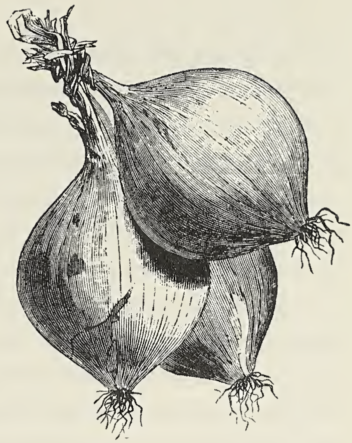
Sinclair, T. R. 1998. “Limits on Land, Water, Energy and Biological Resources: Comment.” In *Plants and Population: Is There Time?* Proceedings of a National Academy of Science Colloquium, Irvine, Calif., December 5–6, 1998. (Retrieved January 31, 1999, from the World Wide Web, http://www.lsc.psu/nas/colloquium.html)

Sundquist, W. B., K. M. Menz, and C. F. Neumeyer. 1982. *A Technology Assessment of Commercial Corn Production in the United States*. Bulletin 546. St Paul: University of Minnesota Agricultural Experiment Station.

Wein, Harrison. 1999. "UC Berkeley and Novartis: An Unprecedented Agreement." Washington, D.C.: Federation of American Scientists, *Global Issues In Agricultural Research* 1 (January 1999).

Biodiversity and Bioprospecting: Conflicting Worldviews

Lori P. Knowles



Much of the debate over the ethical use of agricultural biotechnology focuses on domestic perception and regulation of genetically modified foods. Commentators often neglect the importance of situating this technology within the international political and legal context. The value of agricultural biotechnology to the United States is dependent on the acceptance of its products by overseas markets. Genetically modified (GM) food and crop exports are, therefore, affected by trade negotiations regarding the importation of these goods. In addition, approximately 90 percent of the world's biological resources are found in developing countries. From these biological resources, medicines, pesticides, and other profitable products may be extracted. Exploring agreements affecting international trade will show that conflicting worldviews are embodied in international instruments with respect to the use and protection of the world's biological resources. The primacy of economic value and intellectual property right protections over social, cultural, and ethical values in international agreements has profound implications for both bioprospecting and biodiversity.

Challenging the International Commonwealth

At this time in history we are seeing a shift in global political and legal ideology. Until recently, the international legal system has been based on a commonwealth model.[1] This model has strengths and weaknesses. The commonwealth model is predicated on multiparty diplomacy, global representation, and respect for national sovereignty. In theory, the entire human community is represented by their governments and by non-governmental organizations in organs such as the United Nations. Work generated by parties to the international legal system is largely embodied in agreements, treaties, covenants, and conventions.

Despite the politics of power that exist in any international legal system, many believe that a cooperative model of dispute resolution will best respect and serve the interests of each party as well as the interests of the international community. This method of problem solving has developed tremendously positive and authoritative agreements, not the least of which are the agreements forming the International Bill of Human Rights.[2] The strengths of the commonwealth model are accompanied by some weaknesses; a system based on multiparty diplomacy is complex, somewhat cumbersome, and resistant to change. It also requires a commitment of time and respect for cultural differences by all parties. These characteristics have proven to be impediments in the search for effective responses to international emergencies.

The traditional multiparty diplomacy model of international law is being challenged. Its importance is being rapidly superseded by the emergence of a new international political order resulting from the rise of global capitalism. The World Trade Organization (WTO) best exemplifies the values and workings of this new order. International decision making on a wide range of activities is now to a large extent circumscribed by WTO dispute mechanisms. Accordingly, the economic might of dominant parties in the WTO, such as the United States, plays a tremendous role in the outcomes of various disputes.

Issues adjudicated before the WTO often have more than simple "trade" implications. The WTO's decision-making power is far-reaching; it does not, however, adequately recognize legitimate concerns of a nontrade orientation that are intimately con-

---

[1] Please refer to end notes for all notes in this article.

nected to the trade aspects under consideration. There is disagreement about which criteria are relevant and what values are at stake in trade disputes. Americans argue that only economic concerns are relevant in trade negotiations, with very limited exceptions. For example, with respect to agricultural trade, Americans consider European concerns about animal welfare to be an illegitimate concern in trade negotiations. Several American commentators have even accused the Europeans of raising such concerns as a way to introduce nontrade tariff barriers into international negotiations.[3]

With respect to GM food and bioprospecting (mining biological resources for profitable properties), concerns about corporate ownership of the world's future food supply, benefit sharing, and irreversible environmental degradation cannot be adequately addressed through WTO negotiations.[4] The WTO represents the emergence of an openly competitive and adversarial model of international dispute resolution. It is competitive rather than cooperative and promotes the primacy of economic value in making decisions to order world affairs. Understanding this background helps illuminate the motivations behind recent antiglobalization demonstrations in Seattle and Sweden and the popular backlash against American multinational corporations involved in agricultural biotechnology. Alongside concerns about risks to human health, the environment, and global justice, there appears to be deep concern about the imposition of "capitalist values" on an agrarian tradition that incorporates other frames of valuation: spiritual, cultural, social, *and* economic. The impact of this on the conservation of biological diversity is apparent when one looks at the conflict of worldviews between the commonwealth approach and the trade approach to conservation and use of the world's biological resources.[5]

Intellectual Property Rights

One of the building blocks of global capitalism is the international protection of intellectual property rights (IPRs). IPRs include copyright, trade secrets, patents, industrial design, and trademarks, among other things. Of particular interest with respect to genetically modified organisms (GMOs) are patents. A patent represents a bargain with an inventor that is based on the endowment of a time-limited monopoly (usually 20 years) in exchange for public disclosure of the inventor's creation. In this way patents are thought to stimulate research and development, although in the age of biotechnology this has become a more controversial claim.[6]

Until recently there has been a long tradition of not permitting the patenting of "products of nature"; therefore, animals and plants were not patentable. To provide for the protection of new plant varieties developed by traditional techniques of cross-breeding, plant breeders' rights were introduced. In 1980 in the United States, the Supreme Court of that country opened the gates to the patenting of "non–naturally occurring" living substances.[7] As a result virtually any living thing that can be reproduced by human intervention has become patentable. The ability to patent living products of biotechnology has been controversial for many years. At the same time, this ability forms the backbone of American biotechnology dominance and investment by multinational corporations in exploiting the world's biological resources. European experience with patenting of life forms has been markedly different. Political ambivalence in Europe on this issue for many years resulted in the passage of a moratorium on the patenting of life forms.[8] Recently, in the face of American dominance in global biotechnology that moratorium was lifted, although the change in policy continues to be controversial.

Trade-Related Aspects of Intellectual Property Rights and the Convention on Biological Diversity

It is telling to engage in an examination of the conflicting approaches to the treatment of the world's biological diversity and biological resources as articulated under the Trade-Related Aspects of Intellectual Property Rights (TRIPs) agreement, a product of the WTO; and the Convention on Biological Diversity (CBD), a product of the commonwealth model to international agreement.[9] A cursory examination of the values that motivate these international agreements illustrates the conflicts that exist between them. The TRIPS agreement is based on the protection of economic value, the pursuit of capitalism and profit, and the safeguarding of individual property rights. By contrast, the CBD emphasizes the value of conservation, fair and equitable sharing of benefits, and the value of communities of people.

The TRIPs agreement is a WTO agreement based on the promotion of effective and adequate protection of IPRs. It is also based on the extension of patentability to pharmaceuticals and to the microorganisms and processes for creating plants and animals. All signatories must have an effective plant-protection system in place. Exceptions to the intellectual property protections required by the agreement are permitted if they are based on measures for public health and interest. Permitted exceptions must, however, be consistent with the provisions of the TRIPs agreement. Consequently, whether such measures could be instituted to protect cultural and social welfare in a given country seems unlikely. Valuation of biological diversity, under TRIPs, therefore, is clearly instrumental to the desires and needs of parties wishing to exploit biological resources found around the world or, in other words, those companies and governments engaging in bioprospecting.[10]

The CBD resulted from the Earth Summit in Rio de Janeiro in 1992. It is a product of the commonwealth approach to formulation of international policy. Where the TRIPs agreement is based on economic exploitation of existing biological diversity, the CBD is committed to the conservation of the world's biological diversity. In addition, the CBD is premised on the principle of fair and equitable sharing, not only of the profits from exploiting those resources, but also of the medical benefits derived from them. Furthermore, provisions for transfer of technologies is included. The CBD explicitly provides for the recognition of and compensation for the contributions of indigenous peoples in cultivating and caring for plants that yield patentable properties. In stark contrast to the TRIPs agreement, the CBD states that intellectual property regimes must be consistent with and not detract from the provisions of the CBD. It is clear, therefore, that the values of conservation, stewardship, sharing, and inclusion are paramount values in the vision articulated by the CBD.

Commodification, Exploitation, and the Property Paradigm

The contrasting approaches to biological diversity embodied in the TRIPs and CBD raise a number of other ethical issues. For example, the imposition of property rights on living material raises concerns about the commodification and commercialization of life forms. In addition, introducing Anglo American property schemes into agrarian traditions customarily ordered by other norms may disrupt cultural and societal traditions as well as biological diversity. Finally, the appropriateness of choosing the legal tool of private property to govern our use of biological resources rather than other legal property concepts is at issue.

The application of IPRs to plants, animals, and other living matter has created a significant amount of debate about the commodification and commercialization of life. This concern is popularly articulated as concerns about the appropriateness of "owning life." Although IPRs do not confer ownership in the legal sense, concerns about "owning life" respond more generally to the commodification of living things.

The sentiment is widely shared that living things are sacred or different from nonliving things in a morally relevant way. For many, this special character mandates that living matter not be subject to the rules that govern private property. Many people believe that applying private property rights to living organisms serves to devalue that life by changing it into a commodity that can be transferred in the marketplace much like any other thing. This concern can be seen with respect to the whole spectrum of living matter, be it property rights in the human body, animals, plant life, or embryonic stem cells.[11] Regardless of one's views about the character of living matter, it is true that much living matter does not correspond to our notions of what constitutes fungible property that can be bought, sold, traded, or destroyed according to an individual's whim.[12] This is particularly true when we consider the nature of property in the human body, animals, frozen embryos, and plants that are used as food or for medicine by whole communities of people.[13]

Awarding IPRs to corporations in the industrialized world in products derived from biological resources found in developing nations raises concerns about exploitation. That exploitation concerns the contribution of indigenous peoples who for centuries have cultivated and used plants for their properties that are now patentable. Approximately 90 percent of the world's biological resources can be found in underdeveloped regions of Asia and Africa. Despite this, multinational corporations hold 97 percent of all patents worldwide.[14] Granting IPRs in these biological resources overlooks indigenous contributions that have led to the discovery of the valuable properties in the first instance. In addition, few corporations provide for sharing the financial or medicinal benefits derived from the biological resource with indigenous peoples. Perhaps the most notorious example is the European patent that was granted to the United States Department of Agriculture and the multinational agricultural company WR Grace on fungicidal properties of the neem tree.[15] In India the neem tree is revered. It has been carefully cultivated, and its fungicidal, pesticide, and medicinal properties have been used for centuries. The privatization of those properties for profit in industrialized nations has been widely condemned as a textbook case of biopiracy.[16] Recently that patent was overturned; however, hundreds of other patents on neem are still under consideration.[17]

IPRs can be disruptive and disrespectful of agrarian traditions in countries in which the sharing of crops and seeds is part of the culture. Private property traditions emphasize the dominion of an individual over a good, and in particular the right of that individual to exclude others from using that good. Although many argue that no form of property rights should be used with respect to living matter, in truth property rights have extended to land, plants, and animals for many years. The question, therefore, is whether intellectual property is the best legal tool to describe humankind's relationship to biological resources or whether some other property relationship better describes our relationship and serves our interests.

The ability to protect a resource for the use of many is part of our legal property traditions. Notions of "the commons" reflect the idea that there are some resources, formerly common lands, that should be open to all and cannot be subject to exclusive dominion or exploitation. It is this notion of common property that has been used to protect the integrity and sharing of the deep-sea beds. In addition, notions of common property apply to heritage and cultural property.[18] As with objects of cultural significance to the people of a particular region or heritage, our biological diversity is more than simply a tangible thing to be exploited and used up at the owners' whim. Notions of intrinsic value aside, the world's genetic resources often represent the cumulative efforts of generations of care and cultivation. Consequently, the benefits of those generations of stewardship should be protected and accrue to all people as well as future generations. The interests of all humankind would be better served if the world's biological resources were considered common property to be preserved and shared rather than individual property to be exploited.

Conclusion

Agricultural biotechnology is part of the larger biotechnology industry, which relies on exploiting useful properties from the world's rich biological diversity. Understanding ethical issues associated with this technology requires an examination of the international legal and political context as well as domestic perceptions and regulatory concerns. The rise of global capitalism has created new political and legal norms. A shift from a commonwealth model of international negotiation based on cooperation and equality to a trade-oriented model that is adversarial and favors the economically powerful is taking place. This shift places conflicting worldviews about the value and stewardship of the world's biological resources in stark contrast. Trade agreements involving biological products are intimately connected with intellectual property protections. The extension of intellectual property to life forms has paved the way for industrial countries and corporations to lay claim to biological resources in developing countries with medicinal and other useful properties. With privatization of these resources, social, historical, and cultural traditions are disrupted and the contributions of indigenous peoples are ignored. Not all property notions need lead to this result. The world's biological resources should be conserved and shared. Rather than awarding private property rights to their bounty, we should consider the wisdom of regarding biological diversity as our cultural and environmental heritage and common property for all people.

Lori P. Knowles, LLB BCL MA LLM, is associate for Law and Bioethics and Director of Education and Outreach at The Hastings Center, a nonprofit, independent bioethics research center in Garrison, New York. She researches and publishes in international and comparative health and bioethics law. Knowles is a lawyer with law degrees from Canada, the United Kingdom, and the United States.

Notes

1. I take this notion of the international commonwealth from Peter G. Brown, *Ethics, Economics and International Relations: Transparent Sovereignty in the Commonwealth of Life* (Edinburgh University Press, 2000).

2. *Universal Declaration of Human Rights*, adopted and proclaimed by UN General Assembly Resolution 217A(III) (December 10, 1948). International Covenant on Civil and Political Rights, G.A. Res. 2200(XXI), 21 U.N. GAOR, Supp (No. 16) 52, U.N. Doc. A/6316 (1966). International Covenant on Economic, Social and Cultural Rights, G.A. Res. 2200 (XXI), U.N. GAOR, Supp. (No. 16) 49, U.N. Doc. A(6316) 1966.

3. John Micklethwait, "Europe's Profound Fear of Food," *New York Times*, 7 June 1999, p. A21; Rick Weiss, "In Europe, Cuisine de Gene Gets a Vehement Thumbs Down," *Washington Post*, 24 April 1999, p. A1.

4. Editorial, "The Name of the Game: The Battle over Genetically Modified Foods Is Not What It Seems," *New Scientist*, 22 May 1999, p. 3.

5. See Lori Wallach and Michelle Sforza, *Whose Trade Organization? Corporate Globalization and The Erosion of Democracy* (Washington, D.C.: Public Citizen, 1999).

6. See Robert Mullan Cook-Deegan and Stephen J. McCormack, "Patents, Secrecy, and DNA," *Science*, 13 July 2001, 217.

7. *Diamond v. Chakrabarty,* 447 U.S. 303 (1980).

8. See http://www.European-patent-office.org; Quirin Schiermeirer, "European Union Move to Curb Moratorium on Transgenic Plants," *Nature* 409 (22 February 2001): 967.

9. The TRIPS agreement can be found at http://www.wto.org/english/tratop_e/trips_e/intel2_e.htm. Convention on Biological Diversity, Decreto No. 2519, de 16 de marco de 1998, DO de 17/03/98.

10. See Panos Kanavos, "The WTO-TRIPS Agreement: Areas of Dispute and Implications," *EuroHealth* 6 (Autumn 2000): 21.

11. *Biotechnology, Patents and Morality*, edited by Sigrid Sterckx (England: Ashgate Publishing Ltd., 1997); editorial, "Who Owns Plant Genetics?" *Nature Genetics* 26 (4 December 2000): 385.

12. The body of property law is, of course, more complex than I present it. In a number of circumstances there are restrictions on the uses that an owner can make of his or her property. Those restrictions may take the form of zoning bylaws, or restrictions on the treatment of one's own body or one's pets.

13. See, for example, Andrew Kimbrell, *The Human Body Shop: The Cloning, Engineering, and Marketing of Life*, 2d ed. (Washington, D.C.: Regnery, 1997).

14. "India: New IPR Regime: Protection for Indian Patents," *Financial Times Information*, 24 April 2001.

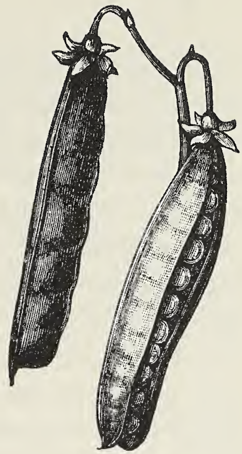
15. Patent 0436257 B1. See also Paul Hoversten, "Legal Battle Takes Root Over 'Miracle Tree,'" *USA Today*, 18 October 1995.

16. Vandana Shiva, "Free Tree," *Hindustan Times*, 9 June 2000, http://www1.hindustantimes.com/nonfram/090600/detOPI01.htm.

17. Karen Hogan, "Neem Tree Patent Revoked," *BBC News*, http://news.bbc.co.uk/hi/english/sci/tech.

18. Joseph L. Sax, "Heritage Preservation as a Public Duty: The Abbe Gregoire and the Origins of an Idea," *Michigan Law Review* 88 (1990): 1142, 1152.

Biotechnology and Genetically Modified Foods: The Role of Environmental Journalists



Richard Manning

This article first appeared in *SE Journal*, the quarterly publication of the Society of Environmental Journalists.

The controversy about genetically modified foods looks so very different when laid out not in the way we who work in environmental journalism usually cover it, in a confrontation between a corporation and food activists, but by three middle-aged women in saris in a spartan lab in Pune, India. The three, each with a Ph.D. and full careers in biological research, are tinkering with the genes of chick-peas but begin the conversation by speaking of suicides.

Their target is an insidious little worm called a pod borer, which makes its way into the ripening chickpea pods and, unseen, eats the peas inside. Subsistence farmers expecting a bumper crop find the fat pods hollow at harvest. Then—and this happens most every year—a few hundred suicides preface a hungry season for entire villages.

Three years ago I began profiling nine agricultural research projects in the developing world. The idea was that these projects, culled from a list of 450 applications for grants from the McKnight Foundation, would distill cutting-edge ag research to its essence and give a mosaic picture of the future of the human enterprise with the greatest environmental footprint on the planet.

There is some urgency to this. In the late 1960s Paul Ehrlich warned of worldwide famine in *The Population Bomb* (Sierra Club–Ballantine, 1968). Population doubled in the past generation to six billion, but doom did not occur, mostly because of the massive increase in yields of grain brought on by the Green Revolution. Now, though, even most unrepentant "Green Revolutionaries" agree those technologies have almost reached their limits for increasing yields. More important, the environmental damage from the Green Revolution's dependence on pesticides and chemical fertilizers, and the consequences—soil and water depletion, and habitat loss—are simply unsustainable at present levels, never mind future increases. Meanwhile, 800 million people are underfed in the developing world. The expected population increase from 6 to 9 billion by 2050 likely all will accrue in the poorest parts of the globe. This is one of the biggest environmental stories of our time, and we're missing it. Worse, our focus on safety and genetically modified foods hypes a developed-world debate that is damaging biotechnology, an important tool to address the bigger problems in the developing world. We are feeding a sort of agricultural NIMBYism.

I went into my piece of this story expecting to write about warm and fuzzy sustainable ag techniques such as crop rotation, intercropping, neglected crops, and integrated pest management. In fact, that's what I found in most of the projects, but what blindsided me was the degree to which each is dependent on some form of biotechnology, even in some of the world's most primitive places. I was in a lab in Uganda that could not regularly flush its toilets because of a lack of running water, but its work relied on biotech.

This, of course, raises the specter of genetic engineering. Because I write books, I don't have to hide my judgments and opinions, but I went into the story almost without an opinion; if anything, I was biased against genetically engineered crops. I remain ambivalent, opposed to some cheap parlor tricks like *Bacillus thuringiensis* (Bt) corn that has gotten all the press in the United States. When all is said and done, Bt corn is simply a passive way of applying insecticide; it doesn't matter a bit that the insecticide is "natural."

Still, I think badly needed biotechnology is being suppressed by overblown fears about genetic engineering. The way the debate is structured—and this is mostly journalists' fault in that we are paid to guide debate—causes us to miss some big pieces of this story.

First, genetic engineering is a subset of biotechnology. We often err by treating it as if it were the whole, and that is dangerous. For more than twenty years, scientists have been able to splice genes from one organism to another and have done so again and again. That technique is controversial. Three of the nine projects relied on genetic engineering, but all relied on what I call biotechnology.

Sequencing, reading, and marking genes does not necessarily imply their manipulation. Traditional plant breeders, for instance, now routinely rely on genetic markers to guide their work. We are entering an exceedingly sophisticated era of science of which the human genome project is a part. A little-noticed parallel to the human genome project has taken place in Brazil, where scientists have mapped the gene of a bacterium that destroys citrus crops. This area of genomics has enormous promise to refine our basic understanding of host-parasite relationships. At the genetic level, those relationships are guided by a series of locks and keys. A firm understanding of them will allow us to gently lock out one burglar—likely without genetic engineering—instead of using the neutron bomb of pesticides to poison every being in the vicinity.

My biggest concern here is that the controversy about genetic engineering will hamper all of biotechnology, and this set of tools will never reach its potential, or, more darkly, that the controversy will leave the corporations, over which we have very little control, operating largely unaffected and tie the hands of public-sector scientists. This is especially important in the developing world, where most crop science is public. Many countries such as India, Brazil, Cuba, China, and Chile are already effectively using these tools, and many more, such as Uganda and Ethiopia, have begun to. The very act of exercising these skills gives them a big leg up in building the infrastructure they need to gain some independence in charting their own agricultural destiny.

The distinction between public and corporate science is key in all of this. We have already seen how corporate science gave us Bt corn, a technology now considered primitive by many working in the field. Corporations such as Monsanto and

Novartis go ahead with these blunt instruments only because a decade or so of research and development money has to be recovered. They are in a time warp, and attaching the discussion to their actions leaves all of us in the same warp. Recovering investment is also why they mercilessly pursue any farmers who break licensing agreements and save seeds. (With the earlier generation of improved crop plants, this was not an issue, because the gains came largely from development of hybrid varieties, and hybrid vigor does not carry to the next generation, so seeds must be bought each year. Many of the transgenics are not hybrids, so the gain is permanent.)

In my mind, I contrast all of this with the case of chickpeas cited earlier. India's protein consumption is about half what it should be, mostly because of losses to this one neglected crop, a situation that has to be corrected if a billion people are to maintain an efficient vegetarian diet. The scientists are getting the genes for resistance to the pod borer from Asian wing bean and peanuts, already food crops. It will cause chickpeas to express not an insecticide, but a protease inhibitor, a common protein that disables the pod borers' digestive enzymes. Humans can and already do digest this same protein in beans and peanuts. The pod borer is now controlled in India with insecticides, which, environmental and health problems aside, most farmers can't afford. Yet if the government gives them this new seed, they need only save seed to keep this resistance on their fields.

And, yes, there are drawbacks, chief among them that the pod borer can and will build resistance to the protease inhibitor, but that's agriculture and has been for 10,000 years. We need to do all the running we can to hold our place. Or at least buy us time to gain the wisdom and will to pursue longer-term solutions.

Genetic modification and even biotech need to be looked at in the context of conventional plant breeding. For all 10,000 years of the history of this enterprise, most gains in agricultural productivity have come through breeding, especially in the time since Gregor Mendel. Breeding haphazardly alters genes through human selection and carries with it many of the same problems now ascribed to genetic modification. Further, breeding has become sophisticated enough to force matings that never would occur naturally, many of them across species lines, some across genera.

In turning all this over in my mind for the past few years, it finally snapped into focus when I heard someone worry that genetic modification could provoke an environmental catastrophe. Maybe, but in a very real and demonstrable sense, all of agriculture already is an environmental catastrophe, in fact, our biggest. News of this has not been in all the papers, but this is journalists' fault.

Aldo Leopold said even a generation ago: "As for diversity, what remains of our native fauna and flora remains only because agriculture has not got around to destroying it."

A century before Leopold, George Perkins Marsh said, "With the pastoral state, man at once commences an almost indiscriminate warfare upon all the forms of animal and vegetable existence around him, and as he advances in civilization, he gradually eradicates or transforms every spontaneous product of the soil he occupies."

That is no less true in our time, and our coverage needs that perspective.

Richard Manning is the author of six books, including Food's Frontier: The Next Green Revolution *(North Point Press, 2000). An award-winning environmental writer, Manning has had articles published in many leading national magazines and newspapers. He lives in Lolo, Montana.*

Adoption of Agricultural Biotechnology by Wisconsin Farmers: Recent Evidence

Bradford L. Barham

Two major types of agricultural biotechnology are currently available to Wisconsin farmers, recombinant bovine somatotropin (rBST) (otherwise known as bovine growth hormone [BGH]) and genetically modified organism (GMO) crops, particularly herbicide-tolerant soybeans and corn and *Bacillus thuringiensis* (Bt) corn. This paper examines the adoption patterns of these two types of agricultural biotechnologies to see what lessons might be drawn from their experiences that might be of relevance to the controversy surrounding genetically modified foods.

Wisconsin agriculture provides a fascinating backdrop for such a study. First, Wisconsin agriculture remains to this day dominated by moderate-scale family farms in both the dairy and grain sectors. For example, 96 percent of Wisconsin dairy farms have less than 200 cows, and more than 85 percent have less than 100 cows (Jackson-Smith and Barham 2000). Similarly, Wisconsin has very few large-scale grain farms. Indeed, most grain production occurs on dairy farms, and most of the rest is on what were once dairy farms. Second, dairy farming remains the dominant sector of Wisconsin agriculture (accounting for 30 percent of the farms and more than 60 percent of the agricultural output), so what happens on dairy farms is crucial to the outcome of agricultural biotechnology adoption in Wisconsin. Third, unlike many other states, the articulation between Wisconsin consumers and Wisconsin's farmers and agricultural sector, overall, remains quite strong. Even though less than 2 percent of Wisconsin's population works as farmers, I would not be surprised if a third to a half of Wisconsin's population knows either through family connections or close friends people who are currently or were recently farmers. This connection is reinforced through farmers' markets, community-supported agriculture schemes, county dairy breakfasts, and all kinds of less formal events that bring consumers and farmers together. Fourth, Wisconsin was very much at the heart of the international debate that preceded the commercial approval of rBST in the United States in the late 1980s and early 1990s, and as such the politicization of these technologies was quite extensive here in Wisconsin, among both farmers and consumers.

One of the major institutional outcomes of the political debate over rBST in Wisconsin was the State Legislature's 1990 decision to create the Agricultural Technology and Family Farm Institute (ATFFI) as an independent research and extension unit at the university dedicated to studying the impacts of new technologies and public policies on family farming in Wisconsin. From its inception in 1992, ATFFI, now known as the Program on Agricultural Technology Studies (PATS), has monitored the commercialization and adoption of rBST and other emerging technologies in Wisconsin. The first survey undertaken by ATFFI in 1993 asked a random sample of 1,000 dairy farmers about their intentions to adopt rBST (BGH) under two potential scenarios of marketing conditions being debated at that time (no labeling of products versus mandatory labeling for all dairy products using milk from cows treated with rBST). Since that time, ATFFI, and later PATS, has surveyed dairy farmers again in 1994, 1995, 1996 (only recent entrants), 1997, and 1999. In 2001, PATS completed two more surveys, a statewide random sample and a statewide panel data sample (including farmers who were interviewed previously in 1994, 1995, and 1997), to examine the dynamics of technology adoption change among dairy farmers over the relevant time period. In the case of GMO crops, PATS has done surveys in 1999 (asking about 1998) and in 2000 (to the same farmers as in 1999, asking about 1999 and looking forward to 2000). This panel has also been recently extended to the year 2001.

Before we pursue the main task of this paper, which is to examine the adoption patterns of rBST and GMO crops among Wisconsin farmers, it is worth briefly contrasting the two technologies to identify some important differences between them. To begin, while rBST works in combination with a suite of other technologies and management practices to augment the productivity of cows, GMO crop varieties are essentially input-reducing technologies aimed at allowing farmers to spend less time in the fields with their machinery and chemicals fighting weeds and other pests. In addition, rBST has a longer commercial history (released in February 1994 vs. 1996 to 1998 for most of the GMO crops) and was much more controversial among both farmers and consumers, especially in their involvement in the protracted political struggle that surrounded its commercial approval and initial introduction. As a result, voluntary labeling of fluid milk and some other dairy products began immediately after the commercial release of rBST in 1994, whereas the push to label products according to their use of GMO crops is still unfolding, several years after the release of these technologies and the ongoing commercialization of processed foods using these crops. Finally, GMO crops in Wisconsin are largely used as inputs to livestock (especially on dairy farms), and because unlike rBST they are essentially input-reducing rather than output-enhancing technologies, they are not as likely to be viewed by farmers (both adopters and nonadopters) as likely to lower prices and revenues.

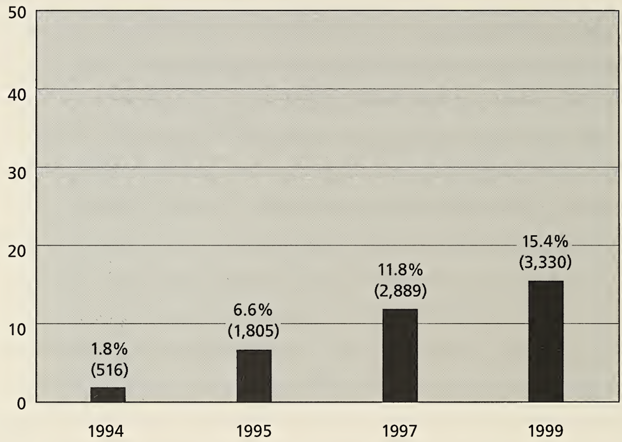
The rBST Experience in Wisconsin

Adoption of rBST in Wisconsin has been quite moderate, especially when compared with most precommercialization predictions of rapid adoption.[1] In 1999, five years after the commercial release of the technology, rBST was being used on 15.4 percent of Wisconsin dairy farms. As figure 1 demonstrates, the rate of adoption increased by more than 1,000 users between 1994 and 1995 and again between 1995 and 1997. However, between 1997 and 1999, the estimated number of new users increased by less than 450. Thus, while figure 1 shows a pattern of increasing adoption, the rate of adoption growth appears to be flattening out. Indeed, as this article goes to press,

[1]The figures and data for this section are from Barham, Jackson-Smith, and Moon 2000.

Figure 1

Percent (estimated number of farmers) of Wisconsin Dairy Farms using rBST



Wisconsin survey data for 2001 show that rBST adoption is 16.5 percent, having grown only slightly in the past two years.

Several factors limited the adoption of rBST among Wisconsin dairy farmers. Certainly, following its commercial release, consumer and farmer resistance to the technology prompted processors and retailers to pursue a voluntary labeling scheme especially for fluid milk, which in most grocery stores led retailers to advertise quite explicitly that their milk came from cows not treated with rBST. In addition, the survey data collected by ATFFI and PATS in those years revealed a surprising percentage of farmers who claimed to refuse to use the technology for essentially political reasons (Barham et al. 1995). Recent studies of rBST adoption (Stefanides and Tauer 1999; Foltz and Chang 2000) and its impacts on profitability suggest another reason that many farmers may not be using the technology, namely that, on average, it does not appear to enhance profitability. If these results are valid, perhaps it should not be such a surprising outcome given that sales of the technology are monopolized by a single company. Finally, there is the fact that for many dairy farmers rBST may not fit with the other production system decisions they are making and the ways in which they are organizing management and labor on their farms.

What types of farms are adopting rBST? As table 1 reveals, there is definitely a strong size bias in the adoption patterns in Wisconsin. Only 5 percent of farms under 50 cows use it. About 15 percent of farms in the 50 to 99 herd size category use it, but over 75 percent of the farms in the over 200 herd size category are rBST adopters. There is no other technology in dairy farming, other than parlors and free stalls that are built *explicitly* for large herds, that demonstrates a similar scale bias.

Table 1
Percent of Farms Using rBST in Wisconsin, by Size of Milking Herd (%, 1999)

Size Categories	1995	1997	1999
1–49 cows	2.2	3.3	5.3
50–99 cows	10.4	13.9	15.3
100–199 cows	20.8	30.1	34.9
200+ cows	46.7	48.3	75.0
All dairy farmers	6.6	11.8	15.4

The interesting puzzle about this size bias in rBST adoption is that, prima facie, the actual application of the technology offers no compelling reason that adoption should be so size biased. Basically, applying it to 200 cows should take a farmer four times as long as applying it to 50 cows would. Of course, applying the technology says nothing about its efficacy, and that is where issues of management and complementary technologies come into play. In fact, effective rBST use depends on careful feed and herd management to insure that the cows can make efficient use of the stimulus to milk production provided by the hormone. As a result, it should not be surprising that rBST adoption, as shown in table 2, is much higher on farms using other productivity-enhancing practices, such as total mixed ration (TMR) equipment, regular feed balancing, herd production record keeping, and regular veterinary services. As shown, rBST adopters in all herd size categories are much more likely than nonadopters to use these other productivity-oriented management practices.

The association of rBST with other productivity-enhancing technology use helps to explain the size bias in rBST adoption, at least in Wisconsin. Adopters of rBST appear to have a certain production system orientation that gives rise to the use

Table 2
Adoption (A) and Nonadoption (NA) of Various Milk Production Practices, by rBST Use Status and Herd Size in Wisconsin (%,1999)

	TMR		Vet Service		Herd Prod. Record		Bal Feed Rations	
rBST Adoption	A	NA	A	NA	A	NA	A	NA
1–49 cows	35.3	6.6	70.6	50.2	88.2	36.6	58.8	41.3
50–99 cows	70.0	27.1	90.2	71.6	92.0	60.5	98.0	74.8
100–199 cows	93.1	50.0	93.1	79.6	93.1	58.5	100.0	90.7
200+ cows	95.2	57.1	93.1	58.5	95.2	42.9	100.0	85.7
All	75.2	19.7	89.8	62.2	92.3	48.9	93.2	60.5

of a whole package of technologies, facilities, and management practices, most of which reward rBST use. Because many of these in turn have strong technical, investment, or labor-scale biases, their differential adoption profiles and their association with rBST use affect the scale neutrality of rBST adoption.

GMO Corn and Soybeans

Nationally, many analysts viewed the 2000 growing season as a potential turning point in terms of the adoption of two of the major GMO crop varieties, Bt corn and herbicide-tolerant (HT) soybeans.[2] From 1996 to 1999, the pace of adoption of these two

[2]The figures and data for this section are from Chen, Barham, and Buttel 2000.

GMO varieties had been precedent setting; no other major agricultural technologies in the United States had been adopted as rapidly as Bt corn (and cotton) and HT soybeans. From minuscule levels of adoption in the first marketing season of 1996, by 1999 about 25 percent of U.S. corn acreage had been planted in Bt corn, and about 57 percent of U.S. soybean acres were in HT soybean varieties.

Then, the European storm clouds of consumer opposition to GMO crops began to roll across the oceans toward the United States. Would the adoption decisions of 2000 be substantially different, as U.S. farmers found themselves facing a more uncertain marketing environment for GMO crops than they had in the first three years of the technology's commercial availability? PATS survey work allows a careful look at that issue for Bt corn and HT soybeans.

As shown in figures 2 and 3, there was essentially no growth between 1999 and 2000 in farmer adoption of Bt corn and HT soybeans, but acreage of soybeans expand-

Figure 2
The Adoption of Bt Corn among Wisconsin Corn Producers

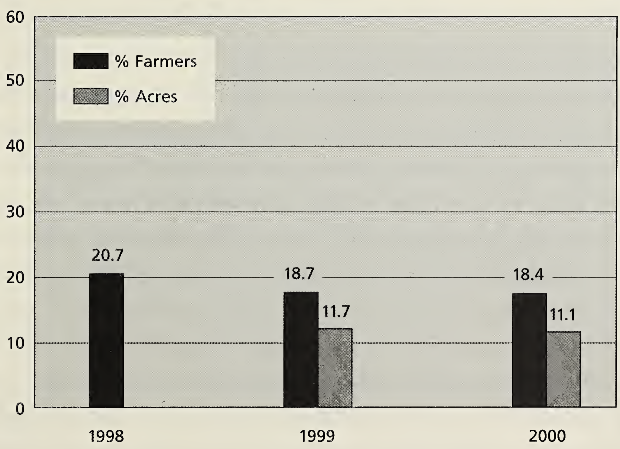
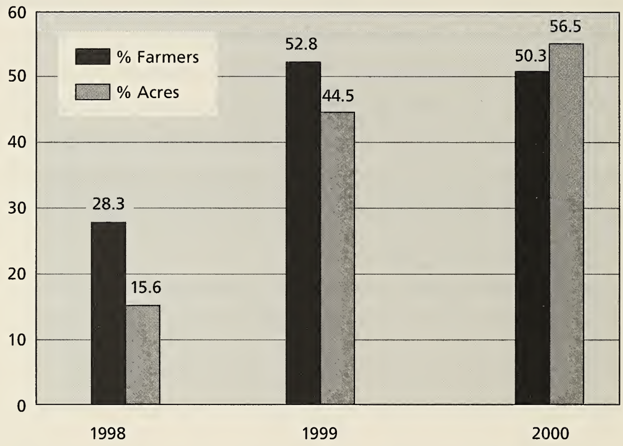


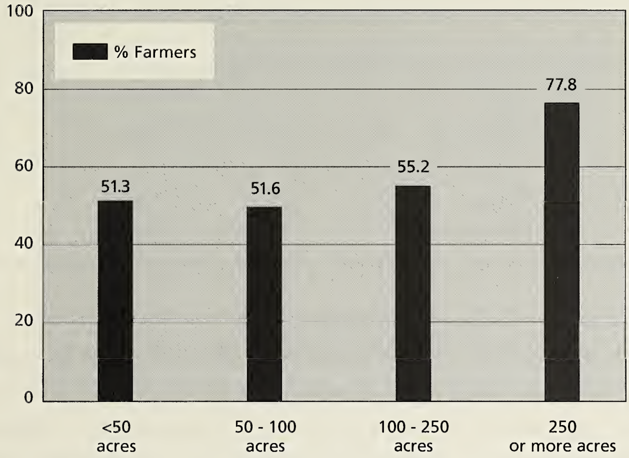
Figure 3
The Adoption of HT Soybeans among Wisconsin Soybean Producers



ed significantly. In particular, Bt corn adoption remained at around 18 percent of farms raising corn and 11 percent of corn acres. Meanwhile, HT soybean adoption fell slightly from 53 percent of farms raising soybeans to 50 percent, while the share of soybean acres accounted for by HT soybean varieties increased from 44.5 percent to 56.5 percent. This rather notable increase in acreage also underscores the size bias in HT soybean adoption illustrated in figure 4. Note that in 1999, whereas HT soybean adoption was around 50 percent on farms with less than 250 acres of soybeans planted, HT soybean adoption was about 78 percent on farms with more than 250 acres of soybeans planted. This size bias is notable but not nearly as strong as the case of rBST.

On the whole, then, 2000 did not give rise to a significant downturn in adoption or de-adoption of GMO crops as some had anticipated it might. That said, there is considerable turnover in adoption from one year to the next. Tables 3 and 4 provide transition data on farmers' decisions across two time periods. It is noteworthy that about

Figure 4
The Adoption of HT Soybeans by Size of Farm in 1999



20 to 25 percent of farmers who adopted one of these GMO crop varieties in 1999 did not use the variety again in 2000 and were replaced by new adopters. While the basis for this turnover is still being investigated, initial analyses suggest that those continuing with the crop report having had higher per-acre yields and profits and less labor effort than those who de-adopted. Relatedly, marketing concerns and uncertainties appear to be considerably less important to the de-adoption decisions than were crop performance variables. In 2001, as this article goes to press, marketing issues continue to appear to be secondary to farmers' adoption decisions relative to production experiences, though there is some evidence of those who choose not to adopt GMOs again being more concerned about marketing problems in the future. The fact that the majority of Wisconsin's GMO crops are destined for animal feed may help to explain what appear to be the rather small impacts so far of marketing concerns on producer GMO adoption decisions.

Table 3
Number and Percent of Bt Corn Adopters and Nonadopters in Wisconsin: 1999–2000

	Bt Corn in 1999 Yes	No
Bt Corn in 2000		
Yes	46	16
(Column %)	(76.7)	(6.3)
No	14	238
(Column %)	(23.3)	(93.7)
(Total %)	(100.0)	(100.0)

Lessons from Wisconsin and Looking Ahead

The experiences with rBST and GMO adoption in Wisconsin offer several important lessons to help guide public policy discussions regarding agricultural biotechnology. First is the fact that adoption patterns of agricultural biotechnology vary substantially. Only HT soybeans appear to be a "juggernaut" technology, where widespread adoption is occurring and perhaps transforming the performance of the sector. In the case of dairy farming, more than five years after the release of rBST, adoption is rather moderate and is having only small impacts on the sector's performance. Similarly, Bt corn appears to be on more of a rBST adoption track, stalling out at a relatively moderate level of adoption rather than becoming widely used and accepted.

Though consumer resistance may have played a decisive role in the early years of the rBST experience (giving rise as it did to a voluntary labeling scheme for fluid milk products), more recent evidence suggests that farm-level characteristics are also playing a crucial role in determining adoption outcomes. In particular, the potential importance of distinctive production systems should not be underestimated and may give rise to considerable heterogeneity in adoption patterns of technologies across similar types of agricultural enterprises. Again, in the case of dairy farming, rBST use is much higher on farms where a suite of other productivity-enhancing technologies are used and is lower where grazing-oriented production systems are in place.

Table 4
Number and Percent of HT Soybean Adopters and Nonadopters in Wisconsin: 1999–2000

	HT Soybean in 1999	
	Yes	No
HT Soybean in 2000		
Yes	57	15
(Column %)	(78.1)	(22.7)
No	16	51
(Column %)	(21.9)	(77.3)
(Total %)	(100.0)	(100.0)

Considerable size bias is evident in the adoption of these three agricultural biotechnologies, especially in the case of rBST. However, the reasons for this size bias may be related more to the overall management orientation and production system being used on the farm than to the inherent properties of the technologies themselves. Nonetheless, to those who argue that these technologies are scale neutral, the evidence from adoption patterns in Wisconsin does not support that contention at all.

The rapid pace of HT soybean adoption illustrates that future agbiotech innovations could sweep rapidly through the system. This experience suggests that a little more attention to up-front review and evaluation will probably not slow down greatly the realization of gains from highly productive new varieties and may save a lot of potential costs and risks for this type of technology in general. Although companies in a hurry to market their new agricultural biotechnologies may not like that advice, except as it applies to their competitors, it may well be that the old maxim holds true here in slightly modified form, that an ounce of precaution might be worth many bushels of returned grains.

Finally, the kind of regular, random-sample-based survey work that PATS undertakes to document the details of adoption patterns can reveal a lot about emerging technologies, the decisions being made by farmers, and hence the likely impacts of the agricultural biotechnology revolution on the economy and society. It would be especially useful if there were other similar programs or centers doing comparable studies in other states. Integrating the findings across different states would allow policy makers a much better picture of the agricultural biotechnology adoption story than current evidence provides.

Bradford L. Barham is an associate professor of Agricultural and Applied Economics at the University of Wisconsin–Madison, where he also serves as co-director of the Program on Agricultural Technology Studies.

References

Barham, Bradford L., Douglas Jackson-Smith, and Sunung Moon. 2000. "The Adoption of rBST on Wisconsin Dairy Farms." *AgBioForum* 3 (2,3):181–87.

Barham, Bradford L., Frederick H. Buttel, Douglas Jackson-Smith, Jason McNichol, and Spencer D. Wood. 1995. "The Political Economy of rBST Adoption in America's Dairyland." Agricultural Technology and Family Farm Institute Technical Report no. 2. Madison: University of Wisconsin.

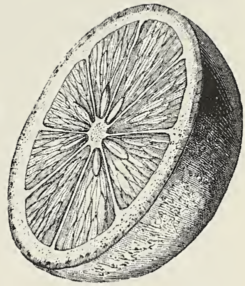
Chen, Lucy, Brad Barham, and Fred Buttel. 2000. "The Adoption and De-Adoption of GMO Crop Varieties in Wisconsin." Program on Agricultural Technology Studies Family Farm Facts no. 10 (September). Madison: University of Wisconsin.

Foltz, Jeremy, and H. H. Chang. 2000. *The Adoption of rBST on Connecticut Farms.* Storrs: University of Connecticut.

Jackson-Smith, Douglas, and Bradford L. Barham. 2000. "The Changing Face of Wisconsin Dairy Farming: PATS' Research on Structural Change in the 1990s." Program on Agricultural Technology Studies Research Report no. 7 (August). Madison: University of Wisconsin.

Stefanides, Zdenko, and Loren Tauer. 1999. "The Empirical Impact of Bovine Somatotropin on a Group of New York Dairy Farms." *American Journal of Agricultural Economics* 81:95–102.

Don't Ask, Don't Tell: U.S. Policy on Labeling of Genetically Engineered Foods



Lydia Zepeda[1]

This paper was presented at the American Association for the Advancement of Science, San Francisco, California, 18 February 2001. It was subsequently presented at the Wisconsin Dietetic Association, Appleton, Wisconsin, 20 April 2001.

Many people assume that the U.S. Food and Drug Administration (FDA) says that *all* genetically engineered (GE) food is safe because it does not require premarket approval. However, the FDA's 1992 policy document identifies specific GE applications that pose potential human and animal health risks.[2] The document indicates that the burden of identifying and reporting potential problems is placed on the companies manufacturing GE products. The policy statement further recommends that manufacturers label foods with any of these potential risks.

---

[1]The author notes that this paper does not reflect the views of the University of Wisconsin, where Lydia Zepeda is a professor in the Department of Consumer Science and director of the Center for Integrated Agricultural Systems. Dr. Zepeda would like to express gratitude to Colleen Curran for feedback on a draft of this paper. Any errors are entirely the responsibility of Dr. Zepeda.

[2]Among those cited by FDA scientists (Department of Health and Human Services, Food and Drug Administration 1992) were the transfer of genes from common allergens (milk, eggs, fish, crustacea, mollusks, tree nuts, wheat, and legumes), known toxicants (protease inhibitors, lectins, and cyanogenic glycosides), antibiotic resistance selectable markers (kanamycin resistance gene), and any change in nutrient or toxicant composition of plants that constitute a significant portion of domestic animals' diet (e.g., field corn).

Subsequent investigations by the Environmental Protection Agency (EPA) (Anderson and Milewski 1999), Health Canada, the European Commission, and others have confirmed or broadened the specific health risks identified in the FDA policy statement. This, along with such controversies as human consumption of Starlink corn, has led to criticism of self-enforcement. In response, the FDA has proposed a revision in its policy that will require premarket review 120 days prior to release of all new GE food and animal feeds.

In contrast to the United States, the European Community (EC) has had a moratorium, recently lifted, on approval of GE food. The proposed legislation had strict labeling and tracing requirements for *all* food with GE ingredients. Individual countries such as Japan, Korea, Australia, and New Zealand have also enacted legislation requiring labels for GE food. Thailand has temporarily banned imports of GE seed. These countries have been buying about 43 percent of U.S. agricultural exports. It is estimated that U.S. farmers lost $300 million in overseas sales in 1999 due to GE corn alone.

Given that some health risks are associated with specific GE applications; that a growing number of major trade partners and competitors, as well as a United Nations agreement, require labeling; and that most U.S. consumers favor labeling, the big policy issue in the United States is not whether labeling will take place. The real questions are how and when, and whether labeling will apply only to the export market.

Consumers Want Labels

Most surveys indicate a high proportion (82 to 93 percent) of U.S. consumers want GE food labeled.[3] Support for labeling is so overwhelming that the Secretary of Agriculture has hinted at being more open to the idea. Outside the United States, support for labeling is high as well: 74 percent in the EC, 80 percent in Australia, 92 percent in the United Kingdom, and 98 percent in Canada (Consumers Union 1999).

That most consumers would use labels to make purchase decisions, whether ver-

---

[3]In a very long question regarding FDA policy, a 1999 International Food Information Council survey found that 58 percent of those surveyed favored the FDA labeling policy. The question is somewhat confusing since it seems to imply that the FDA does not support labeling under any circumstances, which contradicts the FDA's policy document (Consumers Union 1999).

ifiable or not, is probably unlikely.[4] This does not mean that labels would not have an impact. Apart from making it possible to trace any potential problems, labels by themselves serve to reduce the perception of risks associated with GE food. Consumers can choose to incorporate the label information in their buying decision, or not. More importantly, it permits informed consent, that is, it transforms risk perceptions from being "involuntary" to "voluntary" (Thompson 1996). Theoretically and empirically, this reduces the perception of risk. A recent study demonstrated that availability of labels reduces risk perceptions toward GE food (Zepeda, Douthitt, and You, in press), irrespective of whether people act on the information.

Voluntary Labeling: Consumers with Money Will Get What They Want

Voluntary labeling in the United States permits access to GE-free food for some products, generally at a higher price. Voluntary labeling has been exclusively linked to "GE-free" labels. Individual manufacturers of foods with GE ingredients have no incentive to label their products voluntarily given public perceptions about GE food. Collectively, if all manufacturers labeled their products, risk perceptions would decline because involuntary risk exposure would be eliminated.

Agriculture has had a notoriously difficult time finding ways for farmers to capture value-added or to differentiate products. GE-free food is a case where a niche has been created not only at the retail level but also at the farm level. Farmers producing for the export market have already felt the downside of producing unwanted products. The cost savings of pesticide applications due to using *Bacillus thuringiensis* (Bt) corn are estimated to be between $2.80 and $14.50 per acre (Carlson, Marra, and Hubbell 1997). However, given the acres planted to Bt corn in 1999 this was more than offset by the estimated loss to farmers of $300 million in overseas sales attributed to unwanted GE corn. Farmers themselves, concerned about loss of markets at home and abroad, have reduced their use of GE crops. In 1999 about 33 percent of all corn acreage was GE; in 2000 it dropped to 19.5 percent.

---

[4]While for some GE foods labels might be difficult to verify, cheap tests ($5.75) are available for some foods (Bett 1999). The demand for developing such tests has spurred a growing industry.

In the United States, the definition of organic excludes GE ingredients. Organic sales have climbed, driven in large part by the demand for GE-free food. For example, organic milk sales were up 72 percent in 2000. The demand for organic soybeans in the United States is so high that we are importing them from China, one of our largest export markets for commodity soybeans. The net returns per acre of organic soybeans run about a third higher than for commodity soybeans. A study of Midwestern grain and soybean production found that many organic crops were profitable without any price premiums and for those that were not, the current price premiums exceeded break-even premiums (Welsh 1999). Organic prices are running about 75 percent above commodity prices for soybeans and corn.

U.S. food manufacturers are using voluntary GE-free labels to increase sales or prevent loss of sales due to consumer concerns about GE foods. Individual companies (Nestle, Gerber, Heinz, FritoLay, McDonald's, and Iams) have banned all GE ingredients in some food lines, particularly those consumed by babies, children, and pets (Bett 1999).

That voluntary labeling is concentrated in baby and pet foods is entirely consistent with risk theory. Involuntary risk exposure has been shown to increase the perception of risk (Starr 1969; Fischoff et al. 1978). Thus, adult caregivers are more cautious about exposing others to risks, particularly those who cannot make a choice for themselves, such as children and pets.

Mandatory Labeling: Wording Affects Who Pays and How Much

Effective labeling hinges on the existence of four factors: standards, testing, certification, and enforcement. If all four factors are not in place, it leads to confusion and expense. StarLink corn is an example of such an outcome. Bags of the seed were labeled "not for human consumption." However, there was no testing, certification, or enforcement, which led to the corn being mingled with corn directed to products for human consumption. The estimated value of the StarLink crop was only $68 million; however, its manufacturer, Aventis, set aside $92 million to buy the corn, and it is likely the cost will eventually be much higher. Three separate class-action suits in Nebraska, Iowa, and Illinois have been filed by farmers who claim they incurred losses due to their corn being contaminated or commingled with StarLink corn.

Existing labeling laws abroad and those proposed at both state and federal levels in the United States vary in label wording and implementation. In some cases, animal feeds and products in which it is difficult to verify genetic material, such as oil, are exempt. Because corn and soybeans are largely used for animal feed or oil and are also the primary GE crops, such exemptions imply that the legislation would have little impact.

The two phrases "contains GE ingredients" and "may contain GE ingredients" seem only subtly different, but these differences affect monitoring costs as well as who pays them. The first implies that ingredients are tracked or tested, processes that result in additional costs for anyone involved in growing, selling, or using GE crops. Use of the label "may contain GE ingredients" could eliminate monitoring costs for this group. The presumption would be that some ingredients probably are genetically modified, but if using such a label, one would not need to track, and indeed in some cases all of the ingredients might be GE-free. Because it would require no verification, the only additional cost is the trivial cost of the label itself.

Such subtle differences in wording shift the burden of the cost. In the former case, the direct cost of separation and monitoring is placed on producers, exporters, and processors of GE crops. In the latter case, the burden of separation and monitoring is placed on producers, exporters, and processors of GE-free crops. This cost would be recouped through charging a premium for GE-free food, or perhaps by increasing market share, or both. Clearly under mandatory "may contain GE ingredients" legislation no one would voluntarily label their product "GE-free" unless they expected to recover the cost of verifying that it is free of GE ingredients.

While commodity prices have remained low, the demand and premium for organic products (the best approximation for GE-free) have remained strong. Presumably this would provide incentives to shift to GE-free production and price convergence. How fast prices converge depends ultimately on demand and supply response. However, some farmers may not be able to obtain a premium for GE-free crops if there is no local buyer.

The imposition of mandatory labeling in much of the rest of the developed world and in a recent UN proposal (Codex Committee on Food Labelling, 2001) indicate that labeling of U.S. food exports is inevitable to maintain markets. What is unclear is whether it will extend to the entire domestic market and the form the wording of the label will take. Also, will there be a threshold level of GE content, and what might it be? What products might be exempt? Would labels such as organic, biologique, parve, kosher, and vegan be excluded from a GE label? Given the important role exports play in U.S. agriculture, these details are extremely important. Developing a coordinated set of international standards is vital to reduce information costs and send clear signals to farmers. Even if mandatory labeling is not implemented in the domestic market, the United States has an interest in coordinating international standards to ensure overseas markets for U.S. goods.

Opposition to Labeling: Follow the Money

Consumers clearly state they want labels. The proliferation of voluntary GE-free labels indicates that there is a market for such goods. So why is there opposition to labeling? Manufacturers of GE foods are not necessarily acting solely to avoid the direct cost of labeling, but they wish to avoid the potentially greater cost of liability. Under mandatory labeling, because all companies would bear the direct cost of labeling, they could pass it on to the consumers (which consumers bear that cost depends on the type of label, as discussed earlier). Liability costs, on the other hand, generally affect a single company, making it difficult for them to pass the costs on to consumers without becoming uncompetitive.

Fueling these liability concerns are insurance underwriters who either want compensation for underwriting the risk of GE food or wish to shift liability. In Latin America, insurers exclude GE crops from basic insurance policies, charging a special premium to cover them. Indeed, some insurance underwriters refuse to insure biotech firms against potential risks of GE food *at any cost*. Zurich-based Swiss Re, one of the largest international reinsurance companies, refuses to insure *any* risks associated with GE food.

Clearly, liability exposure would be reduced without mandatory labeling. A plaintiff would have a difficult time demonstrating that he had consumed GE food.

Indeed, the British Medical Association, representing over 80 percent of all British physicians, advocates mandatory labeling for the sole reason that it would be easier to identify, trace, and verify problems should they occur (Weiss 1999). Even the wording of the label ("may contain" versus "contains" GE foods) might make it difficult for the plaintiff to prove exposure to GE foods. This is quite apart from demonstrating that exposure to the particular GE ingredient caused harm. In other words, a plaintiff could convince a jury that the substance causes harm but still could lose the case because she is unable to demonstrate that she was exposed to it.

Minimizing liability exposure would explain why efforts to block labeling are concentrated in the litigious United States as opposed to Europe and Asia. Personal injury lawsuits in Europe and Asia are infrequent compared to those in the United States because they are costlier, drag on longer, and rarely result in the level of damages that occur in this country.

Another factor influencing the incentives to label is the distribution of where GE crops are grown. They are predominantly grown in the United States. Worldwide, the United States represents about 74 percent of all GE acreage. Argentina represents about 15 percent, Canada 10 percent, and the rest of the world 1 percent (*Biodemocracy News 2000*).

Conclusions

Human and animal health risks have been identified for only some specific applications of GE crops and are recognized in the 1992 FDA policy document on GE food. Despite this, the policy debate, analysis, legislation, and consumer opinion tend to treat all GE food the same. Indeed, some of our major trading partners and competitors have implemented mandatory labeling of GE food, resulting in lost export sales of U.S. agricultural products. The implication in the United States is that some form of labeling will be necessary for at least some export crops to avoid jeopardizing further sales.

The details of any labeling policy or legislation remain to be worked out, such as threshold levels, overlap or mutual exclusivity regarding other label names, and, most importantly, compatible international standards for labels. The wording and the implementation of any label will greatly affect how much it will cost and who pays for it. Mandatory "may contain GE ingredients" would be much less costly than mandatory "contains GE ingredients" because the latter would require monitoring, testing, or tracking of ingredients whereas the former would not. However, there is already a small and growing market in the United States for voluntarily labeled GE-free products. The purchasers of these products currently bear the costs.

Biotech firms have a strong incentive to oppose any kind of labeling in the litigious United States to minimize their liability exposure. Insurers have increased this incentive by charging extra premiums or refusing to insure at any price. Absence of labels reduces the ability of a potential plaintiff to easily trace consumption of GE food.

Currently, three policy alternatives for GE food labels are being pursued in the US:

1. *Laissez-faire*. Let the market for voluntarily labeled GE-free products evolve.
2. *Build on the 1992 FDA policy recommendations*. Develop explicit procedures and requirements for testing, reporting, and labeling of risky applications.
3. *Labeling legislation*. This is currently proposed in Congress and various state legislatures.

Voluntary GE-free labels are likely to continue even if labeling legislation passes in the United States because such legislation is directed at foods containing GE ingredients. Relatively cheap tests exist to verify the presence of many GE ingredients, and currently the market for GE-free food is profitable.

Domestically, if the laissez-faire policy is the only policy option pursued, it is likely to be criticized as elitist, since it provides choice only to those with money. Particularly if the price differential continues to be large for GE-free food, the poor would be unable to avoid GE foods even if they wished to. Given income distribution in the United States, it would not be long before such a policy would be criticized as one that disadvantages people of color. Not only do they earn less than Caucasians, but they also have a higher prevalence of food-related illnesses and allergies, and tend to have diets heavy in foods that happen to be GE crops.

The second and third options are being proposed in the United States. The FDA has proposed modifications in its GE food policy that would require premarket approval of any new GE food. It affirmed its opposition to mandatory labeling; however, it has provided some guidelines on voluntary labeling. Mandatory labeling legislation has been proposed in Congress and in several state legislatures. For both the second and third options, the details of the wording and implementation will determine who pays and how much they pay. However, the second option does not address the need to develop internationally recognized label standards to facilitate export sales.

Given that labeling legislation already exists outside the United States, it appears to be in our economic interest to have internationally uniform and clear standards. Without them, U.S. farmers will not have clear demand signals and will continue to lose export markets. The current policy disadvantages U.S. farmers and does not serve U.S. economic interests to maintain export markets for U.S. agricultural products. This would argue for having a uniform domestic labeling policy that coincides with internationally accepted standards, even if it applies only to our export products.

Lydia Zepeda is a professor in the Department of Consumer Science and director of the Center for Integrated Agricultural Systems at the University of Wisconsin–Madison.

References

Anderson, J. L., and E. Milewski. 1999. "Regulation of Plant-Pesticides: Current Status" (March). http://www.epa.gov/oppbppd1/biopesticides/otherdocs/ncipm_speech.htm

Bett, K. 1999. "Mounting Evidence of Genetic Pollution from GE Crops: Growing Evidence of Widespread Contamination." From *Environmental Science and Technology*, December 1, www.purefood.org/ge/gepollution.cfm.

Biodemocracy News 30 (November 2000), 2.

Carlson, G. A., M. C. Marra, and B. Hubbell. 1997. "The Economics of First Crop Biotechnologies." Raleigh: North Carolina State University.

Codex Committee on Food Labelling. 2001. "Proposed Draft Recommendations for the Labelling of Food and Food Ingredients Obtained through Certain Techniques of Genetic Modifcation/Genetic Engineering (Proposed Draft Amendment to the *General Standard for the Labelling of Prepackaged Food*). Twenty-ninth session, Ottawa, Canada, May 1–4, 2001. CX/FL 01/7.

Consumers Union. 1999. "Summary of Public Opinion Surveys Related to Labeling of Genetically Engineered Foods." www.consumersunion.org/food/summpollny699.htm.

Department of Health and Human Services, Food and Drug Administration. 1992. "Statement of Policy: Foods Derived from New Plant Varieties." *Federal Register* 57(104, May 29): 22984–23001.

Fischoff, B., P. Slovic, S. Lichtenstein, S. Read, and B. Combs. 1978. "How Safe is Safe Enough? A Psychometric Study of Attitudes toward Technological Risk and Benefits." *Policy Sciences* 9:127–52.

Starr, C. 1969. "Social Benefits Versus Technological Risk." *Science* 165:1232–38.

Thompson, P. B. 1996. "Food Labels and the Ethics of Consent." *Choices* (First Quarter): 11–13.

Weiss, R. 1999. "British Medical Association Warns of Health Hazards of GE Foods." *Washington Post*, May 18, A2.

Welsh, R. 1999. "The Economics of Organic Grain and Soybean Production in the Midwestern States." Henry A. Wallace Institute for Alternative Agriculture, May. www.hawiaa.org/pspr13.htm

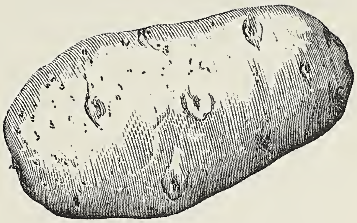
Zepeda, L., R. Douthitt, and S. Y. You. In press. "Consumer Acceptance of Agricultural Biotechnology: The Role of Labeling and Risk Perceptions on Food Demand." In *Transitions in Agbiotech: Economics of Strategy and Policy*, ed. R. Evenson, V. Santaniello, and D. Zilberman. New York: CABI.

For More Information

Environmental Protection Agency. 1998. "Reregistration Eligibility Decision (RED) *Bacillus Thuringiensis*." EPA738-R-98-004. Washington, D.C.: Environmental Protection Agency.

Slovic, P. 1987. "Perceptions of Risk." *Science* 236:280–85.

Off the Farm: Transportation, Storage, and Handling Issues



John Petty

I recently heard a radio commentator state, when questioned as to what to do regarding genetically modified organisms (GMOs), "The simplest answer is to label everything." This statement assumes a great deal of infrastructure and procedures in grain handling that currently, by and large, don't exist. To the uninformed, "label everything" may seem like a quick fix—that is, until we think about the changes such a policy would require.

First, a little history. The current grain-handling system was developed over many years as the most efficient and economical system to gather, store, and transport a fungible commodity. Most grain handlers dealt with two or three different commodities at most. Why? Because it was the most efficient method for them. They had less need for the separate storage bins that would be necessary for multiple commodities, and existing space could be used to maximum efficiency. To paraphrase Gertrude Stein, corn was corn was corn.

If GMO crops were to be labeled, what type of grain-handling system would be necessary? Within the United States there exist two parallel handling systems—one for handling human food grade commodities, and the other for handling animal feed or industrial-use commodities. These parallel systems are not perfectly segregated, and latitude exists in the segregation based on the type of human usage for which the commodity will be processed. For example, corn that is going into cornflake production for breakfast cereal is graded much more stringently than corn going into high-fructose corn syrup (HFCS). Obviously, corn destined for HFCS will be processed much more heavily than corn for cornflakes. Both are perfectly safe for human consumption, but eliminating broken kernels and moisture content is not as critical to HFCS production as it is to cornflake production.

That said, if labeling is mandated, identity preservation is required. And identity preservation means segregation of GMO crops from non-GMO crops in the storage, handling, and transportation of the commodities. This means that every grain handler in the country might have to instantly double the number of commodities they currently handle—that is, they would handle a GMO and a non-GMO version of each commodity. Because of identity preservation, these two versions are viewed (and handled) as separate, distinct commodities. Before GMO, the worst thing that a grain dealer could do was mix two commodities, typically corn and soybeans. The commodity mistakenly put in the wrong storage bin instantly becomes what is known in the trade as *foreign material*. And because there is no economical method of separating the two commodities, the commodity that now contains foreign material has its percentage weight, as determined by sample testing, deducted from the volume of the whole. The net effect is that the grain handler or producer loses the value of the commodity that was dumped into the other commodity's storage bin. Under identity preservation, you wouldn't simply have a commingled commodity—you'd now have a different commodity. And that commodity would have the value of the GMO-grade commodity.

Simple segregation is not as simple as keeping each commodity in its proper bin. Seed companies concede that their non-GMO-labeled seed may contain GMO germ plasm. Cross-pollination can occur in corn when pollen is moved by insects or the wind. Most pollen will fall within 50 feet of its source, and USDA guidelines require buffers of 660 feet around GMO-planted fields to keep pollen drift to a minimum. However, I know of reports here in Wisconsin of corn pollen traveling over a mile and a half. Even if the producer gets a GMO-free seed and experiences no pollen drift, commingling can occur at every step in which the commodity is handled. Planters, harvesting equipment, storage bins, and transportation equipment may have been used to handle a GMO product and were not thoroughly cleaned. A single kernel is enough to change a labeled non-GMO quantity to GMO-positive.

Because so many chances for commingling exist, testing should and will have to be done at every step where the commodity changes hands. But there are problems with testing, too. Currently, there is no quick, inexpensive spot test available to test for any and all GMOs. There do exist "quick tests" that take about five minutes and test for *one* single type of GMO. In this case, if you don't have the right test for the right GMO, your test comes up negative. In order to test a sample for most GMOs, a test costing about $350 that takes two to three days for results to be reported is available. Obviously, use of this test is problematic when a grain handler is faced with truckloads of producer grain waiting to unload at a facility. Also, not all GMO crops express their trait in the seed. Some have the trait *only* in the vegetative parts of the plant, so testing the harvested kernels would yield a negative test even though the plant is definitely GMO.

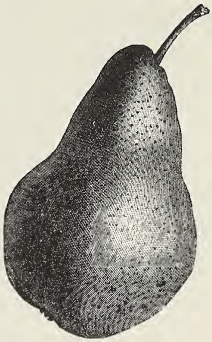
Another problem with any test is the quality of the sample. If a sample isn't representative of the whole, the best test methodology and equipment are worthless and the test itself is called into question. Also, there is currently no available nondestructive test; it is impossible to give complete assurance that a particular quantity is 100 percent non-GMO because by definition, one cannot test every single kernel.

Given the problems and uncertainties of testing, the industry will likely impose a system of warranty conditions on each seller in the line of transactions. This means each seller will be liable for the product they sell if it proves not to match their provided product description. If you wish to see a vision of the future, I ask you only to monitor the news stories concerning the legal battles resulting from the StarLink™ fiasco. In that situation, the StarLink™ hybrid was the only GMO corn not approved for both human and animal consumption. StarLink™ corn eventually was found in several brands of taco shells and resulted in nationwide recalls of the products. All of the affected corn flour was traced to one mill in Texas. In order to keep StarLink™ out of human food channels, Aventis, the company that registered StarLink™, and the U.S. Department of Agriculture agreed to develop plans under which the Commodity Credit Corporation would purchase StarLink™ corn at a cost into the multimillions of dollars. In addition, various food companies that were affected by the recalls sued Aventis. The only definite point that we know now is the USDA's statement that a single market approval of a GMO variety will *never* be allowed again.

So this is where we came in. "Label everything" is not the simplest solution. Labeling advocates must first understand a couple of concepts before we are able to move forward. First, realistic, allowable tolerances must be set to account for adventitious presence of GMO. As an example, the U.S. Food and Drug Administration (FDA) currently allows labels to read "fat-free" or "sodium-free." Does this mean there is 0.0 percent fat or sodium in those products? No, it does not. The FDA allows for a minimal tolerance level while still maintaining the "-free" label. Second, there will be costs involved in expanding the grain-handling infrastructure. These costs will be borne by people at one end or the other of the production/consumption chain. If consumers are willing to pay a premium for non-GMO products over the long term, identity preservation procedures and infrastructure plans will begin developing tomorrow morning. If consumers are not willing to pay a premium for non-GMO products and labeling is required, the costs will be shifted to producers. Given the current state of low prices and a weak agricultural economy, will this alternative be palatable? Either way, "label everything" is not the simple answer some would like to believe it is.

John Petty is executive director of the Wisconsin Agri-Service Association, the trade association for the feed, seed, grain, and farm supply industries in Wisconsin. He has served in many positions in the commercial grain industry thougout the Midwest and has coauthored a standard reference work, The Practical Grain Encyclopedia *(The Commodity Center, Chicago, 1985, revised 1991, 1996).*

University Ownership of Patents: The Bayh-Dole Act and Using Patents for the Public Good



Carl E. Gulbrandsen and Howard W. Bremer

In the university community there has long been a dichotomy with regard to whether universities should own patents and engage in licensing (technology transfer in today's parlance). Pertinent to the opposing views in that dichotomy are three questions:

1. Does patent ownership positively serve or subvert the university's mission?
2. Does patent ownership frustrate or encourage creativity in the university setting?
3. Does patent ownership by the university serve the public good?

An additional, broader question might also be posed:

4. Do the results of university research benefit national industries?

What Is the Bayh-Dole Act?

The Bayh-Dole Act was a seminal piece of legislation that is as pertinent and viable today as when it was signed into law in 1980. Its terms and provisions indicated, after many years of advocacy, that Congress had finally recognized that

1. imagination and creativity are truly a national resource;
2. the patent system is the vehicle that permits the delivery of that resource to the public for its use and benefit;
3. placing the stewardship of the results of basic research in the hands of universities and small businesses is in the public interest; and most significantly,
4. the pre-existing nonuniform federal patent policy was placing the United States's role as a technological and economic leader in peril at a time when invention and innovation were becoming the preferred currency in foreign affairs.

This recognition is clearly enunciated in the policy and objective section of the statute itself.

> **35 U.S.C. 200 Policy and Objective**
> It is the policy and objective of the Congress to use the patent system to promote the utilization of inventions arising from federally supported research or development; to encourage maximum participation of small business firms in federally supported research and development efforts; to promote collaboration between commercial concerns and nonprofit organizations, including universities; to ensure the inventions made by nonprofit organizations and small business firms are used in a manner to promote free competition and enterprise; to promote the commercialization and public availability of inventions made in the United States by United States industry and labor; to ensure that the Government obtains sufficient rights in federally supported inventions to meet the needs of the Government and protect the public against nonuse or unreasonable use of inventions; and to minimize the costs of administering policies in this area.

Of great significance to the universities and other nonprofit institutions as well as small businesses, to which the statute is directed, it changed the presumption of ownership of any invention made by those entities utilizing federally supplied funds from the government to those entities. That change presaged a new and expanding relationship between the universities and industry because it assured industry that certainty of title to the invention lay with the universities.

The original Bayh-Dole Act, enacted as Public Law 96-517, was later amended by Public Law 98-620 in 1984, which removed many of the politically expedient restrictions that were in the original act. The amended act is now part of the *United States Code* and may be found at 35 U.S.C. 200-212. Its implementing regulations are found in the *Code of Federal Regulations* at 37C.F.R. part 401.

The codified act still contains a preference for U.S. industry as well as a preference for small business, with the latter preference undoubtedly arising from the recognition that small businesses create the bulk of new jobs. As for the nonprofit sector, there is a prohibition against assigning rights to an invention created in whole or in part with federally supplied funds without the permission of the government (except that such assignment may be made to an entity that has, as one of its primary functions, the management of inventions). There is also a requirement to share royalties generated on an invention with the inventor and to use the balance of royalties, after expenses, for support of scientific research or education.

In all cases the government retains a royalty-free, nonexclusive license to practice the inventions for governmental purposes and also reserves march-in rights in the event of abuse or when the contractor (university or small business) has not taken effective steps toward practical application of the invention, or the invention is necessary to alleviate health or safety needs not satisfied by the contractor or its license.

The passage of the Bayh-Dole Act may be viewed as the ultimate culmination of a Wisconsin Idea that began with Professor Harry Steenbock and the formation of the Wisconsin Alumni Research Foundation (WARF) in 1925. Professor Steenbock's vision was to develop a plan to make use of patentable inventions generated by the faculty that would

1. protect the individual taking out the patent,
2. insure proper use of the patents, and at the same time
3. bring financial help to the university to further its research effort.

Subsequent efforts by and on behalf of the University of Wisconsin and WARF led to the first breakthrough on reversal of the policy that most government agencies had adopted, which was to take title to all inventions made in whole or in part with federal funds. Under that title policy, the government held title to some 30,000 patents, fewer than 5 percent of which were even licensed for commercialization, and fewer than 1 percent of which found their way into the marketplace.

The breakthroughs represented by the first new institutional patent agreement with the Department of Health, Education and Welfare in 1968 and an agreement with the National Science Foundation in 1973 (the first such agreement issued by that foundation) were highly significant milestones on the road to ultimate negotiation and passage of the Bayh-Dole Act. One might, in fact, view the act as a codification of the terms and provisions of the institutional patent agreements.

Benefits of the Bayh-Dole Act

The benefits the university sector derived from the Bayh-Dole Act are numerous and far-reaching. The number of patents issued to universities has increased dramatically so that of all U.S. patents, the university sector now receives about 3 percent. Moreover, those patents, since they arise primarily from the results of basic research, can often afford the basis for whole new products or even industries, as in, for example, the biotechnology industry. The certainty of title in the universities has permitted a closer relationship with industry. That certainty of title also provides the assurance that the underlying research cannot be frustrated because the rights are given away to industry. There is an opportunity to share in the commercial success of a licensed invention, and in particular an opportunity and basis for start-up companies based on basic research observations and results are provided.

At the same time, university-owned patents protect academic freedom to conduct research. Incentive is provided inventors in that they share in any royalties generated. Any excess over the inventor's share and expenses are utilized to support further research or education. Patents, when issued (or, now, when published as applications), comprise a form of scientific publication for the inventor and therefore contribute to an inventor's scientific recognition in the university community. Through responsible licensing arrangements, university-owned patents serve the public interest by guarding against abuse.

With regard to serving the public interest, in 1980, the same year in which the Bayh-Dole Act was passed, a Supreme Court decision had far-reaching consequences and effect on the patent system as well as on the patenting of "living" things (*Diamond, Commissioner of Patents and Trademarks v. Chakrabarty,* 206 USPQ 193). The essence of the decision was that merely because something was alive (in this case, a bacterium) it was not disqualified from being patentable subject matter—to paraphrase the court's ruling, it considered that "anything under the sun in which the hand of man had intervened" was patentable. This opened the door to the patenting of many life forms and provided the fundamental basis for the biotechnology industry. It also ultimately led to the ability to obtain a utility-type patent on genetically modified organism (GMO) plant products as well as other genetically modified life forms, with the exception of humans.

Patents Serve the Public Good

University-owned patents serve the public good by offering a means to control the irresponsible application of the patented technology. One should not, however, equate such type of control with monopoly. A patent gives the right to exclude others from practicing the invention claimed in the patent document itself. It does not convey an absolute right to practice the invention claimed. There may be other extant patents that may dominate the claimed invention. Thus to practice the claimed invention, a license under the dominant patents would also be required.

Further, the right to exclude others from practicing the invention of a patent extends for a limited time, after which anyone having a desire to practice the invention is free to do so. This was the compromise reached in establishing the constitutional authority for the U.S. patent system. Thus, after patent expiration the invention becomes part of the pool of scientific knowledge available for others to use.

In addition, the protection patents offer, namely, the right to exclude others from practicing the claimed invention, is a strong inducement for the patent holder or its licensee to expend the risk money necessary to develop a given invention for the marketplace. Because the bulk of university-generated inventions arise during the course of basic research, they tend to be embryonic in nature, requiring substantial investment in technical development for commercial application. Also, market development needs to be addressed after technical development has been achieved. The latter two activities, technical development and market development, are generally recognized as requiring substantially more money than the making of the invention itself (although the cost assessment of an invention generally ignores the cost of bringing the inventor to the state of mental preparedness for making the invention).

Before Professor Steenbock's formation of WARF, others at the University of Wisconsin had experienced the pitfalls of not protecting the public through the patent systems. Around 1890, Professor Stephen Babcock at the University of Wisconsin had developed a test and centrifugal machine for determining the butterfat content of milk. He did not seek a patent but merely published his invention, in effect abandoning it to commercial interests. The result was that without the university's ability to exercise control of commercial development for widespread use, commercial development efforts were at best uneven and lacked standardization. In fact, some of the centrifugal machines marketed for conducting the test were so shoddily constructed that they posed a hazard to users. These facts supported the proposition that a patent on an invention that gave the inventor some control over its commercialization seemed appropriate and in the public interest.

University-owned patents in the rapidly expanding field of GMO products may be highly beneficial for the public good. The university researcher has the opportunity to seek the answer to open-ended basic questions, and university-owned patents can help assure that that opportunity remains available. In contrast, industry may not have that luxury, being driven primarily by a product orientation—despite government requirements to test GMO products before their introduction into the marketplace.

These considerations were of vital importance with regard to a particular discovery at the University of Wisconsin–Madison (technology developed by Jerry Kermicle in 1999), and the kind of protection, if any, that should be sought on it. The discovery involved a traditionally bred cross-pollination barrier for corn. With mere publication of the discovery and release of the germ plasm, it could be used by anyone for any purpose, including the preparation of GMO products, in which case the projected special utility of the invention—the value of the technology—would likely be destroyed. If the plant variety protection (PVP), without more, had been sought, again the special utility of the discovery may have been lost because PVP allows free breeding. Seeking utility patents on the discovery was chosen as the mode of protection. This type of patent permitted prohibition of the germ plasm's use in GMO corn while promoting its use as a barrier against convection pollination from GMO cornfields to non-GMO cornfields, since the barrier would prevent pollination by GMO corn pollen. Thus, the patent system gave the means by which both GMO growers and non-GMO growers could be accommodated while permitting the public interest in both kinds of crops to be served.

The University of Wisconsin-Madison and the Wisconsin Alumni Research Foundation

The mission of the university is to discover and transmit knowledge and provide service to the public. WARF enhances those endeavors of and by the university through the management of the intellectual property discovered or developed at the university to support research at the university, and by moving inventions and discoveries resulting from university research to the marketplace for the benefit of the university, the inventor or discoverer, and society as a whole.

WARF was established in 1925 based upon the vision of Professor Harry Steenbock, who had discovered and filed patent applications on a method for producing vitamin D in food and drugs by exposing them to ultraviolet radiation. Professor Steenbock offered his patents to the university but the university declined to accept them. He then envisioned, as opposed to selling his right to a commercial entity, that whatever patents might issue from his applications should be administered and regulated in the public interest by an entity independent of and separate from the university. The fruition of his vision was the formation of WARF as a tax-exempt, not-for-profit corporation to administer inventions made at the university and voluntarily brought to WARF by the inventors. Even today, submission of inventions to WARF by university employees (faculty, staff, and students) is voluntary, since the university does not assert any right to title of inventions made on or in association with its campus. The exception to this position is that for any inventions made in whole or in part with federal funds, the university as the contractor may in the first instance elect to retain title in accord with the terms and provisions of the Bayh-Dole Act. The university has officially designated WARF as its intellectual property manager under that act.

In the year 2000, WARF celebrated its seventy-fifth year in its role as manager of intellectual property on behalf of the university through the patenting and licensing of technology generated at the university to the private sector. That WARF has been an unqualified success in that activity is clear from WARF's consistent position among the top five or ten universities engaged in technology transfer in the United States as measured by its royalty income. With regard to the number of life-saving and other inventions that have contributed to the betterment of the health, welfare, and safety of the public, it is firmly believed that WARF has no peer. Many such inventions generated at the university are still being practiced today, long after the royalty flow from them has ceased, and therefore are still contributing immeasurably to the public benefit.

As a result of WARF's technology-transfer activities and because of the foresight, policies, and management of its trustees, WARF's contributions to the university have been highly significant and have been instrumental in establishing and maintaining the University of Wisconsin as one of the world's premier universities.

Conclusion

Federal support for research in the university sector is essential to the technological leadership of the United States in a global economy. Every indication exists that this

WARF's total grants and commitment to the university since its first grant of $1,200 was made in 1928 through June 30, 2001, are as follows:

General research grants	$400,000,000
Buildings, land, major equipment	60,000,000
BioStar building initiative	80,000,000
Other	80,000,000
	$620,000,000

is a recognized fact, evidenced by that sector's leadership in performing the bulk of basic research in the country. Protection of the intellectual property generated during the course of that research and transfer of the technology that it represents for public use and benefit is viewed as an obligation under the Bayh-Dole Act. The university sector has responded to both the opportunities and the obligations presented by the act, and its performance has reinforced the following perceptions:

1. University-owned patents encourage innovation by providing an incentive to inventors and facilitating publication.
2. University-owned patents support the research function in the university sector by protecting academic freedom to conduct the research; generating royalty income; providing further support for research; and providing an incentive to the researchers.
3. University-owned patents serve the public good by guarding against abuse by irresponsible parties and insuring the opportunity to maximize the transfer of technology that is developed during the course of research conducted at the university in the interests of the health, safety, and welfare of the public.

Howard W. Bremer is currently affiliated with the Wisconsin Alumni Research Foundation (WARF) in a consulting capacity. He served as patent counsel to WARF from 1960-1988. He holds degrees in chemical engineering and law from the University of Wisconsin–Madison.

Carl E. Gulbrandsen has been the managing director of the Wisconsin Alumni Research Foundation (WARF) since January 2000. Prior to that he was the director of patents and licensing and in private law practice. Gulbrandsen received his B.A. from St. Olaf College, Northfield, Minnesota; his PhD degree in physiology from the University of Wisconsin–Madison; and his J.D. degree from the University of Wisconsin Law School.

Appendix

Fall Forum 2000 Agenda

8:30 Welcome Address

Mary Lynne Donohue—Wisconsin Academy Council President

Ben Brancel—Secretary of the Wisconsin Department of Agriculture, Trade and Consumer Protection

Morning Plenary: Overview and Perspective

Philipp Simon—Professor of Horticulture,
University of Wisconsin–Madison
Genetic Modification of Plants: Progress, Processes, and Products

Jeffrey Burkhardt—Professor of Ethics and Policy,
Institute of Food and Agricultural Sciences, University of Florida
The Roles of Differing Ethical Paradigms in Determining the Acceptability of GMOs/GM Foods

10:00 Concurrent Discussion Sessions

I. Farming: Conventional to Organic

Bradford L. Barham—Professor,
Agriculture and Applied Economics, UW–Madison
Adoption Patterns of Agricultural Biotechnology by Wisconsin Farmers: Recent Evidence

Gary Goldberg—CEO, American Corn Growers Foundation
Genetically Modified Crops and the American Farmer: Matching the Rhetoric With the Realities

Steve Pincus—Organic Farmer, Tipi Organic Produce, Fitchburg
Risks, Rewards, & Realities: An Organic Farmer's Perspective

Facilitated by Bradford L. Barham

II. International Dimension: Trade, Technology, World Needs

Lori P. Knowles—Associate for Law and Bioethics,
The Hastings Center, Garrison, New York
Patenting Life: Preserving Biodiversity and Justice in International Trade

Richard Manning—Environmental Writer
Food's Frontier: The Next Green Revolution

Mark Ritchie—President,
Institute for Agriculture and Trade Policy, Minneapolis
International Trade Issues

Facilitated by Karl Nichols, Research Scientist,
Third Wave Technologies, Madison

III. Environmental Benefits/Concerns

Bob Giblin—Morgan & Myers, Public Relations Firm in Jefferson
Biotech Public Relations: Art and Science

John Kaufmann—Science Fellow and Agronomist,
Monsanto Company, Middleton
Ecological Assessment of Biotech Crops

Frederick Kirschenmann—Director,
Leopold Center for Sustainable Agriculture, Iowa State University
Genetic Engineering in Agriculture: Some Underlying Questions

Michelle Miller—Pesticide Use and Risk Reduction Project,
UW Center for Integrated Ag Systems
GE Food, Pesticides, and the Environment: Issues for Developing Public Policy

Facilitated by Craig Trumbo, Professor,
Life Sciences Communication, UW–Madison

IV. Seed to Store

M. Troy Flanagan—Grocery Manufacturers of America
Biotechnology in the Real World

Hemanth Shenoi—Product Manager in Molecular Diagnostics,
Promega Corporation
Methods for GMO Detection: How Do We Determine What's In What We Eat?

John Petty—Executive Director, Wisconsin Agri-Service Association:
Off the Farm: Transportation, Storage and Handling Issues

Facilitated by Frederick H. Buttel, Chair, Rural Sociology, UW–Madison

V. Corporate vs. Public Ownership of Technology and Crops

Kristin Dawkins—VP for International Programs, Institute for Agriculture and Trade Policy
Ownership of Life: When Patents and Values Clash

Carl E. Gulbrandsen—Managing Director, Wisconsin Alumni Research Foundation
University Ownership of Patents: The Bayh-Dole Act and Using Patents for the Public Good

Charles Sara—Partner and Chair of the Intellectual Property Practice Group, DeWitt Ross & Stevens, S.C.
The Private Side of Patent Ownership: The Risks, Rewards and Realities of Intellectual Property Ownership from a Private Business Perspective

Facilitated by Elizabeth Bird, Outreach Specialist, UW Center for Integrated Ag Systems

12:00 Luncheon

Daniel Charles—Science Writer
The Story Is Mightier Than the Data: Instructive Tales From the Brief History of Genetically Modified Crops

1:30 Afternoon Plenary: Risks, Rewards, and Realities: Searching for Common Ground

John Kaufmann—Science Fellow and Agronomist, Monsanto Company, Middleton

Richard de Wilde—Organic Farmer, Harmony Valley Farm

Kristin Dawkins—VP for International Programs, Institute for Agriculture and Trade Policy

Richard Manning—Environmental Writer

Facilitated by Jeffrey Burkhardt, Professor of Ethics and Policy, Institute of Food and Agricultural Sciences, University of Florida

4:00 Closing

Robert M. Goodman—Professor of Plant Pathology, UW–Madison

ISSN 0084-050

Brad Barham
Norman Borlaug
Jeffrey Burkhardt
Dan Charles
Carl Gulbrandsen
Fred Kirshenmann
Lori Knowles
Richard Manning
John Petty
Vernon Ruttan
Lydia Zepeda

What is the promise and what are the dangers of genetically modified foods? Like it or not, such foods are already in our lives. More than half of all foods produced in the United States now contain genetically modified ingredients. Whether you see such foods as a godsend that could end world hunger or a "Frankenfood" leading to disastrous outcomes, it is vital for all members of the public to be informed about genetically modified foods: their risks, rewards, and realities.

This book arose out of a public forum on genetically modified foods that brought together a wide range of leading thinkers from across the nation—scientists, policymakers, conservationists, industry and agriculture representatives, educators, and more—to share their perspectives on the subject. Their diverse viewpoints are reflected in this volume, which provides a sophisticated yet accessible presentation of one of the most complex issues of our time.

Edited by Frederick H. Buttel, Ph.D.,
Professor and Chair, Department of Rural Sociology
and
Robert M. Goodman, Ph.D.,
Professor of Plant Pathology
University of Wisconsin–Madison

Wisconsin Academy of Sciences, Arts and Letters
1922 University Avenue
Madison, Wisconsin 53705
www.wisconsinacademy.org