STATE OF NEW YORK

CONSERVATION DEPARTMENT

A BIOLOGICAL SURVEY OF THE OSWEGO RIVER SYSTEM

Supplemental to Seventeenth
Annual Report, 1927

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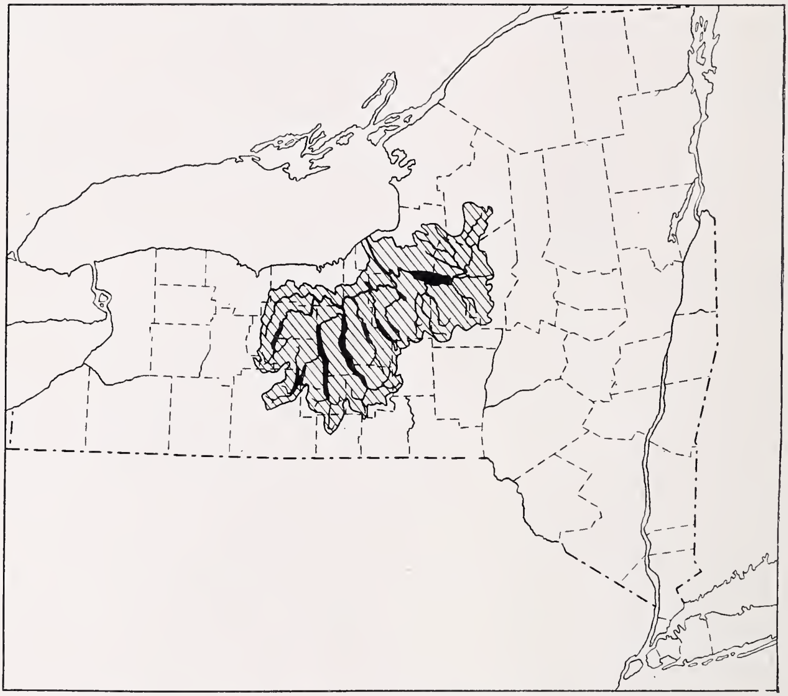

Shaded area is coverage included in the survey of the Oswego river system.
Area 5,002 square miles

A BIOLOGICAL SURVEY OF THE OSWEGO RIVER SYSTEM

Supplemental to the Seventeenth Annual Report, 1927

Introduction

By Emmeline Moore

Investigator in Fish Culture, in Charge of Survey

The report submitted herewith deals with the biological survey of the Oswego river system in its relation to the fisheries. This is the second watershed to receive intensive study since the establishment of the Conservation Fund in 1925. With the completion of the two surveys, the Genesee system last year and the Oswego system this year, the ground covered comprises a little more than one-sixth of the area of the State. As the surveys progress, the Department is enabled to proceed with its program of stocking the streams and lakes of the State on a more intelligent and scientific basis and to provide for further study where the survey brings to light urgent problems bearing on the future status of the fisheries.

Area Covered by the Survey.—The portion of New York State included in the Oswego river system and covered by the survey is shown on the accompanying map (frontispiece). The area of 5,002 square miles covers in part 12 counties. In point of size in the State, this watershed is exceeded only by the Hudson river system.

Within this coverage lies a water storage basin and stream system of unusual interest and importance to the people of the State. The seven Finger lakes are a conspicuous differentiating feature. Each is a deep glacial valley, the reservoir of a vast volume of naturally pure, cold water supplied by underground springs and inlet streams. The great diversity of beauty existing in the valley slopes and the accessibility of the lakes combine to make this region a distinctive recreational resource. The water area of the Finger lakes comprises 195.60 square miles. The largest of these (Seneca) has a length of 30 miles, and a depth of 634 feet. As to fish life, the Finger lakes have a varying reputation in productivity. Oneida lake, the largest single lake in the watershed, with an area of 79.80 square miles, is relatively shallow, rich in the elements that make good fishing water and rates high in productivity.

Besides these larger bodies there is an assemblage of about 40 small lakes and ponds aggregating approximately 95.52 square miles which with the above mentioned areas supply a combined water surface in lakes and ponds of about 289.22 square miles.

The lake and pond water areas are further augmented by about 7,000 miles of streams and 106 miles of barge canal waters. Three large rivers, the Clyde, Seneca and Oneida, unite the outlets of the lakes to form the Oswego river which carries the drainage into Lake Ontario. Of the 7,000 miles of streams in this watershed, 1,688 miles are considered worthy of stocking and of this mileage, 1,430 are suitable waters for trout.

Authorization of Survey.— On March 31, 1927, an appropriation of $50,000 was made from the Conservation Fund (chap. 592 of the Laws of 1925) for "the biological survey, including fish protection." In pursuance of this provision this survey, the second in the series, was undertaken in the Oswego watershed during the summer of 1927. The report of the first survey, that of the Genesee river system, became available for distribution early in the current year.

Statistics.— According to the records of the Conservation Department the number of fry and fingerlings distributed from the State hatcheries into the Oswego river system totals for the ten-year period, 1917-1926, 365,630,572 young fish. The distribution by species is shown in Table 1.

It is a staggering number of fish to have carried through the hatching process and to have distributed in the watershed. The question may well be asked, "What has been the catch?" In practice such data are very hard to get. A few sporadic attempts are made by sportsmen's clubs to collect data on the catch but as a whole interest lags. Yet it is no longer a matter of individual or even local interest but a part of a larger problem of the evaluation of the fishery water. Any sort of satisfactory fishery statistics if they could be obtained would assist in disclosing the condition and trend of each fishery and in the improvement of legislation therefor.

Program of Investigation.— The primary object of this survey, as in the initial one of the series, is the development of a stocking policy for the streams and lakes of the watershed based on a scientific understanding of conditions existing therein. Important considerations relate to productivity, the correlation of species of fish with different types of waters and the control of competitive or destructive species. Investigation has proceeded under three main lines—lake survey, stream survey and carp control studies together with contributory studies dealing with pollution, distribution, parasitism, plankton and other food resources. The several papers on these subjects incorporated in this report present the results of the survey for this year included mainly within the dates of June 15 to September 15, 1927.

It is manifestly impossible in a single season to cover by intensive study all fisheries problems arising in the region of the survey. For this reason each unit stream system is given a somewhat comprehensive treatment with subsequent arrangement and provision for correlated research on urgent problems.

Table 1. — Plantings of Fish in the Oswego System, 1917–1926

Water	Lake trout	Trout species	Land-locked salmon	Whitefish	Smelt	Green-back herring	Pike-perch	Yellow perch	Small-mouthed bass	Miscel-laneous *	Total
Finger lakes											
Canandaigua	941,250	2,000	....	5,750,000	8,500,000	....	3,411,000	43,500	12,500	*e* 9,500	18,669,750
Keuka	2,085,625	92,425	....	....	....	....	....	....	19,400	....	2,197,450
Seneca	2,118,675	186,400	....	1,000,000	....	2,000,000	400,000	10,900	16,700	....	5,732,675
Cayuga	1,472,450	10,600	....	480,000	10,000,000	....	11,400,000	110,450	17,000	*a* 5,440	23,495,940
Owasco	780,300	66,200	....	....	12,854,000	....	4,650,000	4,000	....	*e* 10,000	18,364,500
Skaneateles	404,765	....	25,500	....	5,000,000	....	....	5,000	6,400	*e* 15,000	5,456,665
Otisco	6	3,000	....	....	....	....	4,450,114	15,000	22,959	*a* 859 *b* 10 *c* 10 *d* 55 *f* 75,000 *g* 10 *h* 4 *i* 2	 4,567,029
Oneida lake	....	....	....	350,000	....	....	233,150,000	350,000	513,500	....	234,363,500
Barge canal	....	29,330	....	....	....	....	6,900,000	137,400	4,600	*a* 800	7,072,130
Small lakes and ponds	....	83,762	....	....	....	....	16,545,000	231,600	70,081	*h* 2,252 *a* 1,725 *j* 600	 16,935,020
Trout streams	....	6,051,035	....	....	....	....	....	....	....	....	6,051,035
Warm streams	....	....	....	....	....	....	22,390,000	229,600	103,350	*a* 300 *h* 1,600 *k* 28	22,724,878
	7,803,071	6,524,752	25,500	7,580,000	36,354,000	2,000,000	303,296,114	1,137,450	786,490	123,195	365,630,572

* *a* Bullheads, *b* sunfish, *c* rock bass, *d* strawberry bass, *e* buckeye shiner, *f* muskalonge, *g* pickerel, *h* large-mouthed bass, *i* catfish, *j* calico bass, *k* miscellaneous adults.

The preparation of a program and the conduct of so large a project as the survey involved were made the object of a conference called by the Conservation Commissioner. Scientists representing each of the cooperating institutions and others were present as follows:

Alexander Macdonald, Commissioner, presiding.
Dr. W. C. Kendall, Ichthyologist, U. S. Bureau of Fisheries.
Mr. E. Higgins, Scientific Inquiry, U. S. Bureau of Fisheries.
Dr. Geo. C. Embody, Aquiculture, Cornell University.
Dr. A. H. Wright, Zoologist, Cornell University.
Dr. W. C. Muenscher, Botanist, Cornell University.
Dr. E. H. Eaton, Biologist, Hobart College.
Dr. Chas. C. Adams, Director, State Museum.
Dr. Gertrude Douglas, Botanist, State College.
Mr. F. E. Wagner, Chemist, Rensselaer Polytechnic Institute.
Dr. P. H. Struthers, Zoologist, Syracuse University.
Llewellyn Legge, Chief Protector, Division Fish and Game.
Emmeline Moore, Director of Survey.
Sumner Cowden, Field Superintendent.

General guiding principles were adopted governing action between the Conservation Department and outside agencies (State universities, colleges or other educational institutions) cooperating with the Conservation Department. They are as follows:

1. The present policy of considering watershed areas as the unit area for study shall be continued as the permanent policy.

2. Specialists and workers generally shall be selected on the basis of training and fitness.

3. The distribution of tasks shall be by duties rather than by localities.

4. The individuals in charge of different portions of the survey shall have such measure of freedom in the choice of helpers and in the conduct of their work as is compatible with the objects sought by the Conservation Department.

5. Individuals responsible for suggesting policies shall be given access to all data bearing on their work by whatever portions of the survey gathered.

6. In the publication of results, full credit shall be given to cooperating institutions and individuals.

7. Any financial obligation incurred by special work for the Conservation Department through the use of materials or equipment in the laboratories of the State or other cooperating institutions shall be borne by the Conservation Department only on authorization.

Personnel.— In the conduct of this survey the Conservation Department has had the cooperation of five educational institutions in the State—Cornell and Syracuse Universities, Hobart College, Rensselaer Polytechnic Institute and the State Normal College—with specialists from each of these institutions actively engaged in the field investigations. With such participation there can be no doubt that there has been inaugurated a program of far reaching importance which to an increasing degree as it is continued through the years will provide a sound program of study and form the basis of constructive administration of our fisheries resources.

Stocking Lists and Maps.— A key map of the watershed (see appendix) affords a convenient guide in locating the particular quadrangle, county or township in which the reader is interested. It also serves to orient in the watershed the quadrangle maps (U. S. G. S. topographic maps) adapted for purposes of record in the survey. On these maps (1-7) all streams are shown with suitable indications of dry and permanent streams, the presence of springs, pollution outfalls, favorable places for fish planting and the appropriate species. Accompanying the maps are the stocking lists (App. III-XI) which set forth in tabular form the name of the streams (if not named then numbered), the mileage available for stocking and the stocking policy per mile. By reference to these tables and maps the location of the best places to plant fish and the calculation of the number per mile may be determined readily.

Distribution of Fish in the Watershed.— The contributions to this aspect of the survey supply a wealth of data concerning the species inhabiting the Oswego drainage area. One hundred species of fish representing 24 families are listed. Of these 43 species are of the food and game variety. Of the 57 non-food and non-game species some have inferior value as food and are occasionally so used. Two species have become extinct.

A distribution chart* pictures the whereabouts of the different species in the drainage basin.

The Colored Plates of Fishes.—The twelve drawings of fish shown in color are the work of the artist, Ellen Edmonson, who has reproduced them with great fidelity to scientific detail and to the sensitively beautiful coloring as they appear on coming from the water.

Aside from the enjoyment derived in the beauty of line and color the reproductions serve an important function educationally in emphasizing species of special interest and value to the fishery of the watershed. The sawbelly or alewife, a plankton feeder and a non-competitive species, is the food *par excellence* of the lake trout and where the balance between these two is well maintained, as in Seneca and Keuka lakes, the fishing is good. The cisco and whitefish also plankton feeders wholly or in part are in the same category and should be fostered. The lake lamprey is the "vermin" of the waters in Cayuga, Seneca and Oneida lakes. The eelpout or gudgeon and carp are species of ill repute. The minnows and darters are popular as bait or related in important ways organically to the lake and stream life. The sculpin is an index of brook trout waters.

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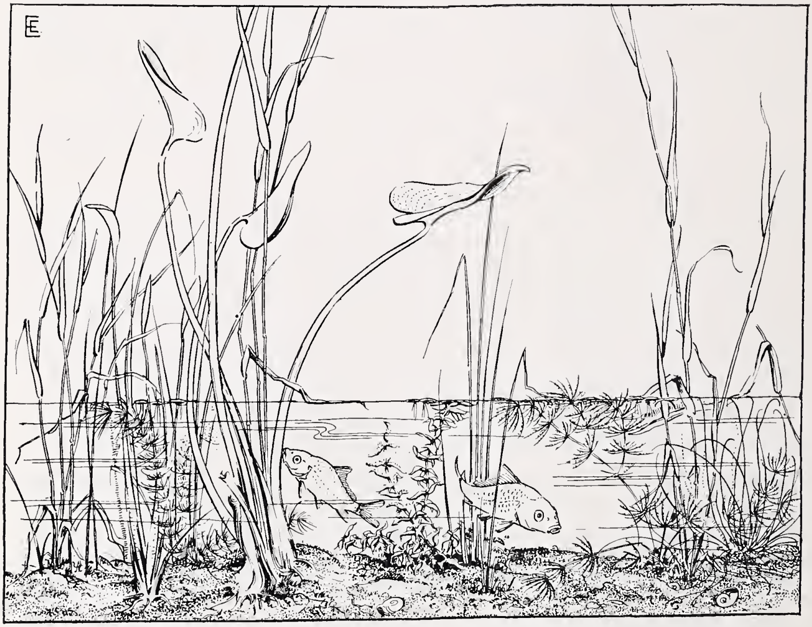
* See page 103–104.

These valuable color drawings add to the collection begun last year with the purpose in view as the survey progresses of bringing them together finally in a record of permanent worth—an illustrated volume of the fishes of New York.

Carp Control Studies.— The intensive study of the carp conducted on Oneida lake this past summer represents the first attempt to focus attention upon the scientific aspects of the carp problem as it relates to large bodies of water in this State. The control of this species which, within a relatively short period after its introduction into this country, has become a dominant factor in our fisheries problems is not a simple matter. It is more than



Habitat sketch of young carp in the advanced fry stage

a seining industry "to keep the numbers down." It is an interpretation of the conditions which contribute to the rapid multiplication of the carp and an understanding of the effects of rapidly increasing numbers of this species upon the native species of food and game fish whose future needs we require under the circumstances to anticipate. The plan and scope of the work coordinate the investigations of the scientific unit engaged upon this study with the operations of a trained and experienced carp seiner.

The efforts of the summer's study have produced positive and constructive results. Over forty-five tons of carp have been seined and marketed covering a period of about five months, from May to October, and it has been demonstrated that carp in these numbers can be taken with minimum interference of game fish.

The dominance of carp in Oneida is evidently correlated with the richness and abundance of certain food elements such as crustacea, mollusca and insect larvae which are the main food staples of the carp in this lake.

Other contributing factors are associated with the unusually favorable physical features which obtain there, such as the extensive shallows and the intersecting barge canal which provide agreeable environmental conditions for this species.

Although much useful information has been gained by the efforts of a single season, relief measures to be adequate, however, must be organized for permanency. In this connection the economic aspect is an important consideration. When more carp are marketed than are yearly produced then we may hope to cope with the carp problem in situations where game fishing is to be regarded as paramount.

Conditions of Pollution in the Oswego Watershed.—An appraisal of the waters from the standpoint of the oxygen supply is shown graphically in the dissolved oxygen profile of the Seneca and Oswego rivers (Fig. 1.) These are the recipients of the miscellany of pollutions of all tributaries, both lakes and streams, in the watershed. Gathering up as they do the waters of the entire drainage basin they become rivers of considerable volume. The profile, therefore, is impressive as showing despite this large volume of water a successively lower and lower oxygen sag until the final entry of the waters into Lake Ontario. Other profiles of the tributary streams interpreting pollution conditions in local areas appear in the report on this subject.

In the biological discussion of the subject (page 138) a useful tabulation of pollution conditions in the watershed provides data of importance to each community in which studies have been made. The types of polluting substances which enter the river system are discussed in their relation to fish life and to the organisms associated with them in the capacity of food of fish either directly or remotely. The mileage of stream noticeably affected by the polluting wastes is estimated at about 108 miles, an approximation based upon the condition of the stream as shown both by oxygen depletion and the presence of biological indicators of pollution.

In stressing the studies of pollution, three objectives stand forth. The first of these is to give information of pollution conditions in the watershed, to visualize, that is, graphically by profile or otherwise the situation as a whole in the area covered by the survey. The second to focus attention upon the bad spots, the conspicuous cases of stream defilement where the normal fauna and flora are completely replaced by pollutional forms and by gaseous or other conditions inimical to fish life, and where under such situations stocking the stream with fish is extravagant and wasteful. And third, to emphasize the responsibility of the individual and the community.

Plankton Studies.— All fish in their young stages require a plankton diet. Some species, like the alewife or cisco, are "plankton sifters" throughout their life span. The studies, therefore, in this field bear directly upon the problem of fish production.

Plankton estimations for the period of the survey cover only the the largest of the deep lakes (Seneca and Cayuga) and the largest shallow lake, Oneida. The values for these lakes are made graphically apparent in the charts (1–8, p. 144), values which represent a stupendous amount of counting of microscopic organisms. A further understanding is gained by direct comparison of plankton quantities as shown in chart 9.

Associated with plankton studies, however, and requisite for any true interpretation of the productive capacity of the lakes, are various complex problems related to the abundance of the rooted vegetation, and to far reaching chemical, physical and physiological relations which play their part in the "going concern" of any lake.

The Lamprey, a Pest of Lake Fishes.— In the several large lakes of the Oswego watershed the depredations of the lake lamprey occur with menacing frequency among the food and game fish. They are blood suckers, attacking fish only and their extraordinarily rapacious habits in this respect call forth discussion of ways and means of combating them.

Fortunately there is at hand in the researches of Professor S. H. Gage of Cornell University, an authority on the lamprey, such completeness of knowledge of the life history of this parasite that methods of control are clearly indicated. Through the courtesy and generous cooperation of Professor Gage the survey report contains the important chapter on the lamprey including in the paper both the life history and the economics of this serious pest of our lake fishes.

Papers by Specialists on the Survey.— The data collected in the several lines of inquiry are presented in full in the following sections dealing with:

(1) Stocking policy for the Oswego river system.
(2) The Finger lakes fish problem.
(3) Carp control studies in Oneida lake.
(4) Fishes of the Oswego river system.
(5) Chemical investigation of the Oswego watershed.
(6) Biological studies of polluted waters in the Oswego watershed.
(7) Plankton studies of Cayuga, Seneca and Oneida lakes.
(8) Life history and economics of the lampreys of New York State.
(9) A quantitative study of the fish food supply in selected areas.

I. STOCKING POLICY FOR THE STREAMS, SMALLER LAKES AND PONDS OF THE OSWEGO WATERSHED

By G. C. Embody

Professor of Aquiculture, Cornell University

The development of a stocking policy for the streams and ponds of the Oswego watershed has been based upon studies similar to those conducted during the summer of 1926 in the Genesee area.

The survey of the present year covered approximately double the area represented in the Genesee drainage, and while the latter contained 3,400 miles of stream, the Oswego with all of its tributaries constituted a total mileage close to 7,000. In attempting to cover such a large stream mileage during a comparatively short period of three months, the time allotted to any particular stream was necessarily short. It was possible to economize in time in the following ways: Dry runs were passed over quickly. Badly polluted streams flowing through cities were likewise given little attention, because in the present state, fishes could not live in them and the nature and degree of pollution was to be adequately covered by another group of investigators. Likewise streams too small for bass and obviously unsuited to trout were passed over quickly. In other cases where trout were observed to occur in abundance, our chief concern had to do with the size and the evaluation of food and pool conditions—factors determining the number of fish to be planted. Finally in the case of Oneida and Tompkins county streams which had already been covered, the former by Dr. W. A. Clemens in 1916 and the latter by the writer in 1918 and 1919, it was likewise sufficient to study them with reference only to the number of fish to be planted. It may be stated here that the stocking policy set forth in the surveys of these two counties has been adhered to in almost every case. In a few instances, however, stream conditions had evidently changed during the last eight or nine years, necessitating some alterations.

In the present survey, field data blanks (Appendix I) slightly modified in form from the Genesee blank, have been used. The work of collecting information on them has fallen chiefly to six persons, namely: Dr. D. J. Leffingwell, Messrs. A. S. Hazzard, R. P. Hunter, R. D. Harwood, R. A. Laubengayer and V. S. L. Pate.

The problem during the past summer has been to determine what streams and ponds are suitable for stocking; what species of food fishes should be planted in them, and in the case of trout streams, approximately how many should be planted per unit of length (See Appendix II–XI and maps). The factors studied with this end in view were discussed in some detail in the Report of the Genesee Survey and are referred to briefly in this paper.

Water Temperature.— The maximum water temperature in a rapid, unpolluted stream suitable for brook trout we have taken as 75° Fahr. even though there is some evidence to show that

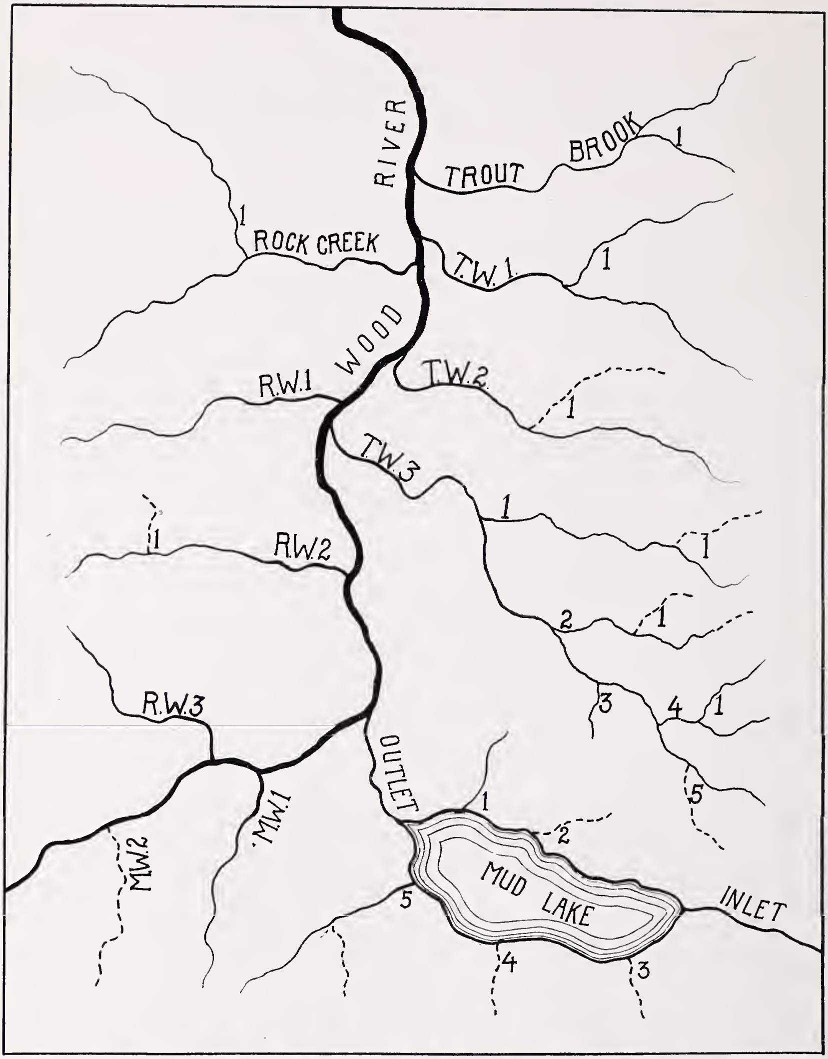


Diagram illustrating the method used in designating unnamed streams. Explanation of diagram:—

Main stream:—Name only is used, i.e., Wood river.

Principal tributaries:—

(a) If they have a name that only is used, i.e., Trout brook, Rock creek.

(b) If they do not have a name they receive two or more letters and a number as follows:—

1st letter is the initial of the first *named* stream below (downstream) on the *same side*, i.e., T. (for Trout brook).

2nd letter is the initial of the main stream, i.e., W. (for Wood river).

Number—indicates that it is the first, second etc., tributary *above* the named stream.

Thus T.W.1. (Trout, Wood 1.) is the first tributary above Trout brook on that side; R.W.1. (Rock, Wood 1.) is the first tributary above Rock creek on the opposite side of the river.

Secondary & tertiary tributaries:—All receive numbers, the tributary nearest the mouth is numbered 1. Thus T.W.3. in the above diagram has 5 secondary tributaries and of these 1, 2, 4, each has one tertiary tributary.

Lake tributaries:—Named streams are not numbered. Unnamed streams are numbered clockwise around the lake, starting from the right of the outlet, see Mud lake in above diagram.

brook trout may sometimes endure slightly higher ones. In the case of brown and rainbow trout the highest suitable stream temperature is believed to be close to 80° Fahr.

In assigning any one of these three species to a stream it is important to know whether the water temperature will exceed either of these points during the summer months. Hot days were too infrequent during the past summer to permit one to secure through actual observation, maxima in more than a few streams. It was thus necessary to estimate them by means of a table. Table 1 was used throughout the greater part of the territory covered with one exception to be noted.

TABLE 1.—RELATION OF AIR AND WATER TEMPERATURES IN TROUT STREAMS

Max. air temp. deg. Fahr.	80.0	82.0	84.0	86.0	88.0	90.0	92.0	94.0
Max. water temp., Brook trout	65.0	66.5	68.0	70.0	71.5	73.0	74.0	75.0
Max. water temp. {Brown trout, Rainbow trout}	69.0	70.5	72.0	73.5	75.0	76.5	78.0	79.0

Checking up on the accuracy of this table in as many warm streams as were found to contain trout there was found but slight error in regions below 1,000 feet elevation, but in the higher forested area particularly about the headwaters of Fish creek (Lewis county) with elevations from 1,600 to 1,900 feet, the error was large, noticeably however, on the safe side. That is, the water temperatures corresponding to certain air temperatures as taken in these streams were several degrees higher than in Table 1, for brook trout.

Two outstanding examples of this were the upper East Branch of Fish creek and its tributary, Alder creek. Both streams were densely populated with brook trout and showed the temperature relations in Table 2.

TABLE 2—RELATION OF WATER TEMPERATURE TO AIR TEMPERATURE IN FISH AND ALDER CREEKS, LEWIS COUNTY, N. Y.

SECTION	Air temperature	Water temperature	Atmospheric condition	Hour	Date
FISH CREEK					
Upper	80	68	Bright	10:30 A. M.	Aug. 1
Lower	81	68	Bright	4:30 P. M.	Aug. 1
ALDER CREEK					
Upper	80	69	Bright	12:05 P. M.	July 28
Middle	80	71	Bright	12:00 P. M.	July 28

Comparing Tables 1 and 2, it is evident that in the latter, the water temperatures are from three to six degrees too high for the air temperatures indicated. This relation (air 80, water 68-71) while commonly found in brown trout streams of lower altitudes and others which do not contain trout has not often been observed by the writer in brook trout streams.

There is a possible explanation for the occurrence of brook trout in these two creeks, namely, that the maximum air temperatures in the Fish creek region do not run nearly so high as those in the lower altitudes. This is shown by the following temperature records furnished by the United States Weather Bureau Office at Ithaca, N. Y., for Turin and Constableville, two towns situated 3 to 4 miles east of the region in question, in comparison with those taken during the same years at Ithaca. With no recent records available from the upper region we must compare those taken from 1890 to 1895 (Table 3).

TABLE 3.—TEMPERATURE DATA FOR TURIN, CONSTABLEVILLE AND ITHACA

YEAR	Summer maxima	NUMBER OF DAYS MAXIMUM 88 OR ABOVE			Place
		June	July	Aug.	
1890	91	....	3	1	Turin
1891	87	....	......	......	Elevation = 1264
1892	85.9	....	......	......	Av. max. 6 yrs.= 88.1
1893	89	....	......	2	
1894	89	....	1	......	
1895	87	....	......	......	
1890	88	1	1	1	Constableville
1891	89	1	......	1	Elevation = 1260
1892	85.5	No data	......	......	Av. max. 4 yrs.= 87.6
1893	88	....	......	2	
1890	96	2	7	4	Ithaca
1891	92	5	3	1	Elevation = 928.5
1892	95	3	10	4	Av. max. 6 yrs.= 94.3
1893	93	4	4	4	
1894	95	2	11	3	
1895	95	6	4	2	

While the altitudes of Turin and Constableville are 1,264 and 1,260 feet respectively, the elevation of upper Fish creek ranges from 1,600 to 1,900 feet with consequently colder temperatures.

A comparison of the summer maxima for the various years (Table 3, column 2) and the average summer maxima for the whole period involved is significant. At Turin the absolute maximum for the six years was 91, while the average for the summer maxima was only 88.1. In the case of Ithaca these two values were 96 and 94.3, a difference of 5 and 6 degrees respectively.

The possible cumulative effect of continued high air temperatures upon water temperatures is probably not nearly so large in the Fish creek region as at Ithaca. This is indicated by the small number of days during which the maximum reaches 88 or above (columns 3, 4 and 5) in the case of Turin compared with the large number for Ithaca indicating rather clearly that the high water temperatures encountered at Ithaca are not possible in the Fish creek country.

It is evident that Table 1 cannot be used for altitudes much above 1,000 feet in New York, and the following revision is proposed for such elevations with the understanding that its limitations are unknown.

TABLE 4.—SHOWING PROBABLE RELATION OF MAXIMUM AIR AND WATER TEMPERATURES IN THE UPPER FISH CREEK REGION, LEWIS COUNTY, N. Y.

Air temperature	80	82	84	86	88	90
Temperature, Brook trout waters	71	72	73	74	75	76

With reference to the basses, sunfishes, perch, catfish and other warm water kinds, it is important to know whether the water becomes sufficiently warm to permit reproduction and normal growth during the warmer half of the year. Experience during the last two summers warrants the assumption that none of our streams or lakes in central New York become too warm for such species. Nor in fact have we found a single stream otherwise suited to these fishes in which the summer water temperatures run too low. It is rather a matter of size, type of bottom and current which restricts distribution.

Gaseous Content of Water. — The dissolved oxygen and carbon dioxide was given attention in but three types of waters, namely, large springs and spring runs, polluted streams, and in some of the colder and deeper ponds. Rapid unpolluted streams are quite generally suitable for any species so far as the content of dissolved gases is concerned, because the water is constantly aerated through the agency of rapids and falls which tend to saturate with oxygen and to liberate carbon dioxide and hydrogen sulphide when present. Many springs, however, are deficient in oxygen and at the same time contain carbon dioxide in quantities dangerous to fish. The matter is important, because, of the practice of planting young trout in spring runs very often too close to the place of origin, the spring itself. According to analyses made by Mr. F. E. Wagner, the springs examined showed anywhere from a fraction of one part per million of oxygen (Price spring near Auburn) to more than nine parts (Beaver brook spring near McLean) and carbon dioxide from 31 parts per million (York Street spring, Auburn) down to one part (Beaver brook spring).

Price spring about two miles north of Auburn may be taken as an example of one forming a short run which is a tempting place in which to plant brook trout. With a flow of 300 gallons per minute more or less, it forms a brook a few hundred yards long eventually uniting with North brook (Price brook or Cold Spring). This latter is transformed from a warm troutless stream into a cold one, which in the past has been locally famous for its fine trout fishing. The main spring issues from a crevice between limestone strata and at this point the water shows the following analysis as given in Table 5:

Oxygen— 0.1 p.p.m.

CO_2—20.5 p.p.m.

Just before the spring run enters North brook (Price brook) the analysis shows:

Oxygen—3.95 p.p.m.

CO_2—13 p.p.m.

Thus the spring water in passing from source to mouth over a gravel bottom with frequent riffles, absorbed 3.8 p.p.m. of oxygen and lost about 7 p.p.m. of carbon dioxide.

Brook trout commonly occur in the lower half of this run but rarely have they been observed much farther upstream. Experimental data indicate that they will live apparently without discomfort in water showing a temperature of 10° C. (50° Fahr.), oxygen content between 2.5 and 3 p.p.m., and carbon dioxide around 15 p.p.m. The run starts as an unsuitable planting place but becomes suitable at a point somewhat more than half way to its mouth. *Trout should never be planted in the pools immediately below the spring nor in any part of the upper one-half of the run.*

It is well to emphasize at this point the necessity of determining the suitability of the water in every spring run before stocking, for it may not always be possible for the trout to work down into a region where gaseous conditions are safe before asphyxiation takes place. While it is not always possible to have a chemical analysis made, any fisherman may make a simple test by placing in the water to be tested, a wire basket containing a few healthy fingerling trout and observing their behavior. Distress is indicated by a marked increase in respiration or a loss of equilibrium. If trout turn over on their backs within a reasonable time—say 10 minutes—it would be a pretty certain indication that the water is bad.

In order to show how variable in oxygen and carbon dioxide content springs and spring runs may be, the data in the following table has been brought together from analyses made by Mr. Wagner.

TABLE 5.—ANALYSES OF SPRINGS AND SPRING RUNS

NAME	Place	Map	Water temp. deg. Fahr.	Oxygen		CO_2 p.p.m.	pH	Methyl orange alkalinity, p.p.m. calc. carb.	Suitability for trout
				p.p.m.	% sat.				
Cold Spring..........	York street, Auburn, N. Y.	4A	51.3	0.1	1.0	31.0	7.1	229	Unsuitable
Price Spring..........	North of Auburn	4A	48.2	0.1	0.9	20.5	7.3	244.5	Unsuitable
Canoga Spring........	Canoga.....	4A	47.8	0.15	1.0	19.0	7.3	223	Unsuitable
Trib. 1 of 137 Cayuga lake...............	Canoga	4A	52.5	4.16	37.3	22.0	7.3	255	Suitable
Trib. 25 of Fall creek..	North of McLean	5	63.0	5.4	56.5	12.5	7.2	169	Suitable
Head of Newfield brook	West of Newfield	6	48.2	7.35	66.0	3.0	7.5	97	Suitable
Trib. 10 of Virgil creek.	East of Dryden	6	56.3	8.7	82.2	0.5	8.0	107	Suitable
Robinson spring......	Stratton.....	6	46.4	9.1	79.0	6.5	7.3	114	Suitable
Spring run, Trib. Catlin Mills creek.........	No. of Odessa	6	52.2	9.9	88.8	0.5	8.0	107	Suitable
Beaver brook.........	East of McLean	5	46.9	9.0	87.0	1.0	7.9	117	Suitable
Spring-fed pond	Union springs	4A							
At surface..........			66.2	8.8	95.0	6.0	7.7	231	Suitable
9 ft. below.........			52.5	3.6	33.0	18.0	7.4	235	Approaching
18 ft. below........ (bottom)			51.4	3.0	27.0	21.0	7.3	238	unsuitability

The gaseous content of the water of two ponds was studied with reference to its suitability for trout,—one known as Lowery pond, a deep marl pond of about 30 acres situated 5.5 miles north of Geneva (Map 4A) and the other, Green lake, a very deep pond of some 62 acres situated in Onondaga county (Map 3B) about 2.5 miles northeast of Fayetteville. In the former although the temperature conditions were suitable at depths ranging from about 16 feet to the bottom (52 feet), the oxygen was found to be zero from about 30 feet down, the asphyxial point being reached at some place between the 16 and 24 foot depths (Table 6). For this and other reasons pertaining to the bottom topography, absence of inlet, etc., the pond was considered unsuitable for any species of trout.

TABLE 6.—TEMPERATURE AND GASEOUS RELATIONS IN LOWERY POND, JULY 18, 1927

DEPTH IN FEET	Temp. C°	O_2 p. p. m.	*CO_2 p. p. m.	pH	Methyl orange alkalinity as p. p. m. calc. carb.
Surface........................	25.3	8.3	0.	8.3	128
8.............................	21.5	11.8	0.	8.4	136
16............................	13.5	3.2	8.	7.5	140
24............................	9.8	0.54	20.	7.1	151
30............................	9.5	0.	60.	7.1	315
52............................	9.5	0.	60.	7.1	442

* Hydrogen sulphide being present, these figures represent phenolphthalein acidity calculated as p. p. m. carbon dioxide.

In the case of Green lake, oxygen was absent from the 65 foot level down to the bottom (185 feet). At a depth of 45 feet, oxygen was present to the extent of 8.8 p.p.m., and with a temperature of 11°C., suitability for a limited number of trout was established over a rather large area and depth.

TABLE 7.—TEMPERATURE AND GASEOUS RELATIONS IN GREEN LAKE, AUGUST 27, 1927

DEPTH IN FEET	Temp. C°	O_2 p.p.m.	*CO_2 p.p. m.	pH	Methyl orange alkalinity as p. p. m. calc. carb.
Surface	20.3	6.9	0.	8.1	132
25	15.7	11.9	8	7.6	183
45	11.	8.8	10	7.5	185
65	10.5	0.0	55	7.1	305
95	9.4	0.0	65	7.1	327
185	9.8	0.0	80	7.1	388

* Ibid., page 23.

Other Factors Studied.—Among the other factors to which attention was given for the purpose of determining the particular species to be planted, were size of stream, velocity, character of bottom and barriers to fish movements. Since these were discussed in the Genesee report, it is sufficient here to say that the size of the water course often determines the practicability of assigning bass; the velocity and character of bottom indicates whether it shall be the large or small-mouthed bass with such associated species as yellow perch, bluegill sunfish and catfish, and finally with reference to barriers, their presence may eliminate the rainbow trout from consideration in many a stream otherwise suitable.

Factors Influencing the Number of Trout to be Planted.—The more important of these are area of stream available to trout, abundance of primary food organisms, pool conditions, and the effects of angling.

Area: The available foraging area was calculated from the average width and the total length of stream bed over which trout might range, the latter being greater than one might at first suppose. During the colder months from September to June water temperatures are low enough to permit trout to forage almost anywhere barring other unsuitable conditions. But during the hottest parts of the year in June, July and August the foraging area may be greatly curtailed by temperatures above the endurable points. It becomes necessary to assign a somewhat greater area than that based solely upon the summer ranges of trout.

Primary Food Organisms: Quantitative estimates were made in essentially the same manner as reported for the Genesee Survey and the streams were graded as to food richness, Grade I indicating the highest value.*

Pool Conditions: A good fish pool is generally deeper and wider than the average for the stream, the current is appreciably slower and hiding places for fish are frequently more extensive. Pools may constitute a more favorable environment for trout by reason of the following:

1. Shelter from light and such enemies as kingfishers, herons and man.
2. Greater forage possibilities.
    a. Larger surface area for the reception of terrestrial food organisms.
    b. More ready detection of food animals falling in or floating on the surface.
    c. Collecting place for food carried down by the current.
    d. Collecting place for detritus which may support a rich fauna.
    e. Exposed pools containing watercress, mosses and other plants in great luxuriance, which may supply the combination of shelter and a dense population of food animals.
    f. Pools margined by willows and certain other trees and shrubs receiving a larger contribution of food by reason of the special attraction of these plants for insects.

Not all pools, however, are equally attractive to fish. A type frequently occurring in deep, narrow gorges is scoured out during heavy rains and has little if any food left. A shallow exposed pool without shelter or food is a detriment to any trout stream.

There is not much information to guide one in evaluating pools, but in the present survey we have tried to study them with reference to size, type and frequency, and have finally put streams into three classes: A, showing what seemed to represent the best pool conditions, B, average and C, poorest.

Effects of Angling: With the exception of those in Lewis county, all streams in the area covered are fished too heavily in comparison with size and productiveness. This is most noticeable in the trout streams located near the cities of Syracuse, Auburn, Geneva and Canandaigua. The few that are suitable for trout are generally small, and many of them might easily be relieved of their quotas of legal sized trout early in the season, thereafter yielding a preponderance of undersized fish. It is not possible for such streams to produce fish flesh rapidly enough to meet the requirements of the ever increasing numbers of fishermen, and here the only hope lies in the planting of larger sizes of trout than has been the practice heretofore.

In that part of Fish creek and tributaries located in upper Oneida and in Lewis counties, the case is much different. Here

* See paper: A quantitative study of fish food supply in selected areas, by P. R. Needham, page 191.

we find streams long stretches of which exceed 30 feet in width with pool and food conditions generally of A-1 grade. The numerous tributaries are nearly all permanent and entirely suitable for brook trout. The country is in most part covered with forest and the streams in general are densely shaded with alders, especially the smaller ones which are too densely covered to permit angling. The main stream can rarely be reached except by trail, and while many local sportsmen fish it regularly, the country is sparsely populated and the stream is far from overfished in comparison with the other localities covered. The density of trout population is easily observed to be far greater than in any other section studied, and at present natural spawning is an important factor in keeping up this population.

Calculating the Number of Trout per Mile of Stream.—The method described in the Report of the Genesee Survey has been used in the present calculations. Reference is made to Table 8 reproduced herewith, showing the number of 3-inch fingerlings per mile for streams of various widths. In order to use this table one must first determine the average width of the stream, the number of miles suitable for stocking and values for pool (A, B and C) and food (1, 2 and 3) conditions as already described.

TABLE 8.—PLANTING TABLE FOR TROUT STREAMS: NUMBER OF 3-INCH FINGERLINGS PER MILE

WIDTH IN FEET	A1	A2	A3	B1	B2	B3	C1	C2	C3
1	144	117	90	117	90	63	90	63	36
2	288	234	180	234	180	126	180	126	72
3	432	351	270	351	270	189	270	189	108
4	576	468	360	468	360	252	360	252	142
5	720	585	450	585	450	315	450	315	180
6	864	702	540	702	540	378	540	378	216
7	1,008	819	630	819	630	441	630	441	252
8	1,152	936	720	936	720	504	720	504	284
9	1,296	1,053	810	1,053	810	567	810	567	324
10	1,440	1,170	900	1,170	900	630	900	630	360

As indicated the table refers to 3-inch fingerlings only. To find the number of 1, 2, 4, or 6-inch fish, multiply by one of the following factors:

Size in inches	1	2	3	4	6
Factor	12	1.7	1	0.75	0.6

This is based upon an expected mortality as follows:

Size	1	2	3	4	6
Mortality	95%	65%	40%	20%	0%

The table covers stream widths up to 10 feet. Values for wider streams up to 16 feet, may be determined by multiplying that given for a stream 1 foot wide, by the width of the stream in question.

Leger,* after studying the biogenic capacity of certain streams in France, concluded that the nutritive richness is proportionately much greater in narrow than in wider streams. In streams above 5 meters in width, the richness in food diminished one-half at a distance of 2 or 2½ meters from the banks. Although this has not yet been proved to hold for New York streams, we shall have to assume that it is true pending future quantitative determinations. With this qualification then, we may calculate the number of fish to be planted in streams more than 16 feet (roughly 5 meters) wide using the following formula:

$$\tfrac{1}{2} n_1 w + 8 n_1 = X$$

n_1 = number of fish recorded in Table 8, for a stream one foot wide.

w = average width of stream to be stocked.

X = number of fish desired.

It must be understood that the above values are merely rough estimations subject to change as more information comes to light.

Miscellaneous Considerations.— *Brook Trout versus Brown Trout:* Which of the two species should receive priority in planting? In talking with various anglers with reference to this question difference of opinion is evident. There is the feeling, probably of the majority, that native brook trout should be encouraged in all fishing waters entirely suitable for them, because among other reasons, their range is gradually becoming more restricted by numerous adverse agencies. The desire to preserve this American species in as many localities as possible in order that its continued existence may be assured for coming generations, is entirely logical and commendable. Yet there is a growing tendency, possibly among the minority, particularly in those regions where it is the most abundant species, to become dissatisfied with the size to which the brook trout attains and to wish to displace it with the larger brown trout.

It is the general belief among fish culturists that the two species are incompatible and should not be placed in the same stream. There is some evidence to bear this out. It is well to note, however, that the brook trout have not in all cases been crowded out or exterminated by the browns, but have held their own in many of the colder streams in which the most favorable conditions for the brook trout are to be found.

It may be pointed out that in the entire Oswego watershed the total stream area for which brown trout have been recommended is more than two-thirds greater than that for brook trout. It would thus seem that there is a sufficient stream area to be found in the warmer streams for brown trout enthusiasts without trying to extend the range of this species to the typical brook trout streams. For this reason we have consistently advised the restriction of

* Leger, L. 1910. Principes de la Methode Rationnelle du Peuplement des Cours d'eau a Salmonides. Travaux du Laboratoire de Pisciculture de L'Universite de Grenoble. fascicle 1, p. 531.

brown trout to those warmer streams in which brook trout cannot hope to maintain themselves, except in a few of the larger streams where stream conditions vary widely and a marked extension of trout fishing may be obtained by planting brown trout in the warmer parts.

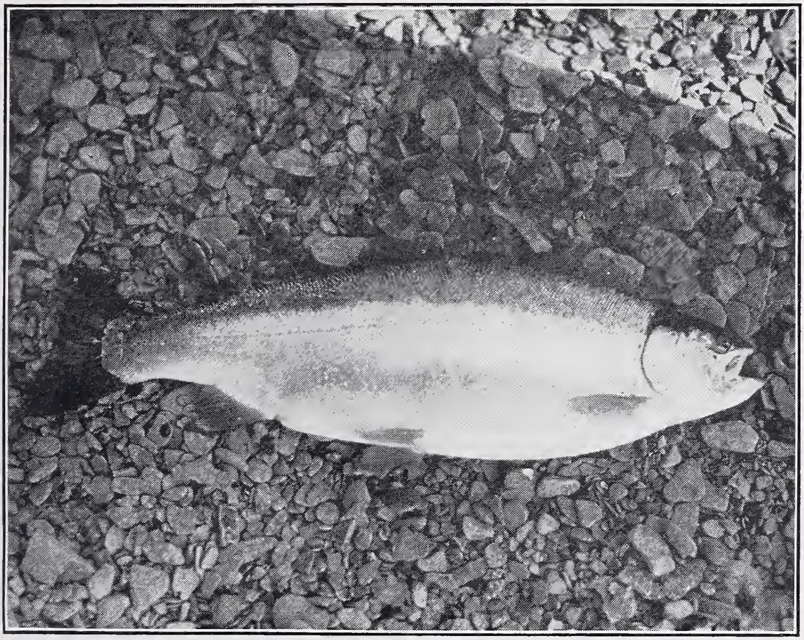
The East Branch of Fish creek is an example in which brook trout are recommended for the upper part from tributary 32 (Pringle creek) to source, while browns have been designated from tributary 32 to mouth.

In the upper section of the watershed located in Lewis county, Map 1, the brook trout stream mileage predominates in the ratio of about 135 to 27 for browns. Undoubtedly this circumstance together with the larger size attained by brown trout have influenced the members of the Fish Creek Club to introduce the latter in that part of the stream controlled by them. Just how far upstream the browns will move is a question, but during the summer of 1927 a few were captured a distance of about 4 miles above the Club preserve.

The conditions as studied indicate that the water of Fish creek even a short distance below the Club property is entirely suitable for brook trout. Nevertheless since the browns are now well established here, it seems unwise to continue stocking the main stream with brooks in any place below the private preserve.

Nursery Streams: Those under three feet in width, without sizable fishing pools may be considered nursery streams and it is advisable to stock them with the sole idea of increasing the population in the main streams to which they are tributary. Quite often, however, we find a nursery stream entirely suitable for brook trout but flowing into a larger fishing stream suitable for brown trout only. Our policy should not change, because we are stocking it for the benefit of the larger stream. In this particular case we would recommend brown trout. If, however, the little stream happened to be tributary to a larger one not suitable for any trout, it is unwise to stock it at all. It is true that a few trout if planted might grow to be 6 or 7 inches long and quite probably they would be caught by the first angler to visit the stream on the opening day. There is reason to believe also that a large proportion might work down into the larger stream during the colder part of the year and disappear altogether. It is much better to omit all such streams from our stocking program and to concentrate our efforts upon those of larger productiveness, stocking more heavily and perhaps with trout of larger size.

Rainbow Trout: The facts concerning the rainbow trout commonly distributed in New York State appear to be as follows: They become sexually mature at the end of the third year counting from the time the eggs are laid in April. Those kept in the spring water of the State hatcheries may spawn at varying times from December to April but wild rainbows in New York streams spawn principally during April. Young rainbows planted in the smaller streams whether cold ones suitable for brook trout or the warmer ones containing browns generally remain there until sometime during the second year after which they migrate downstream. During the second year many of them ranging in size from 6 to 8 inches are of legal size for angling. The migrants may or may not permanently leave the stream apparently depending upon the size and summer temperature of the water to which the stream is tributary and the presence or absence of barriers (water falls or serious pollution), the latter preventing their return even if it is otherwise possible. If it is possible for them to return, they do so towards the end of the third and subsequent years in March and April, and at this time may range from 15 to 24 inches long thus furnishing excellent sport.



Rainbow trout from Seneca lake

Among the waters in the Oswego watershed known to stop rainbows in the downstream movement, may be mentioned the Finger lakes (Skaneateles, Owasco, Cayuga, Seneca, Keuka and Canandaigua), Potters Falls reservoir at Ithaca and Lake Como (Cayuga county).

The question for the sportsman to ponder is whether to stock any stream irrespective of barriers or the condition of the water into which it empties in the hope of catching a few 6 to 8 inches long and losing the remainder of the plant through migration, or to confine them to streams without barriers which empty into suitable lakes, reservoirs or possibly rivers (Genesee) with the probability of catching not only some of the small ones but many of the large sexually mature trout as they return for spawning. In the first case heavy planting will be necessary every year with the probability of huge annual losses through migration. In the second more and larger fish will be available, the plantings need not be so heavy because some natural spawning will always take place, and the losses from migration will be less. Money, space and time will thus be saved in our hatcheries for the propagation of other species. Because of our belief that the second plan is the better rainbow trout are assigned to those streams only to which the adults are likely to return. The writer is aware that in some parts of the country east of the Rocky Mountains the rainbow appears not to be migratory. This circumstance might alter the policy for such localities. What is said here applies only to the two watersheds studied, the Genesee and the Oswego.

Stream Mileage Suitable for Stocking.— The total stream mileage in the Oswego watershed is roughly 7,000. Of this only about 1,688 miles are worthy of stocking. The remainder fall short in one or more particulars—either dry, badly polluted, too warm for trout, too small for bass and too rapid for bluegills and bullheads, or posted. In the last case they may not legally be stocked with State fish. The dry streams appear to be the most numerous while those too warm for trout and too small for bass seem to rank second in numbers. Of the 1,688 miles worthy of stocking, 1,430 are suitable for trout, 133 for large-mouthed bass and 125 for small-mouthed bass. It is well to note that one mile of bass stream represents a greater area than one of trout stream because all bass streams average more than 30 feet in width, while by far the greater number of trout streams are well under this value.

The most important small-mouthed bass streams are the Oswego river (Map 3B), Oneida river, Fish creek, Clyde (Map 3A and 4A), lower Ganargua, Oneida creek, Canandaigua outlet and West river (Map 4B). The better large-mouthed streams are the Oswego river (Map 2), Caughdenoy creek from mouth to Crippen pond (Map 2), parts of Fish creek (Map 2), Seneca river including the barge canal, lower Clyde, Cowaselon and Flint creeks.

The 1,427 miles of trout stream require a total annual plant of about 1,031,461 fingerling trout distributed among the three species as follows:—

Brook trout	685	miles requiring	366,630	fish
Brown trout	642	" "	606,248	"
Rainbow trout	103	" "	58,583	"

The greater stocking requirements of brown trout as compared with brook trout in view of a smaller stream mileage for the former is explained by the fact that brown trout generally range through the warmer waters lower downstream where the width is greater. Consequently a greater area is involved which must be supplied with a greater number of fish per mile.

The following Table 9 shows the comparative figures for the various species in the regions represented by the several maps:

Table 9.—Total Trout Steam Mileage and Planting Numbers by Maps

Map	Brook Trout		Brown Trout		Rainbow Trout	
	Miles	Number of fish	Miles	Number of fish	Miles	Number of fish
1	135	87,638	27.0	30,565	......	....
2	293.4	154,933	158.9	213,581	......	....
3A	20.0	5,414	9.5	2,095	......	....
3B	45.0	12,321	103.8	134,125	......	....
4A	5.2	3,205	33.5	19,298	8.4	1,050
4B	86.0	29,259	116.3	88,473	25.0	5,775
5	83.5	55,006	114.9	64,007	39.4	24,980
6	15.1	16,854	75.3	51,104	27.1	25,778
7	2.0	2,000	3.0	3,000	3.0	2,000
Totals	685.2	366,630	642.2	606,248	102.9	58,583

The region covered by Map 2 has the largest stream mileage but this is also the largest area. The greatest mileage in proportion to area is found on Map 1. This is in the upper East Branch of Fish creek which also has a much higher altitude (1,600-1,900 ft.) than any other region. Here also the brook trout stream mileage and area are much greater than for browns (135 to 27 miles). We likewise find here less pollution, more timber, fewer dry streams, fewer people, fewer roads, a greater advantage for natural spawning and a much denser population of brook trout. The region stands out above others in the quality of its trout streams.

The combined areas represented by Maps 3A and 4A have fewer trout streams than any one of the others except Map 7 which is too small for comparison. There is a total of 66 miles of which 25.2 are suitable for brook trout, 43 for browns and 8.4 for rainbows. Map 3A includes principally that region lying along the route of the barge canal from Cross lake to a place just beyond the Wayne-Monroe county boundary. It covers much of the low lying country in the Montezuma marshes and along the Ganargua creek and lower Clyde river. None of the streams is above the 600 foot contour. They are mostly brown water, often turbid, fairly sluggish, badly exposed, in a densely populated section which is in general the warmest part of the area covered. Here we find but 29.5 miles of trout stream in comparison with 38.7 for Map 4A. The ratio of brook trout to brown trout streams is however lowest in Map 4A (5.2 to 33.5). The few trout streams in these two sections are widely scattered and often are formed by one or more conspicuous springs. North brook near Auburn made suitable for trout solely through the influence of the Price spring is a noteworthy example. It receives pollution. As one goes to higher altitudes either east towards the region south of Oneida, (Maps (3B and 4B) or south toward the headwater tributaries of the various Finger lakes, the trout streams become very numerous, culminating in that section near the heads of Skaneateles, Owasco and Cayuga lakes, (Map 5).

Some of the More Successful Trout Streams of the Oswego Watershed

Map 1. The upper East Branch of Fish creek* with its numerous tributaries is the outstanding brook trout system of the whole watershed. These streams are found within an area of about 78 square miles. Roaring brook, Sixmile, Sevenmile, North Branch and Big Alder are the more important fishing tributaries. The main stream ranges upward to a maximum width of 70 feet, is generally swift, with rubble, coarse and fine gravel bottom. Long deep pools are numerous and spawning beds are frequent. In food richness it ranks high. It is therefore capable of supporting an exceedingly large quantity of trout. On account of the high results from natural spawning, the stocking policy has been placed at the low figure of 2,200 per mile.

Map 2. Here was found the greatest number of trout streams. by far the greater proportion of which were connected with the Fish creek watershed. The East Branch of Fish creek becomes a brown trout stream on this map. Rainbows, however, have also been planted in the past as follows: 1910, 4,000; 1921, 20,000; 1922, 10,000; 1924, 2,500.

A few small rainbows either in the second or third years were reported during the past summer, yet it is not evident that they return to this stream to spawn nor that they mature in the stream. For this reason this species has not been included in this stocking recommendation.

Point Rock creek, Fall brook and Furnace creek seem to be the most important fishing tributaries. The first two are productive brook trout waters, while Furnace creek is probably more useful for brown trout.

The West Branch of Fish creek varies widely in its conditions. It appears suitable for brown trout from tributary 8 nearly to Camden. From thence to Williamstown it becomes warm and sluggish and at present abounds in large-mouthed bass. Above Williamstown it becomes cooler and more rapid and brown trout should succeed nearly to Kasoag lakes. (See stocking list, pp. 216, 217.) The most important tributaries are Little river, Cobb and Emmons brooks and Mad river.

In the southwestern half of Map 2 are located many good trout streams more or less directly tributary to Oneida lake. Many of the better ones are now posted and cannot be stocked with State fish. However, public fishing is permitted in some of them, including Big Bay creek with its tributaries Dykemans creek; Frederick

* In the section just west of Michigan Mills, there would seem to be an opportunity for securing wild brook trout eggs in sufficient quantities to make the attempt worth while.

creek (in part); Spring brook tributary to Scriba creek, and the lower 3 miles of Black creek. Further west, Potts creek tributary to Oneida river has about 4 miles of suitable brown trout water.

Map 3A. The few trout streams occurring on this map are small and not important, yet since there are so few of them, they are more highly prized than would be the case if located in certain other sections of the watershed. Marbletown creek, one of the largest and longest, is apparently suitable for brook trout. The two small tributaries, 14 and 15, should serve merely as nursery streams. Military run, Stebbins brook and to the east, Putnam brook, are also worthy of attention.

Map 3B. The streams of this region are chiefly of the brown trout type in the ratio of about 103.8 miles to 45 for brook trout. Of those flowing directly into Oneida lake from the south, Black creek and tributary 11 are fair brown trout streams, while tributaries 9 and 12 are suitable for brook trout.

Oneida creek receives two brown trout streams, Sconondoa and Mud creek. The former is larger and considerably more productive.

The Cowaselon itself is not a trout stream on this map but it receives three of considerable importance, the Canaseraga, tributary 5 and Clockville creek.

Probably the best trout stream in this section is the Chittenango creek, a large stream averaging 35 feet in width, flowing generally over limestone bed rock and well shaded. Small springs are well distributed throughout its course from Chittenango to the source and being supplied with ample shade the temperature is well within the limits for brown trout. It is exceedingly rich in aquatic insects and should support more trout than apparently exist there now. Continued heavy stocking with the larger sizes of brown trout should make this one of the best fishing streams in central New York.

The chief tributary is Butternut creek which in turn receives Limestone creek. Both streams are above average size and in the past have been successful fishing streams for brown trout.

Farther to the west, Seneca river has one very successful trout stream tributary, Carpenter brook, lately opened to the public. It is exceedingly rich in food, possesses many fine pools, and in the past under private control yielded remarkable catches of good sized brook trout. It is easily accessible to fishermen of Syracuse and Auburn, hence to preserve good fishing, it will be necessary to stock with the larger sizes of trout.

Map 4A. This region is similar to 3A in that it is generally low and contains very few important trout streams. North brook about two miles north of Auburn would be the best fishing stream were it not polluted. The amount of pollution at the present time does not seem to render the water in the trout section wholly unsuitable for brook trout but if in the future it is materially increased, it will undoubtedly ruin this stream as a habitat for trout or any other game fish.

Below the junction with Price spring run, the stream is a rather close succession of short rapids and long, broad, deep pools with overhanging banks often margined with dense patches of water-cress. It is one of the richest in food that has come to the writer's notice containing countless numbers of Caledonia shrimps *(Gammarus limnaeus).* Near the source it receives the effluent from the disposal plant of the City of Auburn. In the past this stream has produced a good many large brook and brown trout. Although brown trout have been planted formerly with success, it would seem wise under conditions regulating pollution to preserve this solely as a brook trout stream, because it is the only sizable stream in this region known to be well adapted for this species. The stream is fished beyond its capacity to produce trout and consequently the only chance of preserving good fishing lies in stocking more intensively with larger sizes.

An experimental planting of brown trout has been suggested for that part of the Clyde river lying between tributaries 29 and 37. This river showed temperatures generally too high for brown trout, yet, in the particular section mentioned, a number of spring runs enter, cooling pools in which there is a possibility that brown trout may find favorable conditions on hot days. In case this section is stocked, it should be watched by local anglers and the result reported.

Map 4B. This region ranks second in the number of miles of trout streams and here as in Map 3B, brown trout waters predominate. Oneida and Chittenango creeks with the latter's tributary, Butternut creek, constitute the largest area suitable for brown trout. Tributaries 8 and 37 of Limestone creek are also important brown trout streams.

Onondaga creek from tributary 26 to source and Butternut from 39 to source are good fishing waters for brook trout, likewise Munger brook and tributary 47, both of the Chittenango watershed. The Butternut has an impassable dam at Apulia which prevents brown trout from reaching the brook trout section above. All of these streams are well provided with nursery runs.

Going towards the southwest the inlet of Skaneateles lake is the outstanding rainbow and brown trout stream.

Entering Owasco lake at Long point, there is a small brook coming down through a densely shaded gorge a distance of three-quarters of a mile. Though small, it has been used by rainbows for spawning during the last 30 years or more. They were first noticed by the writer in 1898 and as studied during various summers up to 1915, it was possible to distinguish three different age groups, namely, young of the year up to 2 inches long, yearlings 4 to 7 inches long and two-year-olds 10 to 12 inches. The longer fish were very poorly nourished and much under weight. Also there were very few of them, not more than five having been observed in any one summer. In the case of this stream at least the greater number probably migrated to the lake some time between the end of the second summer and the beginning of the third, but a few either remained in the stream through the third summer or else migrated normally and later returned early in the third year.

Map 5. The Owasco inlet proper from Moravia to source is one of the most successful brown and rainbow trout streams in the Owasco watershed. A great many large brown trout are caught every year ranging upwards to 5 pounds in weight, and during April and early May adult rainbows up to 3 or 4 pounds are not unusual. It is a good sized stream with numerous fishing pools of the best type and capable of supporting heavy plants of both species. Among the sixty primary tributaries, fifteen are suitable for stocking, though the greater number are more valuable as nursery streams. Among the noteworthy fishing streams are Dresserville creek, Hemlock creek and Peg Mill brook.

The most important and longest tributary of Cayuga lake, occurring on Map 5 is Fall creek. It varies widely in its conditions. The lower part of about 8.5 miles is too warm for trout and at present is overpopulated with small-mouthed bass. From McLean to the Groton city dam, it is worthy of heavy stocking with brown trout. Above this dam, much of the stream is too warm for brook trout; however, there are some cold pools and since many of its tributaries offer good trout fishing, this species has been assigned to this upper section. Fall creek would be more productive of larger fish, if the small nursery feeders were not fished.

Taghanic creek with its principal tributary, the Reynoldsville creek, in the past has furnished some of the best brown trout fishing in Tompkins county. In 1918 the trout population was so dense that immediate stocking seemed unnecessary. At the present time, it is pretty well fished out and should be heavily stocked with the larger sizes of trout.

There are no tributaries of Seneca lake on this map worthy of stocking except the outlet of Keuka lake. Although trout are not known to occur in this stream the lower .3 of a mile should be suitable for adult rainbow trout migrating from Seneca lake. A liberal plant* is recommended in an attempt to establish a run.

In the region around Naples there are a number of trout streams all more or less directly connected with the Canandaigua inlet. West river is the largest and except in the upper 6 miles is too warm for trout. It should be possible to establish a run of rainbows in this section.

Naples creek with its main tributaries, Grimes, Tannery and Reservoir creeks and tributary 12 are all fair fishing streams.

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* Director's note: Because of the conditions of pollution prevailing in the stream (see p. 92 and p. 115) during the spring runs of rainbows it is suggested that such a planting be regarded as experimental only with a view to establishing the future policy for this stream.

Map 6. Many of the streams on this map have already been referred to under Map 5. In the eastern section Virgil creek, a stream tributary to Fall creek, was formerly a noteworthy brook trout stream, and at present there are a few pools containing individuals of this species. However, for the most part the stream has become exposed and too warm for brook trout. Better fishing will doubtless follow exclusive stocking with browns. It is a good sized stream, rich in food and showing the best pool conditions. It should receive a much larger allotment of fish annually in order to fully utilize its productive capacity.

The Cayuga lake inlet system is one of the largest and most important in Tompkins county, furnishing a total of about 48 miles of fishable trout water. The inlet proper has no barriers to the upward migration of rainbow trout from Cayuga lake. It is a rather large stream, rich in food and possessing large pools of the best type. It is too warm for brook trout though brown and rainbows are known to thrive. Specimens of the latter weighing upward of 4 pounds have been taken in April. It is heavily fished and never has been stocked heavily enough to take full advantage of its productive capacity. All of the larger tributaries possess high falls and may thus be stocked independently of the main stream. The principal fishing tributaries are Sixmile, Butternut, Enfield (Fivemile) and Newfield creeks. All are of good size and productive, and are divided by dams or falls into two or more sections. It is thus possible to use both species of trout (brown and rainbow) in stocking.

The upper 3.5 miles of Newfield creek is the most typical brook trout stream in the county, in which brown trout have not yet appeared. Fed at first by three fair sized springs, it flows down through a heavily wooded swamp and receives here and there other smaller springs. It is densely shaded, the water is cold and there are spawning beds near the source which contribute in no small way toward the trout population of the stream.

Seneca lake inlet, known as Catherine creek, is much like the Cayuga inlet in that it is ideal for rainbow and brown trout, the former migrating from the lake. Good catches of large rainbows are reported each spring and many large browns are taken in the upper section in summer. Catlin Mills creek is the principal tributary suitable for stocking. Other tributaries of Seneca lake are Sawmill creek from mouth to falls suitable for rainbow trout, and tributary 44 from Burdett to source together with its main feeder, Texas Hollow brook, suitable for brown trout.

Keuka lake inlet, another stream used for spawning lake rainbows, has an impassable dam located near tributary 5, which limits the upward movement to about 2 miles.

Map 7. But two fishing waters are located on this map. Catherine creek to which reference has already been made (Map 6) and the abandoned Chemung canal. The latter is broad, sluggish and fed chiefly by small springs well distributed throughout its course. The water is cold, temperatures ranging from 63° to 67° Fahr. when the air showed 83° and 84° Fahr. It was exceedingly rich in food but was badly choked with vegetation principally watercress. This latter condition is by no means harmful to trout but interferes seriously with the fishing. By removing about two-thirds of it much better results would be possible without sacrificing the production.

Pond Areas Available for Stocking.—The total pond area exclusive of the Finger lakes, Oneida lake and all posted ponds, is about 6,900 acres of which 137 are suitable for brook trout, 316 for rainbrow trout, 2,334 for small-mouthed bass and 4,113 for large-mouthed bass.

The following table shows the extent of such waters on the several maps:

TABLE 10.—POND ACREAGE SUITABLE FOR STOCKING

MAP	Brook trout	Rainbow trout	Small-mouthed bass	Large-mouthed bass
1	64	....	....	....
2	72	....	....	1,382
3A	....	....	....	1,136
3B	....	72	1,016	1,064
4A	....	....	....	111
4B	1	....	1,280	420
5	....	52	38	....
6	....	192	....	....

The Larger Trout Ponds

Map 1. The largest pond at Paige with an area of about 50 acres, is formed by a dam in one of the upper tributaries of East Branch of Fish creek. It is cold with silt bottom and now contains brook trout.

Map 2. The Oneida reservoir of 60 acres is the largest in this region suitable for brook trout. It is formed by a dam in Florence creek at Glenmore which gives it a maximum depth of about 25 feet. This body of water is the water supply for the City of Oneida and in case of future posting, it would appear advisable to change the species to rainbow trout, because of the probability of the adults moving up into Florence creek where fishing would doubtless be open to the public.

Map 3. The upper Oneida reservoir of 10 acres and Green lake of 62 acres seem favorable for rainbow trout. The former has a maximum depth of about 25 feet and shows higher temperatures than Green lake. The gaseous conditions are much better, however, and it is believed that the area is large enough to be attractive to mature rainbow trout.

Map 5. Lake Como covering about 52 acres is well adapted to rainbow trout but now contains both rainbow and brook trout in addition to a mixed population of bass, sunfish, perch, etc. The maximum depth is about 20 feet and when examined July 19, showed a bottom temperature of 64 and a surface temperature of 76 with a maximum air temperature on this day of 77 Fahr. Both the inlet and outlet contain brook trout. The latter in addition has been stocked with browns and rainbows.

Map 6. The Potters falls reservoir is the only public pond in this area suitable for trout. It is formed by a dam in Sixmile creek approximately 60 feet high just east of the city of Ithaca and covers an area of about 192 acres. At the present time the maximum depth is about 47 feet and the average depth about 20 feet. The bottom is covered with mud, sand and gravel, the first predominating. On July 11 at 5 P. M. the following temperatures were recorded: Air, 87; water at the surface, 80; water at a depth of 38 feet, 58° Fahr. In the past Sixmile creek has been stocked with rainbow trout which have migrated downstream, principally during the second year, into the reservoir where a good many have apparently matured. This is proved by the capture during the past two or three seasons of adults in spawning condition in various sections of Sixmile up to the first dam at Brookton.

The recently constructed settling basin about one-fourth of a mile above the reservoir will hereafter act as a barrier to movement further upstream. However, between the basin and the reservoir, the stream is rapid with gravel and rubble bottom and will, it is believed, supply a sufficient spawning area for trout. The settling basin itself is a pond of several acres and may also prove to be a stopping place for rainbows. Since the stream and reservoir are apparently rich in food, they can stand a very heavy annual plant.

Warm Water Ponds and Lakes

There are approximately 6,447 acres of warm water ponds and lakes. The ratio of small-mouthed bass to large-mouthed bass areas is a little less than one to two. The largest bass areas are to be found in the lower regions, Maps 2, 3A, 4A and 4B. There are no warm ponds in Maps 1, 6 and 7..

Eleven of the ponds or lakes contain 160 acres or more. Only two of these, namely, Cross and Cazenovia lakes, show conditions favorable to small-mouthed bass. The others are shallow, warm, often with brown water, mud bottom and with large areas covered with vegetation both submerged and emergent types, constituting ideal conditions for large-mouthed bass, bluegills and bullheads.

Cross lake is the largest of the group and shows diverse conditions. All types of bottom are present, the vegetation is luxuriant and the food richness is high. It has always been an exceedingly productive body of water and a popular one for fishermen. The principal food varieties are the large and small-mouthed bass, northern pike, chain pickerel, yellow perch, pike-perch, bullheads, and a variety of sunfishes, calico bass, etc. Most of these forms are abundant and run to good size. The yellow perch, however, as is often the case in shallow, weedy lakes, run small as compared to those in some of the Finger lakes.

Cazenovia lake is second in size. It is divisible into two areas. The head of the lake (north end) is narrow, shallow with mud bottom predominating and with extensive areas of vegetation. Margined with water lilies and cat-tails, large-mouthed bass find here congenial surroundings. Going towards the foot of the lake greater depths are encountered, culminating in a maximum of about 48 feet near the south end. The water here is clear and the bottom shoreward is hard, consisting principally of mixed gravel and sand. This lower region is inhabited by small-mouthed bass and pike-perch. Formerly the lake abounded in yellow perch, but since the pike-perch have become established, the yellow perch fishing has fallen off to a marked degree.

Table 11.—List of Ponds of 160 Acres or More

MAP	Name	Area in acres	Fish
2	Gifford lake	230	Lm. B.
2	Panther lake	320	Lm. B.
2	Neatahwanta lake	512	Lm. B.
3A	Duck lake	320	Lm. B.
3A	Otter lake	320	Lm. B.
3A	Parker pond	250	Lm. B.
3A	Stark pond	160	Lm. B.
3B	Cross lake	1,920	Pp. Lm. B. and Sm. B.
4A	Black lake	250	Lm. B.
4B	Jamesville reservoir	320	Lm. B.
4B	Cazenovia lake	1,280	Pp., Sm. B. and Lm. B.

II. THE FINGER LAKES FISH PROBLEM

By E. H. Eaton,

Professor of Biology, Hobart College

Our problem was to discover some means of conserving the fish supply of these beautiful Finger lakes and increasing it, if possible. A hundred and fifty years ago there was a plentiful supply of fish for the 20,000 or more Senecas and Cayugas who inhabited this region, but now that there are more than half a million of inhabitants of the counties which border on these lakes there is no reason to wonder that the supply is not adequate to the demands of sportsmen. However, when we consider that the seven lakes from Canandaigua to Otisco cover a combined area of 195.6 square miles and that their combined volume equals 1,073,606,000,000 cubic feet, with a plentiful supply of plankton and bottom fauna, there is reason to believe that they could be made to support more fish under scientific management. With only three months at our disposal, it was deemed best to concentrate attention on the distribution of fish which now inhabit the lakes, the food which they utilize as revealed by examination of stomach contents, the amount of the available food supply, both plankton and bottom-fauna and food fishes for the larger species, together with an examination of the temperature, oxygen content and other chemical characters of the water. Data already at hand on the plankton and the character of the water as shown in the investigations of these lakes by Birge and Juday* helped in arriving at conclusions.

The Fish Catch.—The object of taking fish in the various lakes was to determine what species inhabit each lake, their relative abundance, their distribution as to depth, temperature and other conditions, to observe the stomach contents and so find out the food preferred by each species. Gill-nets were used at various depths and localities, the size of meshes ranging from ½″ to 4″. These nets were efficient in taking lake trout, whitefish, ciscoes, alewives, suckers, perch, wall-eye or pike-perch, bass, bullhead, pike and pickerel. Wall-eye and bass did not gill as readily as might be expected. In fact the bass was difficult to take by almost all of our methods. Undoubtedly the bass and whitefish could be taken more readily in nets strung with greater "take-up" in such a way that the perpendicular opening is longer than the horizontal. We found the nets much more effective if made of fine thread, that is 20/3 for the larger nets and 50/2 for the smallest. Fykes and the trap-net were effective in taking almost all of the shallow water fishes such as bass, pike, bullheads, suckers and sunfish.

*Birge, E. A. and Juday, C. A. limnological study of the Finger lakes of N. Y., Bull. U. S. Bur. Fisheries, vol. 32, 1912.

See also Plankton Studies of Seneca, Cayuga and Oneida lakes by W. C. Muenscher, in this report, page 140.

Traps made of wire meshing were used successfully in the capture of perch, rock bass, sunfish, young bass, sculpins and sticklebacks, but were rather ineffective in taking minnows. These traps were made 5′ x 3′ x 2′ with a deep funnel opening at one end. The size of mesh used for perch and bass traps was 1″, for the small fish such as blobs and sticklebacks, ⅛″. Set lines were used at various depths baited with worms and alewives. They were the only effective means we had of capturing eels and were useful in taking bullheads, suckers, catfish, whitefish, rainbow trout and lake trout. Seines were found by far the most effective method of taking minnows and other small fish in shallow water. Lengths of thirty to fifty feet, made of linen thread, ¼″ mesh, tied at the joints, with a bag at the center of the net were found best for this lake work.

The various appliances used were tried in widely separated localities so as to get a fair estimate of distribution. For example, in Seneca lake where we worked for four weeks the trout nets were set only four times in situations where we expected a large catch. In three out of four of these sets we took 12, 18 and 38 trout respectively. In Keuka lake we failed to catch trout in any numbers because we found it impossible to set our gill net on the trout grounds, due to the great number of line fishermen. Fishing in this way we did not take a great number of edible fish—not enough, if valued at market prices, to pay the wages of two fishermen for the period. This shows that fish cannot be caught in great numbers except in favored localities. We managed, however, to capture 56 of the 69 species of fish which have been recorded in the Finger lakes. The remaining twelve are fishes of very unusual or accidental occurrence in these waters. Besides several which had not been reported from the lakes we added at least three species which have not formerly been recorded from the drainage, that is: stone cat (*Schilbeodes insignis*); the sturgeon sucker (*Catostomus catostomus*); and the lake chub (*Couesius plumbeus*).

TABLE 1.—FINGER LAKES FISHES

The depth range of the small fishes was from 1 to 10 feet or less. + = Fish taken in seines and the number not counted. R = Fish reported on good authority.

THE SEASON'S CATCH	Canandaigua	Keuka	Seneca	Cayuga	Owasco	Skaneateles	Otisco	Depth (ft.)
Lake lamprey*	R		5	2				60—135
Alewife*		111	4004	323				3—150
Smelt	2				6	R		40—100
Cisco*	4	19	21	4	3	10	2	6—225
Whitefish	8	R	R	R		2		30—150
Rainbow trout	R	R	5	R	1	R		6— 22
Steelhead					R	1		
Lake trout	4	5	89	6	25	19		40—225
Common sucker	131	5	174	33	38	10	14	10— 60
Sturgeon sucker					3			60—175
Chub sucker				R			4	
Carp*	7	+	20	5	2		+	3— 15
Lake chub					+	+		
Black-nosed dace	+		+	+	+			
Long-nosed dace	+		+	+	+	+	+	
Fallfish	+		+	R				3— 25
Horned dace*	+		+	+	+	+	+	
Notropis h. heterodon		+		+				
Bridled shiner	+	+		+				
Black-nosed shiner (*N. heterolepis*)				+				
Spot-tailed minnow*	+	+	+	+	+			
Silverfin (*N. whipplii*)		+	+					
Notropis atherinoides		+		R				
" *cornutus frontalis*	12	2	8	+	20	20		
Golden shiner*	2	33	24	43	3		3	3— 15
Hybognathus nuchalis	+		+	+	+		+	
Hyborhynchus notatus	+	+	+	+	+	+	+	
Cut-lips minnow					+			
Common bullhead	+	55	28	4	6	2	1	4— 13
Yellow bullhead				3				12
Noturus flavus						2		10
Tadpole cat				12	+			3— 10
Schilbeodes insignis		1						12
Mud-minnow	+	+	+	+	+			
Eastern pickerel (*E. niger*)	6	2	3	5	6	5	3	6— 15
Pike (*E. lucius*)				4				5— 12
Eel	R		4	15	2			10— 40
Killifish	+	+	+	+	+	+	+	
Trout-perch	+		+	+				
Yellow perch	11	39	829	148	28	76	8	3— 80
Wall-eye, pike-perch	5		R	R	90			10— 35
Log perch, zebra darter	+	+	+	+	+			
Tesselated darter*	+	+	+	+	+			
Fan-tail darter*					+			
Small-mouthed bass	11	1	124	19	2	12	2	7— 35
Large-mouthed bass		+	+	+			+	4— 15
Bluegill				2				10
Sunfish	3	10	3	70	3	4	2	6— 22
Rock bass	7	2	30	33	3	26	3	6— 32
Crappie (*P. sparoides*)				4				10
Skipjack				1				6
Cottus b. kumlieni	+	+	+	+				2— 60
" *cognatus**	+		+			+		
Common stickleback	+	+	+	+	+	+		10— 55
Nine-spine stickleback	2							30
Burbot*	40							25—150

* See colored plates 1–12.

In addition to these 56 species the following have been reported as accidental in Cayuga lake and local specimens are in the Cornell collection: Lake sturgeon; long-nosed gar; bowfin or dogfish;

gizzard shad; black sucker; red-horse; black-nosed minnow; channel cat; sauger; sheepshead. The white bass is similarly reported from both Cayuga and Seneca. The brown trout has also been rarely taken in at least four of the lakes and the landlocked salmon has been reported by the Skaneateles fishermen.* This brings the Finger lakes list to 69 species not counting those which inhabit the tributary streams.

Distribution of Finger Lakes Fishes.— The lamprey was found only in Cayuga and Seneca lakes and few specimens were taken, but at least 90 per cent of the trout taken in these lakes showed scars, where they had been previously attacked by lampreys. In many cases the wounds were fresh. In Seneca lake it was very evident that the lampreys were more abundant toward the head of the lake, as was expected since they are known to breed in Catherine creek and its tributaries, but not in the other streams. Over 90 per cent of the trout taken at Lamereaux landing had from one to seven lamprey scars each, while of those taken farther down the lake near Reeder's creek only 33 per cent showed scars. The Rev. C. J. Clausen, who has been for many years a trout fisherman on Canandaigua lake, reports that he has taken several trout with lamprey scars and has seen a few lampreys there within the last thirty years. But this parasite if now present in Canandaigua lake must be very scarce.

Alewives are extremely abundant in Seneca, Cayuga and Keuka

* See annotated list, no. 11a, page 96.

A catch of alewives, choice food of lake trout. In Seneca Lake lakes. We believe they entered by means of the canal system which formerly extended to Keuka lake and still enters Cayuga and Seneca. I can find no record of their having been introduced intentionally and know from residents of the section that they have been present in all three lakes for at least fifty years. They are evidently not the remnant of a post-glacial invasion from the sea, nor migrants by way of the Oswego river before the dams were constructed, for they certainly should have entered Canandaigua and Owasco lakes with equal ease. Their appearance in Keuka lake is placed by residents of that section at about sixty years ago.

The smelt has been introduced in recent years into Canandaigua, Owasco and Skaneateles lakes. We took them only in Canandaigua and Owasco but we learned from fishermen that mat re specimens have been found in Skaneateles. They appeared in great numbers in Sucker creek near the foot of Owasco early last spring, evidently to spawn, and soon after the spawning season died in large numbers along the shore of the lake. They are a wide-ranging fish like the alewife and two were taken in trout nets at the depth of 100 feet.

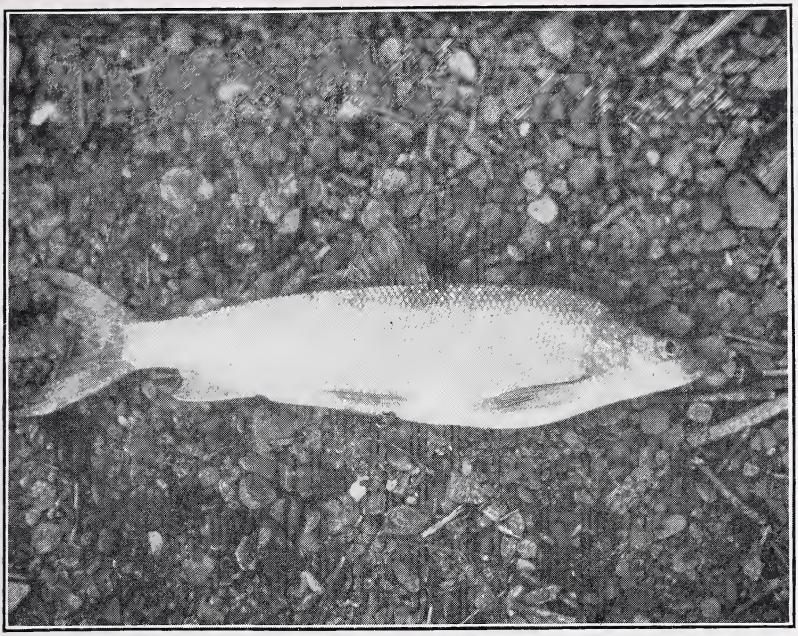
The cisco inhabits every one of the seven lakes surveyed, but it has been planted recently in the eastern-most lakes and in Otisco, at least, we believe that all ciscoes are from stock planted by the Conservation Department. This fish, however, is certainly a native of Canandaigua, Seneca, Keuka, Cayuga and Skaneateles lakes. In Canandaigua lake there is a dwarf race, 4 to 7 inches in length, a somewhat larger one in Keuka lake and, in former years at least, a race which grew to a weight of four pounds in Seneca and Cayuga. This, like the alewife and smelt, is a wide-ranging fish in the lakes and is taken in both deep and shallow water. Great schools of ciscoes are occasionally seen early in the season near shore swimming up or down the lake, but we did not succeed in catching them in large numbers in any of the lakes.

The whitefish is most abundant in Canandaigua and apparently always has been. In Keuka, Seneca and Skaneateles there are still whitefish but in much smaller numbers than formerly, according to the local fishermen. It is mostly a bottom feeder and an inhabitant of the cool, deep water. Early in the season, before the shallows have become warm, they are taken on set lines in water fifteen to twenty feet in depth, and late in the fall they again invade the bars and shallows to spawn.

Landlocked salmon have been introduced into Skaneateles lake on two or three occasions and the local sportsmen feel confident that this is the fish they are now taking in some numbers both by hand-trolling and by rod and reel. We have thus far been unable to secure a specimen of this salmon from the Finger lakes. One secured for us by Skaneateles fishermen, and supposed by them to be a salmon was a steelhead trout.*

The brown trout has been successfully introduced in the inlets

* Loc. cit. page 96.



Whitefish from Canandaigua lake

of the Finger lakes and has been taken by fishermen in the lakes themselves on a few occasions, but it is not naturally a lake fish.

Rainbow and steelhead, however, are unquestionably found in all the Finger lakes and especially in Keuka, Seneca and Skaneateles where they have been taken repeatedly by fishermen. They range the lakes extensively in the summertime but go up the tributaries to spawn early in the spring and then return to the lakes, where they range widely in water of moderate depth. The steelhead is the predominant form in Skaneateles where it furnishes excellent sport.

The lake trout is confined to cool water at depths from 30 to 300 feet in summer. Late in the fall and in the spring it invades the shallower water while the temperature remains below 50 degrees F. to seek a more plentiful food supply. When the shallower water warms it retreats to greater depths. Young trout of the first season, although we took none in the lakes, are unquestionably confined to the deeper water, where both the optimum temperature and a bountiful food supply are found.

The sucker, (*Catostomus commersonnii*) is still common in the lakes in spite of the yearly spearing of mature fish as they are running up the influent streams to spawn, and in spite of the fact that only a minor proportion of the fry that hatch from the eggs which are deposited ever reach the lake, because of the intermittent character of so many creeks which formerly were "living streams." The salvation of the sucker has been the fact that many of them spawn on shallow bars off the stream mouths. This fish is a bottom feeder like the bullhead and when taken from our cool lake waters furnishes a palatable food.

The carp is a fish of the weedy shallows although it wanders widely along the lake shore in depths of from 3 to 15 feet in search of crayfish and other food. Early in the summer it invades the flooded lands to spawn, usually at a date later than the pike and pickerel, but is more or less a competitor of these, as well as the perch, bullhead and large-mouthed bass in these situations.

The golden shiner is a fish of the weedy shallows and rather warm water, and consequently is scarce except in sheltered bays and around the head or the foot of the lakes where they are more or less abundant.

The bullhead is also a fish of the shallows, among the weed beds and on the muddy bottom at moderate depth, but in the summer frequently wanders widely in the open lake on calm evenings, feeding near the surface on the emerging mayflies.

Pickerel and pike are distinctly fish of the weedy shallows and consequently are scarce in most of the Finger lakes except in such situations as the foot of Cayuga and the shallows of Otisco.

The eel is becoming scarcer in all the Finger lakes and as far as we could ascertain has been absent from Keuka for the last twenty-five years. It is very scarce, if not entirely absent, from Canandaigua, although it was fairly common twenty years ago. We obtained two eel "smears" (where eels had squirmed through our nets) in Owasco but got no evidence of the fish in Skaneateles. Dams and other obstructions in the outlets of all these lakes are the principal cause of the eels' disappearance. Of course it must make its way up from the sea to reach the lake, and as the fish mature they pass downstream. Their young can never return because of insuperable barriers. The history of the eel in Keuka lake is a fine demonstration that eels do not breed in fresh water and must return to the sea for this purpose. After the old Seneca and Keuka canal was abandoned, the fall of 250 feet between the lakes and the 7 or 8 dams across the stream some of which are 28 feet in height, could not be surmounted by the elvers and the last one which reached maturity, a large specimen, was captured 25 or 30 years ago. The race is now extinct in those waters.

The yellow perch is the most generally distributed food fish in the Finger lakes. It is found most plentifully around the weedy shallows 5 to 25 feet in depth, wandering widely along the shore in search of food. During the latter part of June we took great numbers of perch in Seneca lake both in gill nets and traps in depths ranging from 10 to 55 feet, but in general the fish is distributed in depths from three to twenty feet. It is by no means confined to the weedy bottom but prefers those situations for spawning purposes.

The pike-perch, or wall-eye, is now a common fish in Canandaigua and Owasco lakes. Although millions of fry have been put in Seneca and Cayuga during the last ten years we took no wall-eyes in either lake, but learned from reliable sources that they are present in certain localities. However they do not succeed as well as in Canandaigua and Owasco.

The small-mouthed bass is confined mostly to water from five to 30 feet in depth. It prefers a hard bottom, especially a stony bottom where its favorite food of crayfish can easily be found. In the spawning season they are found near the mouths of creeks and on gravelly bottoms of moderate depth.

The large-mouthed bass is a fish of the weedy bays and shallows and consequently is found principally in such localities as Otisco lake, the foot of Cayuga, in Dresden bay, and the shallows of Keuka lake near Penn Yan and Branchport. It first appeared in Keuka only a few years ago. We took no large specimens in any of the lakes but quantities of young ones.

The sunfish also prefers the weedy bays. Although found in all the lakes this species is decidedly less common than we expected except in such localities as the foot of Cayuga.

The rock bass is more generally distributed than the sunfish and is found during the summer both on weedy and stony bottoms.

The burbot, ling or eel-pout, as it is called on Canandaigua lake, is mostly a fish of the deep water like the trout and whitefish. Young burbot, however, were taken in the inlet of Canandaigua as far up as the village of Naples in brook trout water. The main catch of burbot, both in winter and summer, is in water varying from 30 to 100 feet in depth. It is mostly confined to the bottom and does not range as widely as the cisco and lake trout. In winter it is taken in the Seneca river and must occur to some extent in Cayuga lake.

Food of Finger Lakes Fishes.— During our operations between June 15 and September 15 about 2500 fish stomachs were examined. Of these 1736 contained food and the contents were carefully analyzed by Dr. Charles K. Sibley. In the accompanying tabulation data have been reduced to a percentage basis to show the food taken by each species (see Table 2).

Remarks on the Food of Different Species.— Of our food fishes it will be evident that the lake trout, pickerel and pike are almost exclusively fish eaters; that the rainbow trout, whitefish, yellow perch, pike-perch, rock bass, black bass, and burbot rely to a considerable extent on a fish diet. Larval insects, besides being a very important food of young fishes, are an important item in the case of the cisco, whitefish, sucker, carp, bullhead, yellow perch, pike-perch and black bass. Flying insects which are mostly species which have dropped on the lake during their peregrinations, and emerging midges and mayflies, are to a considerable extent, in early summer at least, a food of the cisco, the whitefish, perch and all the basses. Small crustaceans or scuds are an important article of food with the sucker, carp, bullhead, yellow perch, rock bass and cisco; but plankton crustacea were food of adult fishes only in the case of the alewife, the whitefish, the cisco and the smelt.* The

* Food of two specimens only was observed.

TABLE 2. — FOOD OF FINGER LAKES FISHES (SHOWN IN PER CENTS)

KIND OF FISH	No. examined	Alewives	Cisco	Sculpin	Stickleback	Perch	Minnows, etc.	Snails	Bivalves	Crayfish	Asellus	Gammarus	Hyalella	Pontoporeia	Mysis	Copepoda	Cladocera	Ostracoda	Mayflies	Caddisflies	Midges	Other insects	Water mites	Oligochaetes	Plant fragments	Bottom ooze
Sawbelly	336											4.45				41.6	5		4.19	1.46	40	3.2				.10
Smelt — Owasco	2														50	50										
Cisco — Seneca	10							2.8	3		15.	23			4				23		8.5	20.7				
Cisco — Keuka	5														95			1							4	
Cisco — Skaneateles	3													2	88	1	3					6				
Whitefish — Canandaigua	9			11	1.2			12.8	7.3					11.1	11.1				20.6	.5	4	5.5			6.4	8.5
Whitefish — Skaneateles	2			35													50					15				
Rainbow trout — Seneca	5			8			20												4	10		38		20*		
Lake trout	108	99.		.50				.01											.3	.05	.10	.04				
Lake trout — Canandaigua	3		70.	30																						
Lake trout — Owasco	13		14.	7.9			†13	4.1						8	50.6										2.4	
Lake trout — Skaneateles	13		39.8	41.5			14								.5				2.8						1.4	
Common sucker	149							2.4	4		15.6	16.2	.6			.2	1	.2	9.3	8.6	31.9	.2			.1	9.7
Sturgeon sucker	1								20					30		5	5	4		1	35					
Red-horse (*M. lesueurii*)	1																100									
Carp	29							4	3		1.5	20					.1	2	.2	.2	20		1		18	20
Horned dace	5											20										70	10			
Golden shiner	49															3					7				89	
Bullhead	46						3			15	11.3	4.9	2.7			2.8		2	1	2	45		2.3		8	
Mud minnow	10							2				96											2			
Pickerel (*E. niger*)	9	5.5			10.5	61	11.5	.5		11																
Pike (*E. lucius*)	2					100																				
Eel	4	25						25		50																
Killifish	12											25.5								36	31.5	7				
Trout-perch	1										50										50					
Yellow perch	513	2		6	10		6	5	.1	7	3	22	.5			.3	1.5		9.8	16	7	1	.5	.3	2	
Pike-perch, wall-eye	56					10	28												49	4	8				1	
Log-perch (*Percina c. zebra*)	4															.3	10				89.7					
Tesselated darter	9						23.3				5.4	47				3.3	2				15				4	
Fantail darter	10											5	9			2.5	4		41.5		48					
Small-mouthed bass	59			10	3	10	11.2			40.7		4.7							4.2	11	5.2					
Sunfish	23							62.1					13						3	4	7.4	7				
Rock bass	41			15.6			14.3	1.2		42.5	.6	17.2							2.1	3.5		3				
Crappie (*P. sparoides*)	2					50											49				10					

Sculpin	7										43	21.3				10	4.3				14.3				7.1	
Stickleback (*Eu. inconstans*)	17										1.5	5.6				31.8	32.3	23.2								
Burbot, ling	28	‡26.2	4	7.6	4	16.7				13				.2	.2	.1			6.5			.5				§21
(*Young Fish*)																										
Alewife, 1½″–2″	22															71	24.5		4.5							
Common sucker, 2½″	14															12.5	19				42.9				¶14.2	11.4
Bullhead, 1″	5												10			3	1.5				80	5	.5			
Yellow perch, 1½″–3″	41										1	12	3			2	26	2		40	12	2				
Small-mouthed bass	11						49					9									20	22				
Large-mouthed bass, 1″–3″	33						20					10	16			2	12		6.7	9.5	9	14			.8	
Rock bass, $\frac{7}{8}$–$\frac{13}{16}$″	2															10	75	15								
Lake trout fingerlings, 100–300 ft. in cages	12													54		46										
Lake trout fingerlings in aquarium	10															67					33					

* Earthworms — taken near stream mouth (after a rain)
† Includes 2 smelts.
‡ Whitefish.
§ Rubbish, ie. sticks, stones, etc.
¶ Mostly desmids and diatoms.

whitefish was not a feeder on the smaller plankton crustacea to the extent it was hoped, most of its plankton food at this season consisting of mysis and others of the larger forms. The crayfish was an important food of the rock bass, black bass, eel and, to a less extent, of the bullhead, pickerel and yellow perch; mollusks of the sunfish and whitefish but to a much smaller extent that we expected of other species. The mollusks taken by the whitefish were largely the small bivalves, *sphaerium* and *pisidium*. Algae and plant fragments were found in several fish but were evidently taken mostly by accident with their other food, except in the case of the carp and golden shiner. The latter is our only predominantly vegetable feeder. We found that the carp* in these lakes fed more extensively on larval insects and small crustacea than we had expected. However, I have found in previous years that carp in Canandaigua lake range the shallows along the shale bluffs at a depth of from three to ten feet in considerable numbers to feed on crayfish which are the natural food of the black bass. It is significant that the carp which inhabits the shallow water is a rival for the food supply of the perch, bass and other valuable species.

The lake trout in Seneca, Keuka and Cayuga lakes feed almost exclusively on alewives. The trout in other lakes were evidently getting an insufficient food supply as rarely did we take one whose stomach was completely filled. In Owasco lake they bore conclusive evidence of being starved. They were scarcely in edible condition. Their bodies were light and narrow, their heads proportionately large and their stomachs contained little but mysis. Only five of the fifteen taken in Owasco had succeeded in capturing fish, and only one of these had a full stomach—one cisco. It was evident that the cisco and smelt in Owasco were not sufficiently plentiful to furnish the trout with adequate food and in Canandaigua we feel sure that the scarcity of trout is due in large measure to the scarcity of food fish on which they can subsist.

The burbot is a gormandizer and feeds largely on small fishes. One specimen contained nine fair sized perch. There can be little doubt that he gathers up a large proportion of the young trout and whitefish before or soon after they leave the spawning beds, for he is a deep water fish and must be considered a serious enemy of our better food fishes. The stomachs of burbots were almost without exception partially filled with sticks, stones and other debris which they gather by accident in rushing after their prey.

A rainbow trout, taken near the surface on Seneca lake and weighing 7½ pounds, was filled with an enormous quantity of land insects which it had evidently taken from the surface of the water,

* See carp studies by Smallwood and Struthers, page 67.

including 12 June beetles, 71 winged carpenter ants, 55 mayflies, 5 bees, an adult sialis, a stink bug, an ichneumon fly and grasshoppers.

During the early summer the cisco also feeds to a considerable extent at the surface during the early evening on emerging mayflies and midges. Specimens taken by fly fishermen early in July contained large quantities of beetles, ants, mayflies and spittle insects.

*Vegetation.**—It is an unfortunate fact, as far as weed beds are concerned, that the Finger lakes lie mostly in a north and south direction so that the prevailing wind from the southwest sweeps down each lake gathering in force, stirring up the lake bottom and churning the shallows at the foot of each lake to such an extent that weed beds are restricted to the sunken delta at the head of each lake and the few sheltered bays which exist along its shores. Furthermore all the lakes drop off so suddenly from the shore to deep water that very few coves or shallows protected from the prevailing wind are to be found. Extensive beds of eel-grass or wild celery (Vallisneria), pondweeds (Potamogeton), hornwort (Ceratophyllum), ditch-grass (Elodea) and other submerged forms are restricted mostly to the head of each lake and a few sheltered bays and occasional lagoons near the foot. The depth to which all these species grow in quiet water with a rather muddy bottom is 10 to 17 and sometimes 25 feet. They do not thrive along the surf-swept shores of these lakes. These plants, of course, furnish the ideal situation for insect larvae, snails, etc., which are the natural food of most of the shallow water fishes. The so-called musk-grass (*Chara foetida*), however, is universally distributed on all the lake bottoms to a depth of at least 20 or 30 feet and in favorable situations thrives at a depth of from 40 to 44 feet. It covers practically the whole bottom of Cayuga from the railroad bridge to Union Springs. Incidentally it may be noted that this *Chara* is the food which attracts the coots, redheads and other ducks where the wild celery and sago pondweed (*Potamogeton pectinatus*) are scarce—as they are in nearly all localities of the Finger lakes. *Chara foetida*, lying closer to the bottom, though frequently uprooted by the south swell, which is so characteristic of these lakes, is the only plant except filamentous algae, desmids, diatoms, etc., of general distribution on the bottom of these lakes. *Nitella* and other species of *Chara* are often associated with the predominant form. This plant is one of the favorite foods of the golden shiner and of course it offers shelter to many snails and shallow water crustaceans which are valuable fish food.

The microscopic algae which constitute a large proportion of the plankton catches must, therefore, constitute the main primary plant food of the small animal plankton which are to furnish the main food supply in these lakes. These floating algae also by falling to the bottom furnish a large portion of the bottom ooze which is the food of midge larvae, small crustacea and other animals which can be utilized as food by the young of deep water fishes.

* See also page 242, Cayuga and Seneca flora.

The Bottom Fauna.— During our survey a large part of our efforts were directed to the study of the bottom fauna to discover the principal source of the primary fish food in the lake. Six hundred and thirty-two samples of the bottom were taken with the Ekman dredge during the three months and carefully analyzed. To supplement these studies 212 samples were taken with the scoop dredge in localities where the Ekman could not be worked satisfactorily and several hundred samples* were taken in the shallows near shore with a Needham dredge.

We find as a result of this work that in the shallow water of all the lakes there is a fair supply of snails, bivalves, and insect larvae, principally mayflies, caddisflies and midges, ranging to a depth of 50 feet. The abundance of these forms in shallow water, however, is not sufficient to supply a preponderant fauna of shallow water

Lowering Ekman dredge for a sample of lake bottom

fishes. The minnows, likewise, which are mostly confined to the shallow water of the lake are not abundant except in a few favored localities.

In the deeper waters we find in all the lakes a plentiful supply of the small crustacean (*Pontoporeia hoyi*), of chironomus larvae, a fair supply of small worms (*Oligochaetes*) and a fair supply of bivalves. (*Sphaerium*). Likewise in most of the lakes near the bottom a fairly plentiful supply of the small crustacean (*Mysis*). These forms are the food of young trout, whitefish, etc., and are often eaten by the larger fish when other supplies fail. In Keuka, Cayuga and Skaneateles lakes we took specimens of *Pontoporeia filicornis*.

* The determination of the organisms captured was the work of Dr. Thomas Smyth of South Carolina University.

We were unable to secure a quantitative determination of *Mysis* and the crayfish. Only 12 specimens of *Mysis* were taken during the summer in the Ekman, but 68 were taken in one haul of the scoop at 45 meters in Owasco. The abundance of *Pontoporeia* and *Chironomus* in deep water indicates a plentiful supply of food for young lake trout and whitefish. The caddisflies were mostly *Molanna, Leptocerus, Heliopsyche, Phryganea, Triaenodes, Mystacides.* The mayflies were *Hexagenia, Heptagenia, Ephemera, Caenis.* With *Chironomus* are included about 1% of *Tanypus, Palpomyia* and *Protenthes.* With *Sphaerium* is less than 1% of *Pisidium.* Large bivalves were poorly distributed. Snails were principally *Physa, Lymnea, Amnicola, Valvata, Goniobasis* and *Planorbis. Hydracarina* were fairly distributed in water from 1 to 75 feet, sometimes to 225 feet.

Conditions Affecting Abundance of Finger Lakes Fishes.—

(1) Overfishing is naturally considered the principal cause of the scarcity of game fish and there can be no question that the increased numbers of fishermen in these waters during the last fifty years has had a very serious effect on the supply of all species which are used as food.

(2) Illegal fishing is talked about in the region very extensively and we took great pains to obtain the most reliable information available on this subject. There can be no hesitation in asserting that illegal fishing with nets occurs to a considerable extent in every one of the Finger lakes. Three rather recent instances of the most flagrant violations of law will serve to illustrate the danger to our fishing interests from this source. About two years ago nearly 300 trout were taken in a single haul with a large seine, late in the season when the fish were in shallow water, probably on the spawning bed. This was in a lake where the scarcity of trout is deplored by many good sportsmen. Last winter in another lake over 200 pounds of trout were taken at one haul in a net which was let down through a long opening in the ice. In another lake where sportsmen are calling for improvement in bass fishing nearly two barrelfuls of bass were taken by fykes in three days. The people who vouch for the truth of these stories would not appear in court against the violators, but deplore the violation. In some of the lakes this fishing is carried on by ''pirates'' for the purpose of selling fish in the open market, but a more general practice is the fishing by farmers and other residents of the lakeside in the fall, winter or early spring to obtain fish for their own tables. It is a quite general practice in most of the lakes to use fish traps of wire netting to capture perch and other pan fish. Where spearing is permitted, trout, bass and other game fish are taken by many of the spearsmen when they feel it can be done without detection. It is also true that a large proportion of the rainbow trout which enter the tributary streams to spawn during the spring are taken by the sucker spearsmen, oftentimes, of course, by mistake but as we know from conclusive evidence, very often because the inhabitants of the countryside feel that they are entitled to an occasional

rainbow instead of saving it for the sportsmen to capture later in the season when the farmer is busy in his fields.

This general feeling of the residents of the lake shore that they are entitled to some of the fish, and the fact that they cannot obtain the fish in a reasonable length of time by legal methods has led to this general practice of evading the law. If the supply of fish is to be improved or even maintained in the various lakes, the practice of illegal fishing, especially for the market, must be stopped.

(3) Spawning grounds. The bowfin, bullhead and pike situation in Cayuga lake is the finest demonstration one could have of the necessity of proper spawning grounds for each species of fish. The draining of the Montezuma marshes and the shutting off of Cayuga from the Seneca river by the mudlock dam have deprived these fish of the spawning grounds which formerly supplied the greater number of them for the foot of Cayuga lake, Now the bowfin is practically unknown and the others are declining. Although there are weedy shallows at the foot of Cayuga the temperature and other conditions there are not as suitable as those that existed in the marshes and there has been a very decided effect on the fish fauna of the shallower part of Cayuga lake. In similar ways the spawning grounds of nearly every fish in our lakes has been more or less seriously affected by changing conditions. For example, the sand and silt brought down by all the tributary streams is very abundant compared to what it was a hundred years ago when the watershed of the streams was protected by forest, and there was less cultivation and rapid drainage of the hill sides. This mud and silt entering the lake from every tributary stream covers many of the spawning beds with a layer of dirt which is unfavorable to the hatching and development of fry. The strong south swells, which are stirred up periodically by the wind, seriously accentuate this unfavorable condition. The waters of these lakes are often much roiled to a depth of 30 to 50 feet off-shore. This condition must be disastrous to the spawn of lake trout, whitefish and cisco, and more or less harmful to bass and perch; for the bass is sometimes unable to keep the spawning bed clean and the partially floating spawn of the perch is filled with mud and buried.

(4) Stocking methods. While our hatcheries have learned to raise trout and other kinds of fish with great success the stocking methods employed by the clubs and individuals which receive these fish from the hatcheries have not resulted in successful planting in many cases. A very careful system of planting each species, based on the best information available is certainly necessary.

(5) The condition of the tributary streams referred to is also the cause of the very serious decline in the numbers of minnows, suckers and other fish which are natural food for the trout, bass, etc. Formerly they were reared in great numbers in the tributary streams and descended to the lake later in the season. Now more than 90% of the streams that flow into the lake dry up in mid-

summer so that a very small proportion of the fry of fish which run up the streams to spawn ever reach the lake successfully.

(6) Obstructions in the outlets have also had an effect. An illustration in the case is mentioned under the distribution of the eel. When fish that were bred in the shallow lagoons of the Seneca river could run up into Cayuga lake and into other lakes of the chain from their outlets, there was a fresh invasion each spring or summer from the streams which tended to maintain a vigorous stock and restore the fish population of the lakes from the more favorable breeding grounds downstream. These obstructions in the outlets of all the lakes are now practically prohibiting migration of fish such as was possible 50 or 100 years ago.

(7) Destructive enemies of the fish we believe are accountable for a large part of the scarcity of lake trout in Canandaigua, Cayuga and undoubtedly in the other lakes. But in Canandaigua the burbot, which is found in the deep water, is a voracious fish and feeds on any kind of fish it can capture. It is unquestionably a scourge of the spawning grounds, devouring the fry and eggs of the trout and so preventing to a large extent the natural reproduction of this fish. He is, of course, an equal enemy of the white-fish and the cisco.

In Seneca and Cayuga lakes the lamprey is a deadly enemy of the trout and all soft scaled fishes. It even attacks carp and bow-fin successfully. However the belief that whenever a lamprey attacks a trout the trout is doomed, must be abandoned, for a large proportion of the trout which we took during the survey bore from one to seven lamprey scars which had healed over completely and the trout was in vigorous condition. The lamprey, of course, sucks the blood of the trout until he is satisfied and then drops from the fish and the wound heals if the fish is sufficiently vigorous or if the wound does not pierce the abdominal cavity. But in the case of young trout, although we cannot prove it, we believe that the attacks of the lamprey are generally fatal. We took no young trout under 18 inches in length which showed a lamprey scar. A further study of this situation is advisable.

Besides the burbot and lamprey many fishes are destructive to the young or the eggs of trout and other food fish. Perch have been taken repeatedly near the spawning grounds of trout with the stomach fully distended with trout eggs. Bullheads have the same habit and, although they probably do not invade the trout grounds to any extent, are destructive of the fishes which breed in the shallows. The sculpin and the spot-tailed minnow are frequently called "spawn eaters." Unfortunately most of our fishes often destroy the spawn not only of other fishes but their own, as has been conclusively proved of brook trout and other fish kept in hatcheries.

The softshell turtle (*Amyda spinifer*) which inhabits Keuka, Seneca and Cayuga is a predacious species which frequently feeds on fish. The same is true of the generally distributed snapping

Photo by C. K. Sibley

Soft shell turtle (Amyda spinifer), enemy of shallow water fish

turtle. I have repeatedly captured water snakes (*Natrix sipedon*) with fish in their jaws which they were carrying to land with the object of swallowing the victim entire. I have taken this snake with a ten-inch brook trout in its jaws which was a fully active, healthy fish; with a burbot 8 inches in length which must have been obtained in rather deep water; with a bullhead which weighed at least a pound; and with numerous other small fishes. I believe the water snake should be destroyed by all sportsmen whenever they have an opportunity. We consider loon, grebes and mergansers also as enemies of our lake fish. I have taken nine good sized chubs from the gullet of a single red-breasted merganser and have found a dozen minnows in the gullet of a loon. The loons and grebes, however, feed mostly on minnows which are of minor importance and the mergansers do not get into deep enough water to be a serious menace to young trout and whitefish. They do, however, diminish the food supply of our larger fishes.

(8) Competition of undesirable fish for the food supply and breeding grounds unquestionably has considerable importance. If the shallows are invaded by bowfins or carp their immediate vicinity is avoided by bullheads or sunfish as a breeding spot and if burbots exist in such larger numbers that they destroy cisco and other fish which the trout need, the trout must decline in numbers. This question of competition works in the case of all our fishes and it is desirable to discourage as far as possible the useless species so that the better varieties may flourish.

(9) The condition of the water as to its temperature, oxygen

content and various other chemical conditions must be considered when determining the stocking policy for the lake. Fortunately all these Finger lakes, with the exception of Otisco, have favorable water for the growth of lake trout, cisco, whitefish and pike-perch as well as bass. In Otisco in mid-summer the deeper portions of the lake, as shown in the table,* are devoid of oxygen sufficient to support any fish. Consequently the deep water fishes should not be planted in Otisco but shallow water fishes, such as pickerel, perch, pike-perch, bass, and pike should thrive there. We have been unable to find any condition of the water which would explain the scarcity of trout in Cayuga lake and believe it should be attributed not to the condition of the water but to the enemies of the fish, to illegal fishing and to mistakes in planting.

(10) Food supply both for the young fish and the mature individuals is the prime requisite next to the oxygen supply. There is no reason, except the burbot, and absence of alewives why Canandaigua lake should not be nearly as good a lake for lake trout as Keuka. There is abundance of food on the bottom for young trout but the older fish have difficulty in obtaining the small fish which make up 98% of their food. The cisco is scarce, the alewife is absent, the smelt, which has been introduced there during the last few years, has not multiplied sufficiently. We believe that a good supply of alewives in Canandaigua would increase tremendously the abundance of trout in those waters. The same is true of Owasco lake where the cisco is too scarce to furnish food for the trout. The smelt has been introduced recently but is not yet abundant. The trout which we took from Owasco lake were almost starved because of the scarcity of proper food for mature fish. They had been feeding mostly on mysis, which is a food adapted especially to young trout. These illustrations should make clear that a proper food supply is the first consideration in waters which are to be stocked and everything possible should be done to increase the food supply of game fish.

General Conditions in the Various Lakes.— In all the lakes examined, except Otisco, the temperature and oxygen content of the water is favorable for lake trout and whitefish. The shallows in all the lakes are fairly well adapted to the black bass and the perch. In all the lakes the tributary streams have been seriously affected by the destruction of the original forest cover and agricultural improvements so that they furnish small encouragement to the suckers and many species of minnows which formerly bred in them successfully. In all the lakes weed beds are poorly distributed except at the head of each lake and in sheltered bays and shallows which are sometimes found along the shore but more often at the foot of the lake. Consequently there is a small acreage available for weed-inhabiting fishes as compared with the large extent of the lake. Therefore fishes which range widely in the lake and are either bottom feeders, plankton feeders or feeders on smaller fishes which feed on plankton are the best adapted for encouragement in these waters.

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* See pp. 117 and 131.

Lowering the water bottle to secure a sample of deep water for gaseous analysis

Canandaigua lake: The trout is relatively scarce in this lake and the whitefish relatively abundant. Pike-perch has been successfully introduced and is an important fish. The black bass is fairly common on the rocky bottoms which are found along large sections of the lake shore. The perch and pickerel which formerly were found in considerable numbers are small and scarce compared to conditions forty years ago. The burbot is abundant in this lake and in our estimation should be removed. Of course a complete destruction of the burbot is impossible but if the use of set lines baited with worms were encouraged and the value of the burbot for salting and pickling were exploited we believe that its numbers could be materially reduced. The small ciscoes which are native to Canandaigua and the smelts which have been introduced in recent years are not sufficiently numerous to feed the trout and we would unhesitatingly recommend the introduction of alewives from Seneca or Keuka lake.

Keuka lake: This lake is the bright and shining example of what might be accomplished in all these lakes if we could control conditions. There are no lampreys or burbots in the lake; the alewife is abundant. Bottom food like Pontoporeia and Chironomus is abundant. There are more tributary streams which do not run dry, and furnish a favorable breeding ground for the minnows. There are weed beds near Branchport and Penn Yan which furnish satisfactory breeding places for the perch, bullhead and large-mouthed bass. The inlets at Hammondsport and Branchport are both good streams for rainbow trout and from these fish descend into the lake and furnish sport for the fishermen. Ciscoes are also found in the lake which supplement the trout food. Whitefish is scarce but could be increased in numbers by proper planting. In this lake more lake trout are taken in a single week than are taken in Canandaigua, Owasco or Skaneateles in an entire season by the line fishermen. Thus it is evident that, in spite of the numbers of trout taken, the supply can be maintained by proper planting, and protection of the spawning grounds. The causes which have maintained the supply of trout in Keuka lake in spite of the abundance of fishermen are a combination of the most careful planting which has been practised in any of the lakes, the guarding of the spawning beds, which was undertaken for several years by the Seth Green Club, the greater abundance of favorable spawning beds in the lake off the mouths of the little tributaries which run down from the hills, by the absence of lampreys and burbots, and the presence of a large expanse of lake bottom lying between 50 and 175 feet in depth.

Seneca lake: Here is an abundance of alewives and, unfortunately, also of lampreys, but no burbots. The eel is fast disappearing from this lake. The whitefish has become scarce, perhaps extinct. The cisco exists in reduced numbers. The pike-perch, although it has been planted in recent years, is scarce and the pickerel is practically confined to the head of the lake and Dresden

Lake trout showing lamprey marks. From Seneca lake bay where it is by no means common at present. Lake trout, small-mouthed bass and yellow perch are the predominant food fishes. On good hard bottom at a depth of 60 to 150 feet the trout is still abundant in such localities as Lamereaux, Lodi, Willard, Pontius, and Reeders. Curiously enough they do not abound off the west shore except at times from Long point to Glenora. They are, however, distributed, though not abundantly, over all the lake. The perch is very plentiful, judging from the catches we made both with trap and gill nets. It is found from Watkins to Geneva harbor. Many perch range from one to two pounds in weight, but curiously enough we heard very little of large catches taken with hook and line. This lake would support a much larger population of trout and with proper planting we believe this could be accomplished. The lampreys of this lake should be reduced by capturing them when they run up the inlet to spawn.*

Cayuga lake: The alewife is plentiful furnishing food for the larger trout. The lamprey, however, is very abundant and is evidently one of the causes of the poor trout fishing. The pike-perch, in spite of recent introductions, seems to be diminishing in number. The whitefish, although formerly present, is scarce. The cisco is less abundant than formerly. The pike, pickerel, large-mouthed bass and bullhead, as well as the undesirable bowfin or dogfish, are becoming scarcer. This we believe is largely due to the destruction of their breeding grounds by the draining of the Montezuma marshes and the erection of the dam at Mud Lock where no efficient fishway has been installed. The eel is commoner in Cayuga than in any other of the Finger lakes because access from the sea is still provided. For some reason, probably extensive netting, poor planting and the presence of the lamprey, the lake trout is scarce in Cayuga. It probably was never as abundant as in Seneca but we see no reason why the stock of trout could not be increased if the lampreys were captured in the inlets as they go up to spawn and the trout fry were properly planted. We learned from many sportsmen who had helped in the planting of trout in this lake that they usually are dumped either off the end of a wharf in shallow water or at the head of the lake just out beyond the lighthouse. We believe that such plantings of trout are practically all wasted. They should be placed in water that is in the vicinity of 100 feet in depth and well scattered along the lake.

Owasco lake: This is naturally adapted to lake trout, rainbow trout, pike-perch and small-mouthed bass. There are no lampreys or burbots in the lake, but unfortunately a good food fish for trout is scarce. The cisco and the smelt, which has been recently introduced, are far too few to feed the trout after they pass beyond the stage in which they feed on the smaller organisms. Almost all the trout taken from Owasco lake during our survey were in an

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* See paper by S. H. Gage on Economics of the Lamprey, p. 180.

emaciated condition and although some of them contained smelts, ciscoes or sculpins we took none which had more than one or two of these fishes in the stomach and most of them had been feeding on mysis or other small organisms. The pike-perch which is a more omnivorous fish seems to find plenty of insect larvae and small fish to grow successfully. This was the only fish which the local sportsmen were taking with any degree of success, while we were on the lake. Eels still exist in Owasco but are fast disappearing. The carp is too abundant near the head of the lake and may interfere seriously with the spawning operations of the pike-perch, perch and bullhead. This fish should be held in check. Suckers were formerly very abundant in Owasco and are still plentiful because there are streams in which they can breed with some success. These same streams are spawning grounds for the rainbow trout which could be encouraged to become an important fish in Owasco. In this lake we took the only sturgeon suckers (*Catostomus catostomus*) which we found in the Finger lakes.

Skaneateles lake: This is a cool, clear water well adapted to the lake trout, the rainbow and steelhead, the whitefish and the cisco. The black bass find favorable breeding and food grounds in the shallower waters and the perch and sucker, among the humbler species, can thrive successfully. On account of the living streams entering the lake in which the rainbow and steelhead can breed we believe these fish should be encouraged. Lake trout, whitefish and cisco should be planted in greater numbers. Possibly the landlocked salmon may yet be firmly established.

Otisco lake: This is the shallowest, warmest and weediest of all the Finger lakes. The deeper water is unfit for fish habitation, at least during the summer, because of the scarcity of oxygen.* It is not a trout lake, but in it the pike-perch, perch, large- and smallmouthed bass, pickerel, sunfish, bullhead and sucker can thrive. Because of the large number of cottagers and fishermen in proportion to the size of the lake, however, general complaints of scarcity of fish were received. The pike-perch, yellow perch and both species of bass should be encouraged in this lake. Incidentally such fish as the bluegill, crappie and catfish could be introduced successfully.

General Suggestions for Improving the Fish Situation.— *Making regulations:* We will cite a single example of many which occurred to us during the season's work. The open season for black bass began on July first, but in both Seneca and Keuka lakes many bass were still on their beds protecting the young fry on that date. We believe that a postponement of the season was advisable, but this could not possibly have been foreseen by last year's Legislature. The temperature in all the lakes was slow to rise to the summer level during the spring of 1927 and the spawning of many shallow water fishes was postponed accordingly.

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* See page 132, chemical analyses.

Law enforcement: After the laws have been wisely formed they should be strictly enforced with absolute impartiality. It is unfortunate that the hunting season in the State comes at just the season when the trout beds should be guarded, when the protectors are mostly in the deer or pheasant country. The spawning beds of trout must be protected or our supply of the finest fish in the lakes will continue to decline. More protectors are needed, at least during the spawning season of lake trout.

Fishways: These should be properly constructed and maintained in many streams where they do not now exist. The one at Mud Lock near the foot of Cayuga lake will serve as an example. If this were an efficient passageway there can be no question that fishing near the foot of Cayuga lake would be considerably improved, although conditions could never be what they were before the marshes were drained by the Barge canal.

Another example, of many, might be the lower falls in Taughannock glen. A fishway at the lower falls might turn this creek into a fine stream for the spawning of rainbow trout, suckers and many species of minnows which furnish food for the game fishes of the vicinity.

Tributary streams: They should not only be provided when possible with fishways, but pollution of the streams at all seasons of the year should be prevented. The Keuka outlet is one example which I might cite. Although there was no serious pollution in this stream during the period of our survey, the paper mills were operating early in the season during the time when rainbow trout were spawning and although several rainbows were captured in this stream at the beginning of the season, indicating that they were ascending to the spawning beds, no young rainbows could be taken by repeated efforts. Evidently the poison from the mills above had destroyed the eggs or fry.

*Elimination of the lamprey:** This parasite is responsible for the death of many trout, especially the smaller trout which presumably do not recover from its attacks as most of the larger ones do.

The burbot: In Canandaigua lake this fish is a serious menace to better food-fish like the trout and whitefish, and any means which would reduce its numbers without serious damage to other fish should be encouraged. It is a member of the codfish family and furnishes a fairly good pickeled or salted product and the fresh fish is by no means bad for the table when properly prepared. The spawning grounds of this fish should be located, if possible, and their numbers reduced by taking them during the spawning season and fishing for them through the ice in winter. Set lines throughout the year should be encouraged as far as possible. Although it could be caught readily with lines baited with alewives or minnows we would not recommend this bait because it would

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* See page 158 for full discussion by Prof. S. H. Gage.

be destructive to trout. Lines baited with worms would also take whitefish, but reduction of the numbers of whitefish could be replenished by planting.

*Carp control**: Although we are by no means convinced of all the evil characteristics which have been attributed to the carp, we do believe that it is an objectionable fish in these lakes, which are adapted to fish which are better than the carp. The danger of carp in the Finger lakes is due to the fact that it increases very rapidly, grows rapidly and consumes a large part of the food which should be conserved for the perch, pike-perch and bass. In searching for insect larvae, snails and crustaceans it roots up the weed beds and roils the lake, in this manner injuring the spawning beds of many fishes and destroying the cover in which a large portion of their food is grown.

Development of fish food: When existing conditions are inadequate to maintain the proper supply of fish in the lake a proper planting of fish food should be made an integral part of the conservation program. Planting fish in a lake where there is no food for them to eat will never make good fishing. The Department has already embarked on the course of planting food for the game fish and we believe it should be carried forward at the same time with the development of fry and fingerlings. The alewife, in our estimation, is the best small fish for lake trout and other fish to feed upon. It is a plankton-feeder. It ranges widely in the lake, descends to the depths inhabited by trout and invades the shallows at all seasons of the year so that it is a good fish food for the perch, pike-perch and bass as well as for lake trout. We see no serious objection to the planting of ciscoes and smelt. But ciscoes do not increase in our lakes as rapidly as the alewife. They do not feed so extensively on plankton, which is the greatest source of food for small fish in the lakes, and the smelt evidently breeds in the tributary streams which are already insufficient for our rainbows, suckers and minnows to utilize, whereas the *alewife breeds in the open waters of the lake and its young grow very rapidly.* Golden shiners are valuable as perch and bass food, and as minnows for bait. These fishes should be encouraged, but unfortunately on account of the scarcity of weed beds they could never become abundant except in the shallows, which are rather restricted in all the lakes. If means could be found of breeding crayfish in large numbers we believe this should be practised as it is a most acceptable food for the black bass, which is the fish most largely sought by the fly fishermen of the region. The shallow water scud, Gammarus, was practically absent from Canandaigua lake. It may be that the netting of Gammarus in large quantities in Seneca lake and planting it at the foot of Canandaigua and at Cottage City, Seneca Cove, Vine Valley and the head of the lake might be successful in developing an abundant food for perch in this lake. It certainly ought to be tried as perch in Canandaigua lake, though fairly numerous, are almost

* See carp control studies, page 67.

universally small except a few at the head of the lake where the abundance of weeds produces the shallow water organisms which are necessary for their growth.

Planting Lake Trout Fingerlings.— In order to determine facts in the much disputed problem of how to plant lake trout fingerlings two series of experiments were performed, one the first week in July, the other the first week in September. Fingerlings from the Caledonia hatchery were placed in an aquarium which contained a liberal mixture of plankton and bottom organisms. These fingerlings fed in about equal proportions on the larger plankton, like Diaptomus, and Chironomus larvae. At the same time fingerlings were placed in cages of wire netting at depths of 10, 30, 100 and 200 feet. Those placed at 100 or 200 feet were raised the next morning and found to be in perfect condition. They had also fed on Pontoporeia and copepods. The fish were kept in these cages for an entire week during both series of experiments and were found in perfect condition at the end. The fish planted at 100 to 200 feet were more vigorous than those at 10 and 30 feet. The absence of Mysis in the stomach content of the fish planted at 100 feet is undoubtedly explained by the fact that the wire meshing was too fine for the Mysis to pass. Furthermore the midge larvae did not enter because they confined their attention to the bottom ooze which was outside the trap. We believe that the trout would naturally feed on the larvae as they did in the aquarium if they were free in the lake, and likewise that they would feed on Mysis. This shows conclusively that young trout thrive at depths of from 100 to 200 feet and find food successfully. The temperature at that depth is that to which they have been accustomed and the pressure has no effect on the fish, even when rapidly lowered or raised from a depth of 200 feet. We believe, therefore, that plantings of fingerling trout should be made in water exceeding at least 60 feet in depth because the oxygen content is adequate, the temperature is much more adapted to the young fish than the temperature to be found in depths of 30 to 50 feet where at the season of planting it is decidedly above the temperature in the hatcheries to which the young trout are accustomed. Furthermore we find that the waters nearer shore to a depth of 50 feet are inhabited by numbers of perch, bass and other predacious fishes which would be a serious menace to the survival of the trout.

The fingerlings should also be well scattered during the planting so that each will have a better chance of finding a bountiful food supply and predacious fishes will be less likely to devour a large percentage of them.

Several outstanding facts immediately engage the attention. There are great areas of the lakes which are fit for fish propagation — a plentiful supply of oxygen, a low carbon dioxide content, a plentiful supply of bottom fauna in most of the lakes and an enormous supply of plankton crustacea. The 50-foot contour line is the general line of division between the realms of the shallow water and deep water fishes. This is near the bottom of the thermocline in most of the lakes and, in general, marks the division between warm and cool water during the summer when the feeding and general life activities are at the maximum. We believe that bass and pickerel confine their attention mostly to water shallower than 50 feet but the perch, which is the commonest and most generally distributed shallow water fish in the lakes, was taken in considerable numbers at depths from 40 to 55 feet. The 150 lake trout captured by our fishermen were taken at an average depth of 85 feet.

In all the lakes excepting Otisco the supply of oxygen and the scarcity of carbon dioxide is such that they are fit for fish habitation to their remotest depths, so far as the gaseous content of the water is concerned.

In Canandaigua, Owasco and Skaneateles the absence of the common scud (Gammarus) is associated with a comparative scarcity of large yellow perch.

The presence of plankton crustacea in the Finger lakes in quantities assumed to be adequate* furnishes the most important clue for an improvement of the fish supply. These minute crustacea are utilized directly as food only by the young fry and fingerling of our important food fishes. But the plankton sifters like the alewife, whitefish at certain seasons and smelt utilize this bountiful food supply and, in turn, are devoured by the lake trout, whitefish, perch and bass. The greatest hope, therefore, for the improvement of fishing in these three lakes lies in the introduction of alewives (sawbellies) or some equally good plankton feeders. Alewives can be taken by the thousand in Seneca lake and immediately transported in trucks to the other lakes. The objection to the alewife that it sometimes dies in great numbers, when it becomes unduly abundant, seems a question of minor importance. No complaints against this fish were heard on Keuka lake where it has been common for fifty years. On Seneca lake there have been complaints early in the summer of the odor of decaying alewives about once in five to seven years. But some of the more intelligent cottagers have maintained that this apparent nuisance is really a blessing because when they gathered the dead alewives from the beaches and buried them in the garden, they found them to be a very valuable fertilizer even as our Puritan forefathers found them at Plymouth. During the summer of 1927 there was no mortality noticeable in the alewife population.

In connection with the general problem of utilizing the plankton in these lakes, it must be borne in mind that these immense volumes of water, amounting to many billions and even trillions of cubic meters in some of the lakes, support a vast amount of plankton crustacea† which can be turned into nourishment for our larger food fishes only through the agency of such plankton sifters as the alewife, smelt and cisco.

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* See Birge and Juday (loc. cit.).

† See Charts 1–8, p. 144; chart 9, p. 154.

Stocking policy.—We advise the planting of the following fishes in the Finger lakes:

Lake trout in all the lakes except Otisco.

Whitefish in all the lakes except Otisco.

Cisco in all the lakes but sparingly in Otisco.

Rainbow or steelhead trout in the affluents of all the lakes wherever suitable. These fish descend into the lakes in the summer and furnish fine sport as well as food.

Yellow perch will take care of themselves where shallow water organisms are abundant. But new stock could be advantageously planted occasionally in Canandaigua and Otisco.

Pike-perch or wall-eye should be planted in all the lakes except Keuka and Skaneateles, where rainbows or steelheads are preferred in the affluents.

Large-mouthed bass might be planted in Otisco and the foot of Cayuga, but we should prefer the small-mouthed bass, even in these lakes, as it succeeds well and is a better fish.

We would suggest continuing the experiment of planting smelts in Owasco and Skaneateles for a few years, and the planting of alewives in Canandaigua where the sportsmen's clubs have made this request. Then, at the end of five years, there would be a better basis for judgment of the relative merits of these two fish as plankton feeders and as food for lake trout and other fish.

By way of variety such fish as the crappie or calico bass, the bluegill and the channel cat could be planted in warmer waters like Otisco and the foot of Cayuga. Where desired by the local fishermen's clubs, pike or pickerel could also be planted in such locations. The golden shiner might also be planted with profit in all these lakes to furnish food for bass and bait for the fishermen.

III. CARP CONTROL STUDIES IN ONEIDA LAKE

By W. M. Smallwood

Professor of Zoology, Syracuse University, and

P. H. Struthers,

Assistant Professor of Zoology, Syracuse University

It was in 1905 that Cole's* paper on the German carp in the United States was published. Little of importance on carp fisheries has appeared since that date. It is greatly to the credit of the Conservation Department that attention is again focused on this species which has become so numerous among our fresh water fish.

Every one who has attempted to work out with accuracy the habits and life history of any animal has recognized that the numerous difficulties are greatly magnified when the object of study lives in a large body of water. Most Natural History studies and the more modern ecological investigations cover a period of years when the object of investigation is a terrestrial form. Years have been given to a study of plant relations in such a habitat. So when we undertook to obtain accurate information concerning the food, daily life and spawning habits of the adult carp, and the development and food of the young carp in a lake containing about eighty square miles with a shore line of nearly sixty-five miles, we recognized that the first summer would be mostly in the nature of reconnaissance and the trying out of methods.

It is generally agreed that the carp have become very numerous in many of the lakes of New York State; and it is equally agreed that sportsmen regard them as a distinct menace to the develop-

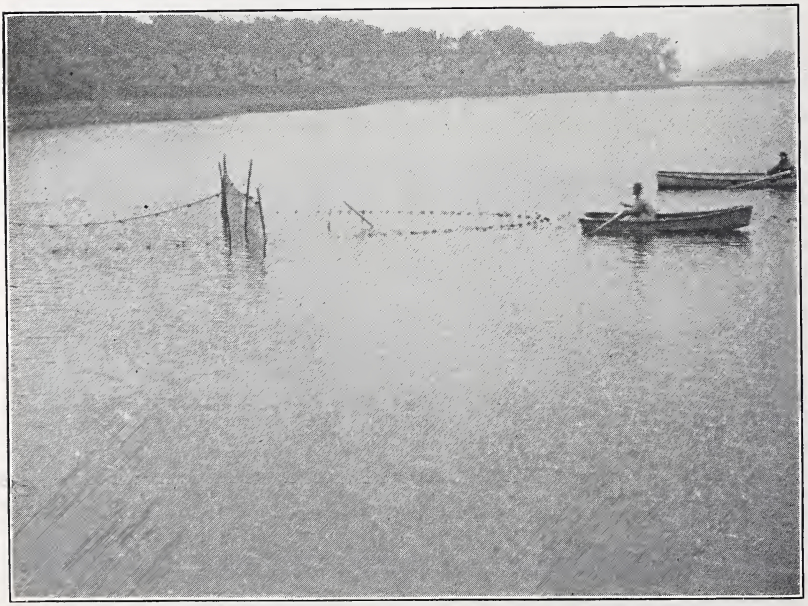
* Cole, L. J. The German Carp in the United States. Rept. U. S. Commissioner of Fisheries. Washington, 1905 (1904).

Channel in the Montezuma marsh, a place where carp spawn ment and catching of game fish. They are certain that they feed on the spawn of game fish and that they destroy the vegetation that is in the last analysis the source of the food of game fish as well as of some of the wild ducks. These and numerous other questions have been submitted to us during our study this past summer. Some of the questions can be answered even from this brief survey, others will require more time.

This preliminary report on carp control studies is submitted under the following:

1. Methods of seining.
2. Statistical evidence.
3. The habits of the adult carp.
4. The food of the adult carp.
5. The habits of the young carp.
6. The food of the young carp.
7. General considerations.

Methods of Seining.— To make statistical studies of the carp a large number of individuals is necessary. To obtain this material, without encroaching upon the time of the scientific staff, the services of Mr. Howard, a trained carp seiner from Bayport, Michigan, were procured. He furnished his own equipment consisting of a flat-bottomed power boat, scows and row boats, a winch engine mounted in the stern of the power boat and two half mile seines, one six feet and the other twelve feet wide. These seines were one an a half inch mesh and each was fitted with a bag or pound forty feet deep. The nets were heavily leaded and



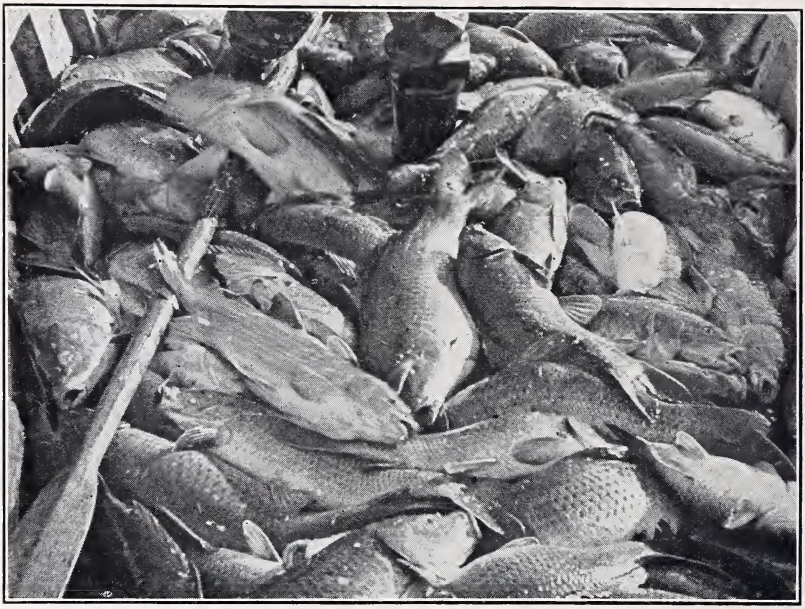
Bag or pocket of net approaching back stop

at forty foot intervals brails were attached to prevent rolling of the seine, especially on grounds with a heavy vegetation. Three men were regularly employed to handle the equipment, but as the work progressed it was found necessary, especially when the bottom was rough, for the game protector detailed to this unit to assist in the hauling of the seine.

A preliminary survey of the carp feeding grounds on Oneida lake showed the advisability of confining the major seining operations to a few stations. It was found that large schools of carp fed in Fisher's bay, at Lakeport, and in the vicinity of Oneida creek. The bottom of the lake in these regions was well suited for seining, possessing large areas of shallow water comparatively free from obstacles such as tree stumps, rock piles or dense vegetation. The north side of the lake would have several excellent seining grounds if the bottom were free from obstacles. Seining was carried on continuously at Fisher's bay from May to the middle of October with occasional hauls being made at other stations on the lake.

It was customary for Mr. Howard to make a scouting trip in his small boat early in the morning or late in the afternoon in order to locate schools of carp. If the fish were feeding their presence could be seen by the roily condition of the water, at other times they were located by fish jumping, while again the carp might be seen lying in shallow water. On locating fish the large seine was laid out around the school, the power boat was anchored inshore from the net and the seine then drawn in by the aid of the winch engine. During the operation the net was watched constantly to guard against its catching on snags or rolling up. In most cases the catch was landed on the shore. Occasionally this was impractical due to the absence of a beach and at such times the bag was drawn up to a back stop, made from a part of the seine, and the catch removed to a scow. The feeding grounds for the carp on Oneida lake are for the most part in shallow water which makes it unnecessary to use a deep water seine or a back stop. Fisher's bay is such a good carp feeding ground, with an abundance of food, protection against wind and its proximity to deep water, that the use of bait such as corn or potatoes does not produce a marked increase in the number of fish. It does however cause the fish of one or more schools to congregate in one place and thus increase the size of a single haul. Because of this two bushels of corn were scattered each week over an area about equal to the space which the seine would encompass.

The seining operations of the scientific staff were confined to the taking of small numbers of carp and game fish inhabiting the seventy-two carp stations made on the lake. Most of the carp were caught in a two hundred and fifty foot gill net (three-inch stretch) laid out loosely around a school of carp. The fish were then driven into the net and seized before they could work themselves free. The gill nets were also used for catching game fish for population studies and to show the movement of fishes.



A boat load of carp, part of a catch weighing one and a half tons

Four such nets, each of a different sized mesh, were placed in a zigzag formation beginning with the fine mesh near shore and grading into the larger sizes offshore. Trap nets were used more successfully for taking fish other than carp. They were used singly or in groups of two or more. By joining the wing of one net with the leader of another a complete barrier was produced. Both trap and gill nets were set for one day a week throughout the summer in Three Mile bay, where an intensive study of a carp ground was made.

The twenty-five and sixty foot minnow seines were found very valuable in collecting young carp and small fish inhabiting carp grounds. Either size of net could be operated by two men, and, except for regions covered with dense flora, they worked perfectly. A rigid trawl, made of fine mesh hardware cloth and shaped somewhat like a Petersen trawl, furnished an excellent means of catching small fishes living in thick vegetation. This trawl was also used for deep water dredging and had an added advantage of being available for a trap when not otherwise in use.

Statistical Evidence.— From May 25 to September 21 more than 45 tons of carp were seined. This represents some 8,000 fish. The exact number cannot be given as accurate records were not made during the first month and in the larger hauls where as many as a thousand fish were successfully taken, some degree of error is to be expected. Those who have not worked at carp seining can hardly appreciate the difficulties. In the taking of this large number of fish, three thousand one hundred and eight other fish were temporarily held in the seine. Just as soon as possible these fish were released and returned to the lake.

All sportsmen and protectionists are anxious to have the detailed facts in regard to the effect of carp seining on the other fish.

Fish other than carp taken in the seines from May 25 to September 22 were:

Catfish	1,216
Bullheads	505
Silver bass	401
Pike	322
Large-mouthed bass	260
Sunfish	248
Rock bass	67
Suckers	38
Pickerel	29
Small-mouthed bass	20
Ling	1
Strawberry bass	1
	3,108

From this list one would judge that not more than 1,000 game fish were caught during this entire period, all of which were returned unless injured by becoming enmeshed in the seine.

Beginning June 18 and continuing from time to time until August 19 we made accurate measurements of 1,643 adult carp. Each fish was weighed and the length from snout to notch in caudal fin taken in inches. Scales from the side of the body dorsal to the lateral line and below the dorsal fin were removed and placed in an envelope. On the envelope was recorded the weight and length. The average weight of these 1,643 adult carp taken with no selection was $8\frac{1}{2}$ pounds. The length of these same fish was 22.12 inches. Scales were taken of the first 25 weighed or the first 50 or the entire lot. Three hundred and thirty-one sets of scales were examined with the microscope. The lines of growth are best seen when the scale is covered with water. The average age of the six sample lots was 5.89 years.

The age of those taken as shown by the study of the lines of growth on the scales ranged from 2 to 13 years with the larger number of specimens four or five years old. But relatively few specimens were taken less than four, actually 13; while the numbers above these dominant age groups gradually decreased. It might be inferred that carp after they became nine years old, either died or ceased to travel in schools. Practically no dead carp were found by us during the summer. What becomes of the older members and what their habits are remain problems still to be worked out.

The habits of the young carp of one, two and three years, especially of the one-year-old carp are mostly unknown. The very few taken during the summer indicate either that they escaped through the meshes of the seine or that they live somewhat apart from the adults which move about in larger schools. This is clearly an important aspect of the carp problem that should be solved.

Cole quotes the English ichthyologist Goode,* in regard to the relation of weight to length. One cannot judge of the variation from this table of Goode. The following summary of our observations is in close agreement indicating that the carp grows rapidly but irregularly. Selecting 62 specimens that were five years old the range of weight was from 4 to 11 pounds and the range in length was from 16 to 26 inches.

No. of specimens	Pounds each	No. of specimens	Length
1	4	2	16 inches
6	5	3	17 "
12	6	2	18 "
15	7	8	19 "
20	8	8	20 "
5	9	15	21 "
1	10	9	22 "
2	11	13	23 "
		2	24 "
		1	25 "
		1	26 "

This variation in the most numerous age taken indicates a larger variation in growth and explains why there is not much significance in the table by Goode.

The following table indicates the range of weight for the same length in fish taken from Oneida lake.

Number of specimens	Length in inches	Weight in pounds
1	7.5	11 ounces
1	11.5	1.25
1	12	1.4
1	13	1.5
1	14	2
2	15	2, 6
3	16	4, 5, 6
4	17	8, 5, 6, 5
5	18	5, 3, 4, 4, 3
6	19	5, 4, 5, 5, 4, 5
6	20	6, 7, 5, 5, 5, 6
12	21	6, 7, 7, 7, 7, 7, 7, 7, 6, 6, 8, 5
5	22	8, 7, 8, 10, 7
9	23	13, 8, 8, 9, 11, 9, 9, 8, 8
5	24	10, 9, 10, 8, 9
5	25	10, 12, 10, 8, 9
5	26	13, 12, 10, 12, 10
5	27	14, 16, 18, 12, 11
3	28	12, 14, 14
4	29	15, 15, 15, 20
2	30	20, 18
4	31	18, 20, 24, 20
3	32	21, 20, 23
2	33	20, 20
1	34	21.5
1	35	24.75
1	39	29
1	40	32

* Goode, G. B. American Fishes. New York, 1888.

The Habits of the Adult Carp.— The limited space at our disposal makes it necessary to consider only those elements in the behavior of this fish, which seem to be directly associated with the problem of carp control. The habits of the carp in Oneida lake agree in general with the description set down by Cole.* Certain habits of breeding and migration seem to be modified to suit the local conditions.

Carp habitats.—An examination of the shores of the lake and islands reveals seventy-two regions inhabited more or less frequently by carp. These stations fall into three distinct types: (1) Rocky shoals typically covered with growths of water-willow (*Dianthera americana*), American bulrush (*Scirpus americanus*) or scattered beds of pickerel-weed (*Pontederia cordata*). Such shoals lying near the feeding grounds as well as deep water afford a place where carp can rest in water made tepid by the summer sun. (2) Protected bays with a bottom of sand, clay or mud which have a wide stretch of shallows separating them from deep water. This type of habitat is rarely visited by large schools of carp although single individuals or small schools seem to live in such places continuously throughout the summer. (3) Protected bays similar to the preceding but close to deep water. Such regions furnish the ideal feeding grounds for the adult carp. Being easily accessible to deep water the fish need travel but a short distance in search of food or escape in case of molestation. During July and the first part of August the shallow parts of such bays supporting growths of cat-tails or bulrush offer excellent places for the carp to rest in the warm water.

The most dominant forms of plants identified in the second and third types of habitat are as follows:

Narrow-leaved Cat-tail	*Typha angustifolia*
Floating Pondweed	*Potamogeton natans*
Clasping-leaf Pondweed	*Potamogeton perfoliatus*
Sago Pondweed	*Potamogeton pectinatus*
Narrow-leaved Arrow-head	*Sagittaria arifolia*
Broad-leaved Arrow-head	*Sagittaria latifolia*
Wild celery, Eel-grass	*Vallisneria spiralis*
American Bulrush	*Scirpus americanus*
Lake Bulrush	*Scirpus occidentalis*
Duckweed	*Lemna trisulca*
Duckweed	*Spirodela polyrhiza*
Pickerel-weed	*Pontederia cordata*
Cow Lily	*Nymphoea advena*
Sweet-scented Water-lily	*Castalia odorata*
Swamp Loosestrife	*Decodon verticillatus*
Water-milfoil	*Myriophyllum verticillatum*
Water-willow	*Dianthera americana*

When the seventy-two stations are grouped according to the types of habitat there are fourteen in type one; fifteen in type two; and forty-four in type three. This last named group, which represents good feeding grounds for carp, is distributed evenly

* Loc. Cit.

between the north and south sides of the lake. At the same time it should be pointed out that the stations along the south shore are generally larger and therefore capable of supporting a greater carp population.

Breeding habits.—The carp spawn principally in May.* This somewhat earlier date than that reported by Cole for the Great

* For other observations in the watershed, see p. 92.

Young stages of carp. The two smallest from Oneida lake, July 21, 1927; young leather carp from Cassadaga creek, July 14, 1925; largest specimen from Oneida lake, Sept. 15, 1927

Lakes may be influenced by the fact that the shallowness of Oneida lake causes the temperature of the water to rise more rapidly in the spring. More information is necessary before it will be possible to state what percentage of the carp spawn in the streams flowing into the lake or the canal. From observations made during the last half of May it is certain that some carp breed in the bulrushes growing in sheltered bays and on the south side of Frenchman's island. Judging from the relatively small number of young carp caught in the lake it seems likely that the majority of the carp may breed in the streams. This idea is further substantiated by the statement of fishermen who say that they find many young carp in the small streams when they are catching minnows for bait. Our observations began June 15 so that we were not able to verify these reports nor to observe personally the spawning habits. Further investigations should be started early enough to permit work on this phase of the breeding habits.

Migration.—In April and May there is a general tendency for the carp to move up the creeks and the canal. In the large creeks such as Chittenango they migrate ten or fifteen miles, often leaving the creek proper to scatter over tillable land inundated by spring freshets. It is not known whether this migration is primarily for breeding or simply foraging for food. By June first the carp have returned to the lake, are very thin and languid and do not move far from the feeding grounds. At this season of the year the carp are gregarious, living in schools of five hundred or more individuals, which migrate from deep water to feed or rest in the shallows. By the middle of July the carp have regained their normal vigor together with a greater feeding range. In October when the water begins to grow cold the large schools are broken up and the carp become sluggish and migrate but little.

Food habits.—Carp are considered bottom feeders, rooting up their food from the bases of pondweed and other aquatic flora. This agitates the sand and mud producing the characteristic carp roil. Contrary to an existing belief that carp eat everything that comes in their way, our observations show that they exercise a preference. As it feeds the fish will every so often eject a mouthful of undesirable material and then continue its feeding. Close observation shows that they also nose along the stems and leaves of plants sucking in a large number of crustaceans and insect larvae. On one occasion carp were seen scooping along the surface of the water in quest of mayflies.

Carp have been accused of driving game fish away from their feeding grounds. In contradiction of this belief we found that catfish, pike and pickerel were frequently taken in the same haul with carp indicating that these game fishes were occupying the feeding grounds together with the carp. In Three Mile bay small-mouthed bass were observed feeding among the bulrushes with carp, neither species seeming to take any notice of the other.

Sunrise and sunset seem to be the preferred hours for feeding. Carp taken during the middle of the day showed their stomachs to be empty. They do not feed every day for they will not venture into shallow water when the lake is rough and even when it is calm the feeding grounds are often deserted. Even while feeding carp are ever on the alert for danger. The creaking of an oar lock or a sudden movement may cause them to rush for deep water not to return again until the following day. If however there is a good cover of vegetation the fish is more likely to lie perfectly still relying on its power of concealment for protection rather than flight.

The Food of the Adult Carp.— There is probably more misconception about the food of the adult carp than about any other phase of its life. This is largely due to the lack of information in regard to their daily activities. Cole comments on the difficulty of studying carp in their natural environment and the even greater difficulty of taking carp at a selected time of day. While we have taken adult carp at all times of the day, in practically every instance the stomach has been empty and the intestinal contents partly digested. Before any very definite conclusions can be formulated in regard to the significance of their diet in Oneida lake additional studies will have to be made. However some facts of importance were gathered as the following, selected from our data, illustrate. These have been taken to show the scope of the feeding habits of the adults:

June 18. Length, 22 inches; weight, 5 lbs. Station 53, Lakeport. Food: small fragments of muscle of fish, fragments of insects and crayfish, copepods, 1700; algae, abundant; bits of leaves and roots of higher plants.

June 10. Length, 15 inches; weight, 2 lbs. Station 60, Sylvan beach. Food: stomach empty and contents of intestines mostly digested; Spirogyra, Vallisneria and insect fragments.

July 12. Length, 20 inches; weight, 8 lbs; age, 5 years. Station 8, Three Mile bay. Food: two small snails; small clam; parts of two young minnows, probably golden shiners; ostracods, copepods, phyllopods and insect fragments; remains of algae and Potamogeton.

July 14. Five carp were taken in Station 17, Poddygut bay, at 4:30 p. m. and the intestinal tract removed and preserved at 6:00 p. m. Carp are found in this habitat during the entire day. Theoretically the food conditions are ideal, but the intestinal tract was practically empty in each one except for sand and a few plant fragments.

August 19. Twenty carp were secured in Station 46, in Fisher's bay and preserved at once. These were taken in the seine which had been placed around an area where corn had been scattered. Three had the stomach full of corn, nine had the stomach empty and three the intestine as well as the stomach empty. In this habitat where the carp were being fed it is interesting to examine the detailed intestinal contents of the following three: First specimen. Length, 27 inches; weight, 12 lbs; age, 12 years; male; stomach contained mostly partially digested corn, a few crustacea and fragments of water plants. Intestine (in order of frequency of occurrence); small snail shells and fragments; caddis worm cases; midge larvae; amphipods; copepods; ostracods; legs and antennae of various crustacea; filamentous algae; small mollusca; cladocera. Second specimen. Length, 21 inches; weight, 6 lbs; age, 5 years; stomach empty; intestine: snail shells and fragments; midge larvae; caddis worm cases; plant fragments; ostracods; cladocera; amphipods; small clams. Third specimen. Length, 21 inches; weight, 8 lbs; male; contents of stomach: caddis worm cases; snail shells; midge larvae; plant fragments and stalk fragments; ostracods; 3 fish scales; water mites; plant leaf; minute algae; crustacean legs.

To test out the report that carp destroyed plants, a cage was constructed at Three Mile bay. Three adult carp were confined for two months in this wire screened cage covering an area of about 25 square feet. At the close of the experiment a few plants of eel-grass had been uprooted but there remained a large number of these plants and others which carp are reported to root up in feeding. The cage was located in a place where carp had been found to congregate and after the cage was constructed carp were repeatedly seen in the weeds close to the cage. The conditions then, were as near ideal for testing out this question as possible, and the result indicates that the damage done to vegetation was insignificant; but on the other hand the detailed studies on the food of adult carp in Oneida lake clearly indicate their preference for animal food.

Cole states that the food is largely vegetable. Tracy[1] reporting on Rhode Island fisheries says that the carp eat principally vegetable matter; and Forbes and Richardson[2] emphasize vegetable food as the main constitutent. It is hardly to be expected that there would be such a marked difference in the food habits of the Oneida lake carp. The explanation may be in the fact that our material was preserved very soon after the fish were caught. The studies of this summer indicate that animal food predominates and that there is some selection in the animals eaten. The finding of muscle fragments and fish scales is rare and probably means that they were taken in with the debris that is so characteristic of the intestinal contents.

The Habits of the Young Carp.— Up to the present time practically nothing has been known about the habits of young carp. This is probably due in part to their hiding in vegetation when disturbed rather than exposing themselves in an attempt to escape. Moreover they do not live in schools as do many of the young game fishes, a characteristic which causes them to escape the notice of a casual observer. It is easy to distinguish carp fry from the young of other fishes for they are a replica of the adult in form

[1]Tracy, H. C. Annotated list of fishes known to inhabit the waters of Rhode Island. Com. Inland Fisheries, R. I., 1910.

[2]Forbes, S. A. and Richardson, R. E. The Fishes of Illinois. Ill. State Lab. Nat. Hist., vol. 3, 1908.

and arrangement of the fins. The back is much lighter in color than that of the adult, being a light mouse gray. At the base of the tail there is a vertically placed black bar, while the abdomen has a distinct yellowish tinge. When young carp are caught in a dip net this yellowish color and the deep body distinguish them from many other species of fish. It is very difficult to identify young carp in the water when looking down on them from above, but a triangular area somewhat lighter than the back can be seen in good light lying just back of the head.

All the small carp found during the past summer were confined to a very characteristic environment. In general this consisted of a region protected against waves by the presence of a sand bar from the open lake. At Lakeport a wide stretch of cat-tails and bulrushes served to break the force of the waves. The bottom of these carp grounds was invariably sandy or a combination of sand and mud, the latter being usually found near shore and therefore associated with the very young carp. In all the habitats observed the water was free from sediment, decaying vegetable matter or contamination from creeks. The temperature of the water in these protected regions ran about ten degrees warmer than that of deep lake water. The shores bordering these carp habitats consisted of low land covered with a growth of meadow grass or bulrushes with here and there small bayous extending shoreward. Each of these set-backs was carpeted with tender grass, Elodea, Chara, or Myriophyllum among which the young carp lived. As the carp increased in size they moved lakeward into deeper water. By September first the young carp were living in one or two feet of water close by scattered beds of Pondweed (*Potamogeton pectinatus*) or of Hornwort.

The rapid rate of growth of young carp is remarkable. This is shown in the following table which gives the dates the fish were caught, the ranges in size and the locality.

July 12	10 mm. long (about 3/8 inch)	Lakeport
July 21	12 mm.—26 mm	Damon's point
July 27	14 mm.—30 mm	Clough's bay
July 29	12 mm.—40 mm.	Lakeport
Aug. 12	38 mm.—42 mm	Frenchman's island
Aug. 20	41 mm.—78 mm	Damon's point
Sept. 5	80 mm.—112 mm	Frenchman's island
Sept. 7	72 mm.—106 mm	Damon's point
Nov. 25	50 mm.—110 mm	Damon's point

The carp caught on July 12 at Lakeport were very young for the yolk-sacs were still present. They were living close to the shore in not over one inch of water. The fish taken in Clough's bay on July 27 were living in the short meadow grass in about four inches of water. The carp taken during August inhabited water six inches to one foot in depth, while those taken the first week of September were living in water from one to two feet deep. Further observations are necessary to determine when the young carp go into deep water. The yearling carp were found in schools similar to the adult carp but not associating with the more mature fish.

Young carp are found scattered over a favorable habitat, each individual conducting itself independently of other young carp. In seining it was never possible to catch more than two or three of them in any one haul. On July 21 at Damon's point twenty little carp were taken from one of the shallow set-backs, covering an area of not over thirty square feet. A similar catch was made at Clough's bay July 27, in a growth of short grass. In each of these instances the cover was excellent and this fact probably accounts for the large number in a small area. On September 7 at Damon's point a strip of shore three hundred feet long and extending fifty feet into the lake was systematically seined. The territory had several beds of Potamogeton pectinatus, Elodea and Chara, each an excellent cover for young carp. Only ten fish were caught in this area. Such data show how widely the young carp of 70 mm. to 100 mm. are distributed over a favorable habitat.

Invariably a little carp will hide rather than seek safety in flight if molested. It is this characteristic which makes them so difficult to find. When catching them with a hand-net it is possible to work over a whole bed of Chara or Elodea without driving the fish away. Not until they reach a length of about 100 mm. do they seem to appreciate the possibility of fleeing from an intruder. On September 15, several carp over 100 mm. in length were seen to dart out from small patches of Potamogeton (*P. pectinatus*). Their movements were very rapid and directed toward deep water. Even the youngest carp observed were fast swimmers, comparing favorably with young darters which are frequently found living in the same habitat. Several pens of young carp were kept in Clough's bay for purposes of study. Here we found they spent a considerable amount of time completely buried in the mud and sand. This habit is undoubtedly valuable for very young fish living in shallow water, as a means of protection, especially against predacious birds and sudden changes in the temperature.

Small carp are very sensitive to temperature changes and also to impurities in the water. To test these reactions, young carp were placed in aquaria with young sunfish, bullheads and common perch. A sudden change of temperature invariably affected the carp first. Any pronounced change in the hydrogen-ion concentration, due to the presence of decaying matter, was fatal to the carp although not to the other young fishes living with them. In their natural habitat young carp were seldom found in the vicinity of green algae such as Spirogyra or Cladophora, decaying vegetable matter, or quagmires.

The feeding habits of young carp are very interesting. On July 21 some carp fry 12–26 mm. long were observed feeding, about noon, in a bed of Chara at Damon's point. Twenty individuals were scattered over an area of some thirty square feet. The fish would start in at the base of the stalk, work up the stem and then down the other side, then go to another plant and repeat the operation. At times they would work out onto the leaves, but never come to the surface of the water. Sometimes two fishes would be working on one plant, each apparently unconscious of the other's presence. At intervals a fish would remain motionless, except for the slowly waving fins, and then suddenly dart off to a new clump of Chara. More detailed observations of the feeding habits of the little carp were obtained from fish living in aquaria and the artificial pens at Clough's bay. The bottom of the aquarium was covered with fine sand and clay rich in organic

Flooded land along old channel of Seneca river, habitat of spawning carp

material. Within a few days the surface showed numerous small pits. These were made by the young carp which often take a position forming an angle of about 90° with the bottom and with the tip of the snout in the sand. Next a cloud of sand is seen passing out of the opercular opening. Sometimes this is all that happens and the fish proceeds to swim about in the aquarium; but at other times the fish takes a position horizontal to the bottom and works the jaws repeatedly as if chewing, the jaws opening and closing from 12 to 18 times according to some of our records. After this chewing, the fish swims around. There is still another feeding habit of the young carp in aquaria that has been interesting to watch. They suck up a mouthful of the debris from the bottom, eject this from the mouth, then dart forward and gobble up bits of desirable food. This preferential type of feeding has not before been attributed to carp. The young fish living in aquaria frequently resort to top feeding, working here and there with their mouths just below the surface of the water sucking up bits of floating matter. This is probably an unusual type of feeding for young carp in their natural haunts, for the fish lives near the bottom. Observations made on the stomachs of little carp taken at different hours during the day, indicate that they have rapacious appetites which keep them busy foraging for food at all hours of the day.

Young carp are very active, strong swimmers and their inquisitive natures keep them continually exploring the domain in which they live. But being more timid than our common game fish it is difficult to observe them. Their tendency to live in dense growths of flora and to bury themselves in the mud indicates that the young fish may be to some extent negatively phototrophic, in which case their behavior differs from the adult, which shows no aversion to light. The instincts seem to be poorly developed in the young carp, for our observations show no indications of pugnacity or on the other hand of a tendency to be gregarious. A characteristic occasional darting about aimlessly through the water might be attributed to play.

The Food of the Young Carp.— Pearse* reports on the food of 42 young carp, ranging from 15 mm. to 460 mm. These were taken between the dates of July 12 and September 14, with one specimen secured April 22. The collections extended over two summers. The summary of the food in percentages of these 42 is as follows:

Food: insect larvae, 39.7; insect pupae, 6.8; adult insects, 3.5; mites, 1.8; amphipods, 6.9; entomostracans, 20.9; snails, 6.9; oligochaetes, 2.8; rotifiers, 1.1; protozoans, +; algae, 0.8; plant remains, 4.9; silt and debris, 1.5.

While several hundred young carp were taken during the summer the study of food contents was made on only 87. The collections were from both the south and north shores and Frenchman's island. Fish taken from such widely separated regions should show variations in their food, if the fish were merely taking what was available or were omniverous, but we find a great similarity in the stomach contents of the young fish taken from these widely separated localities. Animal food dominates throughout the period with the ostracods, copepods, snails, and chironomid larvae persisting as the most important food. It is interesting to discover that the same conditions obtained in these young as are found in the adults, for many had the stomach empty and some the entire intestinal tract. Such conditions cannot be due to the scarcity of food for there was a continued abundance of these food organisms throughout the summer.

The following individual studies introduce the summary in

* Pearse, A. S. The Food of the Shore Fishes of Certain Wisconsin Lakes. Bull. U. S. Bur. Fisheries, vol. 35, 1918.

percentages of the food table of young carp and reveal the selective nature of their food.

I. Length, 16 mm. Stomach empty. Food in the intestine: Cladocera, 10; copepods, 20; ostracods, 60; unidentifiable debris, 10.

II. Length, 16 mm. Food: Planorbis, 75; ostracods, 7; copepods, 4; mites, 3; algae debris, 1; eggs of snail, 10.

III. Length, 18.5 mm. Food: Chironomid larvae, 20; ostracods, 10; copepods, 30; cladocera, 10; debris, 15; eggs of snail, 15.

IV. Length, 23 mm. Stomach filled: Ostracods, 25; copepods, 25; cladocera, 5; debris containing planorbis, 40.

V. Length, 26 mm. Stomach filled: Parasitized by 5 nematodes in the alimentary tract. Food: Ostracods, 80; copepods, 8; misc.: Arcella; mites; insect; cladocera, 12.

VI. Length, 12 mm. Stomach empty. Copepods, 80; ostracods, 15; cladocera, 5.

VII. Length, 40 mm. Stomach empty. Planorbis, 25; chironomid larvae, 35; ostracods, 10; copepods, 5; insects, 6; Arcella, 1; cladocera, 3; water mites, 5; debris, including Planorbis shell fragments, ostracods, plant fragments, diatoms, Pediastrum, filamentous algae, Eremosphera, sand, 10.

VIII. Lenth, 82mm. Weight, 9.5 gm. Stomach empty. Snail shells, 10; copepods, 10; seed pods, 15; ostracods, 15; midge larvae, 10; cladocera, 10; insect larvae, 5; plant leaf and stem fragments, 5; insects, 5; amphipods, 3; fish spine and caudal fin, 3; fish scales, 2; debris, including shell fragments, 5; algae, 2.

Summary of the food of the eighty-seven young carp ranging from 11 mm. to 112 mm.

Food Item	*No. of individuals containing food in the alimentary tract (stomach and intestine)*
Crustacea fragments	70
Ostracods	65
Copepods	61
Cladocera	39
Insect larvae	69
Algae	46
Snails	31
Debris	29
Shell fragments	27
Worms (Nematode)	16
Plants (plant leaf fragments)	16
Mites	15
Eggs	
Snail	4
Insect	5
Copepod	3
Rotifers	3
Clams	2

Eleven had the intestinal tract empty. Thus 70 per cent of the 76 containing food had eaten some form of crustacea.

The individual studies and this table indicate that their food is similar to those found in Casadaga creek*; and that they compete with perch, bass, pumpkinseeds, suckers, bullheads, darters and minnows.

General Considerations of Carp Control.— The studies on carp control which have been carried on during the past summer furnish new and valuable data upon the life of the carp in a

* Genesee Survey, p. 56, 1926.

large body of water. These studies have shown us the wide scope of this carp problem, which presents many phases as yet unstudied or in which the investigation is not complete, and whose solution is necessary before it will be possible to formulate regulations that should be adopted for the control of carp. It is very much to be doubted if any regulations other than the natural consumption of carp will be successful in keeping their numbers down. To just what extent the carp are really detrimental to the development of game fish in large bodies of water, still remains a problem. When the carp come in in large numbers where fishermen are casting for bass, the bass usually cease to take the fly. In this sense they may be characterized as detrimental to the catching of one of our popular game fish. They are exceedingly shy and remarkably swift in their movements, so that any detailed study of their habits in a large body of water presents numerous difficulties. But it is in large bodies of water in the State that they have come to live in vast numbers, so that it is important that their adaptations and habits be closely scrutinized.

In this one summer it has been shown that the food of carp is selected in part, chosen from animal sources. Their breeding habits in the spring should be one of the first problems taken up and this will necessitate beginning observations early in May. We have been able to check up on many of the stories of the fishermen and found most of them to be unreliable but of course we were unable to make observations on the activities of the carp during the early spring when they are said to be present in great numbers in the over-flooded regions in the swamps of Three Mile bay, Chittenango creek and elsewhere.

We are, at the close of the summer not able to give a consistent account of the one-year old carp. Where do they live and upon what do they feed and are they associated with the large schools of adults? Also, when do the young leave their characteristic shallow water habitat and enter the deeper water? Do they continue to select their food and is it almost entirely of an animal nature as it is during the first summer? These and similar problems must be studied before anything like the complete story of the carp in a large lake can be told. Some one should take up the whole problem of marketing carp for we feel that just as soon as a constant demand can be created for carp as food, that the simplest and most reasonable method of their control will have been adopted. Associated with the selling of carp there will develop a rather perplexing problem for the Conservation Department, in giving its endorsement to some means of seining these fish, for they cannot be taken to commercial advantage in any other way. Before it is wise to issue permits for seining, it will be necessary, we believe, to train men in this work, for while carp are abundant, it does not follow by any means that they can be taken regularly so as to meet a continuous demand. The casual and superficial methods of local fishermen if utilized will surely result in financial failure. The man who undertakes to catch carp to supply a market demand must know the detailed habits of carp and he must be equipped with an understanding of seining.

IV. FISHES OF THE OSWEGO WATERSHED

By J. R. GREELEY,

Instructor in Zoology, Cornell University.

The entire Oswego drainage has never before been investigated with the purpose of listing the fishes found within its waters, although the fish fauna of subdivisions of the watershed, the Cayuga and Oneida lake basins, have received much careful study.[1, 2, 3.]

During the summer of 1927 the Conservation Department carried on as a part of its program, an investigation of the fishes of the entire Oswego watershed.

Extensive collecting in the creeks, rivers and ponds of the region was done by one collecting party made up of the writer and Mr. Carl Van Dieman and by another similar unit comprised of Messrs. Myron Gordon and W. M. Reynolds. A survey party under Dr. E. H. Eaton collected in the Finger lakes in connection with work toward the development of a stocking policy for those bodies of water and under Dr. William Smallwood in connection with carp control studies. The work of labeling and cataloguing the collections was done by Mrs. J. R. Greeley, who served as curator.

These collections include over 1,500 lots of specimens. Representative series of all species will be placed on record in the New York State Museum at Albany. As far as possible complete data regarding type of bottom, current and water temperature has been kept for all specimens.

Methods of collecting.—The greater part of the stream collecting was done by means of seines. These ranged in size from a length of 6 feet and a mesh of 1/6 inch to a length of 200 feet and a mesh of 1 inch. Set lines and fyke nets were used in several of the rivers.

In the lakes the collecting methods included the use of gill nets, seines, fyke and trap nets, set lines and dredges.

General Nature of the Region.— The Oswego river drains an area lying within the region of glaciation. Toward the southern headwaters of this watershed, especially in the country drained by tributaries of the Finger lakes, there are numerous high hills. From these run many precipitous streams and here, as in Watkins and Enfield glens, waterfalls are frequently encountered.

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[1] Meek, S. E. Notes on the Fishes of Cayuga Lake Basin. Annals of N. Y. Acad. of Science, IV, March, 1889.

[2] Reed, H. D. and Wright, A. H. The Vertebrates of the Cayuga Lake Basin New York. Proceedings Am. Philos, Soc. Vol. XLVII no. 193, 1909.

[3] Adams, C. C. and Hankinson, T. L. Notes on Oneida Lake Fish and Fisheries. Trans. American Fisheries Society, Vol. XLV no. 3, June, 1916.

Acknowledgements are due Prof. T. L. Hankinson who contributed information on the Oneida lake fishes; Prof. A. H. Wright for valuable suggestions; Prof. C. L. Hubbs who made several determinations of fishes; and many sportsmen and game protectors of the region.

Toward the north however, the country becomes more flat, and is drained largely by less rapid streams. Although a high plateau is to be found north of Oneida lake, even here the descent is generally more gradual than it is in the region of the Finger lakes.

There are many lakes and ponds throughout the Oswego watershed. These tend to prevent floods in the streams which they supply by acting as temporary storage basins. Because of this fact the Oswego river is much less subject to excessive high water, as is emphasized by G. W. Rafter in his work on the Hydrology of New York State (p. 110).

This author gives much important data about the Oswego watershed which may be summarized, in part, as follows: Total catchment area 5,002 square miles; total area of water surface approximately 310 square miles; total area of water surface, flats and marsh, 530 square miles (10.6 per cent of total catchment area); mean annual rainfall 30 to 40 inches; evaporation approximately 28 inches; annual runoff, calculated from a mean annual rainfall of 36 to 37 inches, not more than approximately 9 or 10 inches; highest waters (Fish creek region) about 1,800 feet above tide level; lowest waters (at Oswego) about 400 feet above tide level.

Distribution of Fish in the Watershed.— The problem of the distribution of the various species of fishes throughout this large area is not capable of being entirely solved. There are too many factors to be taken into consideration. Not only would we need to understand perfectly the geologic history of the area but also must we consider the many changes brought about by mankind in clearing the forests, polluting the streams, building canals and otherwise disturbing the natural fish fauna. However it may be of interest to note a few facts that are apparent in regard to the question of distribution.

(1) There are generally more species of fish in the lowland where there are more gradual watercourses, than in the highland where there are more precipitous ones. The tributaries of the Finger lakes are poorer in number of species than are their outlets and conversely, the northern area of the watershed is, as a whole, richer in this respect than is the southern.

(2) The headwaters of some streams of the Oswego drainage have their sources very near others of either the Susquehanna, Mohawk, Lake Ontario or Genesee watersheds and in certain cases have acquired species of fish from the neighboring drainages. This has occurred either by means of a former, natural, direct connection or by a recent artificial one.

The first case is illustrated by upper Buttermilk creek (Cayuga lake drainage), which has its headwaters in close proximity to those of Danby creek (Susquehanna drainage) and, judging by the similarity of the fish fauna of the two streams, was once connected with this creek.

An example of the second case is shown in Catherine creek (Seneca lake drainage), which was joined with the Susquehanna stream system by an artificial canal, which allowed certain fishes notably *Notropis procne*, *Clinostomus elongatus* and *Nocomis micropogon* to enter Catherine creek.

In at least one instance a Susquehanna stream has been artificially diverted into the Oswego drainage. A branch of Tioughnioga creek was made to flow into DeRuyter reservoir by the construction of a dam. This causes its waters to flow into Limestone creek of the Oneida lake basin.

(3) The Barge canal which connects the Oswego watershed directly with the Genesee and Mohawk rivers.

For the purpose of treating the distribution of the various fishes the Oswego drainage has been subdivided into smaller divisions, which are as follows:

1. Canandaigua lake.
2. Canandaigua lake inlets.
3. Kueka lake.
4. Keuka lake inlets.
5. Seneca lake.
6. Seneca lake inlets.
7. Cayuga lake.
8. Cayuga lake inlets.
9. Owasco lake.
10. Owasco lake inlets.
11. Skaneateles lake.
12. Skaneateles lake inlets.
13. Otisco lake.
14. Otisco lake inlets.
15. Onondaga lake.
16. Onondaga lake inlets.
17. Oneida lake.
18. Oneida lake inlets.
19. Oswego river.
20. Oswego river tributaries (exclusive of Seneca and Oneida river),
21. Oneida river.
22. Oneida river tributaries.
23. Seneca river.
24. Seneca river tributaries.
25. Clyde river.
26. Clyde river tributaries.

This chart of fish distribution (p. 103), shows the known distribution of the numerous species of fish throughout the watershed.

Classification of Fish.—In the annotated list (page 95) 100 species of fish representing 24 families are listed from the Oswego drainage. From an economic standpoint these may be divided into food and game fish (those commonly taken for sport or for use as food) and non-food, non-game fish (those not taken for these purposes).

Food and Game Fish.—Under this heading 43 species may be listed. For the entire drainage area, it would be impossible to list these according to their exact rank in importance, partly because of the lack of a statistical basis upon which to consider their importance. Even if the exact number of each taken by fishermen were known, there might yet be some doubt as to the relative value of the various species. Considered from the angler's viewpoint a much sought game fish like a trout might be more important than a less desired species such as the perch, irrespective of the numbers taken.

Statistics regarding the commercial fisheries of the larger lakes and rivers of the region are given by Cobb.* Due to the decrease in this type of fishing such figures cannot be applied at the present time.

Since angling is now more important than commercial fishing in our region, the game fish may be considered the more important ones. The principal species are: The brook, brown, rainbow and lake trouts; the small-mouthed and large-mouthed black basses; the pike-perch; the northern pike; and chain pickerel; the bullhead and spotted catfish; the yellow perch, the rock bass, common sunfish and calico bass; the common sucker, three species of red-horse suckers (*Moxostoma*) and the eel. Other species of food and game fish which are of less importance, due to restricted occurrence or rarity are: steelhead trout, common whitefish, white bass, sheepshead, yellow bullhead, blue pike, sauger, long-eared sunfish, green sunfish, lake sturgeon, eel-pout and smelt. A group of food fishes that are seldom taken by angling are: cisco, tullibee, fine-scaled sucker and the carp. Of the latter, however, a considerable number are speared and used for food. The carp has great possibilities as a commercial fish within the Oswego watershed.

Several species of fishes having inferior value as food are nevertheless occasionally so used. Among these are: hog sucker, chub sucker, fall fish, horned dace, little pickerel and bowfin. As only the larger individuals of most of the species are ever used for food the group perhaps more properly belongs under the next subdivision, that of non-food, non-game species.

Non-food, Non-game Species.— Here we may list 57 species. This group is composed of the smaller fish such as the minnows (*Cyprinidae*) along with a few of the larger varieties which are not of use as food such as the gar-fishes (*Lepisosteus*) and includes the following: the lampreys (2 species), long-nosed gar, bowfin, sawbelly, gizzard shad, nearly all members of the minnow family (29 species), stonecats (4 species), mud minnow, barred killifish, trout perch, darters (6 species), skipjack, sculpins (4 species) and sticklebacks (3 species).

Bait Fish.— The use of small fish as bait for larger ones such as pickerels and basses, is a very common practice among anglers. Judging by the number of persons engaged in selling live bait

* Cobb, John N. The commercial fisheries of the interior lakes and rivers of New York and Vermont; Rept. U. S. Com. of Fish and Fisheries 1903 (1905).

near the lakes, it is here that this style of angling is most common. However along the Oswego and other rivers as well as along the waters of ponds and the larger creeks, live bait fishermen are often seen. The numbers of minnows and other small fish thus destroyed are doubtless great.

The majority of these are taken from the streams for it is generally easier to obtain larger and more suitable minnows here than in the lakes. Certain creeks are netted very thoroughly for this purpose and, due to this cause, some of these creeks are doubtless injured in their productivity of game fish owing to the consequent decrease in the food of the latter. However the actual harm done in this way is difficult to estimate because of other factors operating toward a decrease in the number of food fish. In the few streams not containing game fish, and not directly tributary to other streams containing such, the damage done by taking minnows may be negligible.

The commercial bait fisherman and in many cases the angler taking bait for personal use only, often destroy an unnecessarily large number of small fish. This is mainly due to the fact that there is often a considerable loss from fungus disease when numbers of fish are kept crowded together for several days. This is especially true in summer.

Anglers prefer to use the more silvery varieties of minnows, although they may often use whatever they are able to obtain. For the black basses and pickerels large baits are used. To take perch, calico bass and other smaller game fish, fishermen use minnows of a smaller size. In general the fish used in angling are not those species which are of value as food or game but, unfortunately, such varieties as sunfish and yellow perch are sometimes used for northern pike and other pickerels.

The more common bait fishes in our region are: common shiner (both subspecies), golden shiner, silvery minnow, blunt-nosed minnow, and barred killifish. Numerous other species may be occasionally used not excluding several food species such as the two just mentioned. Sawbellies and ciscoes are used, when obtainable, as lake trout bait.

Habitat Preferences.— Fish seem to have decided preferences in the matter of environment although some species are quite versatile in this respect, occurring in many types of waters. Particular factors must be met, however, for the various species. Among these factors are size of stream, current, type of bottom, temperature, chemical and gaseous content of the water, type and abundance of food, shelter and spawning grounds (Greeley*).

In the case of a particular species of fish, the requirements as to one condition of environment may be more rigid than that regarding another. Brook trout seem not to be limited to any one

* Greeley, J. R. A Biological Survey of the Genesee River System. Part IV. Fishes of the Genesee Region with Annotated List. N. Y. State Conservation Dept. 1926

type of bottom for they occur where the bottom is muck, gravel, rubble, clay and so forth. However they are limited to cold waters. Fan-tailed darters occur in both cold and warm waters. Yet they, unlike the trout, are restricted to shallow riffles where the bottom is hard, usually rubble.

In the annotated list, notes are included for nearly all species as to the environment in which the fish has been taken. For the sake of clearness, the designations there used may be explained. *Rivers:* the Oswego, Seneca, Oneida and Clyde. *Large streams:* tributaries of approximately 15 feet in width such as Canandaigua outlet. *Small streams:* tributaries of less than approximately 15 feet in width. *Lakes:* the major lakes of the region ranging in size from Oneida lake to Neatahwanta. *Ponds:* small bodies of water ranging in size from Duck lake to Mud pond (near McLean).

Types of bottom are characterized as follows: *Bare rock:* bed rock. *Hardpan:* glacial clay. *Gravel:* small pebbles. *Rubble:* large pebbles and loose rocks. *Sand:* fine rock particles. *Silt:* coarse "soil" particles. *Mud:* fine "soil" particles. *Muck:* black swamp deposits formed of decayed plant remains.

Types of currents are characterized as follows: *Torrential;* as in the swiftest "white water" riffles. *Rapid;* as in average riffles. *Moderate;* as in the deeper pools of a stream. *Sluggish;* as in deep, comparatively slowly moving waters such as the Oswego river. *Stagnant;* no appreciable current.

Fish Association.— As has been noted in the works of Forbes* and of other certain species of fish are often found associated together. Doubtless the main reason for this is that the environmental requirements are similar for certain groups. When enough data on these requirements are obtained, facts regarding the presence or absence of certain species may be useful as indicating the suitability of waters for certain others. In this respect we know that the sculpin (*Cottus cognatus*, Plate No. 7) may be regarded as an indicator of brook trout water. We have never taken this fish except in cold spring brooks where trout were present or could have been established.

Although temperature is not the only factor influencing the association of fish, it does play an important part and fish may be classed according to their temperature requirements. From the standpoint of fish culture, fish are often separated into warm water and cold water groups. The first of these groups includes fish such as the black basses which will thrive in water of comparatively high temperature but will not do well in cold waters. The second grouping includes trout and other fish which will not live in warm waters.

The limits between "warm water" and "cold water" fishes are not fixed. There is a gradual differentiation between the extremes

* Forbes, S. A. Fresh water fish and their Ecology. Ill. State Lab. Nat. Hist., 1914.

on the one hand to those on the other. Within each group there are degrees of adaptations. For example brook trout are better adapted to very low temperatures than are brown and rainbow trout. At the fish hatchery at Bath, New York, where the water is very cold, young brook trout grow much faster than do the young of the other two species.

In the Oswego watershed there are streams ranging from a summer maximum temperature of less than 50 degrees Fahr. to a summer maximum of more than 85 degrees Fahr.

The coldest streams were found to be limited to two species of fish, the brook trout and the sculpin (*Cottus cognatus*). These fish were found in the headwaters of Lake Como inlet in water as cold as 45 degrees Fahr.

Generally, the warmer the stream, the more species of fish present. This is illustrated in the case of a stream such as Fall creek. Certain very cold headwaters near McLean, New York, contain only brook trout and sculpins (*Cottus cognatus*). As the water gradually warms, more species appear and throughout the shaded area of Beaver brook (a large tributary of Fall creek) black-nosed dace, horned dace, common suckers, and common shiners begin to appear along with the trout and sculpins. At the point where Beaver brook joins Fall creek the water, being exposed to the sun, has become too warm for trout and sculpins, but the minnows and suckers are very common. Below this point the small-mouthed black bass and pickerel are added to the fish fauna, the bass at least becoming more common downstream, where the water warms considerably. Unfortunately the maximum temperatures of this stream at various points have not been obtained.

The warmest streams contained very many species of fish but were entirely avoided by the trouts, the sculpin (*Cottus cognatus*) and perhaps by certain minnows (*Margariscus* and *Clinostomus*). The abundant fish fauna of a stream of this type is illustrated by Ganargua creek (Mud creek) near Fairville, a shallow wide stream which doubtless reaches a very high summer temperature. Here 15 species of fish were collected: small-mouthed black bass, rock bass, zebra darter, tesselated darter, fan-tailed darter, black-sided darter, green-sided darter, common shiner (*Notropis cornutus chrysocephalus*), satin fin minnow, spot-tailed minnow, blunt-nosed minnow, northern pike, stonecat (*Noturus*), common sucker, red-fin sucker (*M. anisurum*). Yellow pike (pike-perch) are also known to be present here. It may be mentioned that not all warm water streams have as many species as this one. The fauna is, however, rather a typical one for the warm streams of the northern part of the drainage.

Trout Stream Associations.— The temperature of approximately 70 degrees Fahr. is considered as the dividing point between "cold" and "warm" waters in regard to stocking streams with trout. Fishes which were found associated with brook, brown or rainbow trout in streams of the Oswego watershed are as follows: Black-nosed dace, horned dace, common shiner (*Notropis* *cornutus frontalis*), sculpins (*Cottus cognatus* and less often *Cottus bairdii bairdii*), common sucker, fan-tailed darter, pearl minnow (both subspecies), fallfish, red-sided dace, cut-lips minnow, hog sucker, brook stickleback, tesselated darter, black-nosed shiner, long-nosed dace, black-sided darter, and chain pickerel. In no one individual stream were all of these species found.

Vermin Fishes.— Certain fish are themselves of little value as food and are known to eat the more useful kinds. Examples of this type are the gar and dogfish. These fish are usually destroyed by fishermen when they are taken, much as hawks and crows are often destroyed by hunters. Although a certain amount of control of the destructive species may be desirable, it is not wise to wholly condemn any species without exact knowledge.

There is much inter-dependence as well as much conflict among aquatic life. We do not well understand the full rôle played by the various participant species. I have seen golden shiners in the stomachs of large-mouthed black bass and yet seen this same species of minnow eating bass eggs on a temporarily deserted nest. Many of the small fish will eat fish spawn yet if we were to declare them enemies of game fish and destroy them we would curtail one of their chief supplies. At the same time it is quite possible that an overabundance of certain of these small fishes might be greatly detrimental to those game fish whose spawn they might destroy. In such a case it is entirely possible that predacious forms such as the gar and dogfish might perform a useful function by keeping down the numbers of small ones.

Fishes in Regard to Pollution.— Efforts were made to correlate data on the occurrence of fishes with the pollution studies made by Messrs. Wagner, Claassen and Cutler and to this effect seining was done in many polluted streams. Although it was impossible to collect thoroughly in all contaminated waters, considerable attention was given to typical instances.

In certain seriously polluted waters fish were found to be entirely lacking. This condition is illustrated by Skaneateles outlet from Skaneateles to Jordan. The main reason for the absence of fish is probably the low oxygen content of the water at certain times (see Mr. Wagner's report, p. 114).

Several streams of the region, polluted to a less degree, were found to contain fish in considerable numbers. In these instances, however, it was interesting to note that the fish fauna was distinctly different from that of unpolluted streams nearby or even from that of the same stream in its clean parts. Canandaigua outlet furnishes an illustration of such an upsetting of the natural fish population caused by pollution. This stream receives treated sewage and some manufacturing wastes from the city of Canandaigua. At no place was the oxygen found to be dangerously low, but at a point a few miles below the city, organisms indicative of pollution were common, namely, tubifex worms, various snails and leeches. The normal clean-water types of insects and other invertebrate life were absent. Here a collection of fish was made, consisting of only three species: German carp, blunt-nosed minnow and common sucker. No other varieties were collected or reported by persons familiar with the stream at this point.

The same body of water near Phelps, 14-miles below, had completely recovered from the pollution as judged by the clean character of the water and the presence of clean water insect life. Collecting here with a seine yielded 10 species of fish: small-mouthed black bass, rock bass, fallfish, hornyhead, cut-lips minnow, Johnny darter, fan-tailed darter, common sucker and hog sucker.

We might say that Canandaigua outlet illustrates the injury done by a comparatively slight pollution in upsetting the natural conditions in a stream. This has resulted in destroying the food supply of certain species of fish, as in this case, the small-mouthed black bass, while not seriously interfering with that of others, such as the common sucker.

Minnow Tests.— The generally accepted test of the injurious effect of pollution is the minnow test. This consists in placing a number of small fishes in such container that they are in direct contact with the water. During the summer several experiments of this character were made in polluted streams, and these waters were also carefully studied in regard to their fish fauna. It was found that the minnows in the test were not usually killed by the contaminated water even though the entire absence of fish as well as the general condition of the stream clearly indicated that it was unfit to support fish life.

On August 25, 1927, a minnow test was made in a seriously polluted stream, Skaneateles outlet near Skaneateles Junction, at a point where all native fishes were absent. In spite of the very bad pollution the minnows in this experiment were not killed but lived for several hours without apparent ill effects. The oxygen test, made by Mr. Wagner, at this time was 3.3 parts per million, low but evidently not low enough to kill. On a very hot day a short time before, the oxygen test was 1.4 parts per million undoubtedly below the requirement of fishes. Had a test been made at this date the minnows would have lived only a short time. So that, if judged by the one experiment made, this stream would give a misleading impression. Similar tests made in other polluted areas (Keuka outlet and Owasco outlet) merely indicated that small fish could live for at least several hours in waters certainly unfit to maintain them, as judged by their complete absence.

It may be concluded from these experiments that a minnow test does not form a wholly adequate criterion for judging the capability of a stream to support fish life.

Special Problems

The Spawning Behavior of Carp in Relation to Other Fish.— During their breeding season, in the spring, carp congregate in schools. The eggs are shed and fertilized, the process being accompanied by vigorous agitation and splashing. There is reason to suspect that, at this time of the year, the disturbance caused by carp might be destructive to the eggs of other species.

Five days (May 8, 15, 22, 29, and June 5) were spent in studying this question. On all but one of the days of this investigation, I was assisted by Mr. Myron Gordon.

The areas under observation included parts of the old and new channels of the Seneca river (near Montezuma) and the marshes at the north end of Cayuga lake (especially Canoga marsh). Actual spawning grounds included cat-tail marshes, flooded bottom lands, and weed beds. The notes made may be summarized as follows:

(1) Spawning is influenced, to a great extent, by temperature. Due to this fact, the process commences in the shallow, quickly warmed water as in open cat-tail marshes. As the season advanced, carp were seen spawning in deeper water, among weeds (*Potamogeton*). Carp were rarely observed to spawn where the water temperature was below 60 degrees F. On days of considerable breeding activity (May 8, 29) water temperatures where the fish were splashing were respectively, 68 and 65 degrees F. It was noted that a drop to 58 degrees F. (May 15) was accompanied by a virtual cessation of spawning.

(2) Carp extended their breeding season over a considerable interval. During the season of 1927 they were observed to spawn from May 8 to June 27. Examinations of the reproductive organs showed that not all of the eggs of a single female ripen at the same time. Furthermore, individual fishes (male as well as female) showed a wide difference in the period at which they become ready to reproduce. Ripe males, females who had spawned, and unripe females were taken on the same date (June 22) in the Seneca river.

(3) Observations did not show interference of the carp with the eggs of other fish. Although the carp were spawning, in moderate numbers, near the nests of large-mouthed black bass and common sunfish in the Canoga marsh (May 22) they did not seek to molest these. The disturbances caused by their splashing, in the instances noted, produced only extremely local, temporary roiling of the water. The eggs of pickerel and pike (*Esox*) have doubtless hatched before the carp spawn. Yellow perch eggs are also laid earlier than those of the carp, and although perch eggs were taken May 15 near the Canoga marsh, they were found in much deeper water than that in which carp were then spawning.

It should be stated that the weather conditions during the spring of 1927 were such as to prevent very great concentration of spawning carp at any one time. This may not be the case in other years.

Fishways.—At Mud Lock, near Cayuga, New York, there is a fishway which was erected for the purpose of allowing fish from the Seneca river to reach Cayuga lake. Since many sportsmen are of the opinion that numerous fish pass out of Cayuga lake when the canal locks at this point are operated, the fishway was installed to allow these to return. From all evidence secured it seems probable that few if any fish use this fish ladder. Many observers spoke of the great numbers of pike, carp, suckers and others, which congregate in the pool below the dam, apparently wishing to ascend but not knowing how to use this structure. Evidently it is not of a type suitable for many of the species found here. Doubtless it was designed after the manner of a fishway for salmon but does not seem adequate for most other types. If fishways are to fulfill their function in our inland waters, much time and thought should be given to the construction of ways suitable for the species concerned.

Some Factors Contributing to the Decline of Fishes.— Throughout the Oswego drainage complaints are often made by anglers that the fishing is poor. Several old residents, when interviewed, said that the fishing was not as good at the present time as it was some years ago. The full causes for the scarcity of fish are not easy to understand but certain factors which have contributed to this scarcity may be listed:

(1) Angling: The number of anglers has increased in recent years.

(2) Pollution: This has certainly caused a scarcity in certain waters.

(3) Canalization: The construction of the Barge canal resulted in the draining of the Montezuma marshes and other spawning and feeding grounds of fishes. This has changed the character of the Seneca and other rivers to the detriment of angling. A new stream bed made by dredging could not be expected to produce fish food in abundance. The violent agitation of the shores caused by canal boats must also be destructive to fish spawn.

(4) Netting: Formerly there was much netting of fish in the region. Professor Embody [1] cites this factor as a cause for the scarcity of bullheads in Cayuga lake.

(5) Natural enemies: Some losses of food fishes are caused by lampreys, watersnakes and fish-eating birds. However as natural enemies have always existed, even when fish were known to be abundant, they can hardly receive blame for the general scarcity now.

(6) Unwise stocking of waters: There is a common belief that there has been a decrease in the native fishes of certain waters due to the planting of these waters with carp or other non-native species. Doubtless this belief is well founded. As Kendall [2] points out, the artificial introduction of fishes into Sunapee lake, New York, was followed by a decline of some of the native species.

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[1] Embody, G. C. A Study of the Fish Producing Waters of Tompkins County, New York. Conservation Commission 1922.

[2] Kendall, W. C. The Status of Fish Culture in Our Inland Public Waters, and the Role of Investigation in the Maintenance of Fish Resources. Roosevelt Wild Life Bull., Vol. 2, no. 3, March, 1924.

LAKE LAMPREY, *Petromyzon marinus* Linnaeus
From male 14⅜ inches long.

PLATE No. 1.

LAKE LAMPREY, *Petromyzon marinus* Linnaeus
From female 12⅝ inches long.

PLATE No. 2.

SAWBELLY, *Pomolobus pseudo-harengus* (Wilson)
About 5¼ inches long.

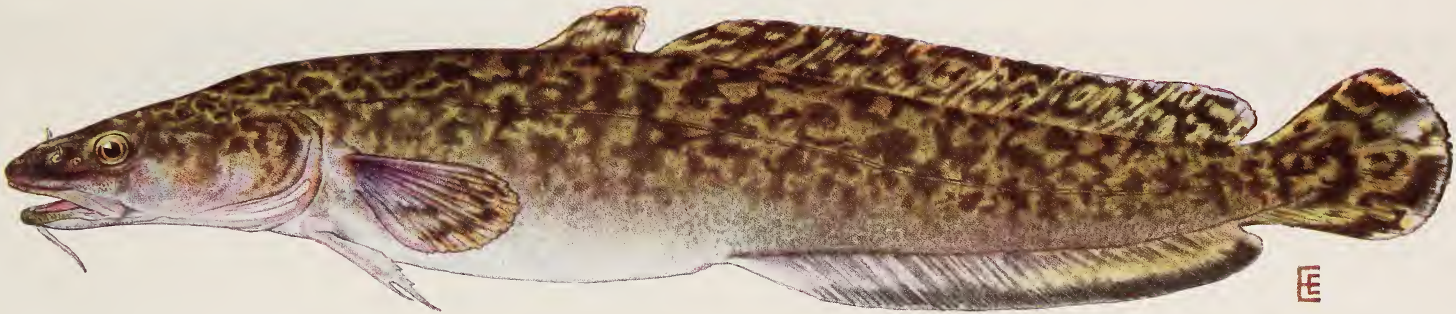
PLATE No. 3.

CISCO, *Leucichthys artedi* (LeSueur)
From female 8¾ inches long.

PLATE No. 4.

CARP, *Cyprinus carpio* Linnaeus
From fingerling 1½ inches long.

PLATE No. 5.



EEL-POUT or LING, *Lota maculosa* (LeSueur)
From female 15⅜ inches long.

PLATE No. 6.

SCULPIN, *Cottus cognatus* Richardson
From male 3½ inches long.

PLATE No. 7.

GOLDEN SHINER, *Notemigonus crysoleucas* (Mitchell)
From female 4 inches long.

PLATE No. 8.

HORNED DACE, *Semotilus atromaculatus* (Mitchell)
Breeding colors from male 9¾ inches long.

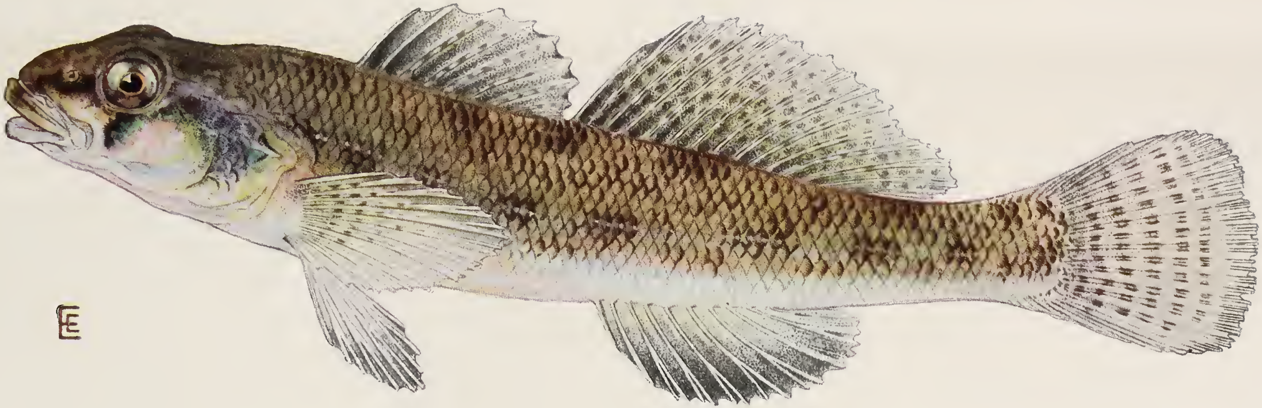
PLATE No. 9.

SPOT-TAILED MINNOW, *Notropis hudsonius* (Clinton)
From male 3¼ inches long.

PLATE No. 10.

FAN-TAILED DARTER, *Catonotus flabellaris* (Rafinesque)
From male 2½ inches long.

PLATE No. 11.



JOHNNY DARTER, *Boleosoma nigrum olmstedi* (Storer)
From male 2¼ inches long.

PLATE No. 12.

Annotated List of Fishes Occurring in the Oswego River Drainage*

PETROMYZONIDAE *Lampreys*

1. *Petromyzon marinus* Linnaeus.—Lake lamprey. Rather common. Lakes and rivers, ascending the streams to spawn. Its distribution, habitats and economics are discussed in detail by Prof. S. H. Gage (see p. 158).

2. *Entosphenus appendix* (DeKay).—Brook lamprey. Rare. Has been found in the inlets of Cayuga and Seneca lakes.

ACIPENSERIDAE *Sturgeons*

3. *Acipenser fulvescens* Rafinesque.—Lake sturgeon. Rare. There are specimen records from Cayuga lake and from the Seneca and Cayuga canal near Montezuma (Reed and Wright 1916). Sturgeon sometimes ascend the lower part of the Oswego river according to Mr. Earl Brown of Oswego.

LEPISOSTEIDAE *Garpikes*

4. *Lepisosteus osseus* Linnaeus.—Long-nosed gar, billfish. Uncommon. Lakes and rivers. Specimens were taken in the Seneca and Oswego rivers. Seems to have declined in numbers along with the bowfin for it was said to have been very common in Cayuga lake and the Seneca river many years ago.

AMIIDAE *Bowfins*

5. *Amia calva* Linnaeus.—Bowfin, dogfish. Uncommon. Lakes and rivers. Occurs in the Seneca river, Cayuga, Neahtawanta and Oneida lakes and other large bodies of water. Formerly it was very common in Cayuga lake and the Seneca river but now nearly exterminated, probably due to the draining of the marsh areas where it spawned. It is used for food to some extent now though during the time of its abundance, it was generally regarded as worthless. It is sometimes called ling by fishermen on the Seneca river but elsewhere this name is more often used for the eel-pout.

CLUPEIDAE *Herrings*

6. *Pomolobus pseudo-harengus* (Wilson).—Sawbelly, alewife. Common. Deep lakes and rivers. Occurs in the Finger lakes. Specimens were taken in the Oswego river at Three Rivers point.

7. *Dorosoma cepedianum* (LeSueur).—Gizzard shad. Rare. Lakes and rivers. A series of about 20 specimens was seined November 11, 1916 from Cayuga lake near Ithaca by Dr. A. A. Allen, (No. 7224 Cornell Univ. Mus.). Mr. Iver T. Johnson of Seneca Falls, who is employed at the canal locks at Mays point, says that a great number of fishes which, according to his description, must have been of this species, came through the canal one winter, a few years ago, many dying under the ice.

OSMERIDAE *Smelts*

8. *Osmerus mordax* (Mitchell).—Rare. Deep lakes. Successfully introduced into Owasco and Canandaigua lakes. Specimens were taken in both places by Dr. Eaton's party.

COREGONIDAE *Whitefishes*

9. *Leucichthys artedi* (LeSueur).—Cisco, smelt. Moderately common Deep lakes. Dr. Eaton's party collected ciscoes in all of the Finger lakes. Some of them, at least, are referable to this species, although it is probable that some others are not.

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* The nomenclature followed is in general that given by Hubbs and Greene (Hubbs, C. L. and Greene, C. W. Further notes on the fishes of the Great Lakes and tributary waters. Manuscript, 1927). For the members of the family Esocidae the names used by Weed are followed (Weed, A. C., Pike, pickerel and muskalonge. Field Museum Nat. Hist. Zool. Leaflet 9, 1927).

9-a. *Leucichthys artedi tullibee* (Richardson).—Tullibee, Onondaga lake whitefish, Oneida lake whitefish. Rare. Lakes. Recorded from Oneida lake (Adams and Hankinson 1916) and formerly occurred in Onondaga lake where it is now extinct.

10. *Coregonus clupeaformis* (Mitchell).—Common whitefish. Restricted to the Finger lakes. Common in Canandaigua lake.

11-a. *Salmo salar* Linnaeus.—Common Atlantic Salmon. Extinct. There are old records of the occurrence of salmon in the Oswego and Seneca rivers and Oneida, Cayuga and Seneca lakes. DeWitt Clinton (as quoted by Richardson *) states "They pass Oswego at the entrance of this river in April, and are then in fine order, and spread all over the western waters in that direction, returning to Lake Ontario in October, much reduced in size and fatness".

11-b. *Salmo sp.*—"Landlocked salmon" of Skaneateles lakes. Said to be not infrequently taken in Skaneateles lake. Members of the sportsmen's association of that city are reported to have obtained eggs of the landlocked salmon from Maine and to have stocked the lake about ten years ago. A specimen approximately one foot in length was taken by Professor Eaton's party. This fish does not agree entirely with the description of the landlocked salmon (*Salmo salar sebago*). Its determination as a steelhead trout is also rather doubtful. Larger specimens are desired.

SALMONIDAE *Salmons*

12. *Salmo fario* Linnaeus.—Brown trout. Common. Cool streams, large or small. Has been widely distributed throughout the region by planting. Often occurs in association with native trout but is often the only species of trout in waters too warm for the latter.

13-a. *Salmo irideus* Gibbons.—Rainbow trout. Moderately common. Deep lakes and cool streams. Although rainbows have been planted in numerous streams of the region the only good fishing for them now is in the vicinity of the Finger lakes, where they are usually taken in the spring of the year when they ascend the streams to spawn. Most of the large fish stay in the lakes except at this time.

13-b. *Salmo irideus irideus* Gibbons.—Steelhead trout. Uncommon. One specimen † was taken in Skaneateles lake by Prof. Eaton's party. This silvery species is apparently the one called "landlocked" salmon" in this lake. The steelhead is less common than the rainbow (subspecies *shasta*). Specimens, in scale count intermediate between the two subspecies, are sometimes taken and are especially common in Skaneateles inlet.

Rainbow trout have been found in the following streams:—*Canandaigua lake drainage*, Naples creek; *Keuka lake drainage*, Branchport inlet, Hammondsport inlet; *Seneca lake drainage*, Catherine creek, Wilson creek, Reeder creek (reported on good authority); *Cayuga lake drainage*, Cayuga inlet (including Fall creek and Sixmile creek), Cascadilla creek (reported on good authority), Taghanic creek, Salmon creek; *Owasco lake drainage*, Owasco inlet, creek at Long point (reported on good authority); *Skaneateles lake drainage*, Skaneateles inlet; *Seneca river drainage*, Kendig creek (reported on good authority); *Canandaigua outlet drainage*, Fall brook (near Clifton Springs); *Oneida lake drainage*, Fish creek (reported to occur occasionally). It should be understood, however, that not all of the above mentioned are good fishing streams for rainbows.

14. *Cristivomer namaycush* (Walbaum).—Lake trout. Common. Restricted to the deep Finger lakes. In several of these it is very important as a game market fish.

15. *Salvelinus fontinalis* (Mitchell).—Brook trout. Common. Inhabits the coldest streams and certain cold ponds of the region. It may be found over a bottom of muck, mud, gravel, or rubble and is equally versatile in regard to current preferences provided the water is cold.

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* Richardson, John. Fauna Boreali-Americana or The Zoology of the Northern Parts of British America. Part III, The Fish. London 1836.

† Identified by Prof. C. L. Hubbs.

Catostomidae *Suckers*

16. *Catostomus commersonnii commersonnii* (Lacépède).—Common sucker, brook sucker, black sucker. Abundant. Warm or cold waters, nearly all types of bottom and current. The most widespread fish of the watershed, occurring in all of the lakes, and nearly all ponds and streams. The commonest of the suckers found in trout streams. The most important member of this family as food, due to its abundance.

17. *Catostomus catostomus* (Foster).—Fine-scaled sucker, sturgeon sucker. Rare. Specimens were taken in deep water of Owasco lake.

18. *Hypentelium nigricans* (LeSueur).—Hog sucker, stone roller sucker. Common. Shallow streams, warm or cold. Sometimes found in trout waters. Seems to prefer strong to rapid current and hard bottom. Unimportant as a food fish.

19. *Erimyzon sucetta oblongus* (Mitchell).—Chub sucker. Common. Shallow weedy areas of lakes, rivers, ponds and warm streams, where the current is moderate to stagnant and the bottom usually soft. Too small to be important as food, weighing usually less than ½ pound.

20. *Moxostoma aureolum* (LeSueur).—Red-horse sucker, red-fin sucker. Uncommon. Adams and Hankinson (1916) cite records from Oneida lake. Small specimens were taken from Canandaigua outlet.

21. *Moxostoma anisurum* Rafinesque.—Red-horse sucker, red-fin sucker. Moderately common. Rivers and large warm streams where the current is strong to sluggish and the bottom gravel, silt or mud. Reaches a large size, probably 7 to 8 pounds, and ranks among the best of the suckers as food.

22. *Moxostoma lesueurii* (Richardson).—Short-headed red-horse, red-fin sucker. Moderately common. Rivers and lakes where the bottom is mud and silt and the current sluggish or stagnant. One of the best of the suckers for food.

Cyprinidae *Minnows*

23. *Cyprinus carpio* Linnaeus.—German carp. Common. Lakes, rivers and sluggish streams. Often found in weedy situations. Carp were seen spawning from May 8 to June 17 at Canoga marsh. This species is not popular with sportsmen but has excellent possibilities in this region as a commercial fish.

24. *Couesius plumbeus* (Agassiz).—Lake chub. Rare. Dr. Eaton's party took specimens from Owasco and Skaneateles lakes in the shallow waters.

25. *Nocomis biguttatus* Kirtland.—Horneyhead. Common. Sluggish to moderate current in warm streams of the northern part of the drainage, often among vegetation.

26. *Nocomis micropogon* (Cope).—Crested chub. Rare. A single record came from Catherine creek near Montour falls, July 8. Doubtless an immigrant species, having entered from the Susquehanna system through an old canal which once connected with this drainage.

27. *Rhinichthys atronasus* (Mitchell).—Black-nosed dace. Abundant. Small, shallow creeks of warm or cold water. Prefers strong to rapid current and gravel or rubble bottom. Often found associated with brook trout.

28. *Rhinichthys cataractae* (Cuvier and Valenciennes).—Long-nosed dace. Common. Shallow streams. Warm or cool water. A fish of the rapids, being found in rapid to torrential current where the bottom is rubble.

29. *Leucosomus corporalis* (Mitchell).—Fallfish, silver chub. Large warm or cool streams, occasionally in lakes. Usually found in moderate to strong current and mud or gravel bottom. The largest native minnow of the region. Will rise to artificial fly. The flesh is bony and rather soft. In Owasco outlet this fish was formerly taken by anglers as "whitefish."

30. *Semotilus atromaculatus* (Mitchell).—Horned dace, chub. Abundant. Warm or cold streams, occasionally in lakes. Inhabits most trout streams. Found usually in moderate to rapid current over bottoms ranging from muck to rubble.

31-a. *Margariscus margarita margarita* (Cope).—Pearl minnow. Rare. Found only near headwaters of certain streams toward the southern limit of the drainage. Probably has reached our watershed by means of former connections with the Susquehanna stream system. Found in moderate to strong current, mud to rubble bottom.

31-b. *Margariscus margarita nachtriebi* (Cox).—Nachtriebs minnow. Rather rare. Inhabits a few streams of the northern part of the watershed. Warm or cold waters in much the same type of current and bottom as the preceding.

32. *Clinostomus elongatus* (Kirtland).—Red-sided dace. Rare. Small warm or cold streams. Specimens were taken in Catherine creek and in several streams in the northern part of the drainage. In several Oneida lake tributaries it was found in brook trout waters.

33. *Notropis procne* (Cope).—Swallow-tailed minnow. Rare. Two specimens were obtained in Catherine creek near Montour falls. This fish is not known elsewhere from Lake Ontario drainage. It has doubtless entered Catherine creek by means of a former canal connection with the Susquehanna system.

34. *Notropis heterodon* (Cope).—Rare. Reed and Wright (1909) record this species from Cayuga lake and from Beaver brook, a tributary of Fall creek near McLean. In Cayuga lake it is usually taken near weed beds.

35. *Notropis anogenus* Forbes.—Black-chinned minnow. Recorded from the old canal near Montezuma by S. E. Meek (1889) and from the mouth of Fall creek and lower course of Sixmile creek at Ithaca (Reed and Wright 1909). No specimens are now on record.

36. *Notropis bifrenatus* Cope.—Bridled minnow, Cayuga minnow. Common. Lakes, ponds and warm streams. Usually taken where the bottom is mud or muck among aquatic plants.

37. *Notropis heterolepis* Eigenmann and Eigenmann.—Black-nosed minnow Fairly common. Northern part of the drainage and Cayuga lake. Lakes, warm or cool streams, usually in sluggish current and over mud or muck bottom.

38. *Notropis volucellus volucellus* (Cope).—Fairly common. Rivers. quite often in weedy situations. Taken sometimes in deep sluggish water over mud bottom.

39. *Notropis dorsalis* (Agassiz), (gilberti, Jordan and Meek).—Gilbert's minnow. Rare. Professor T. L. Hankinson informed me that he and Mr. Dence seined some small minnows identified as this species, from Oneida lake (1927).

40. *Notropis hudsonius* (Clinton).—Spot-tailed minnow. Common. Lakes, rivers and large, warm streams. Stagnant, sluggish or moderate current, usually over a mud bottom.

41. *Notropis whipplii whipplii* (Girard).—Satin-finned minnow. Moderately common. Lakes, rivers and larger, warm streams of the region. Strong to stagnant current, over various types of bottom.

42. *Notropis atherinoides* Rafinesque.—Emerald minnow, slender minnow. Uncommon except in Oneida lake where it is abundant. Rivers or lakes, stagnant or sluggish current.

43. *Notropis rubrifrons* (Cope).—Rosy-faced minnow. Common but restricted to the northern part of the drainage. Warm shallow creeks especially in strong to rapid current where the bottom is rubble.

44-a. *Notropis cornutus crysocephalus* (Rafinesque).—Common shiner, redfin shiner. Very common. Found in lowland creeks and rivers of the northern part of the drainage. In strong to sluggish current and over bottoms ranging from mud to rubble, often taken among weeds. Specimens intermediate between the two subspecies (this and *frontalis*) were often found.

44-b. *Notropis cornutus frontalis* (Agassiz).—Common shiner, red-fin shiner. Abundant. Shallow streams, warm or cold, often found in trout streams. This form of *Notropis cornutus*, characterized by small scales in the dorsal region, is the commonest shiner of the upland creeks. It occurs in various situations, usually in moderate to sluggish current.

45. *Notropis umbratilis* (Girard).—Blood-tailed minnow. Meek records a specimen (as *Notropis lythrurus*) "from a small stream near Montezuma Dry Dock," (Meek 1889). The specimen is apparently lost.

46. *Exoglossum maxillingua* (LeSueur).—Cut-lips minnow. Common. Shallow warm streams usually in strong to moderate current over a hard bottom. Males were seen building nests of stones on June 30 in Cayuga inlet. Some nests contained eggs at this date.

47. *Notemigonus crysoleucas* (Mitchell).—Golden shiner. Abundant. Occurs in lakes, ponds and sluggish warm streams. Often found in weed beds. Seems to prefer bottom of mud or muck.

48. *Hybognathus regius* Girard.—Silvery minnow. Common. Lakes, rivers and some of the larger streams usually over a mud bottom. Taken in moderate to stagnant current.

49. *Chrosomus erythrogaster* Rafinesque.—Red-bellied dace. Rare. Limited to several sluggish swamp streams in a few of which it was found to be the most common fish.

50. *Hyborhynchus notatus* (Rafinesque).—Blunt-nosed minnow. Abundant. Lakes, ponds and warm streams usually over a mud bottom and in moderate, sluggish or stagnant current.

51. *Pimephales promelas promelas* Rafinesque.—Fat-head minnow, black-head minnow. Uncommon. Found in certain of the smaller creeks and ponds, especially in swamp situations where the bottom was muck and the current sluggish or stagnant.

52. *Campostoma anomalum* (Rafinesque).—Stone roller minnow. Rare. Restricted to the western part of the drainage where it occurs in warm shallow creeks over a rubble, gravel or mud bottom in a strong to moderate current.

Ameiuridae *Catfishes*

43. *Ictalurus punctatus* (Rafinesque).—Channel cat, spotted cat. Common in the rivers, Cross and Oneida lakes. Two specimens have been recorded from Cayuga inlet near Ithaca (Reed and Wright 1909) but it is possible that these were escapes from the Cornell University Fish Hatchery. The spotted cat is an important food fish in parts of our drainage, and seems to be highly esteemed. Probably spawns rather late. Female specimens were taken from the Seneca river August 4 containing ripe eggs. Others taken then had apparently spawned.

54. *Ictalurus sp.*—A large very black catfish was taken on a set line August 4 from the Seneca river near Weedsport. It weighed 11 pounds and was 30 inches in length. In characters it is close to *Ictalurus anguilla* but does not entirely agree with this species in all respects. It is probably distinct from *Ictalurus punctatus*, being much wider across the head. More specimens of this fish are greatly to be desired.

55. *Ameiurus nebulosus* (LeSueur).—Common bullhead, hornpout. Abundant throughout the region, in lakes, ponds and warm sluggish streams. An important food fish. Specimens of eggs of this fish, in the Cornell collection, were taken June 16, 1909 from Cayuga lake.

56. *Ameiurus natalis* (LeSueur).—Yellow cat, pollywog bullhead. Uncommon. Seneca river, Cayuga and Oneida lakes and certain warm sluggish weedy streams of the northern part of the drainage. In certain swamp streams very black specimens were taken. The yellow bullhead is a good food fish but much less common than the ordinary bullhead.

57. *Noturus flavus* Rafinesque.—Stonecat. Rare. Only three specimens have been obtained from this drainage, two from Skaneateles lake. The other specimen $2\frac{15}{16}$ inches in length was taken from Ganargua creek near Fairville September 9, the prey of a watersnake 24 inches in length.

58. *Schilbeodes gyrinus* (Mitchell).—Tadpole stonecat. Common in the northern part of the drainage and is also present in Cayuga lake. Found among weed beds usually in shallow water, where there is little or no current.

59. *Schilbeodes insignis* (Richardson).—Margined stonecat, mad-tom. Rare. A specimen was taken in Keuka lake, and one was obtained in Canada creek (near Lee Center). The species was found to be common under stones at the headwaters of Tioughnioga creek (middle branch), a Susquehanna stream that has been diverted artificially into the Oswego drainage.

60. *Schilbeodes miurus* (Jordan).—Bridled stonecat. Rare. Recorded from the Oneida lake drainage (Adams and Hankinson 1916).

UMBRIDAE *Mud minnows*

61. *Umbra limi* (Kirtland).—Mud minnow. Common in the northern part of the drainage, especially in small weedy streams; not rare throughout the rivers and in Oneida lake. Flourishes where many other fish cannot, in the small stagnant pools of creeks where there is much vegetation.

ESOCIDAE *Pickerels*

62. *Esox niger* LeSueur.—Chain pickerel. Common in the southern part of the drainage. In lakes, ponds and sluggish weedy streams. Occurs in Oneida lake and in the Seneca and Oswego rivers. Less important than the northern pike due to its smaller size and fewer numbers. Sometimes occurs in lower parts of trout streams.

63. *Esox lucius* Linnaeus.—Pickerel, northern pike. Common in the lakes, rivers and some of the larger streams (Ganargua creek). Usually taken in weedy situations having a sluggish or stagnant current. A fish of importance to anglers especially in Cayuga lake and the Seneca and Oswego rivers. Spawns in Cayuga lake during March.

64. *Esox americanus* Gmelin (*vermiculatus* LeSueur).—Little pickerel. Not uncommon, but limited to the northern part of the drainage, occurring in sluggish, weedy creeks and ponds and Cross lake. Unimportant as a food or game fish due to its small size; doubtless those caught by anglers are returned with the idea that they are undersized chain pickerel or northern pike.

65. *Esox ohioensis* Kirtland.— Chautauqua muskalonge. Otisco lake has been stocked with this species but there are no authentic records of its capture there.

ANGUILLIDAE *Eels*

66. *Anguilla rostrata* (LeSueur).—Eel. Moderately common throughout the Clyde, Seneca, Oneida and Oswego rivers and Cayuga lake. Is not greatly prized by most anglers but is a good food fish. According to Adams and Hankinson (1916) this fish was at that time rated the most important one in the commercial fisheries of the Oneida lake region.

CYPRINODONTIDAE *Killifishes*

67. *Fundulus diaphanus menona* Jordan and Copeland.—Barred killifish, grayback minnow. Common in lakes, many ponds and rivers. Taken in very shallow water during the warm months. Prefers sluggish to stagnant current and gravel, sand or mud bottom. Females ready to spawn were taken July 18 in Vandermark pond near Junius.

PERCOPSIDAE *Trout perches*

68. *Percopsis omisco-maycus* (Walbaum).—Trout perch. Not uncommon. Occurs in Cayuga and Oneida lakes, and specimens were taken in the Clyde river in deep water where the current was sluggish and the bottom muddy.

SERRANIDAE *Sea basses*

69. *Lepibema chrysops* (Rafinesque).—White bass. Not uncommon in the rivers and a few of the lakes. Two specimens have been taken in Cayuga lake and Cayuga inlet (Reed and Wright 1909) near Ithaca. Generally found in sluggish and rather deep water. This, though not abundant, is an excellent food and game fish. White bass weighing up to several pounds, are said to be taken at certain times, in the Clyde river at May's point. This fish is not at present protected by law at any season, but it may prove advisable to encourage its numbers by adequate protection during the spawning season.

PERCIDAE *Perches*

70. *Perca flavescens* Mitchell.—Yellow perch. Abundant. Occurs in all the lakes and rivers, many ponds and also in sluggish warm streams. Does not

inhabit waters with strong current. Eggs were taken in Cayuga lake near Seneca Falls.

71. *Stizostedion canadense griseum* (DeKay).—Sauger. Rare. There is a specimen (No. 1587) in the Cornell University collection from Cayuga lake. Probably occurs along the Seneca river but there are no specimen records.

72. *Stizostedion vitreum* (Mitchell).—Yellow pike, wall-eyed pike, pike-perch. Common in certain lakes and all rivers of the region.

73. *Stizostedion sp.*—Silver pike, blue pike of Lake Ontario. Not uncommon in the Oswego river near its mouth; apparently does not occur above the first dam at Oswego. As a food fish of less importance than the yellow pike, because of its smaller size and softer flesh.

74. *Hadropterus maculatus* (Girard).—Black-sided darter. Not uncommon in the northern part of the drainage, in shallow, rapid streams, warm or cool, usually over a hard bottom. Was taken, at least once, in a brown trout stream.

75. *Percina caprodes zebra* (Agassiz).—Log perch, zebra darter. Not uncommon throughout the drainage and very common in Oneida lake. Inhabits shallow waters of lakes and large warm streams, usually in moderate to strong current.

76. *Boleosma nigrum olmstedi* (Storer).—Tesselated darter, Johnny darter, abundant. Occurs in nearly all lakes and streams of the region, except in very cold waters. Found in various situations from rapid current among stones to sluggish waters with muddy bottom or among weeds. Usually found in shallow water.

77. *Poecilichthys exilis* (Girard).—Iowa darter. Common in several ponds of the northern part of the drainage. Specimens were taken from Vandermark pond (near Junius), Duck lake, South pond (near Constantia) and Mud pond (near Marcellus). Apparently prefers swampy ponds with a muddy bottom and much vegetation.

78. *Catonotus flabellaris* (Rafinesque).—Fan-tailed darter. Common. Occurs in warm or cool streams usually in rapid parts where the bottom is rubble. A few specimens were taken in shallow areas of the Finger lakes near stream mouths.

79. *Etheostoma blennioides* Rafinesque.—Green-sided darter. Not uncommon. Inhabits several large warm streams of the northwestern part of the drainage occurring in rapid or strong current where the bottom is rubble.

Centrarchidae *Sunfishes*

80 *Micropterus dolomieu* Lacépède.—Small-mouthed black bass. Common. Lakes and large warm streams, often inhabiting waters of strong current. A male was found guarding a nest and eggs on July 1, 1927 in Cayuga lake inlet near Ithaca, and at the same time bass about ½ inch long were common. The young of this species are usually found under shelter of stones, etc., and sometimes in weed beds.

81 *Aplites salmoides* (Lacépède.)—Large-mouthed black bass, Oswego bass. Common in shallow, weedy lakes and ponds and large sluggish streams. Does not occur in as strong a current as the preceding species. Males were seen guarding nests of eggs, May 22, in Canoga marsh on Cayuga lake. The young up to several inches, were frequently taken in weed beds throughout the summer.

82 *Apomotis cyanellus* (Rafinesque).—Green sunfish. Rare. S. E. Meek (1889) took a few specimens near Montezuma. Hankinson and Adams (1916) record a specimen from the mouth of Big Bay creek in the Oneida lake drainage.

83 *Helioperca incisor* (Cuvier and Valenciennes).—Bluegill sunfish, porgy sunfish. Not uncommon. Large, sluggish, warm streams, ponds and weedy lakes. Specimens were taken in the Seneca river, Cross, Cayuga and Neahtawanta lakes and in Junius ponds. This is the largest and best of the sunfishes of the region, from the anglers' viewpoint, and could well be used to stock small bodies of water. However, it is not at present raised in the State hatcheries.

84 *Xenotis megalotis* (Rafinesque).—Long-eared sunfish. A few specimens

were obtained in Oneida lake drainage by Professor T. L. Hankinson. The species probably occurs sparingly in the rivers but none are recorded.

85 *Eupomotis gibbosus* (Linnaeus).—Common sunfish, pumpkinseed. Abundant throughout the drainage in ponds, lakes and sluggish streams. Occurs in sluggish to stagnant current over mud or muck bottom, often among weeds. Males were seen guarding nests, eggs and young, June 16, in Canoga marsh, Cayuga lake.

86. *Ambloplites rupestris* (Rafinesque).—Rock bass. Common throughout the region in lakes, rivers, ponds and warm streams. Often occurs in sluggish current over a mud bottom. Young are usually found in patches of weeds or under other shelter.

87 *Pomoxis sparoides* (Lacépède).—Crappie, calico bass. Not uncommon. Ranges throughout the Clyde, Seneca and Oswego rivers and is sometimes taken in Cayuga lake. Common in Cross and Neahtawanta lakes. One of the important fishes of the pan-fish type, many being taken by angling. A fish of shallow ponds, lakes and large sluggish streams. The young are often found in weed beds.

ATHERINIDAE *Silversides*

88 *Labidesthes sicculus* Cope.—Brook silversides. Uncommon, Specimens were secured in Cayuga lake, the Seneca and Clyde rivers, usually near weed beds. Apparently prefers sluggish or stagnant current and mud bottoms.

SCIAENIDAE *Drums*

89 *Aplodinotus grunniens* Rafinesque.—Sheepshead. Uncommon. A specimen was collected in the Clyde river at May's point, July 25. They are sometimes caught by fishermen in the Barge canal, Clyde, Seneca and Oswego rivers, usually in sluggish waters. This is considered a good food fish in the region although comparatively few are taken.

COTTIDAE *Sculpins*

90a. *Cottus bairdii bairdii* Girard.—Sculpin, millers thumb. Moderately common. Ranges throughout the southern and eastern part of the drainage, occurring in rocky streams and in Oneida lake. Found in cool to warm streams, often near the headwaters. Frequently taken in rapid current among stones although it is not restricted to this habitat.

90b *Cottus bairdii kumlieni* (Hoy).—Lake sculpin, millers thumb. Rare. Moderately common in Cayuga, Seneca, Keuka and Canandaigua lakes. It is not taken elsewhere in the drainage. Ranges from deep waters to rocky shallows in creek mouths usually not in strong current.

91 *Cottus cognatus* Richardson.—Sculpin, millers thumb. Rare. Seems to be limited to southeastern headwaters and certain Oneida lake tributaries. This is a fish of cold waters and is found in brooks at the headwaters of trout streams, in strong or rapid current. It also occurs in the Finger lakes.

GASTEROSTEIDAE *Sticklebacks*

92 *Eucalia inconstans* (Kirtland).—Brook stickleback. Common throughout most of the drainage, inhabiting weedy streams, ponds and lakes in shallow and deep waters. Not infrequently found in trout streams. Does not seem to like strong current.

93. *Pungitius pungitius* (Linnaeus).—Nine-spined stickleback. Rare. Two specimens were taken in Canandaigua lake in deep water, by Dr. Eaton's party.

94 *Gasterosteus aculeatus* Linnaeus.—Two-spined stickleback. Common at the mouth of the Oswego river but has not been found above the first dam at Oswego. It was found in weed beds and shallow rock bottom pools where the current was moderate.

GADIDAE *Codfishes*

95. *Lota maculosa* (LeSueur).—Eel-pout, lawyer, ling. Common in Canandaigua lake, occasional throughout the Seneca river and in Oneida lake. Although its flesh is good there seems to be some prejudice against this fish and it is not popular even though it can be caught with hook and line. It is generally found in rather deep water but young specimens were obtained in a stream (Naples creek) several miles from Canandaigua lake.

Chart of Fish Distribution of Oswego Watershed

X = recorded from actual specimen; R = recorded on reliable authority; E = extinct; S = at spawning season only; St = stocked but apparently not established; ? = identification doubtful.

Subdivisions of the drainage

	List number	Canandaigua L.	Canandaigua L. tribs.	Keuka L.	Keuka L. tribs.	Seneca L.	Seneca L. tribs.	Cayuga L.	Cayuga L. tribs.	Owasco L.	Owasco L. tribs.	Skaneateles L.	Skaneateles L. tribs.	Otisco L.	Otisco L. tribs.	Onondaga L.	Onondaga L. tribs.	Oneida L.	Oneida L. tribs.	Clyde R.	Clyde R. tribs.	Seneca R	Seneca R. tribs.	Oneida R.	Oneida R. tribs.	Oswego R.	Oswego R. tribs
Lake lamprey	1	R				X	S	X	5									X	S			R				X	
Brook lamprey	2						X		X																		
Lake sturgeon	3							X														X				R	
Long-nosed gar	4							X												X		X				X	R
Bowfin	5							X										X				X					X
Sawbelly	6			X		X		X												X		X		X		X	
Gizzard shad	7							X												R							
Smelt	8	X								X		R															
Lake cisco	9	X		X		X		X		X		X		X													
Tullibee	9a															E		X									
Common whitefish	10	X		R		R		R				X															
Atlantic salmon	11					E		E										E				E				E	
Steelhead						R						X															
Brown trout	12	R	X	R	X	X	X		X		X	R	X	R	X				X		X		X				
Rainbow trout	13	R	R	X	X	X	X	X	X	X	X	X	X						X								
Lake trout	14	X		X		X		X		X		X															
Brook trout	15		X		X		X		X		X		X		X		X		X		X		X				
Common sucker	16	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Fine-scaled sucker	17									X																	
Hog sucker	18		X					R									X	R	X		X						
Chub sucker	19							R						X				X	X	X	X	X	X	X	X	X	X
Red-fin sucker	20							R										X			X						
White-nosed red-fin sucker	21															X				X	X	X					

Type of water, type of bottom, type of current

	List number	Rivers (Type of water)	Large streams	Small streams	Lakes	Ponds	Muck or mud (Type of bottom)	Silt or sand	Gravel	Rubble	Hardpan	Bare rock	Torrential (Type of current)	Rapid	Strong	Moderate	Sluggish	Stagnant
Lake lamprey	1	X	S	S	X		X	X	S	S				S	S		X	X
Brook lamprey	2		X	X			X	X	S	S				S	S	X		
Lake sturgeon	3	R			X													
Long-nosed gar	4	X			X		X	X									X	X
Bowfin	5	X			X		X	X									X	X
Sawbelly	6	X			X		X	X									X	X
Gizzard shad	7	R			X													X
Smelt	8				X													X
Lake cisco	9				X													X
Tullibee	9a				X													X
Common whitefish	10				X													X
Atlantic salmon	11	E			E													
Steelhead					X													X
Brown trout	12		X	X	X		X	X	X	X					X	X	X	X
Rainbow trout	13		X	X	X			X	X	X	X			X	X	X		X
Lake trout	14				X													X
Brook trout	15			X	X	X	X	X	X	X	X	X		X	X	X	X	X
Common sucker	16	X	X	X	X	X	X	X	X	X	X	X		S	X	X	X	X
Fine-scaled sucker	17				X													X
Hog sucker	18		X	X	R									X	X	X		R
Chub sucker	19	X	X	X	X	X	X	X								X	X	X
Red-fin sucker	20	X	X		X		X	X								X	X	X
White-nosed red-fin sucker	21	X	X		X		X	X								X	X	X

CHART OF FISH DISTRIBUTION OF OSWEGO WATERSHED — (*Concluded*)

X = recorded from actual specimen; R = recorded on reliable authority; E = extinct; S = at spawning season only; St = stocked but apparently not etablished; ? = identification doubtful.

		Subdivisions of the drainage																										Type of water					Type of bottom						Type of current					
	List number	Canandaigua L.	Canandaigua L. tribs.	Keuka L.	Keuka L. tribs.	Seneca L.	Seneca L. tribs.	Cayuga L.	Cayuga L. tribs.	Owasco L.	Owasco L. tribs.	Skaneateles L.	Skaneateles L. tribs.	Otisco L.	Otisco L. tribs.	Onondaga L.	Onondaga L. tribs.	Oneida L.	Oneida L. tribs.	Clyde R.	Clyde R. tribs.	Seneca R.	Seneca R. tribs.	Oneida R.	Oneida R. tribs.	Oswego R.	Oswego R. tribs.	Rivers	Large streams	Small streams	Lakes	Ponds	Muck or mud	Silt or sand	Gravel	Rubble	Hardpan	Bare rock	Torrential	Rapid	Strong	Moderate	Sluggish	Stagnant
Short-headed red-fin sucker	22							X														X						X			X		X	X									X	X
Carp	23	X		X	X	X	X	X	X	X				X		X	X	X	X	X		X		X		X	X	X	X		X	X	X	X									X	X
Lake chub	24									X		X																			X													X
Hornyhead	25																		X		X	X	X					X	X				X	X	X	X					X	X	X	
Crested chub	26						X						?																X													X		
Black-nosed dace	27	X	X		X	X	X	X	X	X	X		X		X		X		X		X		X		X		X		X	X	X			X	X	X	X	X		X	X	X		X
Long-nosed dace	28	X	X		X	X	X	X	X	X	X	X			X		X		X		X		X						X	X	X			X	X	X	X	X	X	X	X			X
Fallfish	29	X				X	X	X									X		X		X		X		X		X		X		X		X	X	X	X				X	X	X	X	X
Horned dace	30	X	X		X	X	X	X	X	X	X	X	X	X	X		X		X		X		X		X		X		X	X	X	X	X	X	X	X	X	X		X	X	X	X	X
Pearl minnow, M. m. margarita	31a						X		X				X						X																									
Pearl minnow, M. m. nachtriebi	31b																		X		X																							
Red-sided dace	32						X												X		X								X	X			X	X	X	X					X	X	X	
Notropis procne	33						X																						X															
Notropis heterodon	34			X				X																							X		X	X										X
Notropis anogenus	35																						R																					
Cayuga minnow	36	X		X				X										X		X	X	X	X	X	X	X	X	X	X	X	X		X	X								X	X	X
Black-nosed minnow	37							X											X			X						X	X	X	X	X	X	X								X	X	X
Notropis v. volucellus	38																			X		X		X		X		X					X	X									X	
Gilbert's minnow	39																	R																										
Spot-tailed minnow	40	X	S	X	S	X	S	X	S	X	S							X	S	X	X	X	X	X		X		X	X		X		X	X							S	X	X	X
Satin-fin minnow	41			X	X	X	X	X	X									X		X	X	X		X		X		X	X		X		X	X	X							X	X	X
Slender minnow	42			X				X	S									X		X		X		X		X		X			X		X	X	X								X	X
Rosy-faced minnow	43								X										X	X	X	X						X	X						X	X				X	X	X		
Common shiner (N.c. chrysocephalus)	44a							R												X	X	X	X	X	X	X	X	X	X		R		X	X	X	X					X	X	X	X
Common shiner (N.c. frontalis)	44b	X	X	X	X	X	X	X	X	X	X	X	X		X		X		X		X		X		X		X		X	X			X	X	X	X	X	X		X	X	X		X
Notropis umbratilis	45																						X																					
Cut-lips minnow	46				X		X		X	X	X				X		X		X		X	X	X	X	X	X	X	X	X	X	X	X		X	X	X					X	X	X	X
Golden shiner	47	X		X		X		X	X	X				X		X		X	X									X	X	X	X	X	X	X								X	X	X
Silvery minnow	48	X				X		X	S	X	S			X			X	X	X	X		X		X		X		X	X		X		X	X								X	X	X

Red-bellied dace	49								X								X				X									X		X	X									X	X	X
Blunt-nosed minnow	50	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X	X					X	X	X	X
Blackhead minnow	51						X		X								X		X		X	R	X					R	X	X		X	X	X								X	X	X
Stone roller minnow	52		X		X																X								X					X	X	X					X	X		
Spotted catfish	53							R								E		X		X		X		X		X		X			X		X	X									X	X
Ictalurus sp.	54																					X						X					X										X	
Common bullhead	55	X	X	X	X	X	X	X	X	X	X	X		X				X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X								X	X	X
Yellow bullhead	56							X														X					X		X	X	X		X	X								X	X	X
Stonecat (Noturus)	57											X									X								X		X				X	X				X				X
Tadpole stonecat	58							X	X	X								X	X	X	X	X	X	X	X	X	X	X	X	X	X		X	X									X	X
Margined stonecat	59			X															X										X	X	X					X				X	X			X
Bridled stonecat	60																		R																									
Mud minnow	61	X		X		X		X		X								X			X	X	X		X		X	X	X	X	X	X	X										X	X
Little pickerel	62															X					X	X					X	X	X	X	X		X	X								X	X	X
Chain pickerel	63	X	X	X	X	X	X	X	X	X	X	X	X	X	X			X	X		X	X	X	X	X	X		X	X		X	X	X	X								X	X	X
Northern pike	64							X										X	X	X	X	X	X	X		X	X	X	X		X		X	X								X	X	X
Muskalonge	65													St																														
Eel	66	X				X		X		X								X		X		X		X		X		X			X		X	X									X	X
Killifish	67	X		X		X		X		X		X		X		X		X	X	X		X	X	X	X	X		X	X		X	X	X	X	X								X	X
Trout perch	68	X				X		X										X		X								X			X		X	X									X	X
White bass	69					R		R										X		X		X		X		X		X			X		X	X									X	X
Yellow perch	70	X	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X	X	X							X	X	X
Sauger	71							X																																				
Yellow pike	72	X				R		X		X								X	R	X	X	X		X		X		X	X		X		X	X	X							X	X	X
Blue pike	73																									X			X															X
Black-sided darter	74																		X	X	X							X	X	X			X	X	X	X				X	X	X	X	
Zebra darter	75	X		X		X		X	X	X							X	X		X	X	X		X		X		X	X		X		X	X	X	X		X		X	X	X	X	X
Tesselated darter	76	X	X	X	X	X	X	X	X	X	X		X		X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X			X	X	X	X
Iowa darter	77																X	X			X										X	X	X	X										X
Fan-tailed darter	78						X		X	X	X						X		X		X		X				X		X	X	X				X	X				X	X			X
Green-sided darter	79																				X								X						X	X				X	X	X		
Small-mouthed bass	80	X		X		X		X	X	X		X		X			R	X	X	X	X	X	X	X		X		X	X		X		X	X	X	X		X			X	X	X	X
Large-mouthed bass	81			X	X	X	X	X	X	R				X	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X							X	X	X
Green sunfish	82																		R				R																					
Bluegill sunfish	83							X													X	X	X				X	X			X	X	X	X									X	X
Long-eared sunfish	84																	R																										
Common sunfish	85	X		X	X	X	X	X	X	X	X			X		X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X							X	X	X
Rock bass	86	X		X		X	X	X	X	X	X	X		X				X	X	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X							X	X	X
Calico bass	87							X										X		X		X	X	X		X	X	X	X		X		X	X									X	X
Skipjack	88							X										X		X		X		X		X		X			X		X	X									X	X
Sheepshead	89							R												X		R						X			R		X	X									X	R
Sculpin (Cottus b. bairdii)	90a								X								X	X	X					X					X	X	X			X	X	X				X	X	X		X
Sculpin (Cottus b. kumlieni)	90b	X		X		X		X																							X				X	X								X
Sculpin (Cottus cognatus)	91	X				X		X	X		X	X	X		X				X				X							X	X				X	X					X	X		X
Brook stickleback	92	X		X		X		X	X	X							X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X							X	X	X
Nine-spined stickleback	93	X																													X													X
Two-spined stickleback	94																									X		X					X					X				X	X	
Eel-pout	95	X						R								E		X				R						R			X		X	X									R	X

TABLE 1.— FOOD OF SOME OSWEGO DRAINAGE FISHES (EXCLUDING THOSE OF FINGER LAKES) *

Food in per cents.

Length to base of tail, in inches

NAME	Average length	Number examined	Difflugia	Cladocera	Copepoda	Ostracoda	Isopoda	Amphipoda	Crayfish	Mayfly nymphs	Caddisfly larv. and pupae	Midge larv. and pupae	Misc. aquatic larvae	Misc. flying insects	Mollusca	Fish	Misc. animals	Diatoms	Green and blue-greens	Plant fragments	Sand and silt
Amia calva	15	1							100												
Lepisosteus osseus	$17\frac{3}{4}$	1														100					
Coregonus clupeaformis [1]	$15\frac{1}{2}$	2						3		2	3	2		45		25				20	
Salmo irideus	$1\frac{3}{8}$ – $2\frac{1}{2}$	28								20	15	20	10	20		15					
Salmo irideus	$5\frac{3}{4}$	1												100							
Salmo fario	$1\frac{1}{8}$ – 2	18								50	15	15		20							
Salvelinus fontinalis	2	11						1			5	25	7	60			1				1
Catostomus commersonnii	2	8	20	5	15							35						10			15
Erimyzon sucetta oblongus	3 – 5	7	5	15	30							20						10	20		
Erimyzon sucetta oblongus	$1\frac{7}{8}$	3	10	25	10							10					5	10	30		
Moxostoma sp.		4		15								80									5
Moxostoma anisurum	9	3		5								50			40						5
Hypentelium nigricans	$1\frac{1}{2}$	33	10	5	5					9	10	30					1	10	10		10
Cyprinus carpio	14+	8		5	5			5				20	5							50	10
Campostoma anomalum	$1\frac{1}{2}$	20										10						50	10		30
Hybognathus nuchalis	$2\frac{1}{2}$	35																50	10		40
Pimephales promelas	$1\frac{1}{2}$	6																10	60	30	
Hyborhynchus notatus	$1\frac{3}{4}$	13																50			50
Leucosomus corporalis	7	6							50				5	30					15		
Leucosomus corporalis	$1\frac{1}{2}$ – $2\frac{1}{4}$	18								20	15	15	15	30				5	10		
Semotilus atromaculatus	$2\frac{1}{2}$	6										20		80							
Clinostomus elongatus	$2\frac{1}{4}$	11										32		60					8		
Margariscus margarita	$2\frac{1}{2}$	15			5							5						15	55		20
Notemigonus crysoleucas	$3\frac{1}{2}$	2		30														5	65		
Notropis bifrenatus	$1\frac{1}{2}$	17		15	1	1						80					3				
Notropis whipplii whipplii	$1\frac{1}{2}$	12		10	5					30		40		15							
Notropis volucellus volucellus	$1\frac{1}{2}$	16		45		2						3		5			5	20			20

Notropis rubrifrons	2½	23								25	35	25	5	10							
Notropis heterolepis	1⅝	29		95																	5
Notropis atherinoides	1⅝	9		95										5							
Notropis cornutus	1¼ 3	18		25							2	35		5				15	5		13
Rhinichthys cataractae	1 3	8					1			10		40	49								
Rhinichthys atronasus	2	16								5	10	60	5						10		10
Exoglossum maxillingua	2	11								70	5	20				5					
Nocomis biguttatus	2¼	16							10	20	5	40							25		
Ameiurus natalis	2 6	4						15	25				60								
Schilbeodes gyrinus	2	8		6				10		10	25	40	4			5[3]					
Umbra limi	2¾	10						90					8		2						
Poecilichthys exilis	1–2	29		10	5	3					2	80									
Esox niger	2 10	21		1				30	7	3	3	1	35			20					
Esox lucius	3 10+	4 5						10					90			100					
Esox americanus	3 6	6					1	3								96					
Gasterosteus aculeatus	2¼	10						60				40									
Labidesthes sicculus	2½	7		50	5							30		15							
Eupomotis gibbosus	2	7		8		1				5	7	50	26	3							
Pomoxis sparoides	2½ 7	12		15	15			5				20	30			15					
Helioperca incisor	3 6	6		1				17		3	15	45		3			1			15	
Percina caprodes	2	22		55				15		10		15									5
Hadropterus maculatus	1 2½	20		5	2	1		6		25	1	45	15								
Etheostoma blennioides	2½	3				2					90	5	3								
Boleosoma nigrum olmstedi	1¾	4									5	95									
Catonotus flabellaris	1¾	8						5		20	20	50									5
Aplodinotus grunniens	8	1									5	90	5								
Cottus cognatus	2	17						10		29	25	30	1								5
Cottus bairdii kumlieni[2]	2	8										90		3					2		5
Cottus bairdii bairdii	1⅛ 3	9								25	20	50	5								

* Prepared by Dr. C. K. Sibley
[1] Canandaigua lake.
[2] Large worms in body cavity.
[3] Fish eggs.

V. CHEMICAL INVESTIGATION OF THE OSWEGO WATERSHED

BY FREDERICK E. WAGNER,

Fellow, Rensselaer Polytechnic Institute

In this, the second survey of a watershed area taken as a whole, the chemical policy has been necessarily adjusted to meet the requirements of varied conditions.

The waters about which particular interest centered may be classified into three groups, lakes, springs, and streams. included in the last named are those rivers which have entirely or in part been incorporated into the State barge canal system. In regard to the first class, it was desired to determine variation in gaseous and related characteristics between the surface and lower depths of the more important lakes, and to study possible changes in these during the summer season. The importance of the springs lies in their possibilities as sources of cold clear water adaptable for those fish species demanding such conditions.

As in the first survey, of paramount importance in stream studies was the investigation of pollutional factors, and determination of their importance both in regard to intensity and length of stream affected.

Types of Pollution.— The industries with which the Oswego watershed abounds, especially that section containing the outlets of the smaller lakes east of Cayuga continuing down to Oswego on Lake Ontario, and which supply the greatest pollution problems, are the woolen and paper industries. These are pressed closely in prominence by pollution from municipal sewage. Canning factories dot the landscape at sundry places, but in general the summer of 1927 was a slack one for canneries, and numerous cases must be classed as potential sources of pollution which under other circumstances might have been found more serious.

It might be well at this point to call attention to an erroneous impression entertained by certain cannery officials. Several have advised that at considerable expense they have installed screening devices with the understanding that such would completely solve their waste disposal problems, and that the effluents therefrom might safely be passed directly into a convenient stream. The fallacy of such a conclusion is not obscure. Screening out the coarse material such as faulty peas, beans, cherry stones, etc. greatly improves the condition of the wastes for which disposal is sought. But what of that material which passes through the finest of screens, (they are not always fine) and which varies in size of particles from true solutions up to more or less finely divided solid pieces? Obviously that material in a fine state of division is in the most favorable condition for ready decomposition, with consequent threat to the aquatic life upon which it may be thrust, so the

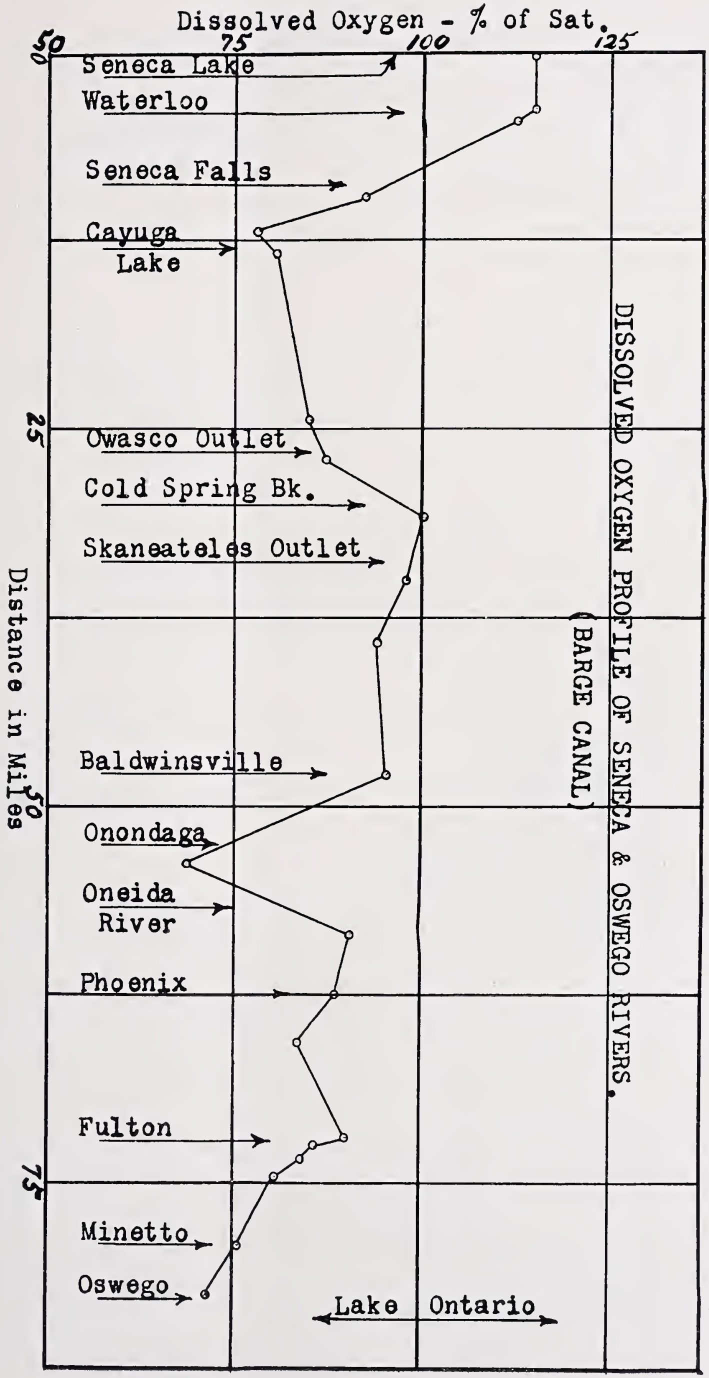


Fig. I

DISSOLVED OXYGEN PROFILE OF SENECA & OSWEGO RIVERS.
(BARGE CANAL)

screening while a big aid is not sufficient in itself to render a waste effluent harmless.

Milk product factories and condensaries were relatively unimportant from the standpoint of numbers, but in at least one case, to be discussed later, the pollution made up in severity for the absence of a greater number of instances. Other sources of pollution encountered were gas and tar works, varnish and enamelware factories, insulator works, Solvay works, rope, shade, shoe, carpet and button factories, typewriter works, foundries, machine shops and feed mills.

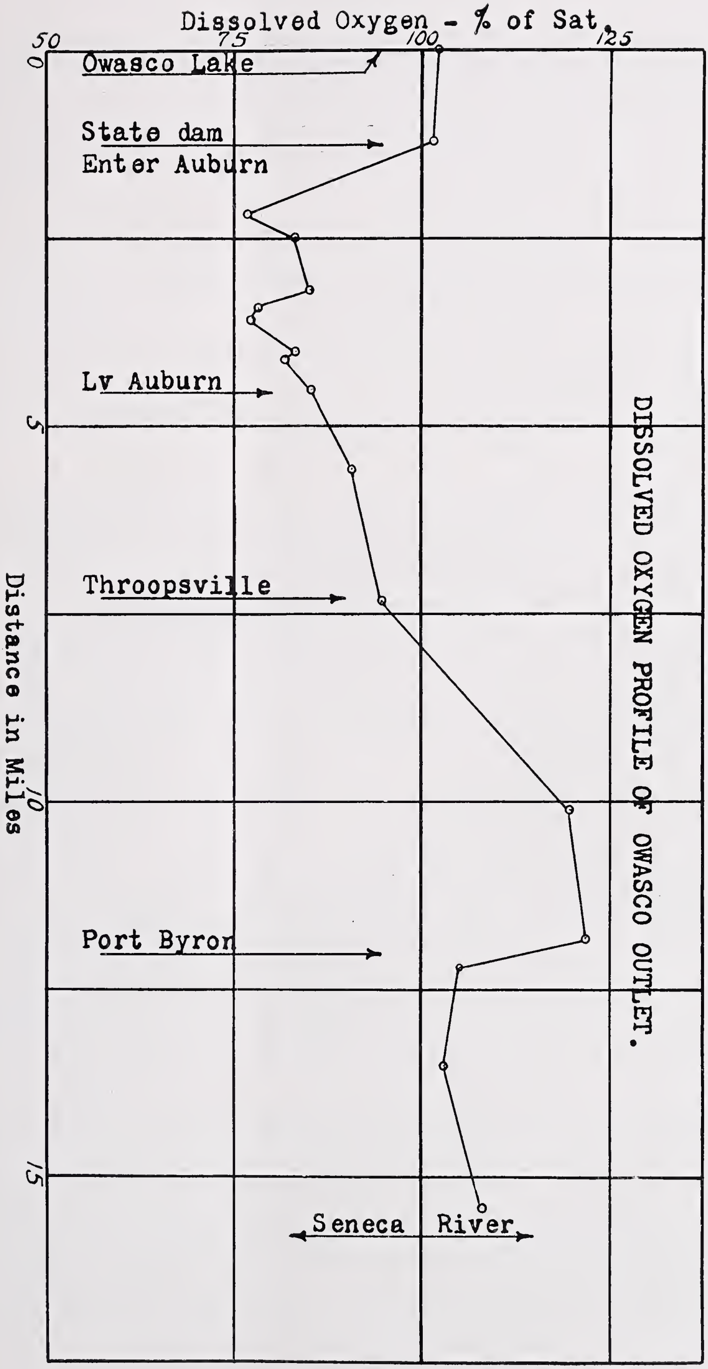
Methods Employed and Effects of Pollution.— For a discussion of the effects of pollution the reader is referred to "A Biological Survey of the Genesee River System," supplemental to sixteenth annual Conservation report, 1926. Analytical methods employed were substantially the same, being those outlined in "Standard Methods of Water Analysis," 6th edition, 1925, American Public Health Association. The values for dissolved oxygen listed in the accompanying tables and represented graphically in several instances have been calculated to percentage of saturation based upon Whipple's values, and the barometric pressures of the regions have been taken into consideration. *The heavy horizontal lines across the graphs* represent *100 per cent saturation.* The values for carbon dioxide refer to free carbon dioxide in all cases unless otherwise indicated.

It is noteworthy that waters which have assimilated quantities of organic and nitrogenous matter and have consequently become abundantly supplied with plant food often support luxurious oxygen producing growths, and give values for dissolved oxygen far in excess of those required for 100 per cent saturation, which figures, as pointed out in the past, refer to water in equilibrium with the atmosphere, about one-fifth of which is oxygen. Excellent examples of such are offered by Canandaigua outlet as shown by the tabulated data in Series I, and by Owasco outlet, data of Series I and Fig. 2.

The Canals.— The State barge canal system forces itself so frequently upon the attention of an investigator that some consideration had to be given it, though a study of such an extensive system offers a weighty problem in itself. Hence where closely linked up with other waters studied the canals have been to some extent included in the investigation.

The effect of wash from passing boats in keeping the water roiled and turbid can only be referred to in passing, as can the considerable quantities of oil which escape or are discharged at times upon the waters.

A fairly continuous canal section is that starting with Seneca lake as a westerly terminus and extending eastward and northward for a stream length of about ninety miles to Lake Ontario at Oswego, joined en route by the Cayuga lake section from the south, the Clyde river section from the west, and Oneida river section



DISSOLVED OXYGEN PROFILE OF OWASCO OUTLET.

Fig. 2

from the east. At accessible points the canal water was sampled, and since an average depth of ten to fourteen feet was found to exist, samples were taken just below the surface and at the bottom. Results are listed in the tabulation of Series I; and Fig. 1 represents a profile of the dissolved oxygen content. For the preparation of this, values found at the bottom and surface were averaged. These figures have been plotted and connected directly with straight lines, no attempt having been made to smooth the curves. The excellent condition of the clear, plant containing water leaving Seneca lake is shown, and effects of Waterloo and Seneca Falls upon the first few miles of its course evident. Proceeding further the inpouring of Skaneateles outlet with its load of unassimilated material is marked, and grossly polluted Onondaga outlet clearly indicated. To contributions of sewage, paper and woolen mill wastes from Phoenix and Fulton must be attributed the continued depression of the profile as it is traced to its end at the lake.

Stream Studies.— The greater part of the story is recorded in Series I of the tabulated data, and at this point any discussion must necessarily be of a supplementary nature and supplied in the hope that it will enable the reader to picture more easily and clearly conditions as found at the time of investigation.

Owasco outlet is a large rapidly flowing stream, dropping approximately three hundred and twenty-five feet in its seventeen and one-half mile passage to the Seneca river. It has been highly industrialized by the city of Auburn through which it flows, no less than nine dams taking advantage of its one hundred and fifty foot drop through the city. Sewage from about two-thirds of the population enters the stream in a raw state. In spite of this the dissolved oxygen content was found reduced only to a minimum of 76 per cent where conditions were at their worst.* The oxygen supply was found to have recovered rapidly, and the stream but a short distance from the city was filled with an exuberant growth of water plants, thriving on the abundance of food, and contributing in well known manner to the reoxygenation of the stream. (Fig. 2). This pollution like all other cases varies in intensity, and in addition, the flow of water is not constant, being controlled at a State dam to meet industrial demand. Effects of dyes and other substances possibly directly poisonous to fish were not studied.

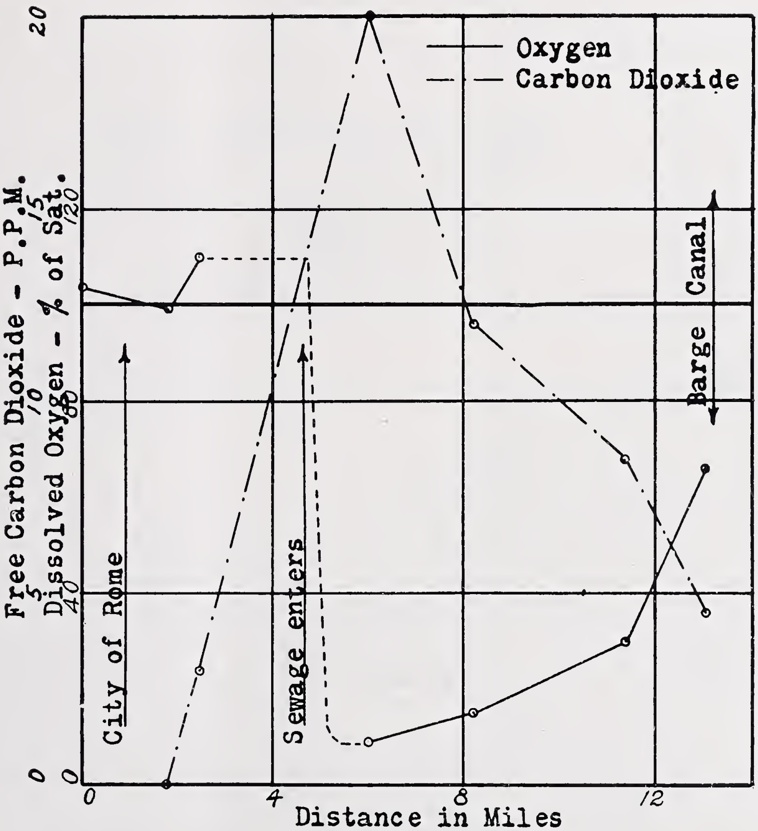
Wood creek is deserving of special mention because it has the questionable distinction of being the worst case of pollution ever encountered. This comparatively small stream receives the raw sewage from the city of Rome, which converts it into a veritable open sewer, absolutely foul, with blackened unsightly shores, and uninhabitable to fish life for miles. The first spot analyzed below sewage entrance, nearly one and one-half miles below in fact, showed an oxygen content of one-half of one part per million. At

* See minnow tests on Owasco outlet, p. 92.

the point where the stream enters the barge canal, about nine miles below the entrance of pollution, the dissolved oxygen had recovered only to the extent of sixty-six per cent of saturation, though the creek's volume had been augmented by such sizable streams as Canada and Stony creeks. Fig. 3 represents an attempt to portray

Fig. 3

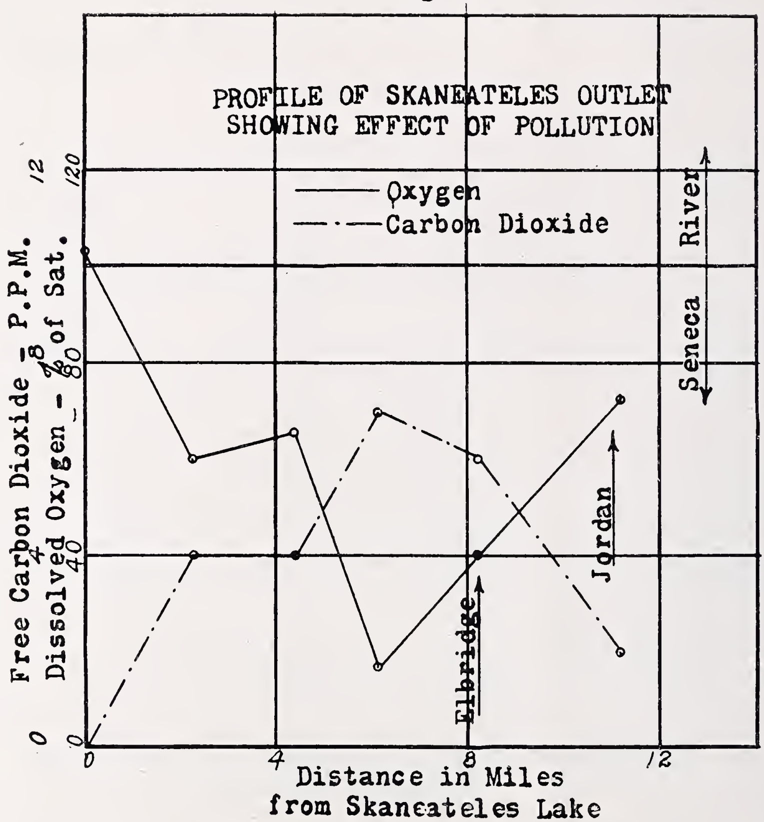
PROFILE SHOWING EFFECT OF ROME SEWAGE UPON WOOD CREEK



the situation graphically. The broken line bridges that section between the two solid parts and represents the probable change through that part of the stream where no samples were taken. This creek flows through a relatively level section of country east of Oneida lake, and has not the opportunity for aeration afforded by the rapid and tumultuous flow of many streams farther west, and the importance of which has been remarked in the Genesee report.

Skaneateles outlet occupies a well deserved second place among the worst cases, offering as it does the severest example of industrial pollution. This stream was passed over rather briefly, having been already intensively studied at an earlier date.[1] This summer's work has indicated that conditions have grown worse since the earlier investigation; heavier consumption of lake water by Syracuse may be partly responsible. Where conditions were at their worst the oxygen was reduced to seventeen per cent of

Fig. 4



saturation, and below Jordan, about two miles from the confluence of the stream with the canalized Seneca river, the oxygen had recovered only to seventy-two per cent of saturation. (Fig. 4)

[1] Unpublished report of Emmeline Moore to Conservation Commission, Nov. 28, 1921.

This is the more pertinent when the character of the stream flow is taken into consideration. The total difference in elevation between the lake and river is about four hundred and seventy-five feet, over a stream length of about thirteen miles, and the flow from Elbridge to Jordan tumultuous. The contrast between the inlet and outlet of Skaneateles lake is extreme. One would travel far to find a more beautiful stream than the inlet, clear, riffly, and abounding with trout. The outlet, which under more favorable circumstances might make an equally fine appearance, now presents pools clogged with filthy, gas evolving sludge, and varying in color from beet red to gray and black.

The last stream of particular note is Pott's creek, which flows southward to the canalized Oneida river, a few miles to the east of Fulton. This stream is an example of the brown or so-called "peaty" water, colored by the vegetation through which it flows. The contour of the land as in the case of Wood creek is conducive to sluggish flow. At Pennellville a milk products factory was found to be discharging its wastes into the stream, and for a considerable distance the dissolved oxygen content found to be almost negligible, about six per cent of saturation as compared with ninety-six per cent above the town. At entrance to the river the oxygen had risen to a value of eighty-three per cent.

Pollution to Virgil creek at Dryden, and to Fall creek at McLean must be classed as potential only, since inappreciable at the time of investigation.

Injury to Owasco inlet at Groton was felt to be greater than the data would indicate, since high water at the time of investigation doubtless conduced to a better than normal appearance.

Cayuga inlet, spring fed and rapid throughout the fourteen miles prior to reaching Ithaca was found un-noteworthy, but in the deeper and quieter portions through Ithaca the effect of sewage was very apparent, though fish life of a tolerant nature probably not endangered.

A great volume of water passes swiftly through Keuka outlet, and the stream has been highly industrialized throughout its upper length. At least six dams take advantage of some portion of the stream's two hundred and sixty-five foot drop to Seneca lake. Pollution enters from Penn Yan in the shape of sewage and cannery wastes, and from paper mills a few miles below the town, but the volume of water is so great and opportunity for aeration so satisfactory that at no point was it found in very bad condition. The several reed bordered mill ponds act as settling basins for solid material carried in suspension. Effects of entering pollution directly poisonous to fish life is problematical.*

The outflow from Canandaigua lake leaves by two channels, which unite after travelling separately a couple of miles. One contains by far the greater volume of water and receives the effluent from a partial sewage disposal plant, gas works and varnish fac-

* See page 92 for minnow test; page 62 on Keuka outlet; page 119 on chemical condition.

tory. These waters are in poor condition for about a quarter mile below their confluence, though richly supplied with aquatic plants and not devoid of such fish as sucker and carp. Farther on the stream continues to improve, and aided by oxygen forming plants attains an oxygen content far beyond its normal saturation limit.

Great brook, tributary No. 43 of Ganargua, was found badly polluted by wastes from insulator works and cannery at Victor.

Naples creek, the scene of serious cannery pollution in past years was found free of such when visited on two separate occasions. Wastes in the cannery ditch were found highly putrescent, but there had been this season insufficient volume to reach the stream.

West river was found to be in very poor condition as the result of cannery wastes at Rushville.

Burrell creek has received attention in the past because of pollution from kraut wastes at Halls Corners. This stream consisted only of isolated pools when investigated during the summer. Analysis during the fall cabbage season showed oxygen content of only 1.6 per cent of saturation, though the stream flow was slight.[1] It would appear that the greatest cause for concern here lies in the possibility of heavy accumulation of decomposable waste being swept by rains or flood waters into valuable fishing waters below, where especially during the spawning season serious consequences might result.

Ninemile creek (Otisco outlet) serves woolen and paper factories, which at time of investigation were operating at but a fraction of capacity, and though pollution was very evident it was not of alarming proportions. Free carbon dioxide in appreciable quantities further indicated that the possibilities for far more serious conditions are imminent.

Chittenango creek was found polluted by cheese factory wastes at Nelson. Appearances indicated that the effect of such were far more serious at times, when the plant was operated more nearly to its capacity, and good fishing possibilities seriously endangered. Effect of sewage from Cazenovia was appreciable, but the volume of water sufficient to assimilate such without serious result. Conditions apparent below Chittenango Falls, a few miles downstream, indicate that the stream has been enriched in a not very appealing manner.

Dairy wastes entering Sconondoa creek at Vernon were found to have been rendered partially inactive by factory disposal efforts. Myriads of small fish just above the sewage entrance indicated that here they had found a source of sustenance.

Oneida creek carries off the effluent from Oneida's partial sewage disposal plant. Oxygen content was reduced about 30 per cent. Wastes from gas works were found to have coated the bed of the stream with tarry sludge.

Spring Studies.— Numerous springs are found at various points throughout the Oswego watershed, and certain ones of prominence

[1] Observations by N. L. Cutler. See table of pollution studies, p. 138.

were investigated. The manner in which springs occur is regulated by geological structure, so that as a result there exist many varieties. Some issue in greater or lesser volume from several spots indicating that the downward seepage of surface water has been interrupted by some impervious stratum, and the flow deflected in accordance with the dip or inclination of such. These springs have been referred to in the tables as surface springs. An important fact in connection with these is that the water seeping through the upper soils and sub-soils has opportunity for correcting any great deficiency in oxygen, which of course is necessary if the issuing waters are to be suitable directly for fish life.

Contrasted to these are the deeper seated springs whose issue depends upon the alternations of permeable and impermeable strata, and which may be the outlets of underground streams having in some cases fairly defined channels. Geological fault fissures or joints afford facilities often-times for the escape of such waters, especially where they bring steeply inclined porous strata against impervious ones. The important fact about these is that the water is rushed to the surface, and its condition depends upon the chemical changes which its constituents have undergone, and the nature of the strata such as limestone with which it has come in contact since it fell as rain at some time and place. Hence as in the case of the Price spring,[1] such waters may be practically devoid of oxygen and highly charged with carbon dioxide, under which conditions fish could not exist.

Lake Studies.[2]— Chemical characteristics of the more important lakes of the watershed were studied. Results are tabulated in Series III. No remarkable seasonal change was found, and at those stations where periodic examinations were made, determinations at one period did not differ greatly from those at another.

It is interesting to note that at the comparatively shallow depth of nineteen meters Otisco lake was found to be only about 3 per cent saturated with dissolved oxygen.

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1 See p. 126.

2 Data supplied by W. L. Tressler, S. S. Britten, and R. Vingee.

Series I

Chemical Analyses — Streams of the Oswego Watershed

Place Sampled and Remarks	Date	Temperature of water, degrees		Dissolved oxygen		Methyl orange alkalinity p. p. m. calcium carbonate	Carbon dioxide parts per million	pH
		Fahr.	Cent.	Parts per million	Per cent of saturation			
Stream:— Virgil, tributary 16 of Fall.								
Pollution:— Milk shipping station at Dryden.								
100 ft. above pollution entrance	June 18	69.8	21	8.7	101	64.4	nil	8.5
500 ft. below pollution entrance	June 18	68.5	20.5	8.9	102	60.4	nil	8.7
Stream:— Owasco inlet.								
Pollution:— Cheese factory and condensary, typewriter works, sewage at Groton.								
Entering Groton	June 20	57.2	14	9.3	93	116	nil	8.1
At Cortland street, water turbid	June 20	59.9	15.5	8.5	87	123	nil	8.1
1.1 miles below Groton	June 20	62.6	17.0	10.4	111	125	nil	8.5
2.8 miles below Groton	June 20	63.5	17.5	10.5	113	131	nil	8.7
Pollution:— Milk shipping station at Locke.								
Stream entering Locke	June 20	65.3	18.5	9.5	103	131	nil	8.5
Stream leaving Locke	June 20	64.9	18.3	9.4	102	138	nil	8.5
Stream:— Fall creek.								
Pollution:— Milk shipping station at McLean.								
Stream entering McLean	June 23	69.8	21	8.7	101	105	nil	8.3
Stream leaving McLean	June 23	70.5	21.4	8.6	100	105	nil	8.3
Stream:— Cayuga inlet.								
Pollution:— Sewage from Ithaca.								
1.7 mi. from source; small, rapid stream	June 24	58.1	14.5	9.6	97	153	nil	8.1
4.0 mi. from source	June 24	57.7	14.3	9.0	91	166	nil	8.1
7.0 mi. from source	June 24	65.3	18.5	9.0	97	169	nil	8.3
9.5 mi. from source	June 24	64.0	17.8	9.4	100	159	nil	8.3
12.2 mi. from source	June 24	66.2	19.0	9.2	100	146	nil	8.3
13.8 mi. from source, entering Ithaca	June 24	63.5	17.5	9.7	102	150	nil	8.1
14.3 mi. from source, at Buffalo street	June 24	68.5	20.3	7.7	85	133	1.0	7.9
15.0 mi. from source, 0.5 mi. from lake	June 24	65.3	18.5	6.1	65	116	2.5	7.7
Off mouth of Cascadilla creek, near point of entrance of Ithaca sewage.								
Bottom, 11 ft. below surface	June 27	59.0	15.0	5.9	59	114	6.5	7.6
5.5 ft. below surface	June 27	67.1	19.5	5.5	60	126	6.5	7.6

At surface	June 27	68.0	20.0	5.3	59	139	4.5	7.6
One-half mile below the above point, and one-half mile from Cayuga lake.								
Bottom, 11 ft. below surface	June 27	57.4	14.1	6.5	64	110	5.0	7.6
5.5 ft. below surface	June 27	64.4	18.0	6.6	70	122	4.0	7.6
At surface	June 27	66.6	19.2	5.3	58	129	6.0	7.5
Stream:— Keuka outlet.								
Pollution:— Cannery waste and sewage from Penn Yan, paper mills, CS_2 factory.								
At state dam, 0.9 mi. from Keuka lake	July 5	61.7	16.5	9.0	94	75	nil	8.1
At Keuka Mills dam, 1.8 mi. from lake	July 5	62.6	17.0	8.9	94	75	nil	8.1
1000 ft. below Keuka Mills	July 8	64.9	18.3	8.3	90	78	nil	8.1
2000 ft. below Keuka Mills	July 8	66.2	19.0	7.9	87	78	nil	8.1
As above but at bottom of pond, 7 ft. deep	July 8	66.2	19.0	8.1	89	78	nil	8.1
500 ft. below Milo Mills	July 5	63.5	17.5	8.7	92	76	0.5	7.9
At power house, formerly Seneca Mills	July 5	65.7	18.7	8.6	93	77	nil	8.0
At CS_2 factory, formerly Cascade Mills	July 5	67.1	19.5	9.1	100	77	nil	8.1
5.6 mi. from Keuka lake	July 8	67.7	19.3	8.9	97	78	nil	8.1
At Dresden, 0.5 mi. from Seneca lake	July 5	67.6	19.8	8.6	95	79	nil	8.1
Stream:— Keuka inlet, about five miles in length, spring fed.								
0.5 mi. from source, at Bath hatchery	July 6	50.9	10.5	7.9	73	160	2.5	7.9
Pleasant Valley, 2.7 mi. from source	July 6	56.3	13.5	9.2	90	170	nil	8.1
Near Hammondsport, 0.5 mi. from lake	July 6	58.1	14.5	9.0	90	168	7.0	7.7
Stream:— Catherine creek, chief inlet to Seneca lake.								
10.8 mi. from Seneca lake	July 7	61.0	16.1	8.9	92	182	nil	8.1
9.0 mi. from lake, rapid and riffly	July 7	64.4	18.0	9.4	100	186	nil	8.2
5 mi. from lake, 1.5 above Montour Falls	July 7	63.0	17.2	9.1	96	197	nil	8.2
Lv. Montour Falls, stream canalized below	July 7	59.9	15.5	8.4	85	174	nil	8.1
Stream:— Burrell creek. Pollution:— Kraut factory, Hall.								
One-quarter mile below pollution	Oct. 4	58.1	18.5	0.15	1.6	219.3	30.0	6.9
Stream:— Canandaigua outlets (two, joining 1.6 and 2.4 miles respectively from lake).								
Pollution:— Canandaigua sewage disposal plant, gas works, enamel and lacquer factory.								
Water leaving lake	July 12	71.6	22.0	7.9	92	106	nil	8.1
Outlet No. 1 — 1000 ft. above junction	July 16	73.0	22.8	5.5	65	112	1.5	7.9
Outlet No. 2 — 100 ft. above junction	July 16	74.8	23.8	4.9	59	111	4.5	7.5
500 ft. below; dense plant growth	July 16	73.0	22.8	5.2	61	111	2.5	7.8
1000 ft. below junction	July 12	74.3	23.5	7.7	92	103	1.5	7.9
0.75 mi. below junction	July 12	76.6	24.8	9.6	117	108	nil	8.4
At Chapin; shallow, vegetation lined	July 12	78.8	26.0	9.8	122	104	nil	8.6
At dam, 2.3 mi. below Chapin	July 12	75.9	24.4	7.5	91	109	0.5	7.9
At dam in Shortsville	July 12	77.9	25.5	10.7	132	106	nil	8.6

Series I — (Continued)

CHEMICAL ANALYSES — STREAMS OF THE OSWEGO WATERSHED — (*Continued*)

PLACE SAMPLED AND REMARKS	Date	Temperature of water, degrees		Dissolved oxygen		Methyl orange alkalinity p. p. m. calcium carbonate	Carbon dioxide parts per million	pH
		Fahr.	Cent.	Parts per million	Per cent of saturation			
Stream:—Canandaigua Outlet, *Continued*								
Pollution:— Paper mill and farm machinery factory at Shortsville.								
Stream leaving Shortsville	July 13	76.1	24.5	7.3	88	113	nil	8.0
1.6 mi. below Shortsville	July 13	77.5	25.3	8.5	104	112	nil	8.1
At Manchester Center	July 13	78.8	26.0	10.7	133	116	nil	8.3
500 ft. above tributary 44, Clifton Springs pollution	July 13	82.0	27.8	9.9	126	117	nil	8.6
500 ft. below tributary 44	July 13	82.0	27.8	8.4	107	121	nil	8.6
2.3 mi. below tributary 44, site of old dam	July 13	83.1	28.5	11.8	151	112	nil	8.8
At dam just above Phelps	July 13	82.9	28.3	13.2	171	120	nil	8.8
Pollution:— At Phelps, vinery and tributary No. 40 bearing cannery wastes.								
Leaving Phelps, 500 ft. below vinery	July 19	74.1	23.4	9.1	107	140	nil	8.1
2.5 miles below Phelps	July 19	78.4	25.8	11.4	140	125	nil	8.3
6.0 mi. below Phelps, stream excellent	July 19	77.4	25.2	13.2	160	130	nil	8.5
At Alloway; pollution from vinery, grist mill	July 19	75.6	24.2	7.1	85	131	nil	8.1
Stream discharging into canal, Lyons	July 19	77.9	25.5	8.8	108	138	1.0	7.9
Stream:— Flint, tributary 40 of Canandaigua.								
Pollution:— Kraut factory, Phelps.								
200 ft. above pollution	Oct. 30	71.6	22.0	9.7	110.3	170.8	nil	8.1
200 ft. below pollution	Oct. 30	71.6	22.0	7.5	86.7	168.8	6.6	7.5
1 mile below pollution	Oct. 30	71.6	22.0	4.7	54.6	183.6	2.0	7.7
1½ miles below pollution	Oct. 30	71.6	22.0	5.2	59.8	194.7	2.5	7.7
Pollution:—Kraut factory, Gorham.								
100 ft. above pollution	Oct. 4	68.0	20.0	7.8	87.6	150.4	0.5	7.8
600 ft. below pollution	Oct. 4	68.0	20.0	6.4	72.0	155.5	3.0	7.7
1½ miles below pollution	Oct. 4	71.6	22.0	7.2	83.8	140.7	1.5	7.7
Stream:— Great brook, tributary 43 of Ganargua.								
Pollution:— At Victor, insulator works (oily wastes), canning factory (cherries), domestic drainage.								
Stream entering Victor	July 15	73.4	23.0	8.2	96	216	nil	8.1
500 ft. below insulator works, stream oily	July 15	72.5	22.5	7.2	84	224	7.0	7.6
100 ft. below cannery, stream black	July 15	72.5	22.5	5.7	67	221	7.0	7.6
Lv. Victor, 0.75 mi. below cannery	July 15	70.9	21.6	3.4	39	256	10.0	7.5
Ganargua brook, 0.4 mi. from confluence, fresh water organisms present	July 15	73.8	23.2	6.7	79	206	2.0	7.9

Stream:— Seneca river (Barge canal). First sample in each case taken at surface, second at bottom.								
Lv. Seneca lake; clear, dense plant growth	July 21	70.2	21.2	10.2	115	92	nil	8.1
Bottom, 14 ft. depth	July 21	67.1	19.5	10.5	115	90	nil	8.1
Entering Waterloo, surface	July 21	69.8	21.0	10.3	116	91	nil	8.1
14 ft. depth	July 21	67.1	19.5	10.4	114	91	nil	8.1
Leaving Waterloo, surface	July 22	66.6	19.2	10.1	110	94	nil	8.1
5 ft. depth	July 22	66.2	19.0	10.0	110	92	nil	8.1
Lv. Seneca Falls, at power house	July 23	71.6	22.0	8.4	97	93	nil	8.1
10 ft. depth	July 23	67.4	20.8	7.9	89	93	1.0	7.9
0.9 mi. west of Cayuga lake	July 23	71.6	22.0	6.9	79	95	2.0	7.7
12 ft. depth	July 23	69.8	21.0	6.9	78	95	2.0	7.7
Lv. Cayuga lake, at canal dam	July 25	71.2	21.8	7.4	85	85	0.5	7.9
11 ft. depth	July 25	69.8	21.0	6.8	77	91	1.5	7.7
10.5 mi. from Cayuga lake	July 25	74.1	23.4	7.3	86	*110	1.0	7.9
14 ft. depth	July 25	73.4	23.0	7.2	84	110	1.0	7.9
1.2 mi. below Owasco outlet	July 25	73.4	23.0	7.6	89	107	0.5	7.9
12 ft. depth	July 25	72.5	22.5	7.2	86	107	1.0	7.9
0.3 mi. below Cold Spring brook	Aug. 6	73.2	22.9	9.0	105	111	nil	8.1
11 ft. depth	Aug. 6	71.2	21.8	8.5	97	115	nil	8.0
0.9 mi. below Skaneateles outlet	Aug. 15	73.4	23.0	9.1	106	102	nil	8.2
15 ft. depth	Aug. 15	71.6	22.0	7.8	90	102	nil	8.1
1 mi. east of Cross lake	Aug. 15	72.1	22.3	8.3	96	106	nil	8.1
12 ft. depth	Aug. 15	72.0	22.2	8.0	92	106	nil	8.1
In Baldwinsville, at dam	Aug. 17	70.7	21.5	8.4	95	106	nil	8.1
8 ft. depth	Aug. 17	70.7	21.5	8.5	97	106	nil	8.1
Just below Onondaga outlet	Aug. 17	71.2	21.8	8.5	97	107	nil	8.2
20 ft. depth	Aug. 17	69.4	20.8	3.7	41	107	5.5	7.7
At Belgium	Aug. 18	71.6	22.0	9.5	109	106	nil	8.2
11 ft. depth	Aug. 18	70.7	21.5	6.4	73	105	1.0	7.9
Seneca and Oneida rivers unite at Three River point to form the Oswego river — all canalized.								
Oswego river at Phoenix	Aug. 18	71.2	21.8	8.0	91	94	nil	8.1
12 ft. depth	Aug. 18	70.7	21.5	7.6	86	94	nil	8.1
At Hinmansville dam	Aug. 19	71.1	21.7	7.6	87	95	nil	8.0
14 ft. depth	Aug. 19	70.2	21.2	7.1	80	96	nil	8.0
Entering Fulton, upper dam	Aug. 24	71.6	22.0	7.9	91	95	nil	8.1
10 ft. depth	Aug. 24	71.6	22.0	7.8	89	95	nil	8.1
At Fulton, lower dam	Aug. 19	72.3	22.4	7.7	89	96	nil	8.0
14 ft. depth	Aug. 19	70.9	21.6	7.3	83	96	1.0	7.9
1 mi. below Fulton, stream reunited	Aug. 24	72.1	22.3	7.5	86	95	nil	8.0
12 ft. depth	Aug. 24	71.4	21.9	7.3	83	94	0.5	8.0
2 mi. below Fulton	Aug. 24	71.1	21.7	7.3	83	94	1.0	7.9
12 ft. depth	Aug. 24	71.4	21.9	6.9	79	93	1.0	7.9
At Minetto dam	Aug. 19	71.2	21.8	6.8	77	96	2.0	7.8
14 ft. depth	Aug. 19	71.2	21.8	6.6	75	96	1.5	7.8

* Clyde river-canal has entered.

Series I — (Continued)

CHEMICAL ANALYSES — STREAMS OF THE OSWEGO WATERSHED — (*Continued*)

PLACE SAMPLED AND REMARKS	Date	Temperature of water, degrees		Dissolved oxygen		Methyl orange alkalinity p. p. m. calcium carbonate	Carbon dioxide parts per million	pH
		Fahr.	Cent.	Parts per million	Per cent of saturation			
Oswego river (*continued*).								
Entering Oswego, high dam	Aug. 22	72.9	22.7	6.2	72	94	3.0	7.7
30 ft. depth	Aug. 22	72.1	22.3	5.8	67	94	3.0	7.7
1000 ft. below Oswego	Aug. 22	72.9	22.7	8.3	96	95	2.5	7.7
6 ft. depth	Aug. 22	72.9	22.7	8.3	96	95	2.5	7.7
0.5 mi. below Oswego, entering lake	Aug. 22	73.4	23.0	8.5	99	95	2.5	7.8
15 ft. depth	Aug. 22	72.9	22.7	8.4	97	95	3.0	7.7
Stream: Onondaga outlet.								
Pollution:— Waste from Syracuse and Solvay.								
At Long Branch	Aug. 17	71.2	21.8	7.7	88	107	nil	8.0
13 ft. depth	Aug. 17	69.4	20.8	4.3	48	107	nil	7.7
Stream:— Oneida river.								
At Brewerton, leaving Oneida lake	Aug. 20	70.3	21.3	8.1	92	78	nil	8.1
12 ft. depth	Aug. 20	69.8	21.0	8.0	90	78	nil	8.1
At Caughdenoy, apart from canal, 3 ft. deep	Aug. 20	71.6	22.0	8.3	95	78	nil	8.1
At Oak Orchard	Aug. 20	72.5	22.5	8.3	96	78	nil	8.1
12 ft. depth	Aug. 20	70.7	21.5	8.2	93	78	nil	8.1
Stream:— Owasco outlet.								
Pollution:— Sewage and industrial waste from Auburn, sewage and creamery waste from Port Byron.								
Water leaving Owasco lake	July 27	72.5	22.5	8.8	102	100	nil	8.3
At state dam, 1.2 mi. from lake	July 27	72.5	22.5	8.8	102	101	nil	8.1
5.5 ft. depth	July 27	72.5	22.5	8.7	101	101	nil	8.1
Logan street dam, 2.2 mi. from lake	July 28	70.7	21.5	6.7	77	103	trace	8.0
Genesee street dam, shallow, plant growth	July 28	72.1	22.3	7.1	83	106	nil	8.1
Hulbert street dam, carp and catfish visible	July 28	73.4	23.0	7.2	85	107	nil	8.1
End of state prison, 3.4 mi. from lake	July 28	73.4	23.0	6.6	78	107	2.0	7.7
Race-way between Washington and Jefferson streets	July 28	73.9	23.3	7.6	90	108	nil	8.1
Division street dam, pond gassing	July 28	74.3	23.5	6.7	79	108	1.0	7.9
7 ft. depth	July 28	74.3	23.5	6.4	76	108	1.0	7.9
Aurelius avenue dam, 4.0 mi. from lake	July 29	73.4	23.0	7.1	83	103	1.0	7.9
Wadsworth street dam, plant grown pond	July 29	73.4	23.0	7.0	82	103	1.0	7.9
Canoga street dam, 4.5 mi. from lake	July 29	74.3	23.5	7.2	85	104	1.0	7.9
1 mi. below Auburn, swift; dense growth	July 29	74.3	23.5	7.7	91	105	trace	8.0

At Throopsville, 7.4 mi. from lake	July 29	74.8	23.8	8.0	95	103	nil	8.1
2.5 mi. below Throopsville	Aug. 1	72.3	22.4	10.4	120	107	nil	8.3
Entering Port Byron	Aug. 1	72.3	22.4	10.6	122	109	nil	8.3
Leaving Port Byron	Aug. 1	72.5	22.5	9.1	105	109	nil	8.3
1.5 mi. below Port Byron	Aug. 1	72.3	22.4	8.9	103	102	nil	8.3
Entering Seneca river	Aug. 1	72.3	22.4	9.4	108	115	nil	8.2
Stream:— Clyde river–canal.								
3 mi. below Lyons, oily film on water	Aug. 3	73.4	23.0	8.2	96	142	trace	8.0
12 ft. depth	Aug. 3	72.5	22.5	7.8	90	142	1.0	7.9
At lock 2 mi. below Clyde, 11 ft. depth	Aug. 3	72.5	22.5	7.2	83	140	1.5	7.9
Bridge, 2.5 mi. above Mays point, 12 ft. depth	Aug. 3	71.6	22.0	6.6	76	140	1.5	7.9
At Mays point, river very turbid	Aug. 3	72.5	22.5	6.9	80	138	2.0	7.9
10 ft. depth	Aug. 3	71.6	22.0	6.8	78	138	2.0	7.9
Stream:— Owasco inlet and tributary No. 17, flowing through Moravia.								
500 ft. above tributary 17, water turbid	Aug. 5	66.2	19.0	9.8	107	126	nil	8.1
Tributary 17 entering inlet	Aug. 5	62.6	17.0	9.4	99	108	nil	8.1
2000 ft. below tributary 17	Aug. 5	65.8	18.8	9.6	105	122	nil	8.1
Stream:— Skaneateles inlet, clear, riffly stream.								
3 mi. from Skaneateles lake	Aug. 5	58.5	14.7	9.1	95	108	nil	8.1
2000 ft. from lake	Aug. 5	66.2	19.0	8.8	91	115	nil	8.2
Stream:— Naples creek.								
Lv. Naples, 4 mi. from Canandaigua lake	Aug. 9	71.6	22.0	9.1	106	143	nil	8.6
2 mi. from lake	Aug. 9	67.1	19.5	9.4	104	155	nil	8.3
Stream:— West river.								
Pollution:— Cannery wastes at Rushville.								
100 ft. above pollution entrance	Aug. 9	71.2	21.8	9.5	110	243	nil	8.1
100 ft. below; turbid, sour smelling, abundant sewage fungus	Aug. 9	70.7	21.5	4.6	53	256	25	6.5
1000 ft. below; fungused	Aug. 9	69.4	20.8	3.4	39	254	8.0	7.7
1000 ft. below, fungused	Aug. 10	60.8	16.0	7.9	82	285	0.5	8.0
0.7 mi. below	Aug. 10	61.3	16.3	10.0	104	286	nil	8.1
Stream:— Ninemile creek (Otisco outlet).								
Pollution:— Sewage, woolen mills at Marcellus; paper mills at Marcellus Falls; drainage from Camillus; waste from Solvay.								
Water leaving lake; swift, shallow	Aug. 11	71.6	22.0	7.9	92	109	nil	8.1
Below Marietta; 1.8 mi. from lake; turbid	Aug. 11	72.5	22.5	8.3	97	113	nil	8.1
4 mi. from lake	Aug. 11	71.6	22.0	8.5	99	121	nil	8.1
Entering Marcellus	Aug. 11	72.1	22.3	8.6	100	125	nil	8.1
First woolen mill dam; blue-greens	Aug. 11	71.0	21.6	8.4	97	129	nil	8.1
Lv. Marcellus, second woolen mill dam	Aug. 11	71.2	21.8	8.7	100	129	nil	8.1
Marcellus Falls, paper mill dam	Aug. 12	64.4	18.0	7.8	84	148	2.5	7.8
Lv. Marcellus Falls, shallow, swift	Aug. 12	64.4	18.0	8.3	89	148	1.0	7.9

Series I — (Concluded)

CHEMICAL ANALYSES — STREAMS OF THE OSWEGO WATERSHED — (*Concluded*)

PLACE SAMPLED AND REMARKS	Date	Temperature of water, degrees		Dissolved oxygen		Methyl orange alkalinity p. p. m. calcium carbonate	Carbon dioxide parts per million	pH
		Fahr.	Cent.	Parts per million	Per cent of saturation			
Stream:—Ninemile Creek—*continued.*								
0.8 mi. above Camillus, at canal feeder	Aug. 12	64.0	17.8	8.3	88	159	1.0	7.9
Lv. Camillus	Aug. 12	64.4	18.0	8.3	89	159	1.5	7.9
At Amboy	Aug. 12	66.6	19.2	8.1	88	161	1.0	7.9
0.5 mi. from Onondaga lake	Aug. 12	68.9	20.5	7.4	83	179	12.0	7.3
Stream:— Skaneateles outlet.								
Pollution:— Sewage and milk waste from Skaneateles, series of paper and woolen mills below.								
Leaving Skaneateles lake	Aug. 13	71.2	21.8	8.9	103	90	nil	8.2
Lv. Mottville; water beet red	Aug. 13	74.3	23.5	5.0	60	105	4.0	7.6
At Skaneateles Falls, water black	Aug. 13	73.4	23.0	5.6	66	123	4.0	7.5
Sluggish spot below Hartlot	Aug. 13	76.1	24.5	1.4	17	143	7.0	7.3
At Elbridge dam	Aug. 12	76.6	24.8	3.3	40	148	6.0	7.5
Lv. Jordan, 2 mi. from Seneca river	Aug. 12	73.4	23.0	6.2	72	164	2.0	7.9
Sluggish spot below Hartlot, 10:40 a. m.	Aug. 25	67.1	19.5	3.6	40	120	5.5	7.6
Sluggish spot below Hartlot, 11:50 a. m.	Aug. 25	68.9	20.5	3.3	37	124	6.0	7.5
Sluggish spot below Hartlot, 4:50 p. m.	Aug. 25	68.0	20.0	2.8	31	119	7.0	7.4
At mill pond, Skaneateles Falls, surface	Aug. 25	69.4	20.8	6.4	73	106	5.0	7.5
10 ft. depth	Aug. 25	67.1	19.5	4.2	47	106	7.0	7.3
Stream:— Otisco inlet (Spafford creek).								
3 mi. from Otisco lake, slightly turbid	Aug. 13	67.1	19.5	8.5	94	140	nil	8.3
1000 ft. from lake; ponding, turbid	Aug. 13	66.2	19.0	9.1	100	153	nil	8.1
Stream:— Chittenango creek.								
Pollution:— Cheese factory wastes at Nelson; sewage at Cazenovia.								
100 ft. above cheese effluent	Aug. 30	60.1	15.6	9.1	96	181	nil	8.1
100 ft. below cheese effluent	Aug. 30	60.1	15.6	8.0	84	186	2.0	7.8
500 ft. below cheese effluent	Aug. 30	60.4	15.8	8.1	85	186	1.5	7.9
Entering Cazenovia	Sept. 1	65.3	18.5	9.2	102	145	nil	8.2
1000 ft. below sewage entrance — point of maximum effect	Sept. 1	64.4	18.0	8.0	84	151	nil	8.1
Stream:— Limestone creek.								
Pollution:— Paper mill at Fayetteville.								
Above Fayetteville	Sept. 1	60.4	15.8	9.7	100	169	nil	8.1

500 ft. below industrial effluents	Sept. 1	62.2	16.[illegible]	9.4	98	141	nil	8.1
1000 ft. below industrial effluents	Sept. 1	62.2	16.8	9.8	102	141	nil	8.1
Stream:— Sconondoa creek.								
Pollution:— Dairy wastes at Vernon.								
50 ft. above effluent (at 38°C.)	Sept. 5	65.3	18.5	9.1	98	176	nil	8.0
50 ft. below effluent	Sept. 5	79.7	26.5	8.0	100	193	8.0	7.7
200 ft. below effluent, sewage fungus	Sept. 5	82.0	27.8	6.4	82	193	6.0	7.7
1500 ft. below effluent	Sept. 5	77.9	25.5	7.3	90	193	3.0	7.9
Stream:— Oneida creek.								
Pollution:— Gas wastes and sewage disposal plant effluent at Oneida.								
Entering Oneida Castle	Sept. 6	63.5	17.5	9.0	95	185	nil	8.1
50 ft. above gas works effluent	Sept. 6	67.1	19.5	10.6	116	183	nil	8.1
Between gas works and sewage disposal	Sept. 6	67.6	19.8	9.5	104	187	nil	8.0
200 ft. below sewage, fungus present	Sept. 6	65.8	18.8	9.0	97	191	3.0	7.8
1500 ft. below sewage, ponded	Sept. 6	67.1	19.5	7.1	78	191	2.5	7.8
2 miles below sewage, dense plant growth	Sept. 6	68.5	20.3	6.7	74	190	2.5	7.8
6 miles below sewage	Sept. 6	71.1	21.7	12.6	144	185	nil	8.4
Stream:— Wood creek.								
Pollution:— Raw sewage from Rome.								
Entering Rome; clear, cold stream	Sept. 7	61.3	16.3	10.1	104	102	nil	8.1
Lv. Rome via abandoned Erie canal	Sept. 7	66.2	19.0	9.1	99	98	nil	8.1
0.6 mi. below town; ponded	Sept. 7	67.3	19.6	10.0	110	112	3.0	7.7
1.4 mi. below sewage entrance, just prior to entrance of Canada creek	Sept. 7	71.2	21.8	0.5	5.7	106	20	6.9
2.9 mi. below sewage entrance, prior to entrance of Stony creek	Spet. 7	68.0	20.0	1.0	11	96	12	7.0
5.3 mi. below pollution	Sept. 7	65.3	18.5	2.8	30	88	8.5	7.1
9 mi. below pollution; entering Barge canal	Sept. 7	69.4	20.8	5.9	66	84	4.5	7.4
Stream:— Pott's creek.								
Pollution:— Creamery wastes at Pennellville.								
1.3 mi. above Pennellville	Sept. 9	60.3	15.7	9.5	96	88	2.0	7.7
Lv. pond at Pennellville, 100 ft. above more serious of two effluents	Sept. 9	69.8	21.0	6.6	74	78	5.0	7.3
300 ft. below pollution	Sept. 9	69.4	20.8	5.0	56	77	8.0	7.1
1000 ft. below pollution	Sept. 9	67.1	19.5	0.6	6.6	78	16	6.8
½ mi. below pollution; small tributary enters	Sept. 9	70.7	21.5	0.5	5.7	84	22	6.8
1.7 mi. below pollution; second small tributary enters; green plants appearing	Sept. 9	68.0	20.0	7.4	82	87	3.5	7.6
3.3 mi. below pollution; entrance Oneida river	Sept. 9	73.4	23.0	7.1	83	84	9.0	7.2

Series II

CHEMICAL ANALYSES — SPRINGS OF THE OSWEGO WATERSHED

LOCATION AND DESCRIPTION	Date	Temperature of water, degrees		Dissolved oxygen		Methyl orange alkalinity p. p. m. calcium carbonate	Carbon dioxide parts per million	pH
		Fahr.	Cent.	Parts per million	Per cent of saturation			
Surface springs * at head of West Branch, trib. 25 of Cayuga inlet	June 21	48.2	9.0	7.3	66	97	3.0	7.5
Price spring — deep seated *— about two miles north of Auburn	June 22	48.2	9.0	0.1	0.9	245	20.5	7.3
1,000 ft. below spring, entering trib. 10 of Cold Spring brook	June 22	50.0	10.0	3.9	35	245	13.0	7.5
100 ft. below confluence	June 22	53.6	12.0	6.3	59	245	8.0	7.5
1,500 ft. below confluence	June 22	55.4	13.0	7.2	69	245	5.5	7.7
Surface springs at head of Beaver brook, east of McLean	June 23	46.9	8.3	9.0	87	117	1.0	7.9
0.5 mile down the spring run	June 23	58.6	14.8	9.1	93	135	nil	8.1
Surface springs at head of trib. 27 of Cayuga inlet	June 29	46.4	8.0	9.1	79	115	6.5	7.3
Spring partially supplying Bath hatchery	July 6	48.2	9.0	3.1	28	168	8.0	7.7
Spring at Canoga — deep seated	July 25	47.8	8.8	0.15	1.0	223	19.0	7.3
Spring-fed pond at Union Springs								
At surface	Aug. 4	66.2	19.0	8.8	95	231	6.0	7.7
Nine feet below surface	Aug. 4	52.5	11.4	3.6	33	235	18.0	7.4
At bottom, eighteen feet below surface	Aug. 4	51.4	10.8	3.0	27	238	21.0	7.3
York St., or Cold spring — deep seated — north of Auburn	Aug. 6	51.3	10.7	0.1	1.0	229	31.0	7.1

* See text for explanation.

Series III

Chemical Analyses — Lakes of the Oswego Watershed

I. Cayuga lake — North. Between Long and Stony points on the east shore.

Depth in meters	Temperature — Degrees Cent. High Date	High Temp.	Low Date	Low Temp.	Av. temp.	Dissolved oxygen High Date	High p. p. m.	High % sat.	Low Date	Low p. p. m.	Low % sat.	Average p. p. m.	Average % sat.
0	Sep. 12	19.7	Jul. 9	14.6	17.5	Aug. 17	9.5	102	Jul. 25	8.5	92	9.2	96
5	" 12	19.1	" 9	14.2	16.6	Jun. 21	10.5	98	" 25	6.9	73	8.9	92
10	Aug. 31	18.4	Jun. 21	10.0	15.6	" 21	10.2	90	" 9	9.4	88	9.5	96
15	" 31	18.3	" 21	6.8	14.5	" 21	10.0	82	" 9	8.7	87	9.5	94
20	Sep. 12	16.8	" 21	6.3	12.2	" 21	10.5	86	" 25	7.5	71	9.2	86
25	" 12	11.3	" 21	6.1	9.7	" 21	12.3	100	" 25	9.5	85	10.4	91
30	" 12	10.3	" 21	5.7	9.2	Jul. 25	10.6	94	Jun. 21	9.0	72	9.9	87
35	Jul. 9	9.7	" 21	5.4	8.1	Aug. 17	10.3	89	" 21	9.7	76	9.9	85
40	Sep. 12	7.8	" 21	5.0	7.1	Jun. 21	11.9	94	Jul. 9	9.7	81	10.6	88
50	" 12	6.7	" 21	4.7	5.8	Jul. 9	11.6	93	" 25	10.4	84	10.9	88

Depth in meters	Methyl orange alkalinity — p. p. m. calc. carb. High Date	High p. p. m.	Low Date	Low p. p. m.	Av. p. p. m.	Free carbon dioxide High Date	High p. p. m.	Low Date	Low p. p. m.	Av. p. p. m.
0	Jun. 21	107	Jul. 25	100	103	Jun. 21	*-.66	Aug. 31	-2.5	-1.6
5	" 21	107	Sep. 12	100	102	Jul. 9	-.66	" 31	-2.0	-1.3
10	" 21	106	" 12	100	103	" 9	-.45	Sep. 12	-2.2	-1.3
15	" 21	107	" 12	99	102	Jun. 21	.22	" 12	-2.5	-.84
20	" 21	107	" 12	100	103	Jul. 9	.76	" 12	-1.5	-.32
25	" 21	107	" 12	102	104	Jun. 21	1.0	Jul. 25	-.62	.43
30	" 21	107	" 12	103	105	Aug. 17	1.0	" 25	-.26	.40
35	Jul. 9	107	" 12	102	105	Jul. 9	1.5	Sep. 12	.51	.81
40	Jun. 21	107	Jul. 9	101	104	" 9	2.0	" 12	.51	1.0
50	" 21	108	Aug. 31	102	105	" 9	1.5	Jul. 25	.51	.84

* The negative figures represent phenolphthalein alkalinity as calcium carbonate calculated to carbon dioxide, this being bound carbon dioxide and hence negative free carbon dioxide.

Series III — (Continued)

CHEMICAL ANALYSES — LAKES OF THE OSWEGO WATERSHED — (*Continued*)

II. Cayuga lake — South. Middle of lake; midway between Esty Glen and McKinneys.

DEPTH IN METERS	TEMPERATURE — DEGREES CENT.					DISSOLVED OXYGEN							
	HIGH		LOW		Av. temp.	HIGH			LOW			AVERAGE	
	Date	Temp.	Date	Temp.		Date	p. p. m.	% sat.	Date	p. p. m.	% sat.	p. p. m.	% sat.
0	Aug. 26	19.3	Jun. 20	11.2	17.0	Jul. 29	9.7	105	Jun. 20	8.4	77	9.3	97
5	" 12	19.1	" 20	7.0	15.5	Aug. 26	9.8	106	Sep. 14	8.0	86	9.3	94
10	" 12	18.8	" 20	6.6	14.6	" 26	10.0	107	Jun. 20	7.8	64	9.1	90
15	Sep. 14	18.5	" 20	6.2	13.4	" 26	11.0	108	" 20	6.9	56	9.1	88
20	" 14	17.9	" 20	6.1	11.3	Jun. 30	11.2	102	" 20	9.2	74	10.2	94
25	" 14	16.6	" 20	6.0	9.8	" 30	11.3	100	" 20	8.5	75	10.0	89
30	" 14	15.1	" 20	5.7	9.1	Jul. 13	11.2	99	" 30	10.5	90	10.9	95
35	" 14	11.5	" 20	5.6	7.6	" 13	11.1	93	" 20	9.3	74	10.2	86
40	" 14	9.2	" 20	5.5	6.7	Aug. 26	11.6	93	" 20	8.9	71	10.4	86
50	" 14	7.9	" 20	5.2	5.9	" 26	11.5	91	Sep. 14	9.1	76	10.7	87
60 (App. bot.)	" 14	7.3	" 20	5.0	5.5	" 26	11.7	92	Jun. 30	9.5	75	10.9	88

DEPTH IN METERS	METHYL ORANGE ALKALINITY — P. P. M. CALC. CARB.					FREE CARBON DIOXIDE				
	HIGH		LOW		Av. p. p. m.	HIGH		LOW		Av. p. p. m.
	Date	p. p. m.	Date	p. p. m.		Date	p. p. m.	Date	p. p. m.	
0	Jun. 20	107	Sep. 14	101	104	Jun. 20	Neut.	Sep. 14	*–1.8	–1.2
5	Jul. 13	106	" 14	101	103	" 20	.51	" 14	–2.0	–.75
10	Jun. 20	107	" 14	101	104	" 20	1.0	" 14	–2.0	–.59
15	Jul. 13	108	" 14	101	105	" 20	1.0	" 14	–1.8	–.45
20	" 13	108	" 14	101	104	" 20	1.0	" 14	–1.6	–.14
25	Jun. 20	108	" 14	102	104	" 30	1.0	" 14	–1.6	.20
30	" 20	107	" 14	102	104	" 30	1.0	" 14	Neut.	.69
35	Jul. 13	108	" 14	102	105	" 30	1.5	" 14	.51	1.0
40	Jun. 20	107	" 14	102	104	" 30	1.5	" 14	.51	1.1
50	Jul. 13	107	" 14	102	104	Aug. 12	2.0	" 14	.51	1.2
60 (App. bot.)	" 13	108	" 14	102	105	Jun. 20	2.0	" 14	.51	1.2

* The negative figures represent phenolphthalein alkalinity as calcium carbonate calculated to carbon dioxide, this being bound carbon dioxide and hence negative free carbon dioxide.

Series III — (Continued)

Chemical Analyses — Lakes of the Oswego Watershed — (*Continued*)

IV. Seneca lake — North. Off Reeder's creek on the east shore.

Depth in meters	Temperature — Degrees Cent.					Dissolved oxygen							
	High		Low		Av. temp.	High			Low			Average	
	Date	Temp.	Date	Temp.		Date	p. p. m.	% sat.	Date	p. p. m.	% sat.	p. p. m.	% sat.
0	Jul. 17	19.2	Jun. 22	13.8	17.9	Jul. 17	9.9	107	Jun. 23	8.1	79	9.2	98
5	Sep. 7	19.2	" 22	13.7	17.6	" 17	9.9	107	" 23	8.4	82	9.3	98
10	" 7	19.0	" 22	13.2	17.2	" 17	9.7	105	" 23	9.5	91	9.6	100
15	" 7	18.4	" 22	12.7	15.4	Sep. 7	9.8	105	" 23	10.1	96	10.0	101
20	Aug. 19	16.0	Jul. 17	9.9	13.4	Jun. 23	11.6	110	Sep. 7	10.0	100	10.8	105
25	" 19	11.8	Jun. 22	7.1	9.7	Aug. 19	11.1	103	" 7	10.0	92	11.0	98
30	" 19	10.5	" 22	6.3	8.3	Jul. 17	11.6	100	Jun. 23	7.8	64	10.3	89
35	" 19	7.6	" 22	5.9	7.1	" 17	11.7	99	" 23	8.3	68	10.6	89
40	Sep. 7	6.8	" 22	5.8	6.4	" 17	11.5	96	" 23	10.5	85	11.1	91
50	Jul. 17	6.2	" 22	5.2	5.7	Aug. 19	12.8	103	Sep. 7	10.9	89	12.2	98

Depth in meters	Methyl orange alkalinity — p. p. m. calc. carb.					Free carbon dioxide				
	High		Low		Av. p. p. m.	High		Low		Av. p. p. m.
	Date	p. p. m.	Date	p. p. m.		Date	p. p. m.	Date	5. p. m.	
0	Aug. 19	103	Sep. 7	97	100	Jul. 17	−.67	Aug. 19	−1.6	−1.0
5	" 19	104	Jun. 23	97	99	" 17	−.67	" 19	−1.9	−1.3
10	" 19	104	" 23	97	100	" 17	−.67	Sep. 7	−1.6	−1.1
15	" 19	103	Sep. 7	98	100	" 17	−.56	" 7	−1.4	−1.0
20	" 19	103	Jun. 23	95	99	" 17	−.44	Aug. 19	−.89	−.67
25	" 19	104	" 23	96	100	Aug. 19	Neut.	Jul. 17	−.36	−.19
30	" 19	102	" 23	97	100	All.....	.51	All.....	.51	.51
35	" 19	104	" 23	97	99	Jun. 23	.51	Aug. 19	1.0	.63
40	" 19	104	" 23	95	99	Jun. 23	.51	" 19	1.0	.67
50 (App. bot.)	" 19	104	Jul. 17	95	99	Aug. 19	.51	Jun. 23	1.0	.84

Series III — (Continued)

Chemical Analyses — Lakes of the Oswego Watershed — (*Continued*)

V. Seneca lake — South. Off Hector Falls on the east shore.

Depth in meters	Temperature — Degrees Cent.					Dissolved oxygen							
	High		Low		Av. temp.	High			Low			Average	
	Date	Temp.	Date	Temp.		Date	p. p. m.	% sat.	Date	p. p. m.	% sat.	p. p. m.	% sat.
0	Sep. 6	19.4	Jun. 24	12.1	16.0	Sep. 6	9.6	105	Jul. 16	8.7	84	9.4	96
5	" 6	18.6	" 24	11.0	15.3	Jun. 24	10.8	101	" 16	9.9	95	10.1	99
10	" 6	18.5	" 24	9.8	14.7	Jul. 16	10.8	98	Jun. 24	9.3	83	9.8	97
15	Aug. 20	16.9	" 24	8.7	12.4	" 16	10.9	102	Sep. 6	9.3	87	10.2	96
20	" 20	11.9	" 24	7.7	9.8	Aug. 20	11.1	104	" 6	10.7	94	11.0	98
25	" 20	11.4	Sep. 6	7.2	8.7	" 20	11.2	103	Jul. 16	10.9	95	11.2	97
30	" 20	11.1	" 6	6.1	8.1	Jul. 16	11.3	96	Aug. 20	9.6	88	10.8	93
35	" 20	9.4	" 6	5.8	7.3	Jun. 24	12.0	99	Jul. 16	10.9	91	11.4	96
40	" 20	8.7	" 6	5.6	6.7	Aug. 20	11.5	100	" 16	10.8	88	11.4	94
50	" 20	8.1	" 6	5.1	6.1	Sep. 6	12.1	96	Jun. 24	10.5	84	11.2	91
63 (Av. bot.)	" 20	5.8	" 6	4.9	5.5	" 6	12.1	96	" 24	11.1	90	11.6	93

Depth in meters	Methyl orange alkalinity — p. p. m. calc. carb.					Free carbon dioxide				
	High		Low		Av. p. p. m.	High		Low		Av. p. p. m.
	Date	p. p. m.	Date	p. p. m.		Date	p. p. m.	Date	p. p. m.	
0	Aug. 20	104	Jun. 24	95	99	Jun. 24	Neut.	Aug. 20	-1.6	-.83
5	" 20	104	" 24	95	99	" 24	Neut.	" 20	-1.3	- 86
10	" 20	103	" 24	95	99	" 24	1.0	" 20	-1.6	-.58
15	" 20	104	" 24	92	98	" 24	.51	" 20	-1.1	-.17
20	" 20	105	" 24	90	98	" 24	.76	" 20	-.44	.10
25	" 20	104	" 24	89	97	Sep. 6	1.0	" 20	-.22	.51
30	" 20	104	" 24	85	97	" 6	.51	" 20	Neut.	.47
35	" 20	105	" 24	84	96	" 6	1.0	" 20	Neut.	.51
40	" 20	104	" 24	93	98	Jul. 16	2.3	Jun. 24	.25	.77
50	" 20	105	" 24	93	98	" 16	1.0	" 24	.25	.82
63 (Av. bot.)	" 20	103	" 24	94	98	" 16	1.4	" 24	.25	.85

Series III — (Continued)

CHEMICAL ANALYSES — LAKES OF THE OSWEGO WATERSHED — (*Concluded*)

VI. Oneida lake. Off Cleveland.

DEPTH IN METERS	TEMPERATURE — DEGREES CENT.					DISSOLVED OXYGEN							
	HIGH		LOW		Av. temp.	HIGH			LOW			AVERAGE	
	Date	Temp.	Date	Temp.		Date	p. p. m.	% sat.	Date	p. p. m.	% sat.	p. p. m.	% sat.
1	Jul. 13	23.5	Aug. 24	20.2	21.7	Aug. 10	8.0	91	Sep. 7	5.3	59	7.0	80
3	" 13	23.0	" 24	20.1	21.5	Jul. 13	8.0	93	" 7	5.9	67	7.3	82
6	" 13	22.5	" 24	19.8	21.4	Aug. 10	8.1	93	" 7	6.8	76	7.6	85
9	" 27	22.3	" 24	19.8	21.0	" 24	8.1	89	" 7	7.5	84	7.8	87
12	" 27	22.2	" 24	19.8	20.9	Jul. 13	8.0	90	Aug. 10	7.2	82	7.7	85
15 (Bot.)	" 27	22.1	Jun. 29	19.0	20.6	Sep. 7	7.6	85	" 24	5.5	60	6.8	74

DEPTH IN METERS	METHYL ORANGE ALKALINITY — P. P. M. CALC. CARB.					FREE CARBON DIOXIDE				
	HIGH		LOW		Av. p. p. m.	HIGH		LOW		Av. p. p. m.
	Date	p. p. m.	Date	p. p. m.		Date	p. p. m.	Date	p. p. m.	
1	Aug. 24	19.8	Jun. 29	9.7	13.5	Sep. 7	2.0	Jul. 13	Nil	1.5
3	" 24	22.6	Jul. 13	11.7	15.5	Jun. 29	3.0	" 13	"	2.0
6	" 24	23.7	Aug. 10	11.9	16.0	" 29	3.0	" 13	0.5	1.9
9	" 24	26.3	Jul. 13	13.2	18.3	" 29	3.0	" 13	1.2	2.1
12	Sep. 7	30.6	" 13	14.3	20.6	" 29	3.4	" 13	1.3	2.4
15 (Bot.)	Aug. 24	31.7	Jul. 27	11.9	20.3	Sep. 7	4.4	" 13	1.9	3.0

Series III — (Concluded)

CHEMICAL ANALYSES — LAKES OF THE OSWEGO WATERSHED

REMARKS	Depth in meters	Temperature of water, degrees Cent.	Dissolved oxygen: Parts per million	Dissolved oxygen: Per cent of saturation	Methyl orange alkalinity p. p. m. calc. carb.	Free carbon dioxide p. p. m.	pH
Keuka lake..............	1	21.3	9.3	107	....	......	8.4
July 7.	15	16.0	9.9	102	....	1.2	7.9
	30	9.2	10.7	95	....	2.1	7.7
	55	6.5	10.5	87	....	3.5	7.6
Canandaigua lake.........	1	20.4	8.4	95	123	—.44	8.3
July 28.	10	20.2	8.9	100	122	—.97	8.3
	20	12.4	10.0	96	126	1.6	8.2
	30	8.0	10.0	86	125	3.5	7.9
	62	5.2	8.8	71	133	1.7	7.9
Owasco lake..............	1	21.8	9.1	105	105	—2.9	8.4
August 4.	15	14.9	8.9	90	114	.94	8.1
	50	7.8	8.3	72	107	2.8	7.8
Skaneateles lake..........	1	19.8	8.9	99	102	3.7	7.6
August 9.	20	15.7	10.4	107	98	—1.1	8.4
	78	6.0	9.0	74	54	1.1	7.9
Otisco lake...............	1	21.4	8.8	101	118	—2.2	8.4
August 11.	10	21.0	8.1	92	120	—1.8	8.4
	14	15.2	5.1	52	132	2.9	7.8
	19	13.1	0.3	2.9	140	8.0	7.6
Seneca lake...............	1	16.9	9.3	97	118	0.84	8.3
1 mile S. of Lodi landing.	20	11.1	8.5	78	106	0.73	8.0
July 15.	70	5.0	8.8	70	108	0.94	8.0
	100	4.4	11.3	88	111	0.53	8.0
	182	4.0	9.2	72	109	0.53	8.0
As above, September 9....	1	19.0	4.7	51	98	—2.1	8.4
	27	11.4	6.8	63	105	0.41	8.0
	70	4.8	7.8	61	109	0.63	8.0
	110	4.2	6.5	51	108	0.84	7.9
	180	4.1	7.5	58	110	1.6	7.7
Cayuga lake..............	0	19.5	9.6	105	106	—1.7	8.5
(off Frontenac point)	5	19.1	9.7	105	102	—1.8	8.4
August 10.	10	19.1	9.3	100	99	—1.2	8.4
	15	18.5	8.9	95	101	—1.2	8.4
	18	17.8	......	......	....	......	.....
	20	14.9	10.2	102	103	— .44	8.3
	23	12.7	......	......	....	......	.....
	25	10.3	10.2	91	104	1.0	8.2
	30	8.9	11.0	95	105	1.0	8.0
	40	6.3	10.7	87	104	1.4	8.0
	50	5.7	11.0	89	106	1.3	8.0
	75	5.0	12.3	97	104	1.3	8.0
	100	4.6	10.0	78	105	1.3	8.0
	120	4.5	10.1	78	104	1.7	8.0

VI. BIOLOGICAL STUDIES OF POLLUTED WATERS IN THE OSWEGO WATERSHED

By P. W. CLAASSEN,
Professor of Biology, Cornell University
and
N. L. CUTLER,
Biologist and Sanitarian, N. Y. State Conservation Department

The object of this investigation was to determine the types of pollution present in the Oswego watershed; the exact location or source of each case of pollution; a study of the plants and animals which are found in polluted water and a study of the extent of pollution present with a view of determining what effect the various types of wastes have upon fish and other fresh water organisms which normally inhabit clean waters.

Unlike the conditions which exist in the Genesee river system where the pollution centers are almost uniformly distributed over the entire watershed we find that in the Oswego watershed the head waters are remarkably free from pollution. Here the pollution areas are largely restricted to the industrial centers and the larger cities and villages along the outlets of the Finger lakes and along the streams below the lakes.

Economic changes during the last ten years have brought about these conditions, for we find in the headwaters of the Oswego watershed a great number of old creameries and milk plants which have ceased to operate. Most of these plants were located in small fresh water streams and constituted one of the chief sources of pollution to the small fishing streams. The milk from these communities is now largely hauled by trucks to the cities where it is bottled or turned into various manufactured products. This, together with a natural increase in the size of cities and villages and the establishment of more industrial plants, has increased the pollution problem in these centralized areas. The only redeeming feature which can here be mentioned is the fact that these industrial centers are nearly all located on large streams or lakes where the large volume of water is able to absorb much of the polluting substances.

The types of pollution found in the Oswego watershed may be grouped as follows: domestic sewage, paper mill wastes, woolen mill wastes, milk wastes, cannery wastes, oil, sulphur and various industrial wastes.

Sewage.— Sewage forms one of the chief sources of pollution in this watershed. The effect of the entrance of raw sewage into a stream is to produce first what is known as a "zone of recent pollution." Here the dissolved oxygen supply of the stream is lowered perhaps 20–50 per cent and fresh water organisms, such as green algae, mayfly and stonefly nymphs give way to more tolerant, and even pollutional forms, such as blue-green algae (Oscillatoria), sewage fungus (Sphaerotilus and Leptothrix) and sludge worms

(Tubifex). The water is turbid and practically devoid of fish life. The lower end of this zone merges into the second, "the septic zone." The establishment of this zone is hastened in the quiet still waters of ponds. The dissolved oxygen may practically disappear. The stream bed is blackened with sludge and foul-smelling gases rise up through the murky water. Green plants are absent. The larvae of the sewage fly and the rat-tail maggot may be found here. The third zone is the "zone of recovery." Green plants such as Potamogetons and eel-grass reappear, thriving on the excessive amounts of organic matter and giving off oxygen to the water. The fresh water organisms find conditions once more to their liking and fish life may thrive again.

Twelve streams, not including the canalized Seneca river, receive sewage pollution of a serious nature at one or more points throughout their course. Most of these, in addition, receive industrial wastes of various kinds.

Two outstanding examples of the flagrant misuse of streams in this watershed are shown by the cities of Rome and Auburn which turn Wood creek and Owasco outlet respectively into what are virtually open sewers.

The condition of Wood creek is very aptly summarized by Mr. Wagner in the introduction to his chemical studies of this survey and need not be further discussed here. It might, however, be pointed out that the "zone of recent pollution" and the "septic zone" coincide in this case. Biologically, it offers little, even the ordinary, visible foul water organisms finding conditions untenable for some distance.

The population of Auburn, according to the 1925 census is 35,677, of these over 25,000 are not connected with either of the 2 small sewage disposal plants. Their sewage enters the Owasco outlet in a raw state through 25 sewer outfalls distributed through the heart of the city, causing what might be characterized as a "zone of recent pollution." Even under conditions of normal flow, 73.8–93.5 cu. ft. per sec.* on week days, the stream is turbid and loaded with the effluent from the sewer outfalls. How much more intensified are they then on Sundays and at night, when, due to the water regulation at the State dam, the flow may be as low as 19–36 cu. ft. per sec. ! *.

By means of the many dams and because of the swiftly flowing nature of the stream the dissolved oxygen is being constantly replenished as it is being used by the decomposing organic matter and, as will be seen by reference to the chemical report, the oxygen never gets lower than 76.0 per cent saturation. Thus a "septic zone" does not get time to become established. Nevertheless many desirable kinds of fish cannot possibly live in a stream that serves as an open sewer, whether it becomes septic or not, and that is just what we find—a few members of the very tolerant species, such as bullheads, here and there until we get well down into the

* Rep. on Sewage Conditions at Auburn, N. Y., by Theodore Horton, Apr. 25, 1917, (letter on file in City Engineer's Office, Auburn, N. Y.).

"zone of recovery" below Throopsville. One further case of stream contamination caused by Auburn sewage is the pollution of Coldspring brook (North brook) for 4½ miles by the partially treated effluent of the sewage disposal plant located there. Thus Auburn sewage pollutes approximately 21½ miles of the stream, the greater part of which would be suitable for fishing streams.

The city of Canandaigua is responsible for the pollution of Canandaigua outlet for some considerable distance as may be seen by reference to the appended tables. No small part of this is due to the partially untreated effluent from the sewage disposal plant.

It seems regrettable that where provision is made for the disposal of sewage and the rendering innocuous of the effluent, that often those facilities are not utilized to their utmost. Instead, either through ignorance or carelessness, partially treated effluents are allowed to run into, and grossly pollute, desirable fishing streams.

Because of the fact that many polluting substances, other than domestic sewage are mixed with sewage it is difficult to state just how many miles of streams are thus polluted but approximately 41 miles are directly affected by sewage pollution, of which 32 would be fishing streams.

Milk Pollution.—It is rather surprising that in so large an area as that covered by the Oswego watershed there should be such a small amount of milk pollution. Apparently not more than a total of 17 miles of streams have become polluted from milk wastes. Most of the milk plants have adopted means whereby the by-products are utilized or else treated before they are allowed to enter fresh water streams. There is however one case of pollution which is so extremely bad that it deserves mention here. The milk plant at Pennellville, which manufactures casein, sugar and albumen, empties its wastes untreated into Potts creek and pollutes the stream to the extent of killing all fish and fresh water life. The entire stream for a distance of about 4 miles has become unsightly and foul and presents a distinct nuisance. Blood worms, sludge worms and tolerant snails are the only animal forms present and blue-greens, tolerant Potamogetons, and sewage fungus the only plants. This stream, if free from pollution, would support fish life.

Paper Mill and Woolen Mill Wastes.— These factories are centered largely along the outlets of Keuka lake, Otisco lake, Skaneateles lake and along the Seneca river. The wastes from these plants consist largely of waste fibers, dyes and the various glues and chemicals used in the process of manufacture. The dyes apparently do not produce any very deleterious effects upon fish life but due to the fact that a small amount of dye stuff will color a large volume of water there is a popular belief that this is very harmful to fish life. Our observations indicate that the dye itself does not materially affect the stream except when it is introduced in very large quantities.

The wastes from paper mills however do considerable harm to fresh water life and along Keuka outlet and Skaneateles outlet they have very decidedly harmed fish life. These wastes encourage a rich growth of blue-green algae (*Oscillatoria* and *Phormidium*) and the development of sewage fungus and sludge worms all of which are indicators of polluted waters.

Skaneateles outlet has been badly polluted for many years and received an extensive biological and chemical investigation in 1921.* Consequently but a brief survey was made on this occasion. Biologically the condition of the stream had not improved but apparently has steadily grown worse in that time. Referring in part to the above mentioned report: The stream may be divided into 3 zones. First the ''zone of initial pollution,'' caused by the sewage from the town of Skaneateles. Second the ''zone of oxygen sag,'' where the presence of 2 paper mills and 2 woolen mills contribute a great deal of waste material. The stream in this section is brown and turbid with its great accumulation of debris. Third the ''lower section'' — the zone of recovery.

Together with other types of pollution the paper mills and woolen mills pollute approximately 33 miles.

Oil Pollution.— Oil undoubtedly has a very deleterious influence on fish life. By reference to the chemical data for the oil pollution in Great brook it will be seen that oil causes a certain drop in the amount of dissolved oxygen. Fresh water food organisms such as caddisfly, stonefly and mayfly nymphs are suffocated by the heavy coating of oil that settles to the bottom and covers the stones, etc. The eventual result is to cause desirable fish species to migrate to a more favorable environment.

Industrial plants of various kinds, such as gas plants, machine shops, automobile garages, etc., are guilty of this form of stream contamination. Witness the black oily drains from garages along Sixmile creek through Ithaca or along Owasco outlet through the city of Auburn. One further aggravating feature of this type of pollution is that the waste is usually ''dumped'' at one time, thus bringing about an extremely high concentration of impurities.

Oil in combination with other wastes pollutes about 12 miles of stream.

Cannery Wastes.— Cannery wastes, being high in organic contents, constitute a very serious menace to fish life when allowed to enter fresh water streams in large quantities. Although there are many canneries in this watershed there were but two cases of serious stream pollution. This is in part due to the slack canning season. The cannery at Rushville pollutes West river and that at Victor pollutes Great brook. Both of these plants have screening devices, but as pointed out by Mr. Wagner in his chemical report, these are never, in themselves, sufficiently adequate.

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* State of New York, Conservation Department, Stream Pollution Studies No. 2, Pollution of Skaneateles Outlet by Sewage and Industrial Wastes. Unpublished report by Emmeline Moore.

Sulphur Pollution.— Tributary 44 of Canandaigua outlet at Clifton Springs shows a unique form of pollution caused by the sulphur springs in the vicinity. This, together with a certain amount of sanitary wastes causes the stream bed to be absolutely covered with a thick mat of sewage fungus intermingled with excessive growths of pollution algae of the blue-green type. It would be hard to conceive of a more luxuriant growth of these foul water plants. They produce a most unsightly and unsanitary condition. Normally this would be a feeder for Canandaigua outlet.

Conclusion.— Certain forms of fresh water plant and animal life are constantly associated with a favorable environment for fish life. This is readily understood when one considers that *their* living conditions must be the same as those that favor fish life, i. e., fresh, clean, well-aerated water. When we find instead an association of foul water plants and animals, i. e., certain blue-green algae, sludge worms, etc., we know that fish cannot thrive under the conditions found there.

The more outstanding cases of pollution in this watershed are the ones that have been discussed in the preceding pages. For a complete survey covering all cases of actual or potential pollution the reader is referred to the tabulation. Particular attention should be given to ''effect on stream and fish life'' in the table below. It must be emphasized, in this regard, that to get an accurate picture of the effect of pollution from any one source, or sources, upon a stream, both the tables and graphs for the biological and chemical data should be studied in conjunction with one another.

A total of 108 miles of stream were found to be polluted. Of this total 60 would be suitable for fishing streams.

It is a significant fact that the outlets of the five Finger lakes, Canandaigua, Keuka, Owasco, Skaneateles and Otisco are all seriously polluted, totalling about 45 miles of polluted stream. Of this amount 20 would be suitable for the propagation of fish were there no contamination present. The reader is referred to page 92 of Mr. Greeley's report for a discussion of the fish life in these outlets.

TABULATION OF POLLUTION STUDIES IN THE OSWEGO WATERSHED

TYPE OF POLLUTION	Quadrangle	Township or post office	Stream	Effect on stream and fish life	Miles of stream affected
Sewage..........	Ithaca.....	Ithaca.....	Cascadilla creek	Moderate, tolerant fish present	½
Sewage..........	Ithaca.....	Ithaca.....	Cayuga inlet.	High CO_2,— a few tolerant fish present	1
Sewage..........	Penn Yan..	Penn Yan..	Keuka lake outlet	Slight, large volume of water	......
Sewage..........	Auburn....	Auburn....	Coldspring brook	Kills fresh water forms above Price spring	4½
Sewage..........	Skaneateles.	Skaneateles.	Skaneateles outlet	Kills all fresh water forms	1
Sewage..........	Chittenango	Canastota..	Tributary 5, Cowaselon creek	Slight.................	1
Sewage..........	Oriskany...	Rome......	Wood creek..	Stream absolutely foul..	9
Sewage..........	Fulton.....	Fulton.....	Oswego river	Raw sewage evident....	1
Sewage..........	Kasoag.....	Camden....	West Branch Fish creek	Potential.............	......
Sewage..........	Clyde......	Lyons......	Clyde river..	Potential.............	......
Sewage and industrial waste	Canandaigua	Canandaigua	Canandaigua outlet	Fresh water forms rare. a few tolerant fish present	2
Sewage and industrial waste	Phelps.....	Shortsville..	Canandaigua outlet	Fresh water forms absent	5½
Sewage and industrial waste	Auburn....	Auburn....	Owasco outlet	Kills most fish and fresh water life	12½
Sewage and industrial waste	Oneida.....	Oneida.....	Oneida creek	Badly polluted, no fresh water life for 3–4 miles	12
Industrial waste..	Syracuse...	Syracuse...	Onondaga outlet	Slight, many fresh water forms present	......
Industrial waste..	Oneida.....	Sherrill.....	Mud creek...	Potential.............	......
Industrial waste..	Fulton.....	Fulton.....	Oswego river	Slight, large volume water	......
Paper mill waste..	Ithaca.....	Ithaca.....	Fall creek...	Large stream, slight effect	......
Paper mill waste..	Penn Yan..	Penn Yan..	Keuka lake outlet	Discolors water, raises temperature, no fish life	6
Paper mill waste..	Syracuse...	Fayetteville	Limestone creek	Most fresh water forms absent	½
Paper and woolen mills	Skaneateles.	Willow Glen to Skaneateles Falls	Skaneateles outlet	Extremely bad, no fresh water forms present	12
Paper and woolen mills	Skaneateles.	Marcellus and MarcellusFalls	Ninemile creek	Stream in poor condition, very little fish food	11
Paper and woolen mills	Baldwinsville	Phoenix....	Seneca river.	Large volume saves greater damage to fish	3
Kraut factory....	Phelps.....	Gorham....	Flint creek, Trib. 40, Canandaigua	Reduces O_2, CO_2 present, spoils fishing stream	2
Kraut factory....	Phelps.....	Phelps.....	Flint creek, Trib. 40, Canandaigua	Kills fresh water forms to some extent	1½
Kraut factory....	Phelps.....	Hall.......	Burrell creek, (Wilson)	Stream goes dry........	......
Cannery.........	Canandaigua	Victor......	Great brook,. Trib. 43, Ganargua	Low O_2, high CO_2, fresh water forms absent	1½
Cannery.........	Oneida.....	Stacy Basin.	Drum creek..	Potential.............	......
Cannery.........	Oneida.....	Vernon.....	Trib. 5, Stony cr.	Potential.............	......
Sulphur and sanitary wastes	Phelps.....	Clifton Springs	Trib. 40, Canandaigua	Badly polluted, normally a " feeder stream "	2
Carbon bisulphide	Penn Yan..	Penn Yan..	Keuka lake outlet	Potential, not operating during summer	......
Milk............	Dryden....	Dryden....	Virgil creek..	Potential.............	......
Milk............	Geneva....	McDougall.	Trib. 8, Kendig cr.	Small stream..........	2
Milk............	Auburn....	Union Springs	Cayuga lake.	Potential.............	......
Milk............	Moravia....	Locke......	Owasco outlet	Slight, fresh water forms present	......

TABULATION OF POLLUTION STUDIES IN THE OSWEGO WATERSHED — *Concluded*

TYPE OF POLLUTION	Quadrangle	Township or post office	Stream	Effect on stream and fish life	Miles of stream affected
Milk	Moravia	Groton	Owasco outlet	Oxygen reduced, normal fish food lacking	3½
Milk	Moravia	McLean	Fall creek	Potential	......
Milk	Skaneateles	Amber	Otisco lake	Potential	......
Milk	Clyde	South Butler	Butler creek	Potential	......
Milk	Weedsport	Meridian	Trib. 12, Muskrat creek	Lost in swamp	......
Milk	Weedsport	Conquest	Trib. 2 of M. S. 7	Bad, volume small, goes dry	1
Milk	Cazenovia	Delphi	Trib. 34, Limestone creek	Potential	......
Milk	Morrisville	Peterboro	Oneida creek	Potential	......
Milk	Morrisville	Munnsville	Oneida creek	Slight	......
Milk	Oneida	Oneida Community	Oneida creek	Potential	......
Milk	Oneida	Oneida Castle	Mud creek	Potential	......
Milk	Oneida	Vernon	Trib. 5, Stony cr.	Potential	1
Milk	Kasoag	Williamstown	Pond, West Branch, Fish cr.	Pond easily absorbs waste at present	......
Milk	Taberg	Thomson Corners	Trib. 7, Cobb brook	Potential	......
Milk	Taberg	Blossvale	Trib. 17, Fish creek	Potential	......
Milk	Taberg	Lee Center	Canada creek	Potential, clears up in ditch	......
Milk and cheese	Clyde	Savannah	Trib. 1, Crusoe cr.	Potential, clears before reaching Crusoe creek	......
Milk and cheese	Weedsport	Cato	Trib. 12, Muskrat creek	Stream volume small	......
Milk and cheese	Syracuse	Cicero	Mud creek	Potential	......
Milk and cheese	Cazenovia	Nelson	Chittenango	Fish and other fresh water life killed	1
Milk and butter	Weedsport	Port Byron	Owasco outlet	Slight	......
Milk and casein, etc.	Fulton	Pennellville	Potts creek	Extremely bad, kills all fresh water life	4½
Pea cannery	Naples	Naples creek	Naples creek	Potential, insufficient waste to reach stream	......
Pea cannery	Phelps	Rushville	West river	Low O_2, high CO_2, fresh water forms absent	2½
Pea cannery	Penn Yan	Penn Yan	Keuka lake outlet	Little effect on large volume of water	......
Pea cannery	Palmyra	Alloway	Canandaigua outlet	Reduces oxygen, also available fish food	1
Oil, garage	Ithaca	Ithaca	Sixmile creek	Fresh water forms killed	½
Oil, garage	Auburn	Auburn	Owasco outlet	Fresh water forms killed	......
Oil, garage	Syracuse	Cicero	Mud creek	Prevents development of fish food	1
Oil, insulator works	Canandaigua	Victor	Great brook	Reduces O_2, kills fresh water forms	½
Oil	Geneva	Seneca Falls	Seneca river	Eliminates some fish food, lowers O_2	......

General indicators of above:

Organic wastes, such as sewage, milk, cheese, kraut factory wastes, canning factory wastes: Black foul-smelling sludge, sludge worms (Tubifex), fungi, blue-green algae (Oscillatoria, etc.), blood worms (Chironomus).

Inorganic wastes.

Machine shops, garages, etc.—Oil on surface and bottom, Melosira (Diatom), blue-green algae.

Paper mill.—Yellow incrustations on stones, fibres, blue-green algae, fungi.

Woolen mill.—Dyes, alkalies, acids (acetic), etc., scrubbings.

VII. PLANKTON STUDIES OF CAYUGA, SENECA AND ONEIDA LAKES

BY W. C. MUENSCHER,

Assistant Professor of Botany, Cornell University

In a biological survey of a body of water for the purpose of determining the factors and conditions which contribute to the production of fish, the source of fish food is of prime importance. In this connection the plankton organisms, those small free-swimming or suspended organisms occurring in the water, furnish, directly or indirectly, one of the chief sources of food for fish and other animals that are eaten by the fish.[1]

The following members of the survey staff assisted in this undertaking: Dr. Gertrude E. Douglas, Albany State Teachers' College, Mr. Paul R. Burkholder, Cornell University, Mr. Willis L. Tressler, University of Wisconsin, Mr. Sidney Britten, Syracuse University, Mr. F. E. Wagner, Rensselaer Polytechnic Institute. This work was greatly facilitated through the co-operation of Cornell University: the Department of Botany made available a laboratory which served as general headquarters from June 15 to September 15, 1927; the Laboratory of Plant Physiology granted the use of equipment and apparatus necessary for certain chemical work and gravimetric determinations of plankton; the Department of Zoology granted the use of the University boat house on Cayuga lake for the storage of boats and other equipment.

The most important lakes of the Oswego watershed are the Finger lakes and Oneida lake. The limnological studies reported by Birge and Juday, [2], [3] already furnished a general preliminary survey of the plankton life of the Finger lakes though not of Oneida lake.

The amount of time and the facilities available for plankton studies precluded the possibility of making very extended studies on all the lakes in the Oswego river watershed. It seemed that, under the circumstances, the most worth while results could be obtained by concentrating the plankton work on a few lakes. Plankton studies were therefore conducted on three lakes; Cayuga and Seneca, the largest of the deep lakes and Oneida, the only large shallow lake in the Oswego watershed.

The aim of this study was to make available more information concerning the abundance, vertical and horizontal distribution, and periodicity of the various kinds of plankton organisms in each lake. An attempt was also made to gain some idea of the condition of the environment under which the plankton organisms occur by measuring some of the factors such as temperature, transparency, dissolved gases, and reaction of the water.

By limiting the work to three lakes it was possible to make the observations and take samples approximately every two weeks in Oneida and Cayuga lakes, and once a month in Seneca lake, from

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[1] For discussion of the larger vegetation see Appendix XII.

[2] Birge, E. A., and Juday, C. A. limnological study of the Finger Lakes of New York. U. S. Bull. of the Bur. of Fisheries. 32: 525–609. 1912.

[3] ——— Further limnological observations on the Finger lakes of New York. Ibid. 37: 211–252. 1919–20.

June to September, 1927. In Cayuga and Seneca lakes samples were taken at two stations,[1] one near the south end and one towards the north end at the following depths: 0, 5, 10, 15, 20, 25, 30, 35, 40, 50 meters and bottom. In Oneida lake samples were taken in only one station[2] at three meter intervals from the surface to the bottom, 15 meter depth.

The following determinations were made at each of the five stations:

1. Temperature of the water.
2. Transparency of the water.
3. Dissolved oxygen.
4. Free carbon dioxide.
5. Total alkalinity of the water.
6. Quantitative determinations of the various kinds of plankton organisms.
7. Total dry matter, organic matter and ash in the lake water.

Temperature of the Water.— A series of temperature readings[3] was taken each time when plankton samples were taken or when water samples were taken for gas determination.

The records taken over a period of about six months in Cayuga lake show a rise in the surface temperature from 3.18° [4] Centigrade on April 16 to 19.3° C. on August 26. The temperature at the 50 meter depth rose from 3.15° C. on April 16 to 7.9° C. on September 14. Near the surface and at the lower depths the decrease in temperature per meter increase in depth was but slight. When a definite thermocline occurred (during August and September) the most rapid drop in temperature was not always at the same depth, although usually this occurred between the 20 and 25 meter depths.

The temperature at the surface of Seneca lake increased from about 12.0° C. to 20.1° C. between June 24 and September 7.

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[1] The locations of the stations:

Cayuga lake. "South station"=near the middle of the lake two miles from the south end. "North station"=about one-half mile off the east shore just south of Stony point about 15 miles from the north end.

Seneca lake. "South station"=about one-sixth mile off east shore south of Hector falls, two miles from the south end. "North station"=about one mile off the east shore opposite the mouth of Reeder creek, six miles from the north end.

The samples could not be taken in exactly the same spot each time, but all of the samples were taken within a radius of about 100 meters of a common point represented by the "station." This is why the depth of the bottom varied from about 50 to 80 meters.

[2] *Oneida lake.* "Station"=approximately one mile off the north shore opposite the village of Cleveland. Depth, approximately 15 meters.

[3] All temperatures recorded in the tables of chemical analysis, Series 111, p. 128 were taken with a Negretti-Zambra deep sea thermometer and recorded without correction for variations due to difference in the temperature of the mercury column. In the few cases where we made these corrections we found the difference to be very small, usually less than 0.1 of a degree.

[4] To change degrees Centrigrade to degrees Fahrenheit multiply by 9/5 and then add 32; eg. $(3.18 \times 9/5)+32=37.7$ (degrees Fahr.).

At the 50 meter depth the increase in temperature between June and September was less than 3° C. In Seneca lake, as in Cayuga lake, the decrease in temperature with increase in depth was very slight near the top and the bottom of the lake. The most rapid drop in temperature occurred between the 20 and 25 meter, or between the 15 and 25 meter depths.

Temperature records show that the water of Oneida lake becomes relatively warm rather early in the summer. The lake is too shallow to show any vertical stratification. At no time was the bottom temperature more than 4° C. colder than at the surface; in four out of six series of readings the bottom temperature was only about 0.5° C. lower than at the surface. Cayuga and Seneca, both deep lakes, are similar in that they warm up very slowly and show a considerable drop in temperature between the upper and lower water. On the other hand Oneida lake, which is very shallow, warms up much earlier in the summer.

Transparency of the water.— The transparency of the water was determined in each lake each time when plankton samples were taken. A Secchi disc having a diameter of twenty centimeters was used for this purpose. The observations were made at noon or as near noon as possible. The depth was determined at which the disc disappeared when lowered in the water and also when it reappeared when raised. The figures in Table 1 represent the averages of these two values recorded in meters. While it must be admitted that this is a crude method for measuring the transparency of the water, the results obtained thereby are sufficient to make possible a rough comparison of the transparency of the water in the three lakes. As shown in the table the water of Seneca lake is much clearer than that of Oneida lake and somewhat more so than that of Cayuga lake.

TABLE 1. TRANSPARENCY OF THE WATER OF CAYUGA, SENECA AND ONEIDA LAKES (1927).

Cayuga lake — south		Cayuga lake — north	
Date	Transparency in meters	Date	Transparency in meters
June 16	4.5	June 21	5.5
June 30	5.5	July 9	7
July 13	7	July 25	7
July 29	7	Aug. 17	5
Aug. 12	5	Aug. 31	4
Aug. 26	4	Sept. 12	3
Sept. 14	4		
Seneca lake — south		**Seneca lake — north**	
June 24	7	June 22	7
July 16	8	July 17	8
Aug. 20	9.5	Aug. 19	12
Sept. 8	11	Sept. 7	10
Oneida lake			
June 29	2.9		
Juln 12	3		
July 26	4.1		
Aug. 23	4		

Water Analyses.—Determinations were made of the amount of dissolved oxygen and free carbon dioxide, the total alkalinity and the reaction of the water each time when plankton samples were obtained. The water samples for all these determinations were obtained with a closing water sampler of one liter capacity.

In general, the results of the analyses* for the four months, June to September, indicate that in Cayuga and Seneca lakes there was no free carbon dioxide in the upper 20–25 meters of water after the last of June. Below this depth about 1–2 parts per million of free carbon dioxide were found in the water during the early part of the summer, but late in August and September this was reduced to about 0.5 p.p.m. Oneida lake showed a greater variation in free carbon dioxide in the water between the surface and the bottom, increasing gradually from 1.5 to 3.7 p.p.m. on June 29, from 1.3 to 2.7 p.p.m. on August 10, and from 2 to 4.4 p.p.m. on September 7. On July 13 there was no free carbon dioxide in the upper 3 meters of water, but it increased from 0.3 to 1.9 p.p.m. between 6 and 15 meters.

The dissolved oxygen in the water of Cayuga and Seneca lakes varied between 6.8 and 12.2 parts per million, the variation in Seneca lake being slightly less than in Cayuga lake. In general, the dissolved oxygen was somewhat less from the surface to about 20–25 meters than between the 25 meter depth and the bottom. The dissolved oxygen in Oneida lake was lower, in most cases between 6.5 and 8 p.p.m. However, on September 7 the oxygen between 0 and 3 meters was as low as 5.3 to 5.9 p.p.m.

The total alkalinity of the water varied from 100 to 107 p.p.m. in Cayuga lake, the water being somewhat less alkaline in the latter part of the summer. No striking or constant difference in alkalinity of the water was noted at the various depths or between the two stations. In Seneca lake the alkalinity ranged between 84.3 and 100 p.p.m.; the lowest was found in June at the south station. Determinations of the water of Oneida lake indicated that the total alkalinity gradually increased between June and September. On June 29 the alkalinity gradually increased from 9.7 to 15.6 p.p.m. between the surface and bottom, on September 7 from 17.8 to about 30 p.p.m. between the surface and bottom.

Quantitative Determinations of Plankton Organisms.—In Cayuga lake, samples of net plankton and nannoplankton were taken at the north and south stations approximately every two weeks between June 15 and September 15, 1927; in Seneca lake samples were taken at the north and south stations once a month from June to September; in Oneida lake, at intervals of two weeks between June 28 and September 6. From these data the accompanying charts (1–8) were prepared.

Charts 1–5 give a summary of the abundance, and vertical and seasonal distributions of the crustacea, rotifera, protozoa, algae and diatoms obtained in the net plankton of Cayuga, Seneca and

* See tables of chemical analysis, Series 111, p. 128.

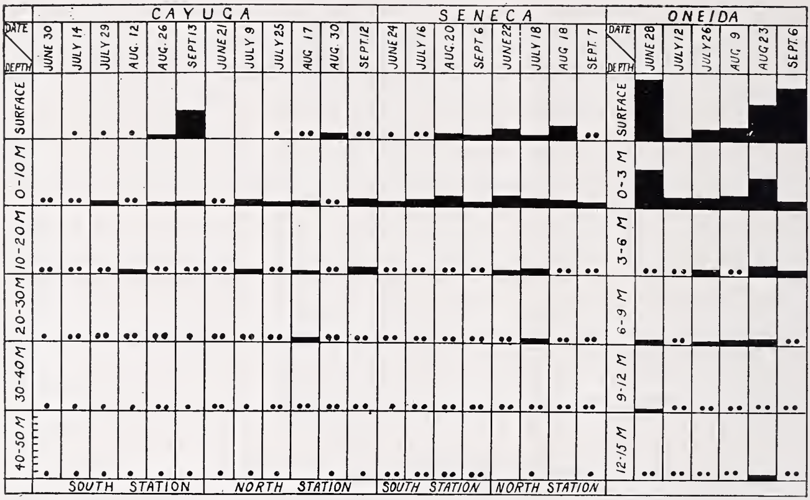

Chart 1. Crustacea in net plankton of Cayuga, Seneca and Oneida lakes.
Scale (number of organisms per liter of water).
1 space = 25; . = less than 1; . . = 1–10; depth = meters.
Genera observed:
Cladocera; daphnia, Leptodora, Bosmina –CS, Polyphemus –CS, Pseudosida –SO, Cerodaphnia –C, Sida –O.
Copepoda; Cyclops, Diaptomus, Nauplii.

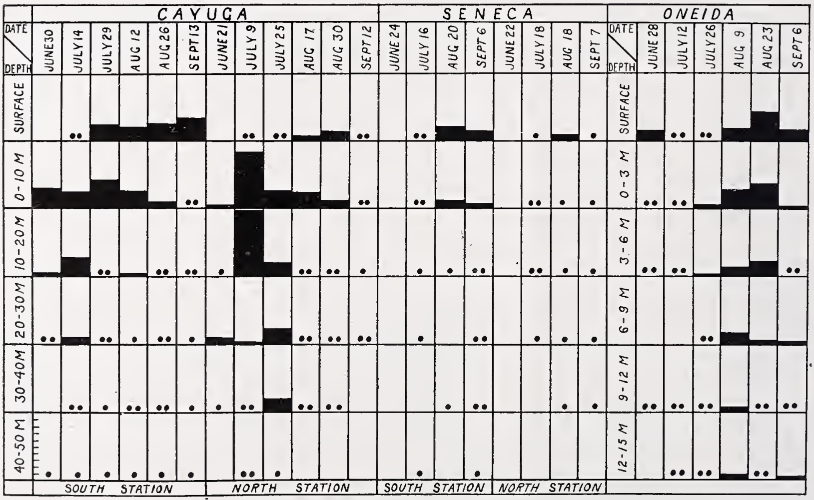

Chart 2. Rotifera in net plankton of Cayuga, Seneca and Oneida lakes.
Scale (number of organisms per liter of water).
1 space = 15; . = less than 1; . . = 1–10.
Genera observed: Anurea, polyarthra, Asplanchna, Notholca, Triarthra, Pleosoma, Conochilus –SC, Synchaeta –C

Oneida lakes; charts 6–8 show the same data for the protozoa, algae and diatoms in the nannoplankton. The genera of which representatives were found are listed under the explanation of the chart showing the distribution of the group to which they belong. Thus the letters C, S. or O following a genus indicate that it was observed in Cayuga, Seneca or Oneida lake respectively. Genera not followed by any letter were observed in all three lakes. The value assigned to the vertical rectangles in the figures varies from 150 to 50,000 depending upon the group of organisms. Each rectangle is provided with a scale of ten equal spaces in the lower left rectangle. The value of one of these spaces, which varies in the different figures, is indicated in the legend. In chart 5, the data for Oneida lake are not to the same scale as the others, and must be multiplied by ten for comparison with Cayuga and Seneca lakes. The various plankton organisms were determined to the genus whenever possible. The number of individuals, or colonies in the case of some of the Cyanophyceae, diatoms, etc., of each genus identified were computed for each sample.

The results of the plankton studies conducted during the summer of 1927 and shown graphically in the charts indicate that Cayuga and Seneca lakes were relatively poor in plankton organisms. Oneida lake was very rich in plankton organisms at all depths during the entire period covered by the observations.

Methods: Samples of net plankton were obtained by drawing a closing net of number 20 silk bolting cloth with bucket, through a vertical distance of 5 or 10 meters of water. These samples were placed in vials or small bottles and enough 95 per cent alcohol was added to make approximately a 70 per cent solution. Later these samples were made up to a uniform volume of 20 cc . For making counts of the smaller organisms, such as algae, diatoms and protozoa, one cc. of the sample was transferred with a volumetric pipette to a Sedgwick-Rafter cell. The counts were made by enumerating under a compound microscope, the organisms present in ten squares taken at random from the cell. For the enumeration of the larger organisms, such as crustacea and rotifers, a two cc. portion of the sample was placed in a watch glass and all the organisms therein counted. The results were reduced to the number of organisms per liter of water. For this purpose the net was considered 80 per cent efficient, that is, it was assumed that it strained the organisms from 80 per cent of the water through which it was drawn. A check on the efficiency of the net was made by determining the organisms in a sample obtained by straining a known volume of water and also in a similar sample obtained by drawing the net slowly through a certain vertical distance of water. The results were approximately equal, indicating that the efficiency of the net approximates 80 per cent.

The samples of nannoplankton were obtained by taking water samples at various depths with a water sampler. The water was strained through the plankton net and one liter samples were centrifuged with a "Foerst number 14 centrifuge" and reduced to a small volume which was placed in a vial and enough distilled water and formaldehyde added to make 10 cc. of suspension in 4 per cent formalin. In a few cases when the water samples could not be centrifuged on the same day that they were collected, liter quantities of water were measured and enough formalin added to preserve them for a day or two when the whole sample was centrifuged and made up in the usual manner. The enumerations of nannoplankton were also reduced to the number of organisms per liter of lake water.

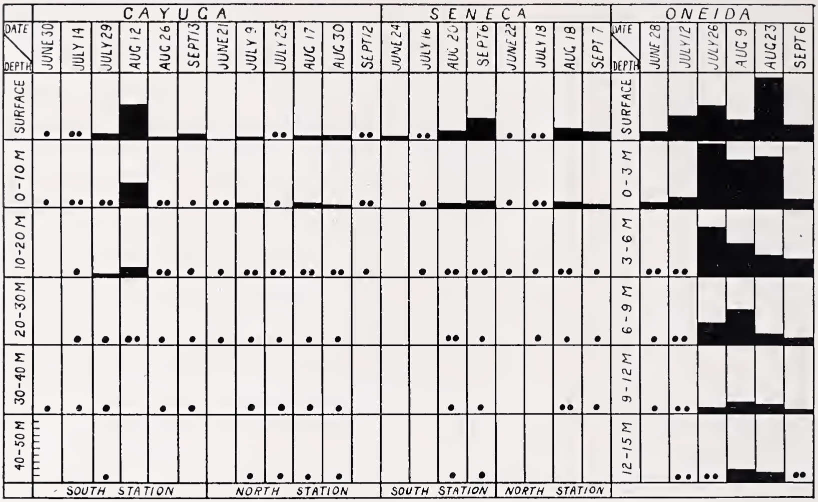

Chart 3. Protozoa in net plankton of Cayuga, Seneca and Oneida lakes.
Scale (number of organisms per liter of water).
1 space = 1000; • = less than 100; •• = 100–500.
Genera observed: Ceratium, Dinobryon, Vorticella, Difflugia, Mallomonas –CO.

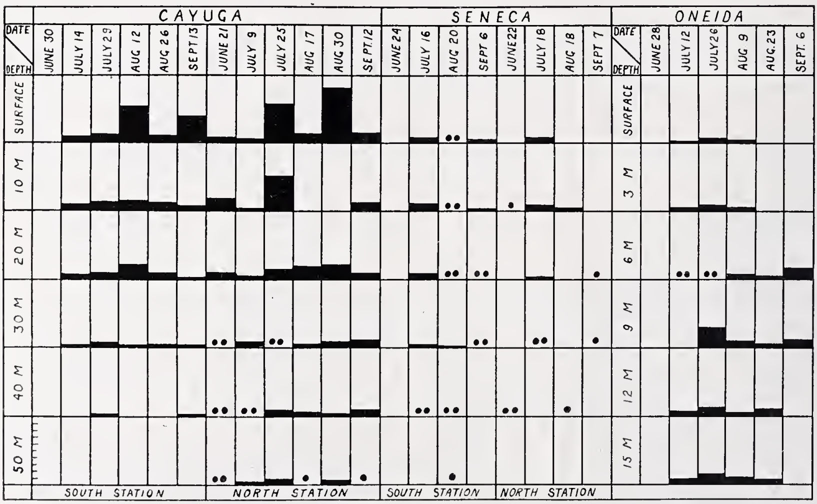

Chart 6. Protozoa in nannoplankton of Cayuga, Seneca and Oneida lakes.
Scale (number of organisms per liter of water).
1 space = 5000; • = less than 100; •• = 100–1000.
Forms observed: Difflugia, Dinobryon, Peridineae –CS, unidentified forms.

Genera of Plankton Organisms in Net Plankton and Nannoplankton

Cayuga Lake.— The great bulk of the organisms occurred in the upper 10 to 15 meters of water. Except for diatoms, the organisms occurring below 15 meters were relatively scarce. There was a striking similarity in the plankton life in the north and south stations. All of the dominant genera were about equally well represented in both localities. Most of the plankton organisms, except diatoms, were found in greatest numbers during July and August.

Net plankton. Cladocera.—*Bosmina* was the only common member of this group. It occurred in greatest numbers between 0–10 meters during July and August. *Polyphemus* was found near the surface in both stations during the middle of August. *Cerodaphnia* was found only once, 0–5 meters, at the north station. Traces of *Daphnia* and *Leptodora* were found in a few samples from each station.

Copepoda.—*Diaptomus* and *Cyclops* were observed each time samples were taken but at no time did they become abundant except in the upper samples taken in September. *Nauplii* were fairly abundant in all samples taken between 0–30 meters.

Rotifera.—*Pleosoma* was the most common rotifer. It was not found in June. It became most abundant between 0–15 meters during July and August. *Conochilus* especially during July and *Anuraea* throughout the season were abundant at the north station but much less common at the south station. *Polyarthra, Asplanchna, Notholca* and *Triarthra* were frequently found at various depths at both stations. *Synchaeta* was found (39 per per liter, 5–10 meters, and fewer at greater depths) at the south station on June 30, but not seen later. At the north station it appeared in only one sample, July 9.

Protozoa.—*Ceratium* was practically absent in June but showed a steady increase until the latter part of August after which it began to decrease. It was most common between 0–15 meters, only traces being found below this depth. *Ceratium* was much more common at the south station than at the north station. Only traces of *Dinobryon* were found before July. It increased very rapidly until the middle of August and two weeks later it had disappeared entirely. *Dinobryon* was very much more abundant at the south station than at the north station. Only small numbers of *Vorticella*, mostly attached to colonies of *Anabaena*, and *Difflugia* were observed, mostly between 0–15 meters and in the latter part of the season. *Mallomonas* was found only at the north station, 0–10 meters, on August 17.

Phytoplankton. Cyanophyceae.—*Anabaena* was found in both station from the latter part of July to the end of August, between the 7–10 meter depth. Traces of *Microcystis* were found at the south station in 0–5 meter depth.

Chlorophyceae.— Small numbers of *Pediastrum* and *Staurastrum* occurred in two samples from near the surface at the north station. Aside from a few undetermined unicellular green algae these were the only Chlorophyceae found.

Heterokontae.—*Botryococcus* appeared in traces near the surface at the south station on August 26. This plant was not seen in any other locality on the lake during the entire summer. In 1921 *Botryococcus* formed a very conspicuous "bloom" on the surface along the east shore of Cayuga lake.

Bacillariae.—The great bulk of the phytoplankton consisted of diatoms represented by three genera, *Asterionella*, *Fragilaria*, and *Tabellaria*. All three of these diatoms were most abundant in the upper 5–10 meters and relatively scarce below the 25 meter depth. *Asterionella* was most abundant in the spring and early summer and decreased in numbers so that by September it occurred only in traces. In plankton samples taken at the south station in early spring, *Asterionella* was the most dominant form observed. The following figures, from the 0–5 meter depth, give an indication of the rapid decline of *Asterionella* in numbers per liter of water: April 16, 3,765; May 14, 1,913; June 16, 987; June 30, 339; July 14, 216. This indicates the necessity of extending the observations over a considerable period of time in order to obtain some idea of the importance of any one form occurring in the plankton. *Fragilaria* was relatively rare early in the season when *Asterionella* was most abundant, but became very abundant in August and early September. *Tabellaria* occurred at all times. It showed some decline but no striking change in numbers in the period during which samples were taken.

Nannoplankton. Cyanophyceae.—The most common blue-green algae in the nannoplankton was *Coelosphaerium* rather abundant during August. *Oscillatoria* appeared at both stations early in the season, but was not seen after the middle of July. *Gloeocapsa* and *Aphanocapsa* appeared rather irregularly. *Merismopedia* was found in only two samples from near the surface at the south station.

Chlorophyceae.—No members of this group at any time formed any dominant part of the nannoplankton. *Scenedesmus* seemed to appear most frequently. It was found between 0–20 meters. *Characium, Crucigenia, Cosmarium, Dictyosphaerium, Eudorina, Gloeotaenium, Lagerheimia, Oocystis, Pediastrum, Quadrigula, Sphaerocystis, Staurastrum, Tetraëdon and Volvox* were found one or more times but never appeared very abundantly.

Bacillariae.—The most abundant diatom was a small *Cyclotella* which was present in nearly all samples. It was abundant from the surface to the 50 meter depth. *Synedra* appeared at all depths. It was more abundant early in the season than later. *Melosira* appeared at all depths early in the season but later was more common in the lower samples. *Stephanodiscus* appeared in only two samples at the north station. In addition to the above diatoms, fragments of *Asterionella*, *Fragilaria* and *Tabellaria* were often found in the nannoplankton in considerable numbers.

Protozoa.—Small numbers of *Difflugia* were found in several samples from various depths. Fragments of *Dinobryon* colonies small enough to pass through the net were very numerous during

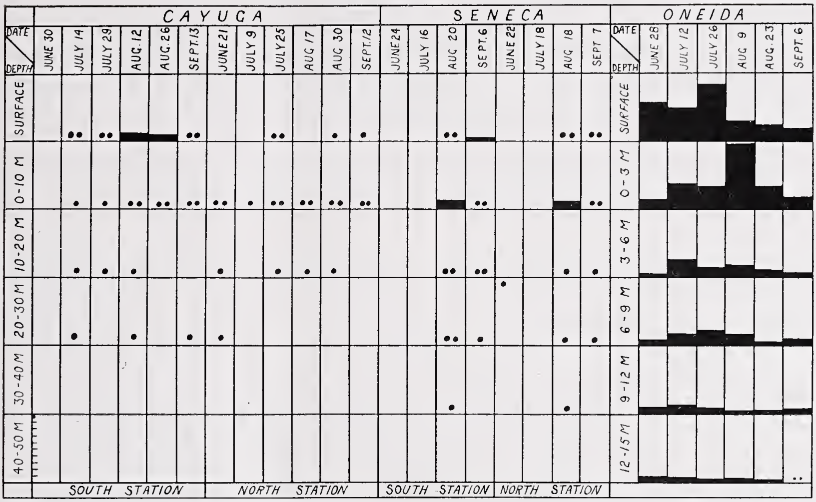

Chart 4. Algae in net plankton of Cayuga, Seneca and Oneida lakes.
Scale (number of organisms per liter of water).
1 space = 1000; . = less than 100; . . = 100–500.
Genera observed:
Cyanophyceae; Anabaena, Microcystis, Gloeotrichia –O.
Chlorophyceae; Staurastrum, Pediastrum –OC, Actinastrum –SO, Dictyosphaerium –SO.

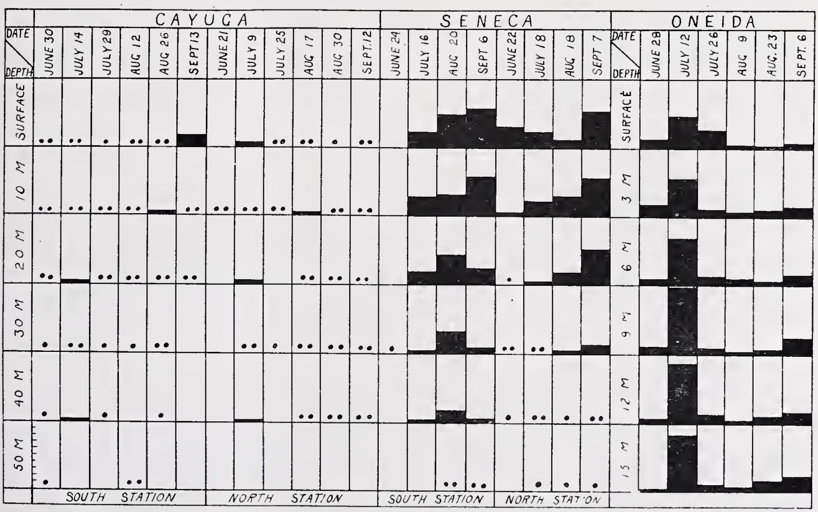

Chart. 7. Algae in nannoplankton of Cayuga, Seneca and Oneida lakes.
Scale (number of organisms per liter of water).
1 space = 20,000; . = less than 1000; . . = 1000–2000.
Genera observed:
Cyanophyceae; Aphanocapsa, Coelosphaerium, Microcystis, Merismopedia –CS, Gloeocapsa –CS, Gloeothece –S, Chroococcus –O.
Chlorophyceae; Characium, Cosmarium, Crucigenia, Dictyosphaerium –OC, Eudorina, Gloeotaenium –CS, Oocystis, Pandorina –O, Pediastrum –CS, Quadrigula, Scenedesmus, Sphaerocystis –O, Staurastrum –CS, Tetraedon –CS.

July. One of the *Peridineae* was common, especially near the surface during the latter part of the season. The figures for Protozoa probably are very incomplete. The more delicate forms were probably lost when the samples had to be preserved for later examination.

Observations show that Seneca lake, like Cayuga lake, was relatively poor in plankton organisms. The samples taken in June contained very few organisms except *Asterionella*.

Seneca Lake.— Observations show that Seneca lake, like Cayuga lake, was relatively poor in plankton organisms. The samples taken in June contained very few organisms except *Asterionella*.

Net plankton. Cladocera.—These organisms were never abundant in Seneca lake. At the south station *Pseudosida*, *Daphnia* and *Bosmina* occurred in very small numbers at various depths in August and September but were absent in June and July. At the north station a few *Bosmina* and *Daphnia* were found in July and August and traces of *Leptodora* and *Polyphemus* were found in the latter part of the season.

Copepoda.—*Diaptomus* and *Cyclops* were found in nearly all samples but appeared in largest numbers during July and August in the upper 15 meters. *Nauplii* were fairly abundant at all times in the upper 15 meters.

Rotifera.—No rotifers were found in the June samples and only small numbers appeared later. *Anuraea* and *Polyarthra* were found in small numbers at various depths at both stations. *Asplanchna* appeared in traces near the surface. *Conochilus* and *Notholca* were found at the north station on July 18. *Triarthra* was found once, 40–50 meters, at the south station July 16, and *Pleosoma* was found in three samples, 0–10 meters at the south station September 6.

Protozoa.—*Ceratium* was absent in June, appeared only in traces in July, and became rather abundant between 0–15 meters during August. *Dinobryon* was found much more irregularly than in Cayuga lake. Small numbers of *Vorticella*, attached to *Anabaena*, and *Difflugia* were found near the surface in the latter part of the season.

Phytoplankton. Cyanophyceae.—*Anabaena* appeared near the surface at the north station on August 20 and between 0–20 meters at both stations on September 6, but at no time was it very common. *Microcystis* appeared in all but the deepest samples on August 20, but only traces were left by September.

Chlorophyceae.—Members of this group were very rare. Only a few traces of *Actinastrum*, *Sphaerocystis* and *Staurastrum* were found.

Bacillariae.—The most common diatom was *Asterionella* which was most abundant near the surface early in the season. *Fragilaria* was found in the latter part of the season. *Tabellaria* was found in traces in only a few samples from near the surface.

Nannoplankton. Cyanophyceae.—*Gloeothece* and *Gomphosphaeria* were the two most abundant blue-green algae in Seneca lake. They were both found in large numbers, especially between 0–25 meters, during August and September. *Microcystis* was fairly common at the north station in August but occurred in only a few samples at the south station. *Gloeocapsa, Aphanocapsa* and *Merismopedia* were found in only a few samples at the north station, but the latter two were found in large numbers at the south station.

Chlorophyceae.—*Scenedesmus* and *Oocystis* were the most abundant green algae. *Scenedesmus* occurred only in traces in June but during the other three months it was rather common. *Oocystis* occurred in July and August. Other genera observed in some of the samples were *Characium, Coelastrum, Crucigenia, Gloetaenium, Pediastrum, Quadrigula, Elactothrix, Cosmarium, Closterium, Eudorina, Staurastrum* and *Tetraëdon.* The last six of these genera were found in only one station.

Oneida Lake.— The waters of Oneida lake were very rich in plankton organisms during the entire period covered by the observations.

Net plankton. Cladocera.—*Daphnia* was the most common genus, occurring in greatest abundance from 0–3 meter depth, in late June and September. Traces of *Leptodora* were found each time, at 9–12 meters. *Sida* and *Pseudosida* were found in small numbers on July 26 and later.

Copepoda.—*Diaptomus,* most abundant from 0–3 meters, and *Cyclops,* less common but more or less uniformly distributed between 0–6 meters, together with *Nauplii* were the only Copepoda observed. There seemed to be a striking decline in the number of Copepoda duing July.

Rotifera.—*Polyarthra* was found in nearly every sample although it was most abundant near the surface in June and again in late August. Early in the season *Anuraea* occurred only near the surface but later it was found at all depths, reaching its greatest abundance on August 22. *Notholca* and *Pleosoma* were found several times at various depths. *Triarthra* was found only once, August 9, at 12–15 meters, and *Asplanchna* occurred from 0–12 meters on Sept. 6.

Protozoa.—*Ceratium* was absent on June 28, appeared in traces on July 12, and reached a maximum abundance, nearly 6000 per liter, on August 23. By September 6, it had decreased in numbers. It occurred at all depths later in the season but it was most abundant between 0–6 meters. *Dinobryon,* which was very abundant from 0–6 meters and less so in deeper water, showed a consistent increase in numbers up to early August and then began to decline. *Mallomonas,* found at all depths, was most abundant during late July and August. *Vorticella,* mostly attached to colonies of *Anabaena,* occurred near the surface early in the season, and during late July and early August also appeared at the 3–9 meter depth. *Difflugia* was found throughout the season, but, except for small traces, only near the surface.

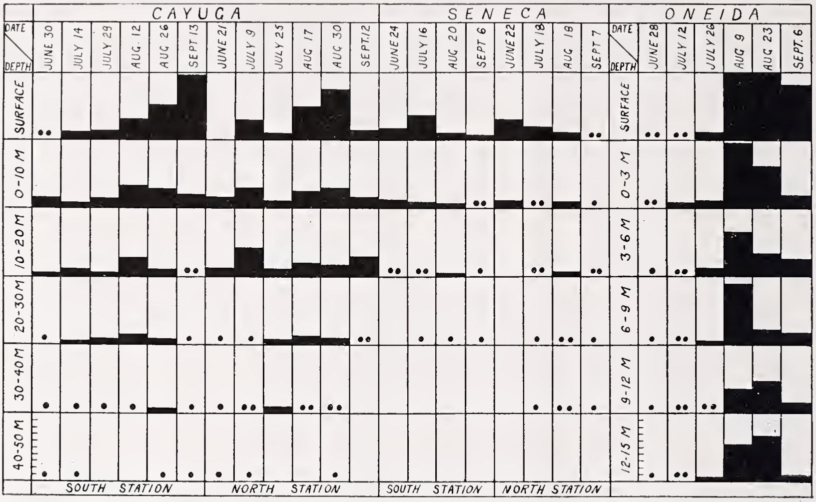

Chart 5. Diatoms in net plankton of Cayuga, Seneca and Oneida lakes.
Scale (number of organisms per liter of water).
1 space = 500; . = less than 100; . . = 100–200.
Scale for Oneida lake:
1 space = 5000; . = less than 1000; . . = 1000–2000.
Genera observed: Asterionella, Fragilaria, Tabellaria, Stephanodiscus –O.

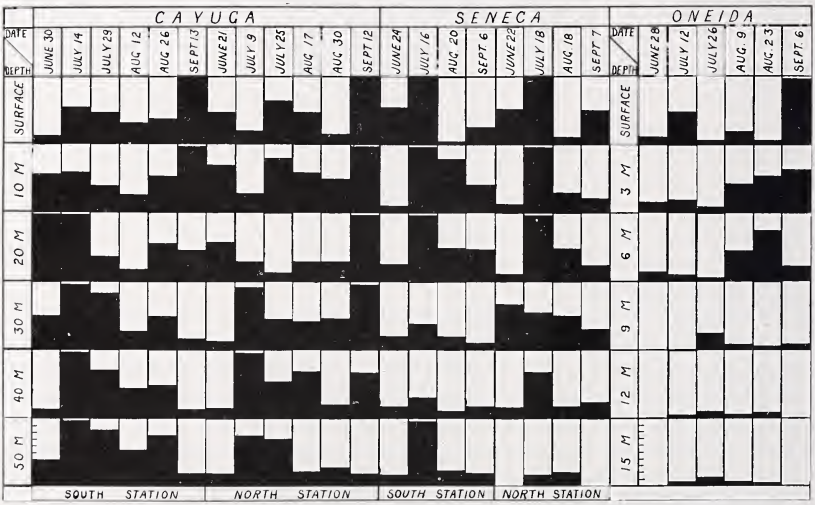

Chart 8. Diatoms in nannoplankton of Cayuga, Seneca and Oneida lakes.
Scale (number of organisms per liter of water).
1 space = 5000.
Genera observed: Cyclotella, Melosira, Stephanodiscus, Synedra –CS, Asterionella, Fragilaria, Tabellaria.

Phytoplankton. Cyanophyceae.—The blue-green algae were well represented in the net plankton by two common genera *Anabaena* and *Microcystis*. *Anabaena* was found at all times and was especially abundant from 0–6 meters deep. It reached its greatest numbers during July and August. Three species, *Anabaena circinalis, A. flos-aquae,* and *A. Lemmermanni* were observed but no attempt was made to count the species separately. *Microcystis* was found at all depths every time samples were taken; it seemed to be most abundant, however, at or near the surface. Traces of *Gloeotrichia* were found near the surface in August, and *Oscillatoria* was found only once, near the surface, on July 12.

Chlorophyceae.—Members of the green algae at no time formed any dominant part of the phytoplankton. *Staurastrum* was the most abundant genus; in addition very small numbers of *Actinastrum, Dictyosphaerium* and *Pediastrum* were found.

Bacillariae.—Diatoms formed the greater part of the phytoplankton at all depths, especially during August and September. *Asterionella* and *Stephanodiscus* were present at all times, the former being the most common. It reached it maximum numbers in August and then declined. *Fragilaria* and *Tabellaria* were practically absent in June and early July but during August formed the predominating organisms of the plankton. *Melosira* occurred only sparingly in the net plankton during the latter part of the season.

Nannoplankton. Cyanophyceae.—*Microcystis* was found in every sample, becoming very abundant at all depths during July and, after a decline, increasing again in September. *Coelosphaerium* was found in large numbers (about 1000 to 6000 per liter) in nearly all samples. No constant variation was noted due to depth or season. *Aphanocapsa* and *Chroococcus* were found in smaller numbers in several samples taken at various depths and at different times.

Chlorophyceae.—*Eudorina Oocystis* and *Characium* were the most common green algae found. These were found mostly in the earlier samples, being practically absent from the later samples. Other genera which were found only occasionally or in small numbers include *Dictyosphaerium, Cosmarium, Crucigenia, Pandorina, Quadrigula, Sphaerocystis* and *Scenedesmus*.

Bacillariae.—*Cyclotella* was the only diatom found in the nannoplankton that was not found in the net plankton. It appeared at all depths in the earlier samples. The figures given for *Asterionella, Fragilaria, Tabellaria* and *Melosira* are probably too high because the counts represent not whole colonies but fragments of colonies which were broken during the process of centrifuging. These samples were strained through the plankton net after centrifuging.

Since the nannoplankton samples could not be examined at the time they were taken, it was necessary to preserve them. It is probable that some of the more delicate organisms, especially smaller protozoa, may have been destroyed beyond recognition and were therefore not observed when the counts were made.

Estimation of Quantities of Dry Matter, Organic Matter and Ash in the Lake Water [1]

In order to make possible a more direct comparison of the plankton quantities than can be drawn from the numerical data obtained, samples of lake water were collected from two to four times at each plankton station and from these samples the total dry matter, organic matter and ash residue were estimated for the water of Cayuga, Seneca and Oneida lakes (Chart 9).

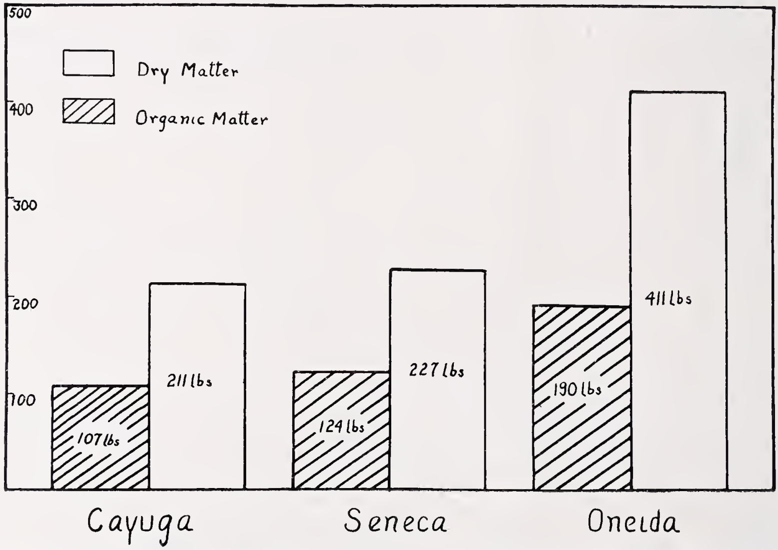

Chart 9. Showing weights of dry matter and organic matter, estimated in pounds contained in an acre of water to a depth of 10 meters (32.8 feet), in Cayuga, Seneca and Oneida lakes.

Method: The water samples were taken in duplicate from five depths ranging from the surface to 50 meters for each station in Cayuga and Seneca lakes and from the surface to 15 meters in Oneida lake. From each sample of water one liter was measured in a volumetric flask. This liter sample was then reduced to about 5 cc. with a Foerst centrifuge number 14, on the same day that it was collected or else formalin was added to preserve it until the next day when it could be centrifuged. This reduced volume was carefully transferred to a porcelain crucible and dried to constant weight in a Freas oven at a temperature of 98° C. for 24 hours, cooled in a dessicator, weighed, and then the dried residue ashed in an electric muffle furnace. The crucibles were heated to a dull

[1] The analytical work upon which these estimations are based was done by Mr. P. R. Burkholder in the Laboratory of Plant Physiology, Cornell University. The water samples from Oneida lake were transferred to the Cornell laboratory where they were dried and ashed.

red heat for 20 minutes and then kept at a cherry red heat for 45 minutes.

It is obvious that this method gives but a rough approximation of the actual weights of dry matter, organic matter and ash in the water of each lake. The data are based upon the solid matter (living organisms, remains of organisms and suspended inorganic particles) that were removed by the centrifuge. Some of the very fine particles as well as inorganic matter and salts in solution, would not be removed from the water by the centrifuge so that the figures for dry weight represent the weight of all solid particles that were so removed. The weight of organic matter represents materials lost upon ignition after the water was removed. The ash represents the residue after the dry matter was ignited. One source of error is the small quantities of water samples employed. However, duplicate samples were analyzed in most cases, and these usually checked closely. The final data in chart 9 represents the averages of analyses of 16 or 24 separate samples of water from each lake and illustrates graphically the differences in the three lakes in quantities of dry matter and organic matter.

The data in Table 2 from which chart 9 is derived show that the organic matter in Cayuga and Seneca lakes in general is greatest between the surface and 20 meter depths and in Oneida lake between the surface and 3 meter depths. The total dry weights show no striking or consistent differences with vertical distribution in any of the three lakes. This is apparently due to the relatively greater ash content in the deeper water. In Cayuga and Seneca lakes the water samples taken in late June and July contain a rather uniformly lower amount of organic matter and usually also less dry matter than the water samples taken later in the season (August). One of the factors responsible for the increase in organic matter appears to be the rise in the temperature, especially in the surface water of these deep lakes. Oneida lake, which is shallow, warms up much earlier in the summer, shows but very little difference in temperature between the surface and the bottom water.* No striking seasonal variation in organic matter was obtained between June and August.

The weights of dry matter and organic matter were computed for each lake by taking the average of the weights obtained from duplicate samples, taken at two depths, surface and ten meters, at two different times at two different stations located near the north and the south end of Cayuga and Seneca lakes. The values for Oneida lake were derived by taking the average weights for duplicate samples taken at five depths, surface to 12 meters, taken four different times. The weights of organic matter and dry matter were computed in pounds per acre of lake water for the upper 10 meters in order to allow a direct comparison of the three lakes. Chart 9 shows that Cayuga and Seneca lakes are relatively low in organic matter, 107 pounds and 124 pounds per acre respectively,

* See tables of chemical analyses, Series 111, p. 128.

Table 2.— Showing Quantities of Dry Matter, Organic Matter and Ash in the Water of Cayuga, Seneca and Oneida Lakes.

(Weights represent milligrams per liter)

Cayuga Lake — North

	Dry weight	Ash	Organic matter
July 9			
surface	2.7	1.1	1.6
10	2.45	1.15	1.3
20	2.7	1.7	1.0
40	....	....	....
50	2.9	1.9	1.0
August 17			
surface	2.45	1.2	1.25
10	2.45	1.0	1.45
20	2.65	1.3	1.35
40	2.6	1.0	1.6
50	2.4	0.8	1.6

Cayuga Lake — South

	Dry weight	Ash	Organic matter
June 30			
surface	1.75	0.7	1.1
10	1.75	1.1	0.65
20	2.45	1.85	0.6
40	2.2	1.5	0.6
50	2.1	1.25	0.85
July 29			
surface	3.0	1.9	1.1
10	2.4	1.35	1.05
20	2.5	1.45	1.05
40	2.35	1.45	0.9
50	2.55	1.6	0.95

Seneca Lake — North

	Dry weight	Ash	Organic matter
July 18			
surface	2.15	1.3	0.85
10	2.6	1.4	1.2
20	2.1	0.9	1.2
40	1.9	1.15	0.75
50	1.45	0.6	0.85
August 18			
surface	2.2	0.5	1.7
10	2.6	0.9	1.7
20	2.75	1.1	1.65
40	2.95	1.75	1.2
50	2.2	0.9	1.3

Seneca Lake — South

	Dry weight	Ash	Organic matter
July 16			
surface	2.3*	1.2*	1.1*
10	2.1	1.0	1.1
20	2.4*	1.2*	1.2*
40	2.15	1.25	0.9
50	4.4*	3.5*	0.9*
August 19			
surface	2.85	1.35	1.5
10	3.65	1.85	1.8
20	2.7	1.4	1.3
40	2.55	1.75	0.8
50	3.1	1.85	1.25

Oneida Lake

	Dry weight	Ash	Organic matter
June 28			
surface	4.85	2.5	2.35
3	6.45	3.65	2.8
6	4.95	2.65	2.3
9	4.8	3.0	1.8
12	5.85	3.6	2.25
15	6.25	3.95	2.3
July 12			
surface	4.45	2.1	2.35
3	3.9	1.7	2.2
6	5.25	2.55	2.7
9	5.45	2.75	2.7
12	4.95	2.55	2.4
15	7.0	4.45	2.55
July 26			
surface	4.3	2.5	1.8
3	3.85	1.65	2.2
6	3.3	1.95	1.35
9	3.85	2.0	1.85
12	3.65	2.05	1.6
15	3.15	1.9	1.25
August 23			
surface	4.65	2.15	2.5
3	5.35	2.9	2.45
6	4.65	2.6	2.05
9	4.3	2.6	1.7
12	3.7	2.35	1.35
15	4.1	2.5	1.6

* Figure represents analysis of one sample; all others are averages of duplicate samples.

and also in dry matter, 211 pounds and 227 pounds per acre respectively. Oneida lake, on the other hand, contains much more organic matter, 190 pounds per acre, and dry matter, 411 pounds per acre. Such an increase in the organic matter in Oneida lake when compared with Cayuga and Seneca lakes represents a large increase in plankton organisms, as has been shown by their numerical counts made in the three lakes. Undoubtedly some of the increase in organic weight also represents the remains of decomposed plankton organisms, rooted aquatic plants, and particles of organic material carried into the lake by streams. The weight determinations, as well as the numerical counts of the plankton organisms, indicate that the water of Oneida lake is capable of supplying, directly or indirectly, a much greater amount of food for fish than either Cayuga or Seneca lake.

VIII. THE LAMPREYS OF NEW YORK STATE—LIFE HISTORY AND ECONOMICS

BY SIMON HENRY GAGE, B. S.
Professor of Histology and Embryology, Emeritus, Cornell University

Life History of Lampreys

Character and Distribution of Lampreys.— The lampreys or lamprey eels are aquatic animals having an elongated rounded body with a tail fin and two dorsal fins, but no pectoral or ventral paired fins like ordinary fishes. They have seven gills on each side, each gill having a separate opening. In the adult stage they have a disc-like, sucking mouth with numerous horny teeth. They have no bones, but simply cartilage and connective tissue for a skeleton; and are among the lowest of the vertebrate animals. They are found in the temperate regions of both hemispheres, but more abundantly in the northern with its greater amount of land and more numerous, fresh water streams.

Like the frogs and toads the lampreys have a young or larval stage which is very unlike the adult, indeed so unlike their parents that only since 1856 have scientific men known that they were the young of the free-swimming lampreys.

A young frog or toad is called a tadpole or pollywog, or sometimes the classical name is used and it is called *gyrinus*. So with the lampreys, their young are called mud-lamprey or sand-lamprey, and frequently in scientific writing the Greek name *ammocoetes* is used. It is true that the larval lamprey does not look so different from its parents as does the frog or toad tadpole, still the difference in structure and habits of life are fully as great.

All lampreys lay their eggs in fresh water streams, and the young grow up in the mud banks along those streams. Some of the adults, like the brook lamprey, live all of their life in the streams where they were born; others like the lake lamprey, spend their adult life in fresh-water lakes; but the sea lamprey, as its name indicates, spends its adult life in the ocean. When fully mature, however, it returns to the fresh-water streams to lay its eggs for a new generation.

Distinction of the Sexes, and Coloration in Lampreys.—In the active, predatory life the coloration is in shades of gray. Where the pigment cells are numerous there are black spots, and where fewer, deeper or lighter gray. The fishermen call them spotted lampreys. Sometimes the pigmentation in the dorsal half of the animal is almost uniform, then they appear black or blue-black, or dark brownish. The brook lampreys are more inclined to the browns than the deep blacks.

During the breeding season the coloration may be black and gray as in the predatory period, or with the lake and the sea lamprey the epithelium may be filled with a golden lipochrome. Then the gold and black give the animal a very striking, and beautiful appearance. Sometimes it is the male that is brilliantly colored and sometimes the female, and sometimes both are almost equally favored by the gorgeous mating costume. This is well shown in the pair of lake lampreys (Plates 1 and 2). The specimens for these plates were found in a nest near the entrance of Enfield creek into the main inlet of Cayuga lake, May 31, 1927. The distance up the valley from the lake is about seven kilometers (4 miles).

During the free-swimming, predatory life of the lampreys the two sexes are so nearly alike that they cannot be distinguished except by dissection, and even then, except near the breeding season, it is difficult with the naked eye because the gonads appear so much alike. That is, to the naked eye the eggs and the sperm-cysts are nearly of the same size, and give the gonads the same general appearance. A microscopic examination, however, shows with the

Acknowledgements: For information like that in the following report, help must be gleaned from many sources: fishermen, naturalists, much personal observation, books and periodicals. In the text I have noted special pieces of help, but would like here to express my thanks to some not there mentioned: To Dr. J. B. Sumner, biochemist, for assistance with the anticoagulating secretion of the buccal glands; to Dr. and Mrs. W. A. Clemens, Pacific Biological Station, for supplying me with the buccal secretion of the Pacific lamprey, Entosphenus, and for abundant material of both adults and young; to Dr. Vera Mather, University of Oregon for the adults and young of the large Entosphenus of the Willamette river valley; to Dr. B. F. Kingsbury, to Marguerite and Ernest Kingsbury for help in securing lampreys from Cayuga and Seneca lakes; to F. W. S. Scudder for lampreys from the Connecticut river valley; to Dr. J. C. C. Loman of Amsterdam for adult and larval brook lampreys from Holland; to Drs. P. Okkelberg and C. L. Hubbs of the University of Michigan for brook lampreys from that region; and finally to my sister, Dr. Mary Gage Day, for aid with the buccal gland secretion, and for critical reading of the manuscript.

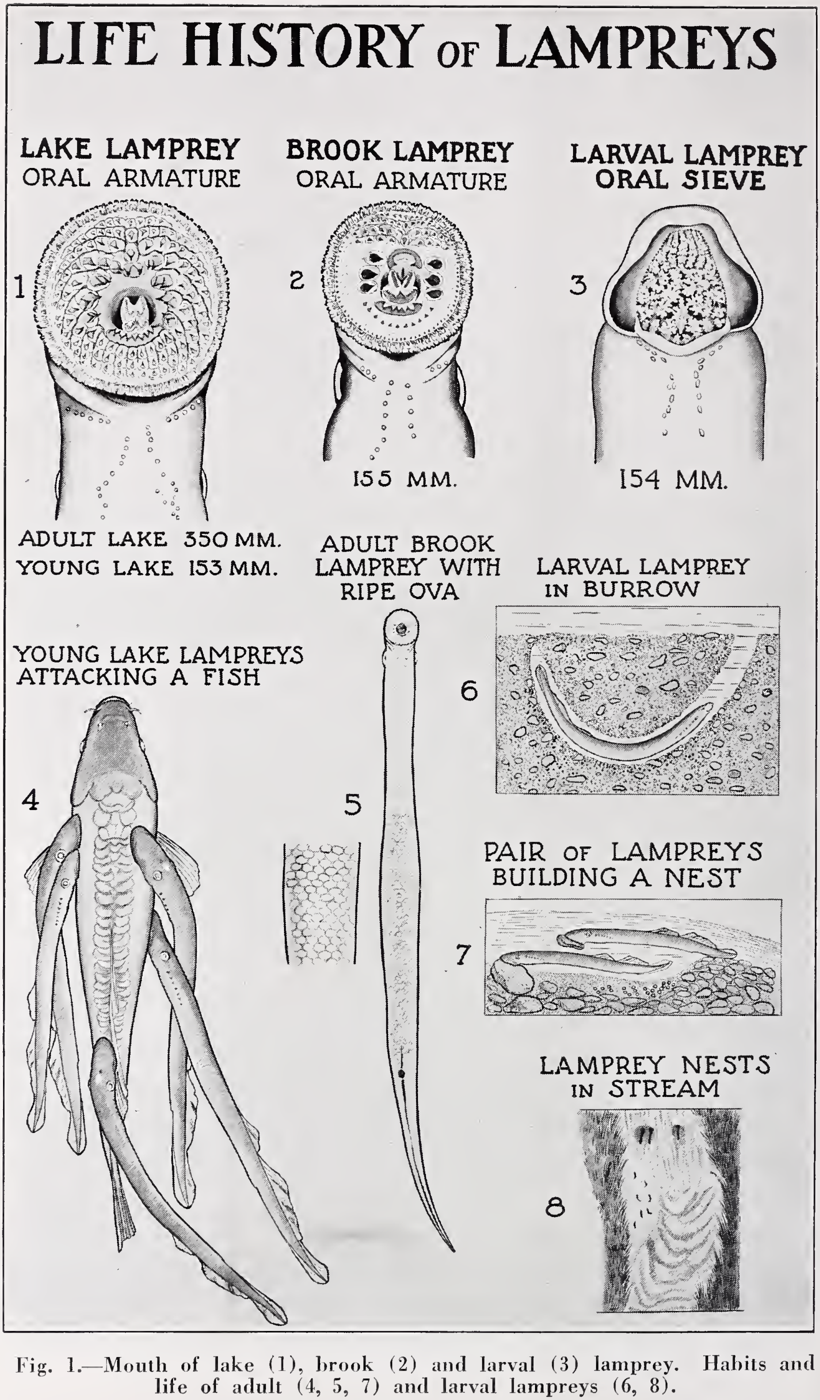

Fig. 1.—Mouth of lake (1), brook (2) and larval (3) lamprey. Habits and life of adult (4, 5, 7) and larval lampreys (6, 8).

greatest clearness the difference between the single ova and the multitude of young sperms in the sperm-cyst.

There is one structural feature that distinguishes the male in all forms during the breeding season. It is the greater length of the genito-urinary tube in the male. With the brook lamprey this is very striking (Fig. 2), though not so marked in the sea and lake lamprey. In the female there is a fin-like fold developed between the genito-urinary opening and the caudal fin in all the forms, and with the brook lamprey from Cayuga lake inlet, at least, there is an oedema in the second dorsal fin which makes its cephalic edge very thick. Sometimes, especially rather late in the spawning time, this oedema is often suffused with blood, making a brilliant scarlet spot in the fin shown by the dark shading in the dorsal fin (Fig. 2, No. 3).

With the lake and the sea lamprey there is a very striking growth in the male during the spawning season. This is a rope-like ridge along the back between the head and the first dorsal fin. It is also found in the sea lampreys on the spawning beds, but it may be lacking earlier when they are going up the river, as was shown by specimens the first of the season that were going up the fishway at Lawrence, Mass. Those at the end of the season had a well marked ridge when they reached the fishway.

Kinds of Lampreys in New York.— In the waters of New York State there are three, possibly four, kinds of lampreys:

The large sea lamprey, which during the spawning season is found in the rivers and tributary streams connected directly with the ocean.

The lake lamprey, about half as long as the sea lamprey. It is found in some of the larger lakes during the entire year, and in the streams entering those lakes during the spawning time (Plates 1, 2 and Fig. 1).

The brook lamprey, less than half as long as the lake lamprey. It is found during its entire life in the brooks, never in the lakes (Figs. 1, 2).

The silvery lamprey (*Ichthyomyzon*) about three-fourths the size of the lake lamphrey, is reported as present in Lake Erie. The writer has made no personal observations on this lamprey.

Up to the present the different lampreys have been found in the following waters of the State:

(A) The large sea lamprey (*Petromyzon marinus*). (1) In the Susquehanna river. Personal knowledge, and abundant information given by friends, naturalists and fishermen.

(2) The Delaware river and its branches. Adults furnished by D. F. Hoy, Registrar of Cornell University; larvae supplied by A. S. Hazzard and information given by J. R. Greeley.

(3) The Hudson river* and its branches. Information given by a resident of the Hudson river valley some years ago.

* DeKay, J. E. Zoology of New York, or the New York Fauna. Part 3, p. 379. Albany 1842–44.

Fig. 2.—Brook lampreys (natural size). (1) Female with eggs showing through abdominal wall. Dark spots along the side show where male had attached his sucking mouth. (2) Male showing elongated genito-urinary tube. (3) Spent female from the spawning grounds in May. Second dorsal fin shows position of oedema and scarlet spot.

(4) The streams of Long Island, especially the Nissequogue river flowing into Long Island sound.

The group of sea lampreys building their nest in the American Museum of Natural History, N. Y., was founded upon material and observations obtained by Dr. Hussakof[1] in this river.

(B) The lake lampreys (*Petromyzon marinus unicolor*) are believed to be the descendants of sea lampreys, which became land-locked at the close of the glacial period. They now remain their entire life in fresh water, never going to the ocean, and are only about half the length of their sea brothers. During their active, predatory life they are found in the larger lakes of the State as follows:

(1) Cayuga lake. Special attention was called to the lake lampreys in 1875 when a specimen was brought to Cornell University from Cascadilla creek during the spawning season. Since 1875 it has been shown to be present in other lakes also:

(2) Lake Erie. Specimen caught at Merlin, Ontario, 1921, by A. E. Crewe.[2]

(3) Lake Ontario. Specimens from Salmon creek at Hilton, N. Y. by Dr. A. H. Wright, and in the Humbert river near Toronto.

(4) Seneca lake (1894) and Oneida lake near that time. The writer has made personal observations on the Cayuga lake lamprey every year since 1875, and at frequent intervals, those of Seneca lake since 1894.[3]

The lake lamprey looks exactly like a small sea lamprey, and passes through the same special as well as general changes during its life such as coloration at the spawning season; the formation of a rope-like ridge on the back of the males in front of the dorsal fins; the separation of the dorsal fins during their predatory life in the lakes, and their close approximation or fusion making them look like a single fin during the breeding season.

(C) The brook lamprey (*Lampetra wilderi*). The brook lamprey like the lake lamprey passes its entire life in fresh water. Unlike the lake lamprey, however, it never goes down to the lakes but spends its whole life in the streams. It is found swimming freely in the water only during the breeding time, April and May in New York. It was first taken in the inlet of Cayuga lake by Gage and Meek,* May 8, 1886. Before this it was not known in America outside the Mississippi basin. Since 1886 it has been found and studied in many other places and at present

[1] Hussakof, L. The spawning habits of the sea lamprey (Petromyzon marinus). American Naturalist, p. 729, 1912.

[2] Crewe, A. E., In: Breeding habits of the landlocked sea lamprey (lake lamprey). Ontario Fisheries Laboratory Studies No. 9, 1922.

[3] Gage, S. H. The lake and brook lampreys of New York. The Wilder Quarter Century Book, p. 421–493, 1893.

* Gage, S. H. and Meek, Seth E. The lampreys of the Cayuga lake basin. Proc. Am. Assoc. Adv. Sc. vol. 35, 1886.

it is known to be present in New York State in the following streams:

1. Inlet of Cayuga lake.

2. Inlet of Seneca lake (secured by Gage in 1894).

3. Cassadaga creek, a tributary to the Alleghany river (specimens and information supplied by V. D. Smith).

4. Chadakoin creek, the outlet of Chautauqua lake, and tributary to the Alleghany river (information given by Dr. G. W. Cottis of Jamestown, N. Y.).

5. Spring creek, a tributary to Cattaraugus creek, which finally empties into Lake Erie (information by Dr. E. H. Eaton of Hobart College, Geneva, N. Y.).

6. In 1897 Dean and Sumner found brook lampreys in Tibbits brook, Lincoln Park, New York City. Their account of the spawning of these lampreys is most excellent, and the picture which they published of them building their nest and spawning "Shaking together" is the best representation ever published (Fig. 3).

Doubtless brook lampreys are present in many other streams of the State. As their free-swimming life is only during the spawning season, which is very short, it is quite intelligible that they may have been missed in brooks where they are actually present. Furthermore the water is likely to be rather high and turbid in April and May when they spawn, and a zoologist or fisherman would need to be on the lookout for them especially, or they would escape observation.

Outside the State of New York brook lampreys are reported by Jordan[1] to be present in the streams of New Jersey, Pennsylvania, Indiana, Wisconsin and branches of the Ohio river. Creaser and Hubbs[2] report its presence in southern New England, and as far south as Maryland.

In the streams of Michigan the zoologists connected with Michigan University have found them in abundance near Ann Arbor and have made fundamental studies of their classification, habits and development (Reighard,[3] Young and Cole,[4] Okkelberg,[5]).

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[1] Jordan, David Starr and Evermann, Barton Warren. Bulletin of the U. S. National Museum No. 47. The Fishes of North and Middle America. A descriptive catalogue of the species of fish-like vertebrates found in the waters of North America north of the Isthmus of Panama. Lampreys in Part I. Four parts, 1896 to 1900.

[2] Creaser, C. W. and Hubbs, C. L. Revision of the holarctic lampreys. In: Occasional papers of the Museum of Zoology, No. 120, University of Mich., 1922.

[3] Reighard, J. and Cummins, H. Description of a new species of lamprey of the genus Ichthyomyzon. Occasional papers, Mus. Zool. Univ. Mich. No. 31, 1916.

[4] Young, R. T. and Cole, L. J. The nesting habits of the brook lamprey. Am. Nat. vol. 34, 1900.

[5] Okkelberg, P. Notes on the life history of the brook lamprey. Occasional papers, Mus. Zool. Univ. Mich., No. 125, 1922.

Very closely related brook lampreys are present on the west coast of America, and in the streams of Europe, Siberia and Japan (Regan [6]).

In size, the brook lampreys are the smallest of all the lampreys. Those of New York State are on the average only slightly longer when they transform than the transforming sea and lake lamprey, but unlike them, the brook lamprey never increases in size after transformation (Fig. 7).

Nest-Building and Egg-Laying.—These activities are so similar in all the different lampreys that a description of one is practically a description of all.

No matter whether the lampreys live in the ocean, the lakes or the brooks during their adult life, they all go up the fresh-water streams to lay their eggs. The time in this State is from April to the first of July. The brook lampreys are the earliest. In the western part of the State the egg-laying some years may begin the last of March and continue into April, while in New York City it may begin as early as the middle of April. In Ithaca the season is from the first to the 20th of May, but in different years may be somewhat earlier or later following the temperature (Fig. 3).

Occasionally the spawning period of the brook lamprey may continue until the first lake lampreys appear, but the overlapping is quite infrequent and happens only in years when the season is unusual.

The spawning time of the lake and the sea lampreys commences most often during the latter part of May, reaches its height in June and may extend into July. They do not all go up at the same time. It has been frequently noticed that after a warm rain many new pairs of lampreys ascend the streams; also that in the same or neighboring nests there may be completely spent females and those full of eggs.

Brook lampreys may lay their eggs in water as cold as 10° to 12° Cent. (50° to 54° Fahr.) but more often the water is from 15° to 18° Cent. (59° to 64° Fahr.). With the lake and the sea lampreys the water at the spawning time is usually from 15° to 21° Cent. (59° to 70° Fahr.).

Nest-building: In raising a family the first thing needed is a home and the home-maker is very often and ought always to be the male. All the lampreys follow the good rule, and the male goes ahead and starts things, but the female is no sluggard and when she comes along she joins vigorously in the nest-building. This nest or home is built in running water, most often a short distance above rapids or riffles, as the fishermen call them. It is a wash-bowl shaped excavation in the bottom of the stream made by pulling the stones away from an area selected and depositing them around the edge, especially the lower edge. To remove the

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[6] Regan, G. C. Tate. A synopsis of the Marsipobranchs of the Order of Hyperoartii. Annals and Magazine of Natural History, ser vii, Feb. 1911.

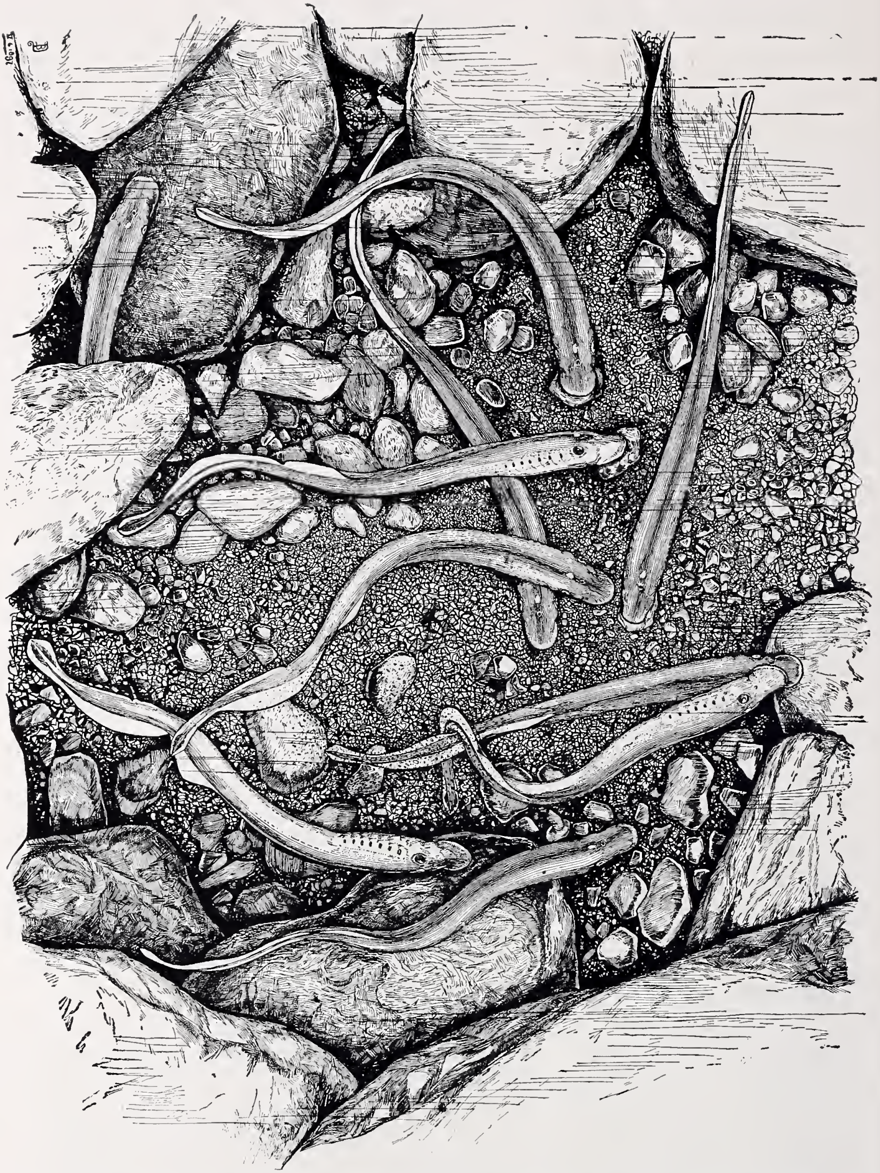

Fig. 3.—Nest building and spawning of the brook lamprey from a drawing made at Lincoln Park, April 16, 1897 by Bashford Dean, about half natural size. Cut loaned by the N. Y. Acad. of Sciences.

stones the lamprey attaches its sucking disc to the stone and then by powerful swimming jerks pulls the stone loose. If the stone is small it is lifted up and carried down the stream (Fig. 1, No. 7). If the stone is too large to lift the lamprey drags it along downstream to the edge of the nest. By working more in the middle than around the edges the nest is deeper and freer from stones in the middle and assumes the wash-bowl shape. This also leaves sand and fine gravel in the middle.

Most often there are but two to a nest, but sometimes there may be five or six of the lake lampreys and sometimes as many as twenty of the brook lampreys. All may be working to build and perfect the nest. I have watched them by the hour but have never seen two lampreys pulling the same stone although one individual often needed help badly. Others, however, have described such joint efforts. Occasionally there is a stupid lamprey which after carrying a stone to the edge brings it back and drops it in the middle. Mostly, however, they act as if they knew exactly what to do and proceeded to do it.

Egg-Laying: When the nest is partly finished the egg-laying may begin if the female knows that some of the eggs are ready. The ovary is a single, elongated body extending practically the whole length of the abdominal cavity and filling it almost completely. The eggs at the caudal or hinder end ripen first and are shed into the abdomen. There is a short tube extending from the abdominal cavity to the exterior (the genito-urinary tube). The eggs and milt which are shed into the abdomen are forced out through this tube into the water.

When the female is ready to lay a batch of eggs she fastens her mouth to a large stone at the side of the nest, and the male fastens his mouth to the back of her head and twists his body partly around hers (Fig. 3). Then, both arch their backs some what to bring their tails down to the sand and fine gravel in the middle of the nest. They both vibrate their tails with great rapidity, "shake-together" as it is called, and stir up the sand and gravel into a kind of cloud. At the same time the muscles of the abdomen contract powerfully and force the eggs and milt out through the abdominal pore into the mixture of water and gravel. If the operation takes place in a good light, especially if the sun is shining on the nest, one can see the stream of white eggs pouring out into the cloud of sand and gravel. If the nest is examined immediately after an egg-laying many eggs will be seen scattered over the bottom of the nest, and if one takes up some of the sand it will be found that the eggs are sticking to the bits of sand and gravel.

Before the eggs are laid the ovary puts on each one a coating which becomes very sticky just as soon as it gets into the water. This enables the eggs to stick to the sand and gravel which the lampreys stir up when they shake together. The heavy sand particles sink quickly and carry the eggs down into the nest instead of letting them float downstream.

Just as soon as a batch of eggs is laid the lampreys commence to jerk the stones from the edge of the nest. That seemed puzzling at first, but on watching further it was found that while many eggs were visible immediately after they were laid, they were soon all covered up by the sand washed down when the stones were loosened at the edge. It is of great advantage to have the eggs buried in the sand for they do not stick tightly to the sand particles very long. Soon they are quite free among the sand grains, and might be washed downstream if not covered.

If one examines a lamprey in the early part of the egg-laying time, only a limited number of the eggs will be found free in the abdominal cavity, all of the others will be imbedded in the ovary. As stated above, they ripen from behind forward, so that the last eggs to be laid are from the cephalic or front end of the ovary. This explains, too, why the eggs are laid in batches. After one lot is laid the lamprey works at the nest to get those well covered with sand, and then by some means, she knows when another batch is ready and proceeds to lay them, and so on till all are laid. From my own and the published observations of others, the egg-laying at its height recurs frequently, sometimes every two to five minutes with the brook lamprey, but the intervals may be much longer. Apparently it requires only a day or two for all the eggs to be laid, but the lamprey remains around the nest for several days, and spends much time and effort in moving stones around the edge of the nest, and thereby loosening the sand and gravel which washes down and covers the eggs securely.

With the lake lamprey in one especially favorable case where the egg-laying was at its height the pair of lampreys ''shook together'' 5 times and at 5, 10 and 15 minute intervals. With the sea lamprey the egg-laying as described by Hussakof* is fully as rapid as with the lake lamprey. It sometimes happens when there are several lampreys in a nest that the males attack each other. Then there is a lively scrap. One male grabs another by the back or in almost any place and jerks him out of the nest. They writhe and struggle in the stream making a great splashing. This explains in part at least why there are lamprey marks on the males. Other authors have commented on the attachment of male brook lampreys and their leaving the nest together. With the lake lampreys as described above, there is no doubt of the unfriendliness of the encounter.

Number of Eggs Laid by Different Lampreys.— The number laid by the different kinds is roughly in proportion to their size.

In round numbers they have been found as follows:

Sea lamprey	236,000
Lake lamprey	108,000
Brook lamprey	3,000

In determining the number of eggs the female is selected at the beginning of the spawning season on the way to the spawning

* Loc. cit.

grounds before any of the eggs have been laid. The abdomen is freely opened for its whole extent and the ovary—there is but one—carefully dissected out. It is weighed entire on accurate scales. Then, using chemical scales if possible, enough of the ovary is cut away to weigh one gram. The eggs in this weight are actually counted. Assuming that the number in a gram of ovary is uniform throughout, the whole number present can be determined by multiplying the number in one gram by the number of grams in the whole ovary.

In case the eggs are not easily separated from the ovarian tissue, the weighed gram can be macerated over night, or if necessary longer, in 20 per cent nitric acid in water. After the nitric acid, the piece of ovary should be soaked for half an hour or more in water. Then the eggs are easily separated and counted.

The following were the actual counts made for the different lampreys and the number of eggs estimated in each:

Sea lamprey from Lawrence, Mass., on the way to the spawning grounds.

Weight of the entire animal	640	grams
Weight of the entire ovary	121	grams
Number of eggs in one gram	1,950	
Number of eggs in the whole ovary of 121 grams..	235,950	

Lake lamprey from Cayuga lake, before the spawning time:

Weight of the entire animal	124.6	grams
Weight of the entire ovary	45.	grams
Number of eggs found in one gram	2,406	
Number of eggs in the entire 45 grams	108,270	

Two other lake lampreys taken from the spawning beds yielded: one, 63,000, the other 65,000. Evidently a part of the eggs had already been laid.

Brook lamprey (transforming):

Weight of the entire animal	8.5	grams
Weight of the entire ovary	150	milligrams
Eggs counted in 50 milligrams	1,092	
Entire number of eggs in the animal	3,276	

The transforming brook lamprey was used because it is practically impossible to secure a female at the spawning time which has not already laid a part of the eggs. Dean and Sumner estimated from a gravid female taken at the spawning time that she contained 860 eggs. It seems almost certain that a part of the eggs had been laid as with the lake lampreys from the spawning grounds. (See above.)

Death of Lampreys After Spawning.— The question is often asked: What becomes of the lampreys after the eggs are laid? The answer is simple and certain. They all die, and none of them ever return to the ocean or the lakes to recuperate and prepare for an additional generation. This has been the belief of fishermen for many years, also, of scientific men, for the ovaries after spawning contain no immature eggs as with animals that lay eggs more than one season. For the sea and the lake lampreys the number of dead ones found in the streams shows at least a high mortality. Mr. Holmes of Lawrence, Mass., who has collected sea lampreys for many years as they went up the fishways, wrote to me that he had seen all kinds of fish going up and down, but he never saw any large lampreys on their return to the ocean. He often found the small, just transformed ones going down, but never the large ones. Much evidence also came from fishermen familiar with the sea lamprey that they all die after spawning.

Proof that the Lampreys Die After Spawning.— Brook lampreys have been kept under observation after spawning, and they always die in a relatively short time. There are no microscopic eggs in their spent ovary, and as these animals never feed after transformation, even before spawning, it is certain that they die soon afterward. Dead ones have also been found in the spawning streams, and sometimes these dead ones are so covered with the mold, *Saprolegnia*, that they look as if wrapped in cotton. That the lake lampreys die after spawning seems probable from the anatomical degeneration of the liver and intestine, and from the absence of minute ova in the ovary. Also from the number of dead animals found in the spawning stream.

Experimental evidence.—As the situation in Ithaca is so favorable it seemed that the opportunity to make a crucial test should not be neglected. Some vigorous lake lampreys from the spawning beds were put in a covered spring with bullheads to see if they would feed upon them. As will be shown later, the lampreys during their predatory life attack fish in an aquarium as readily apparently as in the waters of the lake, therefore it seemed that this was a fair trial. The water of the spring was cold. All of the lampreys died, although the bullheads (*Ameiurus*) lived for a long time. To make the experiment as normal as possible a wire cage was placed in the spawning stream in deep water, and bullheads and lampreys put into it. As before the fish lived, but the lampreys all died. As the assumption always is that the lampreys return to the lake before they commence to feed, another cage was sunk in the lake and lampreys and bullheads added. The bullheads were used because the lampreys are particularly fond of bullheads and the experiment attempted to make the conditions as favorable as possible. The lampreys died as before, but the bullheads did not.

Persistence of the Notochord.— It is often argued that if the lampreys all died after spawning their dead bodies would be more in evidence. This season (1927) and the season of 1911 were especially favorable for testing the matter. It is evident that if there were heavy rains and consequent high water, the dead bodies would be washed down stream and quickly disappear, but on the dates mentioned there was very little rain and the streams were clear and low. Careful observations were made for several miles along the main inlet to the lake where the spawning occurs both during and immediately after the spawning season was over, and then some weeks after. In the silt along the edge of the stream, and in the brush and other obstructions that catch floating objects many dead lampreys were found. In dislodging the drift in a brush obstruction in 1911, a couple of weeks after the spawning was over, several long whitish bodies were found. They looked like very long round-worms. Investigating further these were found attached in some cases to a partly decayed lamprey. It was soon realized that these round-worm appearing bodies were the notochords of the decayed lampreys. These notochords seem to be the most persistent part of the lampreys, and they may be found at least a month after the lampreys have died. Since 1911 notochords have been found every favorable year including 1927. Also this year Mr. J. R. Greeley found them in the Beaverkill, a tributary of the Delaware, where the large sea lampreys spawn. As some of them were connected with partly decayed lampreys there was no doubt of their character (Fig. 4*).

The persistence of the notochords in the spawning streams has been somewhat emphasized because if they were found by a naturalist or a fisherman entirely separate from any part of a lamprey they would certainly be a puzzle. In case a paleontologist were to find a fossil notochord what would he call it?

All of the above evidence for the death of the lampreys after spawning makes the statement seem wholly justified that all the lampreys spawn but once, and that after spawning they die. No doubt death is not due wholly to starvation, although none of them take food during the spawning time, but there are many contributory factors. In attaching to each other by the sucking mouth, the epithelial protection is removed leaving an opening for infections of various kinds, the most common being the mold, *Saprolegnia*. Even the large lake lamprey, may be almost covered with it, as described for the brook lamprey above.

In passing it may be added that the lampreys seem to be subject to the ordinary defects that mar even the highest in the animal kingdom. For example, something happened to one specimen, for its oral disc was imperfect; another had but a single eye and another a single kidney, and still another only an excuse for a tail. Only one albino larva was ever found, all the other lampreys, young and old were properly pigmented. Taking it by and large, the lampreys on the spawning grounds are quite perfect physically. Probably the weaklings are ground to dust by the all-prevailing law of the "survival of the fittest."

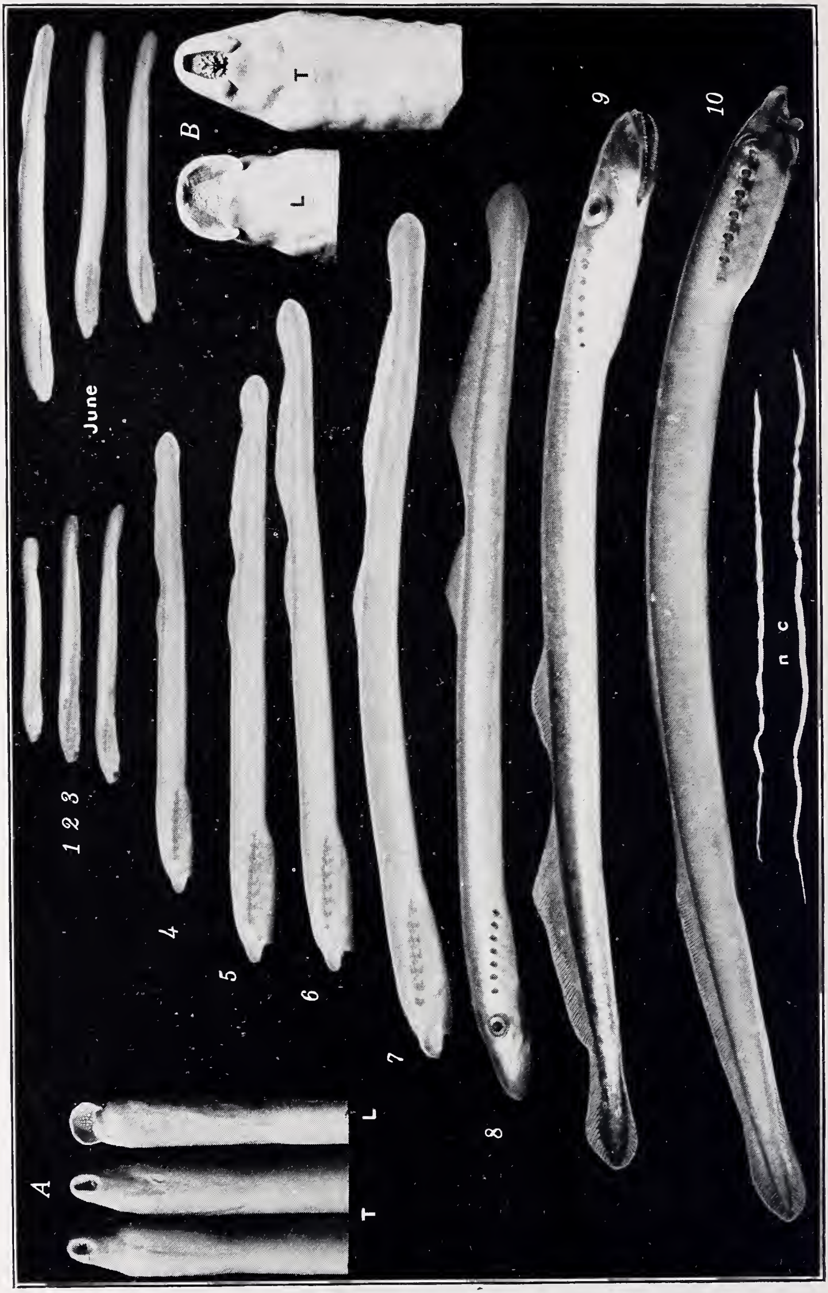

Fig. 4.—Larval and transforming lake lampreys (nearly natural size).

* 1, 2, 3, growth to Oct. of the same season. 4, 5, 6, 7, larvae possibly of different years. 10, larva of unusual length, Dec. Transformation the following year. 8, transforming lake lamprey that remained in an aquarium a whole year in the larval stage after reaching full length, transformation apparent in late August. 9, transforming lake lamprey from the mud-bank, Dec. June, three larvae taken from the mud-bank showing growth in one year. A, two transforming lake lampreys with contracted circular mouths, T, Aug. One larva of the same length, L, with the characteristic hooded mouth, upper and lower lip. B, about twice natural size. L, larva with hooded mouth. T. transforming lamprey in a very early stage, Aug. n.c. notochords of decayed lampreys found in the stream in June. The cephalic end points to the right.

Development of the Eggs and Larval Life.— The eggs are only about one millimeter (1/25 inch) in diameter and undergo total but unequal segmentation, something like those of the frogs and toads and other amphibia. At first, as stated above, they are sticky, and cling very tightly to pieces of sand and gravel, but after a few hours the covering loses its adhesive quality and the eggs are then free and lie loosely among the sand particles.

The development begins almost immediately after the eggs are laid and fertilized. The temperature retards if low and hastens if warmer. In an experiment with artificially fertilized eggs with the water at 22.5° Cent. (73 Fahr.) the eggs reached the two-cell stage within six hours. In another experiment they were carried till hatching in the laboratory at about 20° Cent. (70 Fahr.) and it required nine days. In colder water the time is considerably extended. When hatched the larvae have a considerable amount of food-yolk remaining, and they stay in the nest until this is used up, from two to three weeks. When the food-yolk is exhausted they have reached a stage of development when they can take and digest food. As the microscopic life in the nest is scanty, they migrate down the stream to a mud bank in relatively quiet water. Here the microscopic organisms are more abundant and they are not so crowded. They secure their food in this way: For breathing the gill chamber is alternately filled with water and emptied. Going in with the stream of water are the microscopic forms on which they feed. In some way, no one knows just how, the young lamprey is able to separate at least a part of the food bodies from the water and pass them on to the intestine where they are digested. Apparently the selection is not discriminative, for particles of sand or any other substance in the water are passed down to the intestine as well as the infusoria, diatoms, desmids, etc. That only a part of the particles go on to the intestine may be shown by putting one of the ammocoetes in a test tube or slender bottle with water to which a small amount of starch or flour has been added. By using a lens and holding the animal in a good light, it will be seen that a stream flows into the mouth and out of the gill openings or branchiopores. The starch particles help one to follow the stream, and it will be seen that starch grains come out with the expired water. Probably this also happens with the microscopic organisms used for food, that is, only a part of them are made use of. If there is considerable starch in the water one can see very clearly the use of the oral sieve over the opening to the throat (Fig. 1, No. 3). A part of the starch grains is caught by the processes making the sieve, and after a while they tend to clog the openings and thus hinder the free entrances of the respiratory water. Any other particles like the silt in muddy water would produce the same result. Now when the clogging has gone to a certain extent, the young lamprey fills its branchial chamber, and then closes the branchiopores so that the water cannot escape in the usual way in expiration. Then by a powerful constriction of the branchial chamber the water is forced out of the mouth in a rapid stream which clears away the clogging material.

This method has been adopted by the sanitary engineers for cleaning their filter beds for water by reversing the current and allowing the dirt to flow off the top.

Length of Larval Life.— It is not known how long the young lampreys live in the mud as larvae. The only way to find that out with certainty would be by an experiment in which natural conditions were imitated closely and the animals kept from the egg until the transformation. This has never been done. The nearest approximation can be found by seeking the animals from month to month in the mud banks where they naturally live. This has been done for the brook and the lake lamprey in the Cayuga lake inlet, and in the photographs one can see the different sizes and appearance. There is a good certainty for the first season, that is from May and June until Nov.-Dec. (Fig. 5). The brook lamprey is three to four weeks earlier than the lake lamprey hence its young are further advanced. In May and June eggs and larvae may be found in the same nest, showing that some of the eggs were laid earlier than others. It often happens that successive pairs of lampreys use the same nest during the spawning season. This difference in time of laying the eggs also accounts for the difference in size of the larvae of the brook or of the lake lamprey during the same month; for example in this figure, Nov. and Dec.

From a somewhat limited series of sea lamprey larvae and transforming ones, the conclusion seems justified that the larval life is precisely like that of the lake lamprey. From the groups of sizes found by Dr. Okkelberg* of the brook lamprey in Michigan, he has, by a series of average curves, concluded that their larval life extends over a period of five years, possibly four years. From my own observations of both the lake and the brook lamprey larvae obtained nearly every month throughout the year, it seemed to me that the time could not be less than four years.

Wishing to study the structural changes in the various stages of transformation, many large larvae were secured in Aug. and Sept., 1913. These larvae were as long and some of them longer than most of the transforming ones obtained in previous years so that it seemed sure that they would transform during that summer and autumn. They were kept in a large tank with sand and gravel in the bottom and a constant stream of water was turned on so that the conditions would be like that in the natural stream. They were dug up occasionally to see how they were progressing. Some of them commenced to transform in the usual fashion, but to my

* Loc. cit.

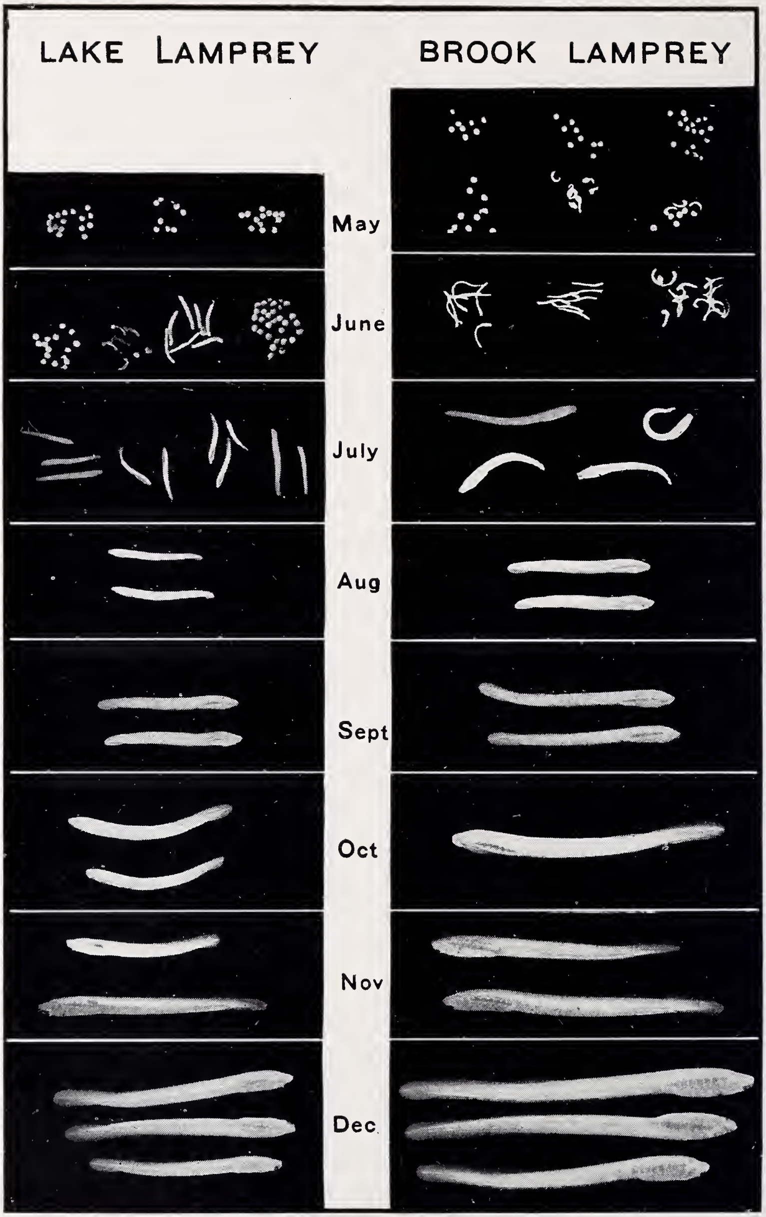

Fig. 5.—Eggs and young of the lake and the brook lamprey to show the growth from month to month during the first season (May to Dec.). Note that the brook is constantly in advance. Nearly natural size).

astonishment some of the large larvae showed no change. These were kept over the winter and following summer. They commenced to transform in August, 1914, but one not until September (Fig. 4, No. 8). That is, some of the full length larvae lived a whole year after they had reached full size before they commenced to transform. As one can find larvae as long or longer than many transforming ones any month in the year, it is believed that all of them live a year in the larval stage after they reach full length. If this is a correct conclusion, then one year must be added to every estimate based upon size of larvae. From present knowledge it seems to me that the time passed in the larval period in the mud must be at least five years (Figs. 4, 5).

Transformation of the Larva to the Adult Condition.— When the larval lamprey attains a certain definite maturity, which, as shown above, may take a year after it has reached full length (5 to 7½ inches), the process of structural changes begins to prepare it for its free-swimming, predatory life. The hooded, horseshoe shaped mouth with an upper and lower lip gradually changes to a circular disc-shaped mouth. The sieve over the throat disappears, and on the circular disc appear numerous horny teeth, and in the throat appears a piston-like tongue armed with a double row of rake-like, horny teeth (Figs. 1, 4).

The eyes instead of being rudimentary and deeply imbedded in the tissues of the head, appear at the surface and have a transparent cornea. A good crystalline lens and a more perfect retina, and eye muscles are developed. In place of the single chamber for food and respiratory water in the gill region, a separate oesophagus and bronchus are formed, and the gills are arranged in seven separate sacs or pouches, each with an external opening (external branchiopore) and an opening to the common bronchus (internal branchiopore).

Buccal glands for producing the anticoagulating secretion are developed and their ducts open into the mouth just below the rasping tongue (Fig. 6). The liver loses its gall bladder, and its duct leading to the intestine, so that in its adult life the liver has no duct opening into the intestine. The intestine is also much modified. Many other profound changes occur and finally the young lamprey is ready for its predatory life. At transformation the different lampreys are of about the same size, the brooks being slightly longer than the sea and the lake lamprey. The brook lamprey never increases in size, but as shown in the diagram (Fig. 7) the lake and the sea lamprey increase greatly.

As larvae they all look so much alike that up to the present no clear distinctions have ever been made, but very early in the transformation stages, the color changes and the breadth of the oral disc mark differences evident to any one. The brook lamprey changes very little in general coloration, but the sea and the lake lamprey change from the chestnut brown-black of the larva to blue-black. Indeed everywhere they are known by the fishermen as "blue lampers," and are greatly prized for bait (Figs. 4, 5).

The transformation begins in the summer. Some have been found commencing as early as the middle of July. From this time all along through August, and sometimes the first signs begin early in September. The transforming lampreys remain in the mud and sand the same as larvae, but they are more often found in deeper water. The time required for the transformation is more easily determined than for either the larval or the adult life. This is because it is shorter, and during the transformation time, no food is taken by the lamprey.

In 1897 and 1898 especially, but repeated occasionally for the next fifteen years, large larvae and those showing the beginnings of transformation have been kept in an aquarium with sand and gravel and stones on the bottom to simulate the natural stream. As stated above, these transforming animals remain under the sand and gravel like larvae until they are ready to commence their predatory life. They do not all begin their transformation at the same time, and naturally do not all finish on the same date. When they are ready for their free life in the water they leave the covering of sand and appear above it in the water. Some come out during the last of January, and others during February, and some as late as March.

Fish of different kinds, bullheads and carp, have been put into the aquarium to serve as food for the young lampreys if on emerging they were ready for it. They certainly were ready and pounced upon the poor fish like a pack of wolves (Fig. 1, No. 4).

The aquarium experiments have been confirmed by the actual happenings in nature, for the fishermen have brought to the laboratory young lampreys caught on fish in January, February, March and the later months. It can be affirmed then with confidence that in nature it takes the transforming young lampreys between six and seven months, that is from the middle of July to the middle of January, or for those commencing in August, until February and the beginning of March, to complete the profound modifications in structure to render them adapted to their free-swimming, predatory life. These experiments were made with lake lampreys, and from the stages of growth found with the large sea lamprey larvae and transforming young, it seems highly probable that they are an equal time in changing from the larval to the adult stage. Indeed the more one studies the marvelous changes that occur, the less one wonders that it requires six months or more to complete them.

Brook Lamprey Not Parasitic.—The changes undergone in the transformation of the brook lamprey are almost precisely like those in the sea and the lake lamprey. The time they remain covered in the sand and gravel of the stream is considerably longer, and the subsequent life is markedly different. This was shown in 1897–1898, and has been repeatedly confirmed many times since that original experiment.

The very large larvae and those showing signs of change were kept in an aquarium with sand and gravel and with running water flowing over them as in the natural stream. Small bullheads were put in the aquarium for them to feed on if they wished when they emerged. But they paid no attention to the fish. Their sucking mouth, piston-like, rasping tongue and the horny teeth on the oral disc seemed to fit them for parasitism, but they never molested the fish. It was noticed, however, that when they attached to the sides of the glass walled aquarium that they looked very much as do the ones that are on their way to the spawning ground. That is, one could see the eggs through the thin wall of the body; and later after they were shed into the abdomen they looked like little pills in a homeopathic vial (Figs. 1, No. 5; 2, No. 1).

To make sure that such apparently, premature ripening of the eggs also occurred in nature, my trained lamprey digger and catcher was commissioned to get specimens from the Cayuga lake inlet. In these the eggs and milt were well advanced toward maturity, but not quite so far as with those in the laboratory aquarium with the warmer water.[1]

This experiment and its subsequent verification proved conclusively that the *brook lamprey is not parasitic,* but like many insects lives its growing life in the larval state, and during its adult life does nothing but look out for the next generation and then die. In 1897–1898, it was almost or quite universally believed that the brook lamprey with its apparently complete armature for parasitism, was really parasitic (Fig. 1, No. 2). The experiments at that time, were the first, so far as I know, to really set the matter at rest. And now it is universally understood that the brook lamphrey in all regions is non-parasitic, and that its free life in the water is only a few weeks in length, only long enough for it to reach the spawning grounds, build its nest, lay its eggs and care for the nest a few days. Its life work is then finished.

A very interesting anatomical fact was recently brought out by Keibel,[2] viz., that in the German brook lamprey, while it undergoes apparently all the transformation changes, the oesophagus does not become hollow all the way from the throat to the intestine, but for a short distance near its cephalic end contains a solid plug of epithelium. This is true of a goodly proportion of the American brook lampreys, but by no means of all. Many of them have the oesophagus open the entire distance as with the sea and the lake lamprey. Of course those with a solid oesophagus could not swallow the blood if they were to suck some from a fish, but the American ones with open oesophagus could do so. But none of them ever attack a fish.

No doubt the brook lamprey was at one time parasitic the same as the lake and the sea lamprey. Even now its first cousins

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[1] Gage, S. H. Transformation of the brook lamprey (non-parasitism). Proc. Amer. Assoc., Adv. Sc. Vol. 47, 1898. Science, 1898, p. 401.

[2] Keibel, Franz. Eroeffnungsansprache der anatomischen Gesellschaft, Wien. Anat. Anz. Bd. 60, p. 3, 1925.

(*Entosphenus*) of the Pacific Coast are parasitic, and some of them, found in the Columbia river and its tributaries, grow to a size almost equal to that of the sea lamprey of the Atlantic.

This change from a predatory life must be very recent, geologically speaking, for the animal has all the machinery for parasitism; even the buccal glands with their anticoagulating secretion still persist. The piston-like tongue and the sucking mouth are still useful for nest building and mating, but the horny teeth of the disc and the sharp rake-like teeth of the tongue seem wholly uncalled for. Indeed, as shown by Dr. Reighard and his pupils, some of the Michigan brook lampreys have almost lost these weapons.

Summary of the Life History of Lampreys:

1. Lampreys are among the lowest of the fish-like forms and are found in the temperate zones of both hemispheres but are more abundant in the northern than in the southern hemisphere.

2. There are three, possibly four kinds of lampreys in New York State waters.

3. The eggs are always laid in fresh water streams, mostly during the months of April, May and June.

4. The lampreys spawn but once, soon after which they all die.

5. There is a young or larval stage corresponding with the tadpole of the frog and toad, in which the structure and mode of life is quite different from the adult.

6. The young or larval lampreys, *ammocoetes* or *mud lampreys*, live from four to five years in the mud and sand along the streams where the eggs are laid.

7. When sufficiently mature at the end of four to five years the larval lampreys transform to the adult stage. In this process they acquire new structures which prepare them for their free, parasitic life.

8. The time required for transformation is from July-August to the latter part of January and extends in some to February and March. During transformation they remain under the sand and gravel for protection.

9. When transformed, the sea lamprey migrates from the fresh water stream to the ocean. The lake lamprey migrates down the stream to one of the large, fresh-water lakes. In the ocean or the lake the adult lampreys prey upon fish, sucking their blood. Their parasitic life continues for one and one-half to three and one-half years, then they return to the fresh-water streams to lay their eggs for a new generation.

10. The brook lamprey grows to its full size in the larval stage. When fully transformed, it does not, like the sea and the lake lamprey, go to the sea or lake to prey upon fish, but proceeds at once to the spawning grounds up the stream where it builds its nest, lays its eggs and then dies. Their free life in the water is then only two or three weeks, perhaps less.

Economics of Lampreys

Economically the lampreys have two sides, good and bad. On the good or credit side, they supply food for human consumption and also for fishes; and they form excellent bait* for fishing. In England especially, according to Couch and Seeley, as many as 45,000 have been used in a single year in the cod and turbot and other deep sea fisheries. Also they were much sought after for human food as shown by the literature of England and the Continent. In our own country, in New England, the large sea lampreys were much used as food in the early days, and still are used, but to a less extent. On the bad or debit side, the lampreys destroy and injure many food fishes during their parasitic or predatory life.

Economics of Larval Lampreys.— The larvae, mud-or-sand-lampreys, ammocoetes, of all kinds have only the credit side to their account as they eat microscopic animals and plants abundant in the mud-banks where they grow up, and therefore never injure human food supplies. They, on the other hand, furnish excellent fish food when by chance of freshets or other means they are turned free in the water. This is probably one strong reason why they are so restless when free in the water, and why they seek so eagerly the protection of the covering of sand and mud. From their excellence as fish food, and their tenacity on life, they make good fish bait and are much sought after for that purpose. Formerly, and still to a less degree, there is and was quite a trade in larval lampreys for the fishermen. From Owego, Binghamton and Ithaca, the mud-lampreys were sent in milk cans in all directions. Still in the branches of the Delaware the larvae are much sought as fish bait to be used in the streams of the Catskill mountains and in New England they are supplied by the bait dealers. In a word, the larvae or immature lampreys in the mud-banks, are not at all harmful, and wholly beneficial.

Economics of the Brook Lamprey.— As was proved by exact experiments in 1897–98, and subsequent years, the brook lamprey never takes food in its adult life, and therefore never harms in any way, human food supplies. Its larvae or mud-eels, eat only microscopic organisms, and besides are excellent bait for fishermen. The brook lamprey then is never harmful, and may be made beneficial if its young are used for bait.

* The larvae or young living in the mud and gravel where there is slack water along the streams where the eggs are laid may be secured by means of a scoop-shovel or more abundantly with a hand-dredge. A scoop partly full of the mud where they are supposed to be is taken out on the shore and spread out on the ground. The larger ones will squirm out as the water drains away, and the smaller ones can be seen when the mud and gravel is spread out rather thin. They look something like angle worms. From successive freshets, they are carried downstream so that for the larger larvae one searches farther downstream, and also in somewhat deeper water.

Economics of the Sea Lamprey.— On the good or credit side the sea lampreys always spawn in fresh water, and on their way from the ocean to the spawning grounds are in excellent condition. They take no food on this migration, and therefore do not injure the fishes in the rivers and streams where they spawn. On the other hand they make wholesome food for human beings; and their young, the mud-eels or sand-lampreys make good bait. After laying their eggs, the sea lampreys die and never return to the ocean. Hence, in the river fisheries of New York, the sea lamprey is not injurious but beneficial. In New England, they were much sought after, and were caught by the barrel, and salted down for future use. The farmers away from the rivers, according to Goode,* would trade a barrel of pork for a barrel of lampreys.

In Alaska, the Indians look forward to the annual migrations of the Pacific lampreys (Entosphenus) up their rivers and collect large numbers of them to supply food for their dogs as well as for themselves. By personal experience it is known that lampreys are good food when in full vigor on their way to spawn.

The bad or debit side of the sea lamprey is comprised wholly in its predatory or parasitic life, and this is practically all spent in the ocean. The transformed young in the streams leading to the sea might attack river fish for a meal or two, but they are very small and the injury to the inland fisheries is therefore negligible. On the other hand no doubt many of these transformed ones on their way down the river are snapped up by the river fish and are themselves turned into food.

Once in the ocean, those which survive must increase 35 to 55 times in length and 95 to 135 times (Fig. 7) in weight before they are ready to migrate up the streams where they were born to start a new generation. This means an enormous amount of food, for in addition to the increase in weight there must be a much larger amount of food taken to keep them alive, and furnish energy for hunting their prey.

The fishes known to be fed upon by the lampreys in the sea, as given by Goode[1] and Bigelow,[2] are: cod, haddock, mackerel, shad, sturgeon, salmon and even the basking shark.

Economics of the Lake Lamprey.— Unlike the sea lamprey, the lake lamprey passes its entire life cycle in fresh water. All its predatory life is in the lakes of the State, and therefore its

* Goode, G. Brown. The fisheries and fishery industries of the United States. Section 1, Natural History of useful aquatic animals. Lampreys, pp. 677–681, Washington Government Printing Office, 1884.

[1] Loc. cit.

[2] Bigelow, H. B. Fishes of the Gulf of Maine. Bull. Bur. of Fisheries. Vol. 40, part 1, p. 19, 1924.

influence on the inland fisheries is considerable. On the good, or credit side their young, the ammocoetes or mud-lampreys, are excellent bait for fishing, and no doubt many of them serve as fish food when washed from the mud-banks by freshets, also when migrating down the streams to the lakes.

When they reach the lakes, there is, so far as known, no good economic side. They prey upon the food fishes, and in return never are turned into human food as are the sea lampreys. The food fishes that I have known to be attacked are: pike, pickerel, bullheads, carp and suckers. Although present in Lakes Erie and Ontario, their destructive habits have been most studied in connection with the fishes of Cayuga, Seneca and Oneida lakes. They attack all food fishes, and when hungry enough, attacked a ganoid (bowfin) in our aquarium. According to Surface * and Bensley, they have been known to tackle even a garpike. (*Lepisosteus osseus*). Old fishermen have told me that when the sturgeon was still found in Cayuga lake, the lampreys were particularly attentive. Often six or seven might be found attached to one fish, something as shown for the carp in Figure 1.

Drs. Smallwood and Struthers, investigating the carp in Oneida lake this summer (1927), told me that often more than half of the carp in a haul would be lamprey marked. Dr. Eaton in his work found that 34 out of 38 of the lake trout caught in Seneca lake were lamprey marked; and in Cayuga lake, two of the four trout caught were so marked. Several years ago when there was commercial seining of carp in Cayuga lake the fishermen told me that fully half of the carp seined had lamprey marks upon them. Dr. Embody in securing fish early in the season for the spawn for the Cornell fish hatchery, told me that he had never found more fish that had been mangled by the lampreys. The large number of mature lampreys at the head of Cayuga lake this spring was abundantly confirmed by me later in collecting them on the spawning grounds. They seemed as numerous as twenty-five years ago.

As pointed out to me several years ago by Dr. A. H. Wright, the depredations of lampreys are greater at the head, or southern end of Cayuga lake than near the foot, and Dr. Eaton told me that this summer more of the fish at the southern or upper end of Seneca lake were lamprey marked than at the lower or northern end. The observations of Drs. Smallwood and Struthers in Oneida lake this season, point in the same general direction, that is, in all the lakes, the greatest destruction by lampreys is near the entrance of the streams in which they spawn. In Oneida lake the spawning streams are more distributed than in Seneca and

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* Surface, H. A. The Lampreys of Central New York. Bulletin of the U. S. Fish Commission, Vol. 17, 1897.

Cayuga. In these last, so far as known, only those streams entering the southern end of the lake serve as spawning places.

In trying to estimate the damage done to the food fishes by lampreys it would be of great help if it were known just how long it takes the lampreys to mature in the lakes.

During the last 50 years many lampreys preying upon fish have been taken from Cayuga lake at all seasons of the year, even during the spawning season, and from a careful study of the size and stage of development of these direct from the lake it does not seem possible that any of them could reach maturity and lay eggs during their first parasitic year. It is possible that they might be ready to spawn during their second year. As they commence their predatory life mostly in February and March and lay their eggs in May and June, this would make one and one-third years the shortest possible time for their predatory life. From the material studied it seems much more likely, however, that eggs are laid when the lampreys have been from two and one-third or three and one-third years in the lake. Possibly the time may be longer.

As stated for the time required for their larval growth and development, the only sure way to find out how long a time is required for the growth and maturity of the adults is to secure just transformed lampreys and keep them under as natural conditions as possible until they are completely mature. There is no difficulty in keeping them alive in running water in an aquarium, and they are not at all backward in securing a meal of blood from any fish that is available. Unfortunately no such experiment has been tried with any parasitic lamprey, therefore at present one must depend on estimates.

Experiments on the Predatory Habits of Lampreys.— In order to see how the lampreys and fish act when in the water together, and how the lamprey attaches itself to a fish, one of the bathtubs in the house was turned into an aquarium. Large and small stones were put in the bottom to make the place as homelike as possible, and running water was supplied all the time. The experiment was begun in December 1914 and continued until late in March, 1915, that is, somewhat over three months. At different times there were one or more bullheads (*Ameiurus*), suckers (*Catostomus*) and carp (*Cyprinus carpio*) with the lampreys. To make the fauna more complete some frogs and a necturus were put in the tub.

When first brought from the lake the fish and the lampreys were rather restive and tried to get behind or under the stones in the bottom. Then a cover was put over a part of the tub, and they remained most of the time in the shadow. In the evening they swam around anywhere in the tub, but when the light was turned on they mostly retreated to the shaded part.

The lampreys and the fish seemed wholly indifferent to one another. Often a lamprey would swim alongside a fish or a fish would bump into a lamprey. This seemed strange, for chickens are much agitated when they see or hear a hawk. Perhaps this is because in the racial history a hawk in the neighborhood practically always meant an attack, while with the lampreys there is only occasionally an attack. In this experiment it was noticed that at night the lampreys were of a considerably lighter tint than in the daytime. That is, in the day time the pigment cells seemed to be spread out more evenly, and gave therefore a darker appearance.

As stated, ordinarily the lampreys and the fish swam around together without apparently noticing one another. When, however, a lamprey felt the need of a free meal he would swim along near a fish as usual, and then suddenly with a side movement, the sucking mouth was brought up against the body of the fish and stuck fast. Great excitment followed. The fish would dash around the bathtub as if bewitched, and run up the sloping end of the tub almost out of the water. But it was of no use; the harder the fish tore around the tighter the lamprey stuck.

After several minutes the fish seemed exhausted and thoroughly discouraged and remained rather quiet. On watching the lamprey it seemed to be working hard to get something from the fish. The movements of its head and body reminded one of the actions of a suckling pig or kitten. After some especially hard suck the fish would jump and struggle as if it hurt. It probably did, for when the lamprey let go or was taken off there was always an ugly hole rasped in the fish.

I saw many attachments, and found that the lamprey could hold fast in almost any position, although a favorite position was near one of the fins. Sometimes the attachment was over the eye. In that case the rasping tongue would dig the eye out. This happened in several instances. The lamprey could change the position of its sucking mouth without letting go. This was strikingly shown in a fully scaled carp. The lamprey apparently did not strike a good blood supply when it drilled the first well, so it slid along and dug another so that there were two ragged holes only a short distance apart.

Besides the above, these experiments were carried on to settle the following points:

Does the lamprey always kill the fish it preys upon?

How long does a lamprey remain attached to a single fish?

How often does a lamprey need a full dinner?

What is the nature of their food?

How much blood is required for a full meal?

(a) In answer to the first point, it was found that if the fish was relatively large, the lamprey does not usually kill it, but if the fish is small, the lamprey may kill it. Several examples with large and with small fish showed this over and over.

(b) It was shown by repeated observations that when a lamprey was fully satisfied, it would let go of the fish. In one especially satisfactory case a lamprey attached itself to a bullhead (*Ameiurus*) at 8.30 a. m. January 14, 1914. At 9 p. m. January 19 the lamprey was still attached, and the bullhead seemed greatly dejected. At 5 a. m., January 20, the lamprey had released the bullhead. It showed a savage hole in its side where the lamprey had been attached. In this case the lamprey had been with the fish for about five days. From this experiment, then, it would appear that a lamprey remains only a few days attached to a single fish, and when its hunger is completely satisfied it lets go of the fish and swims freely in the water. This conclusion is supported by the observations of fishermen that lampreys often attach themselves to their boats and sometimes to the oars.

The confirmation is emphatic in the lamprey given me by Professor Smallwood. This was found clinging to the rudder of their boat when they returned from a cruise in Oneida lake. On opening the lamprey it was found with the entire intestine filled with blood. Further confirmation is given by fishermen who sometimes find on a single large fish several lamprey marks, some fresh and some partly healed.

Taking all the evidence of personal observation, the attachment of lampreys to boats and partly healed lamprey scars on fish, it seems certain that, as with the laboratory experiment, a lamprey remains with one fish only a limited time, when both go free. When again hungry the lamprey hunts up a new victim.

(c) With reference to the frequency of their meals: Naturally their meal time must be rather irregular, but judging from the observations made in the bathtub experiments it seems to be once in about three weeks. This conclusion is reached because the lampreys brought fresh from the lake in December and January always had the intestine full of blood. These were kept in the bathtub with fish. The one described above in (b) came December 9, and remained in the tub with the fish until January 14 before attacking the bullhead for a new food supply. In this case the lamprey went 36 days without seeking food, when plenty of it was in sight all the time. It then took about five days to get a new supply from the bullhead. This experiment shows then that the lampreys need a full meal about once a month.

(d) For determining the nature of the food of the lamprey many have been killed immediately upon their receipt from the lake, and the intestinal contents examined both with the naked eye and with the microscope. The one described in (b) above was studied with especial care for it could be investigated within a very short time after it had liberated the fish. There was found first of all blood. The color alone might have been sufficient, but it was put under the microscope and the blood corpuscles, and blood crystals demonstrated. Then it was subjected to the spectroscope and the characteristic absorption spectra found.

In the second place there was a small amount of minced striated muscle, and some connective tissue with fat and pigment cells. The presence of the muscle, the connective tissue and the fat and pigment cells is perfectly intelligible for all these were torn away by the rasping tongue in order to reach the blood supply. But as stated, the principal bulk of the food in the intestine was blood. Many other examinations showed the same to be true.

Especial care was taken to determine the kind of food, for various authors have stated that lampreys eat insects and worms, the slime of fish and even small fish and fish eggs. The oesophagus of the lamprey is not well adapted to the taking of any but liquid food, and according to the easily verified researches of Vera Mather,* there is a special grating over the entrance to the oesophagus of the Pacific Coast lampreys (*Entosphenus*) which would make the swallowing of insects, worms, etc., very difficult. Neither is the mouth and rasping tongue adapted for the securing of such food. The whole mechanism is adapted for securing and swallowing liquid food, that is blood, and any minced muscle or other finely divided tissue present in the intestine with the blood is accidental, a by-product, so to speak, of the process for getting the blood.

Furthermore in confirmation that the natural food is blood it was found the present spring, (1927) that all the lampreys have special glands, buccal glands (Fig. 6), to produce an anticoagulat-

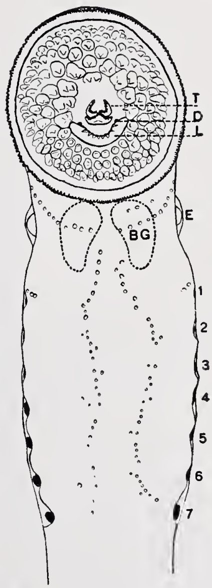

Fig. 6.—Ventral view of the head and branchial region of a lake lamprey to show the position of the buccal glands and the opening of their ducts. BG. The bean-shaped, buccal glands at the level of the eyes (E). T. The rasping tongue. D. The duct-opening of the left buccal gland. L. The infraoral lamina. 1, 2, 3, 4, 5, 6, 7. The seven branchiopores or gill openings on the left side. (From Science, Sept. 27, 1927).

* Mather, Vera G. The velar apparatus of Entosphenus tridentatus (Pacific lamprey). Anat. Rec. Vol. 34, 1926.

ing substance which is poured out near the rasping tongue where it can bathe the torn surfaces and come in contact with the blood as it emerges from the vessels, and keep it liquid.

(e) The amount of blood required to fill the intestine of a full-grown lake lamprey was found on measurement to be about 25 cubic centimeters (nearly a fluid ounce). The fishermen often speak of the paleness of the fish which they find a lamprey attached to; is it any wonder if they look pale after losing so much blood?

Estimation of Damage Done by Lampreys.— With the above facts in mind, it is possible to give an intelligent discussion of the very practical question of how much injury the lampreys actually do to the food fishes in the waters where the lampreys are found. As shown above, large numbers of fishes are attacked, and of course the greater the number of lampreys the more damage they do.

One year accurate count was kept of all the lampreys caught on the spawning beds, and the number of nests in the main inlet of Cayuga lake. Over four hundred nests were counted in the extent of about 2½ miles, and more than one thousand lampreys were actually caught. That of course did not make the full number that spawned that year. They are not so numerous every year. On May 31, 1920, members of the department of zoology were taken to the inlet of Seneca lake above Montour falls. The water was teeming with lampreys and nearly five hundred were secured in a couple of hours. Great numbers have also been secured at other seasons in that place, so that it is quite intelligible why so many of the fish in Seneca lake are lamprey marked.

Suppose that Oneida, Seneca or Cayuga lake has one thousand lampreys in its waters at one time. This would represent only a part of those that went down to the lake to begin their predatory life. In nature there is a great mortality. Of the hundreds of thousands of eggs deposited in a stream any one year, only a very few survive to reach maturity and return for laying eggs for another generation. Many of the larvae are caught by fish when they are washed out of the mud, and even the transformed ones at the beginning of life "the blue lampers," are snapped up on their way to the lake and in hunting for victims.

"To eat and be eaten" is the law of the water as of the jungle. There are also unknown causes that produce mortality with the lampreys as of other living things. Death may come at any time from the egg to the adult stage of life. One lamprey was found early in the season up one of the spawning streams with its branchial region so far digested that the cartilages of the branchial basket were exposed. Dr. Wright told me that on one occasion he was watching the lampreys in the inlet and saw a big water snake go in, grab a lamprey and carry it out on land. In spite of the great mortality there must be a large number preying on the fish of the lake all the time.

The question then is how much fish food in the form, mostly of blood, is necessary for the young lake lamprey to grow from a length of 13-14 centimeters (about 5 to 6 inches), to a length of 40 centimeters (15 to 16 inches), and from a weight of 5 grams (1/6th oz.) to 200 grams (7 ozs.).

Every one who has had experience in feeding growing animals knows that it takes much more than a kilogram, or a pound of food to have the animal increase that amount of weight. This is because it requires so much food just to keep an animal alive and supply the energy needed for the heart to beat and the respiration to be carried on, and many other activities of the living body. So with the lamprey, a great deal of the energy supplied by its food is used to maintain its life processes and to hunt its prey, and once attached to rasp away the tough skin and the muscles and thus open the blood vessels and suck out the blood.

As the lamprey is a cold-blooded animal and does not require any of the energy of its food to maintain a constant temperature it may be fairly assumed that more of its food might be utilized for growth and increase in weight than with a warm-blooded animal. Unfortunately there is not the wealth of nutritional information for cold-blooded animals as for man and the domestic animals that have a fairly uniform body temperature.

During the last year, however, at the Connecticut fish hatchery some exact experiments* have been made with known diets, and the amounts utilized for growth have been determined with scientific accuracy. Three standard diets of liver, skim-milk, and supplementary small amounts of yeast and cod liver oil were fed to groups of fifty trout. An average of 29% in weight of the food was utilized in growth by the trout. Assuming that the lamprey would gain an equal amount as the trout on this liver-skim-milk

Fig. 7.—Diagram showing the relative weight and length of lampreys at maturity (m) and at transformation (t). The sea lamprey (S) is about five times as long and weighs over one hundred times as much at maturity (m) as at transformation (t). The lake lamprey (L) increases about three times in length and twenty-seven times in weight, while the brook lamprey (B) is practically unchanged in length and weight from transformation (t) to maturity (m).

* Information and permission to use by Dr. C. M. McCay.

diet, then to grow from five grams to 200 grams in weight— or to increase 195 grams, would require 195 grams divided by 29%=672.41 grams or 1.48 lbs. of this food. But the natural food of the lamprey is fish blood, and from the tables in Lusk's Nutrition, p. 579, the average nutritive value of fish flesh is less than half that of the liver and skim-milk, hence it would require at least twice as much blood, probably much more, for the lamprey to gain 195 grams, that is 672.41x2=1344.82 grams or 2.96 lbs. If there were one thousand lampreys in a lake—and more than that have been caught from Cayuga lake some years—it would require at least three thousand pounds of fish blood to bring them to maturity. Every one would probably agree that this would be a heavy toll to pay, when the only return is a limited amount of fish bait supplied by the ammocoetes!

Possibility of Ridding a Lake of Lampreys.— In the economic struggle with insects, and other creatures that claim a part of the products of the earth and waters that man wants for his own sustenance, man's success in overcoming his competitors depends largely upon the completeness of his knowledge of their life history.

With practically every living thing there is some time in the life cycle when they are most easily destroyed. It is evident to every one that it would be hopeless to try to catch and destroy all the lampreys scattered throughout the waters of a lake. It would be equally hopeless to try to dig all the larvae out of the mud-banks along the spawning stream; but there is one time when the lampreys that have reached maturity are particularly exposed, and that is when they run up from the lake into the small streams to lay their eggs. If weirs or traps are put across those spawning streams and all the lampreys caught and destroyed before any eggs were laid there would be no new generation started. In streams where high dams have been constructed and no fishways arranged for, the fish that ascend the streams to spawn soon disappear above the dams. Also in some streams so much pollution has been poured into them that all the young fish are destroyed. It looks absolutely simple on the face of it to deal with the lampreys. But it is far from simple. If even one pair got through and laid the thousands of eggs carried by the female, enough of the eggs would hatch, and young survive to restock the lake in a few years.

Again in the mud-banks of the spawning streams there are four to five generations of larval lampreys growing up to enter upon the predatory life, and every year for four to five years a generation would mature and go down to the lake and remain from one and a third to three and a third years.

If then every lamprey going up to spawn were caught and killed, this must be done for from six to eight years to get the last pair. Of course the more that are prevented from spawning the fewer would the predatory lampreys be, but to eliminate them absolutely would require the time mentioned. Furthermore as the waters of the lakes communicate through their emptying streams—Seneca river, for example,—it would be necessary to prevent their wandering from one lake to the other. Probably the simplest method would be to rid all the lakes of lampreys; but if that is undertaken it is worth while to know exactly what the effort would involve. A trial (Surface*) was once made in the inlet of Cayuga lake and many early lampreys caught, but a freshet washed away the lamprey traps, and the late lampreys went gaily up the swollen stream to their spawning grounds as usual.

As a final word, the lampreys can be eliminated but it would be neither a short job nor an inexpensive one.

Summary of the Economics of Lampreys:

1. In general, lampreys are both beneficial and injurious.

2. The brook lamprey does no harm to human food supplies, and its larvae furnish excellent bait for fishing. This lamprey in the New York waters may be put down as wholly beneficial.

3. The large sea lampreys in the ocean feed upon the blood of fishes and this species is therefore injurious to the sea food-fish. In the rivers on its way to the spawning grounds in the headwaters it takes no food, and is in itself a good food for human consumption. Its larvae are excellent for bait. In the inland waters of New York, then, the sea lamprey is beneficial.

4. The lake lampreys in their larval stage are excellent for bait, and that is their only redeeming feature. The adults live in the waters of the lakes and grow up on the blood sucked from food-fishes, killing some and weakening all they feed upon.

5. Each lake lamprey lives from 1 1/3 to 3 1/3 years as a parasite on fishes in the lake, and requires for its growth to full maturity, probably at least three pounds of fish blood.

6. For ridding the lake of lampreys, advantage must be taken of the weak spot in their life cycle, viz. their migration up the small streams to spawn. If they are trapped and killed before laying their eggs, no new generation can be provided for.

7. As the spawning time extends from the last of May to the first few days of July, the trapping season must correspond, for one pair with their hundred thousand eggs would soon restock the lake.

8. As the larvae or ammocoetes remain in the mud-banks from four to five years, a new generation would pass down to the lakes for a predatory life each year for that period.

9. Also as the predatory life is from 1 1/3 to 3 1/3 years it would require from six to eight years continuous effort to rid a lake of lampreys, and every stream in which they spawn would have to be trapped.

10. And finally provision must be made by which lampreys from neighboring lakes could not reinfest the lake through communicating streams: (For example, the Seneca river for Cayuga and Seneca lakes.)

* Loc. cit.

IX. A QUANTITATIVE STUDY OF THE FISH FOOD SUPPLY IN SELECTED AREAS

By P. R. NEEDHAM,

Instructor in Limnology and Ecology, Cornell University

The immediate purpose of these studies was to determine, as far as possible, the relative amounts of fish food available in different types of stream conditions, an important consideration in the development of a stocking policy. Further, it was desirable to begin research work on a few main problems in trout culture under wild conditions which could be carried on from year to year, the results, as obtained, being applied toward improvement of fishing conditions.

The following problems were selected for study:

1. Relation of width of stream to quantity of primary food organisms.
2. Relation of types of bottom to quantities of food.
3. Amounts of terrestrial food animals which fall into the water and probably serve as food for trout.
4. Comparison of quantities of available food found in various types of submerged plant beds.

By designating the animals found in streams as "available" food, it is meant that while some of the animals may not actually be eaten by trout, nevertheless they are present in streams and represent possible or potential foods which could be eaten if the trout desired. In quantitative studies, in order to establish averages with a low probable error, much data must be available as a working basis. In these studies, with limited time, insufficient figures were obtained with which to calculate true averages and hence the probable error is doubtless greater than if more figures had been available. Therefore it seems desirable to consider these results as tentative until further work can be done and to consider this in the nature of a progress report.* The summer season of three months from June 15 to September 15 was devoted to the study of these problems.

These results having entirely to do with potential or available food as it is found in the streams in this vicinity, should in future studies be correlated with the actual food of trout under these same conditions to determine what foods are actually turned into fish flesh and the proportionate amounts of each. Once this knowledge is gained, it will be possible to work towards increase of natural foods under wild conditions.

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* Lack of space did not permit insertion of full proof of all statements and description of apparatus and methods used. This can be found in the files of the N. Y. State Conservation Department and in the Limnological Laboratory of Cornell University.

Mr. Deleon Walsh worked with the writer during the entire period both in the field and in the laboratory.

Streams near Ithaca were chosen for study because first of all, indoor laboratory facilities were essential and easily obtained here, and secondly, the trout streams in this vicinity are typical of thickly populated regions, are heavily fished, and flow, for the most part, through cultivated lands.

Places in streams where studies were made are designated by the term "station" and given numbers (see appendix, maps 1 and 6). Stations were not numbered in sequence or any particular order and were given numbers after a given set of studies had been completed. Stations number 1, 2, 3, 4, 6, 8, 9, 12 and 17 were located on Sixmile creek; numbers 7 and 15 at the headwaters of Newfield creek; 5 on a tributary of Virgil creek about three-fourths of a mile east of Dryden, N. Y.; 10, on lower Enfield creek and 18, on the East Branch of Fish creek (Lewis county) about 1 mile west of Michigan Mills.

Relation of Width of Stream to Quantity of Food Organisms.— Leger* states that the food of a stream decreases by one half from the shore line to the middle of the channel in a stream five meters or more in width (16.4 ft.) and that the nutritive elements are found mostly along the banks at a distance of 1-2 meters from the shore. He also notes that small headwater streams, narrow in width, are usually very rich in food.

In order to gather data on this problem all the animals were collected from three separate square feet of bottom taken transversely across each stream over three feet in width, arranged as follows: the first square foot unit area was taken in shallow water, near one shore and in relatively slow current; the second in mid-stream in the center of the channel in the deepest water and the swiftest current, and the third was in shallow water, moderate current near the opposite margin and in approximately the same corresponding position as the first square foot.

The apparatus used in making these unit area catches consisted of a galvanized iron box, one foot square inside measurements, 18″ deep with square sieve dipper for washing and dipping out organisms (Fig. 1). This apparatus was found very satisfactory for obtaining practically all the available fish food from one square foot of bottom in all situations studied.

After collection the specimens were brought to the laboratory, sorted and weighed. The total catch of available food from one square foot was weighed together, separate individuals or categories of organisms not being weighed unless an extra large individual or group was taken, which would throw the weight off in proportion to numbers.

Table 1 shows the results obtained. The weight in grams obtained by weighing the animals taken from the separate square feet of bottom are given by station number and in sequence by stream width. The column "Av. difference wt. in grams" gives by

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Loc. cit. p. 27.

Fig. 1.—Galvanized square foot with sieve dipper in use

averages, at each station, whether or not the center of stream beds contain more nutritive elements by weight, than is found at the sides of stream beds.

By comparing bottom studies made in streams under seven feet in width with those above seven feet, it is evident that these small, cold headwaters produce much more available fish food per unit area than the larger, warmer main trunks. The average weight of nutritive elements per square foot of bottom in streams under seven feet is 2.36 grams, for those above seven feet it is 1.04 grams, a difference of 1.32 grams; or in other words, streams below seven feet in width probably produce more than twice the food by weight per unit area of bottom.

It is readily seen that the quantity of food organisms in streams above 18 ft. in width decrease from the shore line to the middle of the channel. At the fifteen foot (station 6) stream width the three bottom catches weighed almost the same showing that the food was fairly evenly distributed over the bottom, but still higher in the center. At the eighteen foot stream width (stations 1, 3) the food has materially decreased in the center of the stream bed

TABLE 1. — SHOWING DISTRIBUTION OF AVAILABLE FISH FOOD IN STREAMS ABOVE AND BELOW 18 FEET IN WIDTH

Approximate location of separate square feet from which collections were made.
1st sq. ft. . . in shallow water near one shore.
2d sq. ft. . . in center of stream bed
3d sq. ft. . . in shallow water near opposite shore.

	STATION NO.	Width	1st sq. ft. wt. in grams	2d sq. ft wt. in grams	3d sq. ft. wt. in grams	Av. difference between 1st–3d sq. ft and 2d sq. ft., in grams
Below 18 ft.	11	3 ft.	.98	2.5	1.5	1.26 higher in center.
	15	6 ft.	3.97	4.19	.65	1.88 higher in center.
	4	6 ft.	.99	1.98	1.01	1.01 higher in center.
	7	7 ft.	3.64	1.59	5.36	2.91 higher in sides.
	10	11 ft.	.78	1.43	.75	.67 higher in center.
	1	14 ft.	2.73	1.5	1.4	.57 higher in sides.
	6	15 ft.	.65	.75	.65	.098 higher in center
Above 18 ft.	1*	18 ft.	1.72	.53	1.24	.96 higher in sides.
	2	18 ft.	1.37	1.04	1.14	.21 higher in sides.
	8	25 ft.	.33	.065	.63	.41 higher in sides.
	18	30 ft.	3.67	1.67	2.18	1.25 higher in sides.

* These three bottom studies were weighed from alcohol after preservation for several weeks and the results corrected by a coefficient which reduced the probable error due to loss of body weight by alcohol.

and the sides have become more productive. No studies were made in streams intermediate between 15 and 18 feet in width, though it is possible that the change may occur at some width lower than 18 feet or above 15 feet. Thus these figures agree in general with Leger's work but are too few to calculate with certainty the rate at which this occurs.

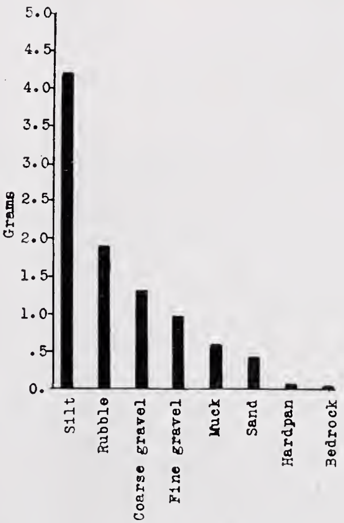


Chart 1.—Showing relative amounts of available fish food by grams per one square foot in selected types of stream bottoms

Relation of Bottom to Quantity of Food.— Table 2 shows the stream bottom types studied and the relative amounts of food found on each type of bottom. Silt bottom supported the greatest amount of fish food, there being an average of 4.29 grams in one square foot. Rubble sheltered the next largest amount in having 1.88 grams per square foot. Coarse gravel was nearly as productive as rubble, having 1.281 grams. Fine gravel, muck and sand offered about the same amounts, while hardpan and bedrock were very poor in food. Chart 1 shows graphically the relative amounts found on the different types of bottom.

Comparison of Quantity of Food in Stream and Pool Bottoms.— Unit area bottom studies were made in pools to determine the forage possibilities which pool bottoms offer as compared with stream bottoms. The average amount of available fish food by

TABLE 2.— SHOWING STREAM BOTTOM TYPES OF AVAILABLE FISH FOOD

NUMBER SQUARE FEET TAKEN	Type of bottom	Average weight in grams per sq. ft.
4	Silt	4.29
12	Rubble	1.88
18	Coarse gravel	1.281
7	Fine gravel	.98
1	Muck	.65
2	Sand	.46
1	Hardpan	.1
1	Bedrock	.0065

Average for all sq. ft. .... 1.21 grams

weight in one square foot of pool bottom was found to be .26 grams, covering all types and sizes of pools. The average amount of available food by weight in one square foot of stream bottom was 1.21 grams covering all types of streams. By dividing it it is seen that the food, by weight, in one square foot of stream bottom is approximately 4.6 times as rich as the same size area in a pool bottom, i.e., there is 4.6 times the potential food in a stream bottom as compared to pool bottoms. The pool bottoms and stream bottoms in which these studies were made contained little or no aquatic vegetation which, when abundant, supports large numbers of animals. The populations of submerged plant beds are considered in another section of this report.

The low average weight of food found in a unit area of pool bottom is somewhat compensated for by the fact that there is greater area for foraging in a pool per given unit of stream, because pools are generally wider and deeper than the average for the stream.

Comparison of Quality of Food in Stream and Pool Bottoms.— By referring to Table 3, it is seen that 36.9% of the 6,277 stream bottom animals taken were mayfly nymphs, while in pool bottoms they constituted 41.24% of the 565 animals collected. Whereas the per cent of mayfly nymphs in rapid water bottoms was 36.9% as compared to 41.24% in pool bottoms, it must be kept in mind that they constituted the largest single food element taken in stream bottoms, while in pool bottoms they occurred second to fly larvae and pupae, showing a decided preference for lotic water. Stonefly nymphs, caddisfly larvae and pupae, beetle larvae and adults, crayfish and shrimps (Crustacea), snails and clams (Mollusca) were found in greater numbers in rapid water bottoms. Sialis larvae (*Neuroptera*), dragonfly and damselfly nymphs showed a preference for the quieter pool waters.

TABLE 3.— SHOWING COMPARISON OF AVAILABLE AQUATIC FISH FOOD FROM BOTTOMS IN RAPID WATER AND IN POOL BOTTOMS.
(Given in numbers and per cent by order)

ORDER	RAPID WATER BOTTOMS		POOL BOTTOMS	
	Number	Per cent	Number	Per cent
Mayfly nymphs	2,316	36.90	233	41.24
Stonefly nymphs	921	14.67	23	4.07
Caddisfly, larvae and pupae	1,335	21.27	7	1.24
Beetle, larvae and pupae	476	7.58	15	2.65
Fly larvae and pupae	869	13.84	264	46.73
Sialis larvae et al. (Neuroptera)	58	.92	12	2.12
Dragonfly nymphs and damselfly nymphs	8	.13	3	.53
Crayfish and shrimps	235	3.74	1	.17
Snails and clams	15	.24	1	.17
Miscellaneous	44	.7	6	1.06
Totals	6,277	99.99	565	99.98

Terrestrial and Other Food Animals Falling Into Streams.— For this class of food material the name "drift food" is proposed, a term including all forms of available food, both plant and animal, which may be carried by a current of water in a stream.

Drift food was collected from streams of various types and widths in different localities in an effort to find out the relative amounts available under different conditions and widths of streams. It has long been known that terrestrial insects and other food animals accidentally falling into the water furnish abundant food for trout, though the relative amounts of such food and the types of stream environment which furnish the greatest amounts of such food have never been known.

The apparatus used in collecting the drift food consisted of a "drift net" (Fig. 2) and a "stop net" (Fig. 3). The drift net collected the drift by straining the water and retaining the organisms. The stop net was placed 250 yards upstream above the drift net and strained all the drift food from the water which was being carried downstream from sources upstream, so that the drift food could be taken from a given area of stream (250 yards) over a standard period of one hour in each study.

All the drift organisms from a 1-hour, 250 yard catch, were weighed together, separate food organisms not being weighed unless extra large individuals were taken which would throw the weight off in proportion to numbers.

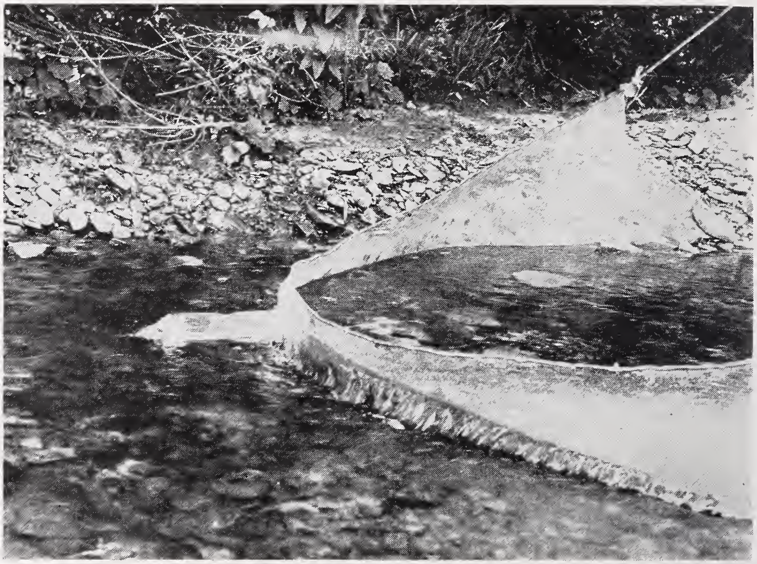


Fig. 2.—Drift net in use

Selection of areas in streams for study of available drift was based on their ability to illustrate as far as possible the relative amounts of available drift food found in given types of stream environment. These fell roughly into four classes: arboreal (forest covered), areas covered by thick growths of brush, semi-exposed and exposed. No two selected areas will ever be exactly alike for many factors other than merely cover or the lack of it go into the making of any environment.

Table 4 gives a summary of the results obtained. The right hand column of figures gives the estimated production of drift food in grams per 100 square feet of surface* for each type of habitat. These estimates are based upon the average weight of

* This includes not only animals found floating on the surface but also those carried in suspension beneath the surface.

drift food from each type and are calculated from the formula: $\frac{grams \times 100}{square\ feet}$ = weight in grams of drift food per 100 square feet.

TABLE 4.— SUMMARY OF STREAM DRIFT

No. of determinations	Type of stream environment	Average weight in grams of drift food from 100 sq. ft. of surface
5	Arboreal	.013
6	Densely shaded with low brush	.0095
9	Semi-exposed	.0091
9	Exposed	.0074
29	Average over all types of environments	.0097

Stream width being considered first, without taking into account types of stream environments, it was found that in general the greatest quantities of drift food were taken in streams having the greatest widths. However it was observed that some narrow streams due to their more favorable surroundings yielded greater amounts of drift food, per 100 square feet of surface, in pro-

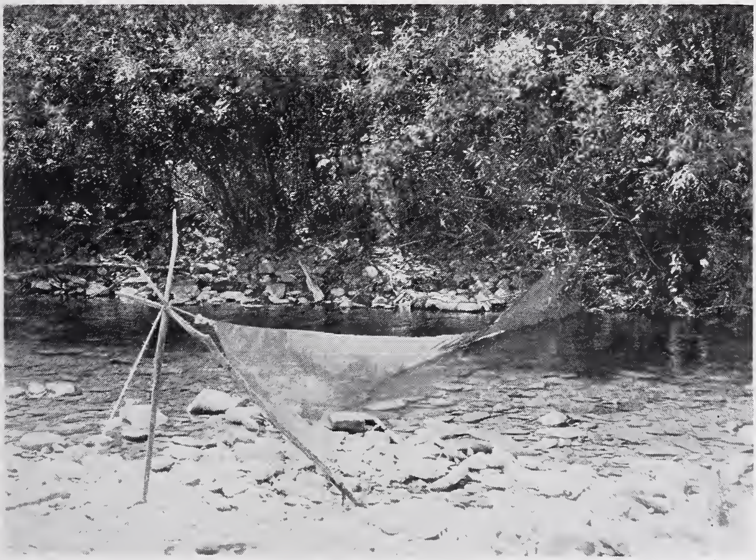


Fig. 3.—Stop net

portion to their width than wider streams less favorably situated. Thus it is shown that width alone is not a true criterion for available drift food in streams. Stream environment must also be considered.

By comparing the average weights, shown in Table 4, of drift food per 100 square feet found in each type of stream habitat, i. e., arboreal, densely brush-shaded, semi-exposed and exposed, it is seen that the arboreal type of environment contributed the most food per 100 square feet of surface, .013 grams. The four types of stream environment intergrade more or less but are sufficiently distinct for general comparisons.

The arboreal type of stream environment as considered here consists of a tall growth of hard woods and conifers bordering the stream and generally not shading the stream center. Such habitats naturally shelter large numbers of terrestrial insects and since it is somewhat open to the wind, many are doubtless dislodged and fall into the water. Probably because of these factors, this type of habitat furnished the largest amount of drift food per 100 square feet of surface. Stream habitats densely shaded with low brush and small trees are common at the headwaters of streams in this vicinity. These also shelter many insects but being less open to the force of the wind, fewer insects are dislodged into streams at such places and less drift food is present in them. Semi-exposed stream habitats are bordered partially by pasture and partially by scattered trees such as alders, willows and sycamores. In exposed habitats the streams flow entirely through meadows and pastures and have only low grasses and herbs on their margins. The semi-exposed habitats furnished slightly more food, per 100 square feet of surface, than the exposed, probably because the few trees growing along the banks of the former, harbored more terrestrial insects than the low grasses and herbs along the banks of exposed streams, and because the force of the wind on the scattered clumps of tall vegetation found in the semi-exposed areas, would dislodge many possible forage organisms.

Three drift catches were made at dusk at stations 1, 2, and 6 in July to determine whether or not more food was available in streams at this time of day. It was found that slightly less drift food was available at this time as compared to that found during the full daylight hours. Two drift studies were also made at midnight. Although the differences in productivity per unit area were very slight between dusk and midnight drift catches, it was found that in daylight hours, slightly larger amounts of forage organisms were available, less being found at dusk and least in the midnight catches. However, the figures available are too few to draw definite conclusions on the diurnal fluctuations in stream drift at this time.

A general comparison of weights of the drift catches showed that the greatest amounts of drift food was available in June, there following a decrease through July and the least in August.

The Relative Abundance and Kinds of Animals Taken in the Stream Drift Studies.— Considering per cents (Table 5) over the entire three months, it is seen that the flies were numerically dominant constituting 38.46% of all the animals taken and hence furnished one large possible sour?e of food for the trout. Mayflies came second making up 28.94% of the total, while stoneflies formed 3.43%, caddisflies, 1.43% and butterflies and moths only .36% of the total number collected. The mayflies, stoneflies and caddisflies having aquatic larval stages are available as food for trout during their entire life cycle. Ants, bees and wasps formed 4.33% of the total number and have long been known to furnish excellent food for trout. Both larvae and adults of the butterflies and moths are good trout food, but do not seem to

TABLE 5.— SHOWING AVAILABLE FISH FOOD TAKEN FROM STREAMS IN DRIFT NET BY MONTH

(Given in numbers and per cent by order)

ORDER	JUNE		JULY		AUGUST		Total number	Per cent
	Number	Per cent	Number	Per cent	Number	Per cent		
Flies (diptera).............	629	30.95	1,173	51.2	242	24.42	2,044	38.46
Mayflies (ephemerida)......	548	26.97	623	27.19	367	37.03	1,538	28.94
Aphids et al. (homoptera)...	483	23.77	218	9.52	91	9.18	792	14.91
Ants, bees and wasps (hymenoptera)................	102	5.02	34	1.54	94	9.49	230	4.33
Beetles (coleoptera)........	100	4.92	65	2.84	39	3.94	204	3.84
Bugs (hemiptera)..........	85	4.18	25	1.09	39	3.94	149	2.80
Caddisflies (trichoptera)....	27	1.33	22	0.96	27	2.73	76	1.43
Spiders and mites (arachnida)	18	0.89	12	0.52	8	0.81	38	.72
Stoneflies (plecoptera)......	17	0.84	104	4.54	61	6.16	182	3.43
Butterlies and moths (lepidoptera)................	15	0.74	.....	.....	4	0.4	19	.36
Miscellaneous..............	8	0.39	15	0.65	19	1.91	42	.79
Totals................	2,032	100.00	2,291	100.05	991	100.02	5,314	100.01

be generally available as very few were taken in the drift net. Beetles and bugs occurred in the catches in about the same numbers and are generally considered as second rate food because of their very hard, thick, chitinous exoskeletons and usually small size. Aphids and their near relatives, while they formed 14.91% of the total number of animals taken, offer little actual food for trout on account of their exceedingly small size. Members of other orders of insects which Embody and Gordon* list as being found in trout stomachs, but which were not taken in these drift studies, were adult fishflies and grasshoppers. In the miscellaneous list are included a few leeches, hairworms, springtails, millipedes, worms and one snail.

* Embody, G. C. & Gordon, Myron. A Comparative Study of Natural and Artificial Foods of Brook Trout. Transactions Amer. Fisheries Soc., Vol. 54, pp. 185–200, 1924.

Considering next, the months when the different kinds of insects were most available, it is seen that the aphids, true bugs, beetles, butterflies, moths, spiders and mites were taken in the greatest numbers in June. In July the flies reached their highest numbers as taken in the drift net catches, and in August mayflies, stoneflies, caddisflies, ants, bees and wasps were most abundant.

A study of all the stream drift organisms showed that 93.02% were terrestrial in origin, i. e., adult animals non-gill-bearing and non-aquatic. The remaining 6.98% was aquatic in origin, i. e., nymphs, larvae or pupae of insects which are generally gill-bearing and live in the water during their immature stages. This shows that some aquatic insect larvae, which normally live attached to the stream bed in a more or less fixed position, are constantly being swept downstream by the current and when found thus, they are probably consumed by trout.

Pool Drift.—This was studied to determine the relative amounts of drift food available in this type of stream condition. The same apparatus was used in making these studies as was used for collecting the stream drift. The stop net was always placed at the point where the water flowed into the pool, to stop stream drift from entering the pool. The drift net was placed at the lower end of the pool where the water flowed out and thus the drift taken was only that from the pool alone.

Pools densely shaded by low brush (Table 6) produced the largest amount of drift food, .13 grams per 100 square feet of surface. The average production over all types of pool habitats studied was as shown .0535 grams.

TABLE 6.— SUMMARY OF POOL DRIFT

No. of determinations	Type of stream environment	Average weight in grams of drift food from 100 sq. ft. of surface
1	Low brush densely shaded	.13
3	Exposed	.042
1	Semi-exposed	.021
2	Arboreal	.0205
7	Average over all types of environments	.0535

By comparing the average production in drift food per 100 square feet of surface over all types of habitats in streams and pools (Tables 4 and 6), it is seen that pools are richer in drift food per unit area by a difference of .0441 grams in favor of pools. This being the case, then the more abundant drift organisms in pools compensate somewhat for the lack of available bottom foods in pools.

93.48% of all the forage organisms taken in pool drift were terrestrial in origin, the remaining 6.52% aquatic in origin. It is interesting to note the close correlation between percentages of aquatic and terrestrial food in stream drift and pool drift. In the former, 6.98% was aquatic and 93.02% was terrestrial. In the latter 6.52% aquatic, and 93.48% terrestrial, slightly less of the organisms being aquatic in origin in pool drift.

Comparison of Total Available Food and Food Actually Eaten by Trout.— An angler permitted us to remove the stomachs from twelve brook trout he had caught in the same section of the stream (station 15) in which drift and bottom studies were being made. Examination of the food found in these stomachs correlated with data on total available food permits this comparison.

Table 7 shows that the trout had largely eaten of the most available type food, the aquatic. More than 83% of the food found in the twelve stomachs was aquatic in origin, i. e., it was food indigenous to and grown in the stream itself. The remaining 17% was terrestrial in origin, i. e., adult animals, non-gill-bearing and non-aquatic, which had probably fallen into the water accidentally. As taken in the drift net catches here, the latter type of food formed only .7% of all available foods. Insects formed 61% of the diet of the trout and formed 59.93% of all available foods. Crayfish

Table 7.— Summary of Total Available Food and Food Actually Eaten by Trout

Type of food	Total available foods	Foods consumed
A. As to origin:		
Aquatic	99.3	83%
Terrestrial	.7*	17%
	100%	100%
B. As to classes of foods:		
Insects	59.93	61%
Crayfish and shrimp	40.07	32%
Worms and millipedes	....	7%
	100%	100%
C. As to origin of insects:		
Aquatic	99.3	50%
Terrestrial	.7	11%
	100%	61%

* Foods listed in the above table as being "terrestrial", can all properly be termed "drift food."

and shrimps constituted 32% of foods eaten and formed 40.07% of that available. No worms or millipedes were taken in either the drift or bottom studies, yet they formed 7% of the food found in these stomachs.

Gordon and Embody[1] state that insects constituted 88.88%, crayfish and shrimps 8.23%, fish 2.52% and clams and snails .27% (excluding plant and animal debris) of the total contents of 161 brook trout stomachs examined by them. We found no fish in any stomach examined by us. These results are not truly comparable to our figures since they are given in per cent by volume while ours are expressed in per cent by number, although they both show about the same choice of foods taken by the trout. They quote from Juday[2] that "with the exception of small brook trout and fry, insect material found consisted of such forms as fell into the water accidentally." This is the reverse of our findings, only 11% of the insect material being terrestrial in origin. Needham[3] in reporting the food of 25 brook trout taken from Bone pond, Saranac Inn, New York, found the food all aquatic in origin but two beetles. This is more in accord with our findings at this station.

Available Fish Food in Submerged Plant Beds.—The available fish foods found in various types of submerged plant beds were studied to ascertain the relative value of such beds in relation

TABLE 8.—TYPES OF SUBMERGED PLANT BEDS AND THE WEIGHT IN GRAMS PER SQUARE FOOT OF AVAILABLE FISH FOOD

Common name	Scientific name	Date and place collected	Wt. in grams of fish food from 1 sq. ft.
Stonewort	Chara	North brook, Price spring, Auburn, N. Y., Aug. 17, 1927	37.0
Watercress	Nasturtium nasturtium-aquaticum	Price brook, Auburn, N. Y., Aug. 17, 1927	12.8
Pondweed	Potamogeton americanus	East branch Owego creek, Hartford Mills, Aug. 25, 1927	5.85
Willow roots	Salix (sp.)	Sixmile creek, Slaterville, N. Y., Aug. 13, 1927	4.88
Water buttercup	Ranunculus aquatilis	West branch Owego creek, Caroline, N. Y., Aug. 23, 1927	3.51
Sago pondweed	Potamogeton pectinatus	East branch Owego Creek, Hartford Mills, N. Y., Aug. 26, 1927	3.19
Water moss		Sixmile creek, Slaterville, N. Y., Aug. 15, 1927	*3.12
Horned pondweed	Zannichellia palustris	Canoga Spring brook, Canoga, N. Y., Aug. 16, 1927	2.93
		Average weight in grams per unit area over all types	9.16

* Based upon actual weight of available fish food from one-twelfth of one square foot.

[1] Loc. cit.

[2] Juday, C. A. Study of Twin lakes, Colorado, with especial consideration of the food of the trouts. Bull. U. S. Bur. of Fisheries, Vol. 26, 1906.

[3] Needham, J. G. Food of Brook Trout in Bone Pond. Bulletin 68, New York State Museum, Albany, N. Y., 1903.

to trout streams. Due to lack of time the potential animal foods were taken from only one square foot in each of the eight types selected and hence the weight in grams of available food given for each type, cannot be considered as average. The bottom fauna as well as organisms on or about the plants in one square foot were taken in each study and therefore the available food cannot be considered as that which the weed beds alone produced. All of these studies were made in quiet or semi-quiet waters. The plant beds were practically pure stands, occasionally having small amounts of other plant forms growing with them.

In chart 2 the plant beds from which the forage organisms were taken are shown in order of their productiveness in grams per unit area (derived from Table 8). It is seen that the largest amount per square foot 37.0 grams was found in a chara bed,

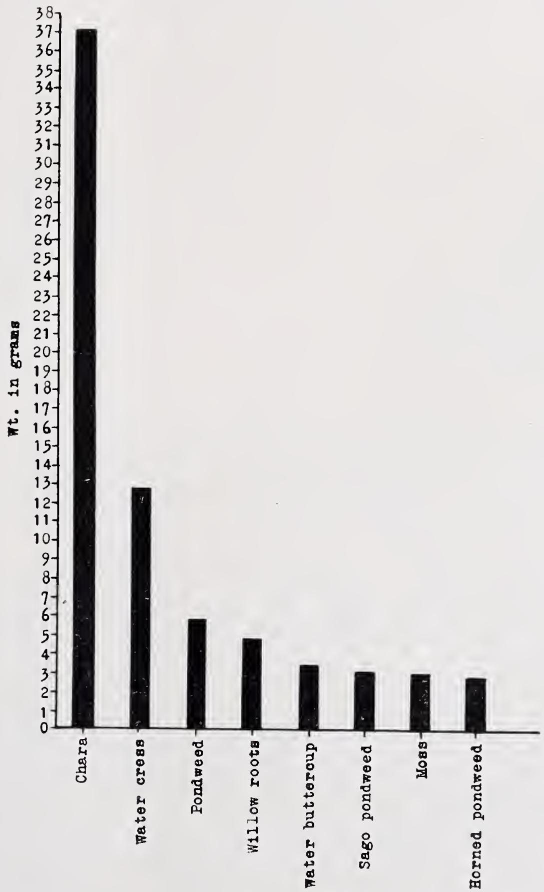


Chart 2.—Showing available fish food by weight in grams per one square foot in certain types of submerged plant beds.

watercress was second with 12.8 grams; pondweed* third, 5.85 grams, while willow roots, water buttercup, sago pondweed and water moss produced less each respectively down to horned pondweed which gave the least, 2.93 grams per one square foot.

Considering next, the potential fish foods available over all types of plant beds, Table 9 shows the relative abundance of each class of food. In a total of 7,505 organisms collected, crayfish and shrimps constituted the highest percentage, 40.95%. Most of these were Caledonia shrimps (*Gammarus limnaeus*), other crustaceans being comparatively rare.

If a comparison is made of the average weight in grams of potential food found per unit area of one square foot as taken in pool bottoms, stream bottoms and plant beds, it is seen that

TABLE 9.— AVAILABLE FISH FOODS BY NUMBER AND PER CENT COLLECTED IN SUBMERGED PLANT BEDS *

ORDER	Number	Per cent
Crayfish and shrimps (Crustacea)	3,073	40.95
Flies (Diptera)	1,618	21.56
Bugs (Hemiptera)	710	9.46
Caddisflies (Trichoptera)	710	9.46
Beetles (Coleoptera)	567	7.55
Mayflies (Ephemerida)	416	5.54
Stoneflies (Plecoptera)	83	1.11
Snails and clams (Mollusca)	64	.85
Sialis larvae et al. (Neuroptera)	11	.15
Dragonflies (Odonata)	1	.01
Miscellaneous	252	3.37
Totals	7,505	100.01

* This table includes the bottom fauna in all square feet studied as well as the animals on or about the plants.

the plant beds were by far the most productive, giving an average of 9.16 grams against .26 grams for pools and 1.21 grams for streams. From these figures plant beds plus the bottom foods beneath, are 35.2+ times as rich in food as pool bottoms, and 7.5+ times richer than stream bottoms, As stated elsewhere, stream bottoms were found to be 4.6 times richer in potential food than pool bottoms per unit area. Thus it is seen that great increase in potential food is found in bottoms in which various types of aquatic vegetation have developed. The reason for greater productivity in plant beds, aside from the fact that they are largely responsible for the oxygenation of the water, must be due to the fact that they furnish more food and shelter for aquatic organisms than do merely bare pool or stream bottoms.

* Long-leaved pondweed.

Appendix I.—Blank Forms Used in the Field

NEW YORK STATE CONSERVATION DEPARTMENT

STREAM SURVEY

Name...**Length**....................**Date**....................

Tributary to...**River System**..

Town..............................**County**..............................**Authority**....................

REGION	UPPER	MIDDLE	LOWER	REGION	UPPER	MIDDLE	LOWER
Width				Air temp.			
Flow				Water temp.			
Velocity				Hour and weather			
Color and turbidity				Food grade			
Permanency				Pool grade			

Fish Food: Upper; mayflies, stoneflies, caddisflies, blackflies, midges, shrimps minnows.

Middle;..

Lower;..

Pools: Upper; size....................type....................frequency....................

Middle;..

Lower;..

Bottom: mud, silt, sand, detritus, hardpan, gravel, rubble, bedrock..........................

Vegetation: watercress, pondweeds, water moss, chara, filamentous algae, water lilies, cat-tails..

Springs: location, temperature, flow, sulphur, iron, lime..

Dams and Falls: location, height. Area and depth of pond..

Pollution: location, extent, nature, index organisms..

Game fish present:..

Character of region: open fields, wooded, wild, cultivated, hilly, low, swampy....................

....

....

Value of fishing:..

....

....

Planting places: location..

Posted area: length....................owner's name....................town....................

Length suitable for: S. T..........B. T..........R. T..........Sm.B..........Lm.B..........Pp..........

Miscellaneous:..

Stocking policy: species....................size....................number....................

Appendix II

ABBREVIATIONS AND SYMBOLS USED IN STOCKING LISTS FACING MAPS

S. T. = Brook trout (speckled) advanced fry.
S. T.+ = Brook trout fingerlings.
B. T. = Brown trout advanced fry.
B. T.+ = Brown trout fingerlings.
R. T. = Rainbow trout advanced fry.
R. T.+ = Rainbow trout fingerlings.
Sm. B. = Small-mouthed bass.
Lm. B. = Large-mouthed bass.
Y. P. = Yellow perch.
Pp. = Pike-perch
Bg. S. = Bluegill sunfish.
G. Sh. = Golden shiner
Co. = Calico bass.
C. = Bullhead.
Bh. C. = Bullhead catfish.
Pkl. = Pickerel.
M. = Maskinongé (Muskalonge).

Legend for maps:

▬ ▬ ▬ ▬ Boundary of watershed.

_ _ _ _ _ _ _ Dry runs or streams becoming dry.

⊙ Spring.

× Outfall of pollution.

— Dam.

Appendix III

Stocking List to Accompany Map 1

Highmarket and Port Leyden quadrangles

Stream and tributary number	Mileage available for stocking	Stocking policy per mile
14 (East Branch Fish creek)	14 miles, 32 to source	2,200 S. T.+
	(Posted 1.25 miles above and below 32)	None.
	4 miles below 32	5,000 B. T.+
	(Posted 1 mile between 27 and 29)	None.
9 (Point Rock creek)	3 miles	270 S. T.+
9	1 mile	90 S. T.+
16	0.8 mile	90 S. T.+
18	0.5 mile	180 S. T.
(8, 14, 15, 17, 19 and tributaries of 9 and 16)	Small	None.
18	0.5 mile	450 S. T.
21 (Beaver Meadow brook)	6.5 miles	630 S. T.+
2 (Broad brook)	5.5 miles	360 S. T.+
2	2.5 miles	90 S. T.
(1 and tributaries 1, 3, 4 and 5 of 2)	Small	None.
22 (Mud brook)	4 miles	540 B. T.+
1	0.5 mile	70 B. T.+
2	Small	None.
23	2 miles	360 S. T.+
25	0.5 mile	180 B. T.+
26	1.5 miles	90 B. T.+
27	1 mile	180 B. T.+
28	Warm or small	None.
29 (Alder creek)	12 miles	900 S. T.+
1	0.6 mile	100 B. T.+
3	1 mile	180 B. T.+
5 (Sucker brook)	9 miles	650 B. T.+
1 (Little Alder)	5 miles	450 S. T.+
1	Small	None.
8	1.5 miles	180 S. T.+
9	1.5 miles	70 S. T.+
10	1.5 miles	360 S. T.+
11	1.5 miles	360 S. T.+
12	1 mile	90 S. T.+
13	2.5 miles	540 S. T.+
(2, 4, 6, 14, tributaries 2–8 of 5, 1 of 9 and 1 of 11)	Small	None.
Pond at Paige	50 acres	300 S. T.+
30	1.5 miles	500 B. T.+
1–2	Small	None.
31	1.5 miles	270 B. T.+
32 (Pringle creek)	Lower 0.3 mile (posted)	None.
	Upper 7 miles	720 S. T.+
1 (Moose Meadow stream)	2.5 miles	540 S. T.+
1	2 miles	125 S. T.+
2	0.6 mile	70 S. T.+
1	Dry	None.
3	Small	None.

Appendix III—Continued

Stream and tributary number	Mileage available for stocking	Stocking policy per mile
32 (Pringle creek) — (*Cont'd*)		
Moose Meadow stream–(*Cont'd*)		
2	1 mile	50 S. T.
3	0.5 mile	70 S. T.
4	1.5 miles	585 S. T.+
5	Small	None.
6–8	0.5 mile	Natural spawning. adequate S. T.
33 (Dirreen creek)	5 miles	700 S. T.+
Michigan Mills pond	4 acres	300 S. T.+
1	Small	None.
34	1.5 miles	234 S. T.+
35	0.8 mile	575 S. T.+
1	Small	None.
36 (Roaring brook)	4 miles	720 S. T.+
1	0.5 mile	90 S. T.
2	1.5 miles	125 S. T.+
3	2.5 miles	180 S. T.+
1–2	Small	None.
4	1.5 miles	180 S. T.+
1	1 mile	90 S. T.
5	1.5 miles	180 S. T.+
37	1.5 miles	430 S. T.+
1	0.3 mile	117 S. T.
38	1.8 miles	700 S. T.+
1	1 mile	230 S. T.
1	Small	None.
2	0.5 mile	230 S. T.+
39 (Six Mile creek)	4 miles	600 S. T.+
1	0.3 mile	70 S. T.
2	1 mile	125 S. T.
1	Small	None.
3	Small	None.
40	Small	None.
41 (Seven Mile creek)	5 miles	1,000 S. T.+
1	1 mile	126 S. T.+
2 (Deep creek)	2 miles	360 S. T.+
(3, 4 and tributary of 2)	Small	None.
42–43	Small	None.
Railroad pond	10 acres	300 S. T.+
44	2 miles	360 S. T.+
1	0.4 mile	90 S. T.
45	0.5 mile	90 S. T.
46	0.5 mile	90 S. T.
47	Small	None.
48	1.5 miles	90 S. T.
49 (Dunton creek)	1.5 miles	800 S. T.+
1	1.5 miles	180 S. T.+
50	0.8 mile	117 S. T.
51 (North Branch)	4 miles	810 S. T.+
1	1 mile	234 S. T.+
3	1 mile	90 S. T.
4	1 mile	270 S. T.+
5	1.5 miles	180 S. T.+
1	0.5 mile	90 S. T.

Appendix III—Continued

Stream and tributary number	Mileage available for stocking	Stocking policy per mile
(2, 6, 7 and tributaries of 1 and 3)	Small	None.
52	Small	None.
53	0.4 mile	180 S. T.+
54	1.5 miles	180 S. T.+
55	Small	None.
56	0.4 mile	90 S. T.
57	1 mile	180 S. T.+
1–2	Small	None.

Appendix IV

STOCKING LIST TO ACCOMPANY MAP 2

Oswego, Fulton, Mexico, Kasoag, Taberg and Boonville quadrangles

Stream and tributary number	Mileage available for stocking	Stocking policy per mile
Oswego river	19 miles	Lm. B., Pp., Bg. S.
Black creek	Warm	None.
1–5 and tributaries	Dry, warm or small	None.
Paddy pond	50 acres	Lm. B., Bg. S., Bh. C.
Crooks pond	50 acres	Lm. B., Bg. S., Bh. C.
Mud pond	50 acres	Lm. B., Bg. S., Bh. C.
Black creek 0.1–3	Dry, warm or small	None.
Oneida river	4 miles	Sm. B., Pp.
Sixmile creek	Dry, warm or small	None.
Potts creek	Below Pennellville, polluted	None.
	Pennellville to tributary 4, 4 miles	700 B. T.+
	Tributary 4 to source, warm	None.
1	1 mile	125 S. T.+
2	1 mile	125 S. T.+
3	2.5 miles	180 B. T.+
4–6 and tributary of 3	Small	None.
Potts creek 0.1	Warm	None.
Potts creek 0.8 to P. O. 10 and tributaries	Small or dry	None.
Caughdenoy creek	Mouth to Crippen pond, 5 miles	Lm. B., Y. P., Bg. S.
	Crippen pond to source, warm and small	None.
Crippen pond	Dam out, too small	None.
Caughdenoy creek 0.1 and tributary	Dry	None.
*Oneida lake:		
1, 2 and tributary and Little Bay creek and tributaries	Small	None.
Big Bay creek	Mouth to Mallory Sta., warm	None.
	Mallory to source	600 B. T.+
1–6 and tributaries	Small or dry	None.
7 (Dykeman creek)	5 miles	360 B. T.+
Mallory pond	15 acres	Lm. B., Bg. S., Bh. C.
2 (Shanty creek)	Lower, 1 mile	235 B. T.+
4	0.6 mile	280 B. T.+
(1, 3, 5, 6, 7 and tributaries of 2 and 4)	Dry or small	None.
8–11 and tributaries	Small	None.
Threemile creek and tributaries.	Small	None.

* The forthcoming report of the Roosevelt Wild Life Forest Experiment Station covering a period of several years, gives special attention to the fish of Oneida lake.

Appendix IV—Continued

Stream and tributary number	Mileage available for stocking	Stocking policy per mile
Scriba creek	Mouth to Gayville, warm	None.
	Gayville to source (8 miles posted)	None (1,000 B. T.+)
1 (Frederick creek)	Below pond, warm	None.
	Pond to posting, 3 miles	450 B. T.+
	Upper 1.5 miles (posted)	None (180 B. T.+)
2–4	Small	None.
5 (Spring brook)	5 miles	850 S. T.+
1–2 and tributaries	Small or warm	None.
Pond	25 acres (posted)	None.
6–8 and tributaries	Small	None.
9 (Potter creek)	7 miles (posted)	None (250 S. T.+)
1–3 and tributaries	Small or warm	None.
4	1.5 miles (posted)	None (180 S. T.+)
1, 2, 5, 6	Small or warm	None.
10–11 and tributary	Small or (posted)	None.
12–14 and tributaries	Small	None.
15 (Crandall creek)	2 miles (posted)	None (450 B. T.+)
1	Small	None.
2	(Posted)	None (180 B. T.+)
1–2 and pond	Small	None.
16–17	Warm	None.
South pond	50 acres	Lm. B., Bg. S., Y. P.
18	2.5 miles (posted)	None (600 B. T.+)
19	1 mile (posted)	None (90 B. T.+)
20	Small	None.
Myer creek (Dolby creek)	3 miles (posted)	None (600 S. T.+)
1	Small	None.
2	1 mile (posted)	None (90 S. T.+).
3	2 miles (posted)	None (180 S. T.+).
4	1 mile (posted)	None (180 S. T.+).
Kibby lake	30 acres	Lm. B., Bg. S., Y. P.
6–7	Small, warm or (posted)	None.
Vandercamp lake	49 acres (posted)	None.
8 and tributaries	Small	None.
Black creek	Lower 3 miles	650 B. T.+
	Upper 2 miles (posted)	None (600 B. T.+).
2	2 miles	90 B. T.+
3	Small	None.
Pond	10 acres	Lm. B., Bg. S., Y. P.
4	1 mile	235 B. T.+
(1, 5 and tributary)	Small	None.
9	Dry	None.
2	0.5 mile	350 S. T.+
3 and Cleveland reservoir	Small	None.
11	1 mile	350 B. T.+
2	Small	None.
3	0.5 mile	180 B. T.+
12	Small	None.

Appendix IV—Continued

Stream and tributary number	Mileage available for stocking	Stocking policy per mile
Fish creek	Tributary 7 to Camden, 18 miles	4,000 B. T.+
	Camden to Williamstown, 12 miles	Lm. B.
	Williamstown to Kasoag lakes, 6 miles	1,350 B. T.+
	Kasoag lakes to source, 6 miles	315 S. T.+
1 (Wood creek)	Lorena downstream, 2 miles	200 S. T.+
	Remainder, warm or polluted	None.
10 (Canada creek)	Upper, warm	None.
	Lower, 4.5 miles	1,600 S. T.+
2 (Beaverbrook)	Lower mile	180 S. T.+
2	0.3 mile	90 S. T.+
(1, 3 and tributary of 2)	Small	None.
3	2 miles	126 S. T.+
4 (Frog Harbor brook)	3 miles	180 S. T.+
1	Upper 1 mile (posted)	None.
	Lower 0.7 mile	180 S. T.+
1	0.4 mile	450 S. T.+
2	0.3 mile	450 S. T.+
5 (Golly brook)	Upper 0.5 mile (posted)	None.
	Lower 0.5 mile	180 S. T.+
6–12	Small, warm or dry	None.
16–18	Small or dry	None.
2, 3, 4 and tributary	Small	None.
8	0.4 mile	270 S. T.+
9 (Sash Factory brook)	6 miles	720 S. T.+
2	1.5 miles	180 S. T.+
2	0.2 mile	125 S. T.+
3 (Jones brook)	1.5 miles	360 S. T.+
(1, 4 and tributary of 2)	Small	None.
10 (Baker brook)	1 mile	65 B. T.+
11 (Buttermilk brook)	Small	None.
12	0.3 mile	190 B. T.+
13	(Posted)	None.
14 (East Branch of Fish creek)	13 miles	4,000 B. T.+
1	Small	None.
2 (Furnace creek)	12 miles	720 B. T.+
1 (Green brook)	1.5 miles	270 B. T.+
3 (Horse brook)	2 miles	450 B. T.+
5 (Lasher brook)	4 miles	270 B. T.+
1	1 mile	270 B. T.+
2	Small	None.
3	0.5 mile	750 B. T.

Appendix IV—Continued

Stream and tributary number	Mileage available for stocking	Stocking policy per mile
(2, 4, 6, 7 and tributaries)	Small	None.
3	Small	None.
4 (Florence creek)	3 miles, below dam at Glenmore	1,600 B. T.+
	Above Glenmore, 9 miles	720 S. T.+
1 (Christian brook)	4 miles	180 B. T.+
Oneida reservoir	60 acres	300 S. T.+
3	3 miles	180 S. T.+
Spring run	1 mile	180 S. T.+
4 (Big brook)	8 miles	450 S. T.+
6	1 mile	180 S. T.+
7	3 miles	360 S. T.+
(2, 5, and 8; tributaries of 1, 4 and 7)	Small	None.
5 (Fall-Sullivan brook)	11 miles	1,400 S. T.+
1	0.5 mile	400 S. T.
2 (Mack brook)	4 miles	270 S. T.+
3 (Hennesey brook)	3.5 miles	270 S. T.+
1	Small	None.
Spring run	0.3 mile	1,200 S. T.
4	7 miles	150 S. T.+
1	Small	None.
2 (Cody brook)	3.5 miles	540 S. T.+
1–2	Small	None.
3	1 mile	80 S. T.+
5 (Finn brook)	2.5 miles	234 S. T.+
1	2 miles	180 S. T.+
1	Small	None.
6	0.7 mile	1,000 S. T.
6 and tributary	Small	None.
7	2 miles	150 S. T.+
8 (Cold brook)	1 mile	90 B. T.+
9 (Point Rock creek)	Below dam, 0.5 mile	2,300 B. T.+
	Above dam, 11.5 miles	2,000 S. T.+
1	0.3 mile	2,000 S. T.
2	0.3 mile	2,000 S. T.
3	Small	None.
1	0.2 mile	1,000 S. T.+
Point Rock pond	50 acres	Lm. B.
4	2 miles	270 S. T.+
1 and tributary	Small	None.
5	1.5 miles	180 S. T.+
1	Small	None.
6	2 miles	100 S. T.+
1	Small	None.
7	1 mile	240 S. T.+
1	Small	None.
2	0.3 mile	120 S. T.+
8 (Pond brook)	Below Mud pond, 0.7 mile	90 S. T.+
	Above pond, small	None.
Mud pond	12 acres	100 S. T.+

Appendix IV—Continued

Stream and tributary number	Mileage available for stocking	Stocking policy per mile
9 (Point Rock creek) — (*Continued*)		
9	1.5 miles	270 S. T.+
1–2	Small	None.
10–14 and tributaries	Small	None.
10	1.5 miles	270 B. T.+
1	1 mile	180 B. T.+
11	0.5 mile	125 B. T.+
12	2.5 miles	270 S. T.+
1	2 miles	700 S. T.+
13	0.2 mile	1,000 B. T.+
14	2 miles	470 S. T.+
1	Small	None.
15	0.5 mile	180 B. T.+
16	Small	None.
17	25 miles	900 S. T.+
1	2 miles	450 S. T.+
2–4 and tributaries	Small	None.
18	2 miles	540 S. T.+
1–2	Small	None.
19	2 miles	350 B. T.+
1–4	Small	None.
20	Small	None.
21	1.5 miles	540 S. T.+
1 and tributary	Small	None.
2	0.5 mile	360 S. T.+
22	1 mile	540 B. T.+
1	0.5 mile	70 B. T.+
23	0.6 mile	360 S. T.+
24 and tributary	Small	None.
25	1.2 miles	180 B. T.+
1	Small	None.
15–16	Dry	None.
17	1.25 miles	100 B. T.
18 (Cold brook)	7 miles	720 S. T.+
2	1 mile	300 S. T.+
1	1 mile	90 S. T.+
3	1.5 miles	90 S. T.+
5	1 mile	180 S. T.+
(1, 4 and tributary of 3)	Warm or small	None.
Mack pond	10 acres	Sm. B.
19	1 mile	180 B. T.
20	Upper 1 mile (posted)	None.
	Lower 1 mile	702 S. T.+
1	0.3 mile	180 S. T.+
21 and tributary	Small	None.
22 (Little river)	Below dam at Carterville, 11 miles	1,800 B. T.+
	Above dam, 7.5 miles	441 S. T.+
1	1.5 miles	75 B. T.+
1	Small	None.
2	1.5 miles	70 B. T.+
3, pond and tributaries	1.5 miles (posted)	None.

Appendix IV—Continued

Stream and tributary number	Mileage available for stocking	Stocking policy per mile
22 (Little River)—(*Cont'd*)		
4 (Pierce brook)	5 miles	540 B. T.+
1–3	Small	None.
5 (Fields brook)	3 miles	585 S. T.+
1–3	Small or dry	None.
6 (Trout brook)	2 miles	350 S. T.+
1–2	Small	None.
7 (South Branch)	6 miles	540 S. T.+
1	1 mile	180 S. T.+
2	3 miles	360 S. T.+
1	1 mile	270 S. T.+
3	2 miles	140 S. T.+
1	1.2 miles	180 S. T.+
8, 9–13 and tributaries	Small or warm	None.
14 (Bullhead brook)	2 miles	190 S. T.+
1 (Hopkins brook)	Small	None.
15 West Branch, Panther lake outlet	3 miles	250 B. T.+
1 and tributaries	Warm	None.
Panther lake	0.5 square miles	Lm. B., Pp., Bg. S., Y. P.
16	1.5 miles	350 B. T.+
17	2 miles	270 B. T.+
1	Small	None.
18	1.5 miles	75 B. T.+
19	Lower 1 mile (posted)	None.
	Upper 1.5 miles	270 S. T.+
1	Small	None.
Carterville pond	(Posted)	None.
20	Lower (posted)	None.
	Upper, small	None.
21–22	Small	None.
23	1 mile	270 S. T.+
24	Small	None.
23 (Cook brook)	2 miles	350 S. T.+
1	Small	None.
24	0.5 mile	400 B. T.
25 (Colburn brook)	1.5 miles	360 B. T.+
1	0.5 mile	180 B. T.+
26 (Cobb brook)	10 miles	1,000 S. T.+
1	2 miles	117 S. T.+
3	0.5 mile	180 S. T.+
4	0.6 mile	90 S. T.+
Spring run	0.3 mile	90 S. T.+
1	0.2 mile	90 S. T.+
5	1 mile	180 S. T.+
6	0.4 mile	235 S. T.+
1	0.2 mile	90 S. T.
7	2.5 miles	360 S. T.
5	0.5 mile	180 S. T.+
6	Small	None.
9	0.3 mile	90 S. T.+
11	0.3 mile	180 S. T.+
12	0.4 mile	90 S. T.+

Appendix IV—Continued

Stream and tributary number	Mileage available for stocking	Stocking policy per mile
(2, 8, 10, tribs. of 1 and 1-4 of 7)	Small	None.
27 (Emmons brook)	4 miles	600 S. T.+
1 and tributary	Small	None.
2	1 mile	235 S. T.+
3	0.5 mile	235 S. T.+
Spring run	0.3 mile	90 S. T.+
4	0.6 mile	180 S. T.+
28 (Mad river)	Below dam at 14, 11 miles	1,400 B. T.+
	Above dam, 5 miles	1,250 S. T.+
1	0.2 mile	700 B. T.
2	Dry	None.
3	0.7 mile	700 B. T.
1	Small	None.
4	2 miles	270 B. T.+
1	Small	None.
5	0.5 mile	125 B. T.+
6 (Williams brook)	2 miles	315 B. T.
7 (Finnegans brook)	4 miles	450 S. T.+
1	0.7 mile	125 S. T.+
3	1 mile	125 S. T.+
(2, 4, and tributaries of 3)	Small	None.
8 (Wickwire creek)	3 miles	270 B. T.+
1	Small	None.
9	Small	None.
10 (Stamford brook)	1 mile	270 B. T.+
1-2	Small	None.
11 (Little river)	3 miles	500 S. T.+
1	1 mile	190 S. T.
2	3 miles	450 S. T.+
3	1 mile	180 S. T.+
(4, 5 and tributaries of 1, 2 and 3)	Small	None.
12 and tributaries	Small	None.
13 (Spellicy creek)	4 miles	360 S. T.+
1	1 mile	270 S. T.+
2	1.2 miles	216 S. T.+
(3, 4 and tributary of 2)	Small	None.
14	Lower 1 mile warm	None.
	Upper 1 mile	180 S. T.
1	Small	None.
15 (Perry brook)	3 miles	190 S. T.+
16-17	Small	None.
18	1 mile	126 S. T.+
1	Small	None.
19 and tributaries	Small or (posted)	None.
20	2 miles	200 S. T.+
1	1 mile	100 S. T.+
2	1 mile	100 S. T.+
29-30	Small or warm	None.
31 (Thompsons brook)	1.5 miles	200 B. T.+
1-3	Small or warm	None.
32-37 and tributaries	Dry, small or warm	None.
Gifford lake	1.2 x 0.3 miles	Lm. B., Y. P., Bg. S., Bh. C.
38 (Mower brook)	Small	None.

Appendix IV—Continued

Stream and tributary number	Mileage available for stocking	Stocking policy per mile
39 (Walker brook)	3.5 miles	450 S. T.+
1	1 mile	180 S. T.+
1	Small	None.
2	Small	None.
40 (Hare brook)	Lower 1.5 miles (posted)	None.
	Upper 1.5 miles	180 S. T.
1 (Hyatt brook)	2 miles	270 S. T.
1–2	Dry or small	None.
3	1 mile	180 S. T.
1	Small	None.
2–4	Dry or small	None.
41	3 miles	540 S. T.+
1	1.5 miles	270 S. T.+
2	0.2 mile	180 S. T.+
3	1 mile	90 S. T.+
42	3.5 miles	540 S. T.+
1–2	Dry or small	None.
43	1.5 miles	360 S. T.+
44 (Wells brook)	Lower 5 miles (posted)	None.
	Upper 3 miles	270 S. T.+
1 (Rowell brook)	2.5 miles	270 S. T.+
(2, 4 and tributary of 1)	Small	None.
45, 46 and tributary	Small	None.
Pond at Williamstown	10 acres	Lm. B., Y. P., Bg. S., Bh. C.
47	2.5 miles	75 B. T.+
1	Small	None.
2	0.5 mile	180 B. T.
48	Dry	None.
49 (Poth brook)	3 miles	360 S. T.+
50	0.7 mile	90 B. T.
51	Small	None.
52	Lower 0.5 mile (posted)	None.
	Upper 3 miles	315 S. T.+
1	Lower 0.3 mile (posted)	None.
	Upper 1.5 miles	180 S. T.+
53	Small	None.
54	0.5 mile	70 S. T.+
55	3 miles	360 S. T.+
1–2	Small	None.
Kasoag lake	(Posted)	None (Lm. B., Bg. S.).
Green lake	Shallow	None.
56, 57 and tributaries	Small, warm or dry	None.
58	1.2 miles	180 S. T.+
59	Small	None.
60	2.5 miles	270 S. T.
1	0.5 mile	126 S. T.
61	Small	None.
62	0.5 mile	126 S. T.
Ontario-West 0.1–2 and tributaries	Dry, warm or small	None.
Lake Neatahwanta	0.8 square mile	Lm. B., Bh. C., Bg. S., Y. P.
Ox creek and Ox creek 0.1	Warm or small	None.

Appendix V

STOCKING LIST TO ACCOMPANY MAP 3A

Macedon, Palmyra, Clyde and Weedsport quadrangles

Stream and tributary number	Mileage available for stocking	Stocking policy per mile
Seneca river	21 miles	Lm. B., Pp.
1 (Cross lake)	Small and warm	None.
Skaneateles creek	Polluted	None.
1	Small and warm	None.
S. S. 1–3	Small and warm	None.
North brook (Cold spring)	Small or warm	None.
1 (Putnam brook)	From tributary 3–9, 2.5 miles	370 B. T. +
3	1 mile	70 B. T. +
5	2 miles	180 B. T. +
6	2 miles	180 B. T. +
1	1 mile	180 B. T. +
1, 2, 4, 7, 8, 9 and tributaries	Small or warm	None.
2–10	Small or warm	None.
Owasco outlet	Polluted or warm	None.
1–5 and tributaries	Small or warm	None.
O. S. 1, Old Erie canal and tributaries	Small, warm, dry or fluctuating water level	None.
Crane creek	2 miles, lower	Sm. B.
	Small or warm, upper	None.
1–4 and tributaries	Small or warm	None.
C. L. S. 1–2	Small and warm	None.
Muskrat creek and tributaries	Small, warm or dry	None.
Parker pond	320 acres	Lm. B., Bg. S.
Otter lake	256 acres	Lm. B., Bg. S.
M. S. 1 and tributaries	Small, warm or dry	None.
Stark pond	160 acres	Lm. B., Bg. S.
M. S. 4 and tributaries	Small, warm or dry	None.
Slayton pond	60 acres	Lm. B., Bg. S.
M. S. 8	Small or warm	None.
3	2 miles	190 B. T. +
Duck lake	320 acres	Lm. B., Bg. S.
1, 2 and 4	Small and warm	None.
M. S. 2, 3, 5, 6, 7, 9, 10, 11, Crusoe creek and tributaries	Small, warm, dry or (posted)	None.
Clyde river (including Canandaigua outlet)	29 miles	Sm. B., Pp.
1–22 and tributaries	Small, warm, dry or sluggish	None.
23 (Ganargua creek)	34 miles	Sm. B.
1 (Marbletown creek)	9 miles	450 S. T. +
14	1.5 miles	70 S. T. +
15	1 mile	90 S. T. +
1–9, 11–13, 16, 17 and tributaries	Small, warm or dry	None.
11 (Military run)	3.5 miles	75 S. T. +
1–4 and tributaries	Small, warm or dry	None.

Appendix V—Continued

Stream and tributary number	Mileage available for stocking	Stocking policy per mile
Seneca river — (*Cont'd*)		
Clyde river — (*Cont'd*)		
23 (Ganargua creek — *Cont'd*)		
14 (Stebbins brook).......	0.5 mile, middle (posted)..........	None.
	2.5 miles............	250 S. T. +
1.....................	0.25 mile...........	70 S. T. +
2–5 and tributaries.....	Small, warm or dry..	None.
Spring brook.............	0.5 mile............	90 S. T. +
24 (Red creek)...........	Warm, dry or intermittent..........	None.
3.....................	1.75 miles..........	125 S. T. +
1–5.................	Small, warm or dry..	None.
1–2, 4–15 and tributaries	Small, warm or dry..	None.
2–10, 12, 13, 15–23, 25–40 and tributaries.........	Small, warm or dry..	None.
24–29 and tributaries.......	Small, warm or dry..	None.

Appendix VI

STOCKING LIST TO ACCOMPANY MAP 3B

Baldwinsville, Syracuse, Chittenango, Oneida and Oriskany quadrangles

Stream and tributary number	Mileage available for stocking	Stocking policy per mile
Oswego river	5.5 miles	Sm. B., Pp.
B. 0.3	Dry	None.
Oneida river	13 miles	Sm. B., Pp.
B. 0.3	Dry	None.
Sixmile and Potts creeks	Warm	None.
P. 0.1	1 mile	180 B. T. +
P. 0.2—C. 0.2	Dry, small or warm	None.
Tributaries on south side Oneida river S. 0.1—Y. 0.5	Dry, small or warm	None.
Pleasant lake	20 acres (posted)	None.
*Oneida lake		
1–8 and tributaries	Small or warm	None.
Black creek	1.5 miles	900 B. T. +
1	1 mile	180 B. T. +
9	2 miles	540 S. T. +
1	Small	None.
2	0.3 mile	400 S. T. +
10	Small	None.
11	0.5 mile upper	470 B. T. +
1	0.5 mile	180 B. T. +
1	0.5 mile	180 B. T. +
12	2 miles (lower)	540 S. T. +
1	Small	None.
13–16 and tributaries	Dry or small	None.
Fish creek	14 miles	Pp., Sm. B.
1 (Wood creek)	Polluted	None.
4 (Beaver brook) and tributaries	Warm	None.
Teelins pond	4 acres	Lm. B., Bg. S.
8 (Stony brook)	7 miles	Bg. S., Bh. C.
1–9 and tributaries	Warm or small	None.
10 (Canada creek)	S. T. above Coonrod (Map 2)	None.
	Below Coonrod too warm	None.
(1–3; 5–7; 9; 11–15)	Dry, small, warm or polluted	None.
2–7	Dry or small	None.
Oneida creek	Mouth to Oneida, polluted	None.
	Oneida to Bennet Corners, 7 miles	Sm. B.
	Bennet Corners to No. 22, warm	None.
6 (Sconondoa creek)	12 miles	1,000 B. T. +
11	0.5 mile	90 B. T. +
12 (Dix brook)	2.5 miles	180 B. T. +
1–3	Small	None.
13 (Porter brook)	2 miles	180 B. T. +
1–2	Small	None.

* Loc. cit. p. 212

Appendix VI—Continued

Stream and tributary number	Mileage available for stocking	Stocking policy per mile
Oswego river — (*Cont'd*)		
(1–10, 14 and tributaries	Dry, small or warm	None.
9 (Mud creek)	7.5 miles	380 B. T. +
Sunset lake	60 acres	Sm. B.
12	3 miles	150 B. T. +
Lower Oneida reservoir	2 acres	None.
Upper Oneida reservoir	10 acres	3,000 R. T. +
1–3	Dry or small	None.
16	1.5 miles	150 B. T. +
20	1 mile	180 B. T. +
1–2	Dry	None.
(1–5, 7, 8, 10, 11, 13–15, 17–19, 21, 22 and their tributaries	Dry, small or warm	None.
17–23	Dry	None.
Cowaselon creek	19 miles	Lm. B.
2 (Canaseraga creek)	9 miles	1,300 B. T. +
2	2 miles	200 B. T. +
1–2	Small	None.
5	1 mile	280 B. T. +
1–4	Dry, small or warm	None.
(1, 3–4, and tributaries)	Dry, small or warm	None..
5	7 miles	900 B T. +
2	3.5 miles	190 S. T. +
1–4	Small	None.T
8	2 miles	60 S. . +
(1, 3–7, 9 and tributaries)	Dry or small	None.
13 (Clockville creek)	6 miles	450 S. T. +
2	4 miles	270 S. T.+
2	0.25 mile	125 S. T.+
3	0.25 mile	65 S. T.+
(1, 4)	Small	None.
6	1 mile	450 S. T. +
7	0.5 mile	150 S. T.+
8	1 mile	180 S. T.+
(1, 3–5, 9–11 and tributaries)	Dry, small or warm	None.
14	0.5 mile	50 S. T.+
15	0.5 mile	100 S. T.+
16	0.5 mile	90 S. T.+
18	0.25 mile	80 S. T.+
19	0.5 mile	180 S. T.+
25	0.25 mile	360 S. T.+
(1, 3, 4, 6–12, 17, 20–24)	Dry, small or warm	None.
24–26	Dry or small	None.
Chittenango creek	24 miles	2,000 B. T.+
6 (Butternut creek)	13 miles	1,400 B. T.+
2 (Limestone creek)	9 miles	3,500 B. T.+
1–6	Dry or small	None.
Snooks pond	35 acres	Lm. B., Bg. S.
Evergreen lake	35 acres	Stocking not desired.
7	Small	None.
9	0.5 mile	150 B. T.+
10	Small	None.
3–12	Warm, small or polluted	None.
13	(Posted)	None (S. T.+)
8	2 miles	400 B. T.+

Appendix VI—Continued

Stream and tributary number	Mileage available for stocking	Stocking policy per mile
Chittenango creek (*Cont'd*)		
1 (and tributary)	Warm	None.
Green lake	62 acres	20,000 R. T.+
Round lake	(Posted)	None (R. T.+)
9 (Pools brook)	3 miles (above Mycenae)	540 S. T.+
1–3	Dry or small	None.
4	0.5 mile	S. T.+
18	0.2 mile	100 B. T.+
19	0.2 mile	150 B. T.+
20	0.5 mile	180 B. T.+
(1–5, 7, 10–17, 21–24 and tributaries)	Dry or small	None.
27–32 (and tributaries)	Dry, small or warm	None.
Seneca river	From Cross lake to Three rivers	Pp., Lm. B.
*O. S. 1–5	Small or warm	None.
Onondaga outlet (and tributary)	Polluted	None.
Onondaga lake	Polluted	None.
Ley creek	Warm	None.
1 (Bear Trap creek)	Upper 2 miles	270 S. T.+
2–11 and tributaries	Small or warm	None.
(1–2, Onondaga creek, Ninemile, No. 4 and tributaries)	Small, warm or polluted	None.
†O. S. 1–O. S. 3	Small or warm	None.
Dead creek	Warm	None.
6 (Gully brook)	3 miles	360 S. T.+
(1–5, 7)	Small or warm	None.
D. S. 1–D. S. 4	Small or warm	None.
Carpenter brook	7 miles	300 S. T.+
1	5 miles	180 S. T.+
2	1 mile	350 S. T.+
3	Dry	None.
Cross lake	3 square miles	Bg. S., Co., Sm.B., Lm. B., Pp.
1–2 and tributaries	Small or warm	None.
Skaneateles creek and tributaries	Small, warm or polluted	None.
Ox creek	Warm	None.
1 (Little Ox creek) upper	1 mile above pond	125 S. T.+
1–4 (and tributaries)	Dry or small	None.
Mud pond	Area, 65 acres; depth, 40 feet	Lm. B., Pp., Pkl., Bh. C.
2–4	Small	None.
Ox cr. 0.2 and tributaries	Small or warm	None.
Ox cr. 0.3–Ox. cr. S. 8	Small or warm	None.

*O. S.=Oswego–Seneca.
† O. S.= Onondaga–Seneca.

Appendix VII

Stocking List to Accompany Map 4A

Canandaigua, Phelps, Geneva and Auburn quadrangles

Stream and tributary number	Mileage available for stocking	Stocking policy per mile
Seneca river	19 miles	Lm. B., Pp.
North brook (Cold spring)	1.5 miles (Price spring to Throop)	1,600 S. T.+
1 (Putnam brook)	Not on this map	....
6	Warm, above No. 3, below 3, 0.5 mile	180 B. T.+
1 (Crocker brook)	2 miles	180 B. T.+
2	Small	None.
3 (Cady brook)	2 miles	200 B. T.+
4	Small	None.
10	Small	None.
1	Small and warm	None.
10 (Wheeler brook)	2 miles, uppermost, above tributary No. 3	180 B. T.+
	2 miles, lower	110 B. T.+
1–7 and tributaries	Small and warm	None.
8	0.5 mile	180 B. T.+
Spring run (Payne spring)	0.1 mile	200 S. T.+
Price spring run	Oxygen content too low	None.
11–13 and tributaries	Small, warm or dry	None.
Coldspring brook (E. C. 4)	Warm or sulphurous	None.
Owasco outlet	1.5 miles (lake to Woolen mills)	Sm. B., Pp.
6–9	Small and warm	None.
Owasco lake		
Dutch Hollow brook	2.5 miles near sources*	270 S. T.+
	5 miles (lower)	R. T. natural spawning adequate.
4 (Long Point brook)	0.25 mile	R. T. natural spawning adequate.
1, 2, 3, 5, 35–49 and tributaries	Dry, warm or small	None.
Crane creek, Crane S. 1–4 and tributaries	Warm	None.
Cayuga lake		
Sawyer creek	4 miles (middle)	380 B. T.+
8 and pond	Private preserve	None (R. T., S. T.)
137	0.7 mile	300 R. T.+
1	0.5 mile	100 R. T.+
1–3, 4–7, 9–21, Great Gully brook, Glen creek, Dean creek, Schuyler creek, Salmon creek, 121–136, 138 and tributaries	Dry, warm or small	None.
Cayuga lake S. 1–2, Sucker brook, S. S. 1–3 and tributaries	Dry, warm or small	None.

* See map 4B.

Appendix VII—Continued

Stream and tributary number	Mileage available for stocking	Stocking policy per mile
Seneca river — (*Cont'd*)		
Kendig creek	1 mile (lower)	Lm. B.
1–8 and tributaries	Warm or dry	None.
Seneca lake		
Reeder creek	2 miles	400 R. T.+
1–5, Silver creek, Wilson creek (east shore), Kashong creek, 107–109, Benton run, Wilson creek, White Spring brook, 110–114 and tributaries	Dry, small or warm	None.
Clyde river (including the Canandaigua outlet)	34 mi. { 5 mi. (lower)	Lm. B., Pp.
	6 mi. (29-37)	1,500 B. T. (trial planting).
	18 mi. (37–Chapinville)	Sm. B.
1–15 and tributaries	Small, warm or dry	None.
18 (Pond brook) and tributary streams	Warm	None.
Newton ponds	12 acres, municipal water supply	None (Lm. B.)
Lowery pond	30 acres (posted)	None (Lm. B., Bg. S.)
Phillips pond	15 acres (posted)	None (Lm. B., Bg. S.)
Vandemark pond	40 acres	Lm. B., Bg. S.
23 (Ganargua creek, including Mud creek — headwaters of Ganargua creek)	Warm and polluted	None.
45 (Fish creek)	6 miles	720 B. T.+
7	1.5 miles	190 B. T.+
8	2 miles	120 B. T.+
1	0.5 mile	18 B. T.
2	Small and warm	None.
3	0.5 mile	180 B. T.
1–6, 9–11 and tributaries	Small, warm or dry	None.
(41–44, 46–77 and tributaries)	Small, warm or dry	None.
Sterling pond (near East Bloomfield)	64 acres	Lm. B., Bg. S.
30	0.5 mile	180 B. T.
Spring run	0.25 mile	300 B. T.+
Spring run	0.75 mile	300 B. T.+
Spring run	0.5 mile	300 B. T.
35	2 miles	300 B. T.
1, 2, 3, 4	Small, warm or dry	None.
(29, 31–34, 36–39 and tributaries)	Small, warm or dry	None.
40 (Flint creek)	Mouth to tributary 7, warm	None.
	Tributary 7–13	Lm. B., Pp.
1 and tributary streams	Small and warm	None.
Newark reservoir	Newark water supply (posted)	Stocking not desired.
2–15 and tributaries	Small, warm or dry	None.

Appendix VII—Continued

Stream and tributary number	Mileage available for stocking	Stocking policy per mile
Clyde river — (*Cont'd*)		
41	1 mile	300 S. T.
1	Dry	None.
2	0.1 mile	200 S. T.+
42–58 and tributaries	Small, warm, dry and polluted	None.
Canandaigua lake		
West river	5 miles, lower	Lm. B., Pp.
	Remainder, dry or small	None.
(1–14, 31–48 and tributaries of West river)	Dry, small or warm	None.
Back Channel (Seneca river)	3 miles	Lm. B., Pp.
1 and pond	Small	None.
Black lake	As Seneca river	Lm. B., Pp.
1–2 and tributaries	Warm and small	None.
Clyde S. 1–5 and tributary streams	Small, warm or dry	None.
Gem lake	7 acres	Lm. B., Bg. S.

Appendix VIII

STOCKING LIST TO ACCOMPANY MAP 4B

Skaneateles, Tully, Cazenovia, Morrisville and Sangerfield quadrangles

Stream and tributary number	Mileage available for stocking	Stocking policy per mile
Oneida creek	10 miles	1,000 B. T.+
6 (Sconondoa creek)	3 miles	315 B. T.+
15	0.5 mile	190 B. T.+
18	1 mile	180 B. T.+
20 (Knoxboro brook)	0.5 mile	50 B. T.+
25	1 mile	50 B. T.+
1	1.5 miles	50 B. T.+
2	Small	None.
14, 16, 17, 19, 21–24, 26. 27 and tributaries	Dry, small or warm	None.
23	1.5 miles	100 S. T.+
24–28 and tributaries	Small	None.
29	0.5 mile	125 B. T.+
30	0.75 mile	125 B. T.+
31–34	Dry, small or warm	None.
35	4.5 miles	250 B. T.+
1	3 miles	150 S. T.+
3	0.75 mile	75 S. T.+
1, 2, 4–6 and tributaries	Small, warm or dry	None.
36–39 and tributaries	Small, dry or warm	None.
Cowaselon creek	2.5 miles	360 S. T.+
Canaseraga creek		
5 and tributaries	Small	None.
13 (Clockville creek)	0.5 mile	180 S. T.+
25 and tributary	Small	None.
26–27	Dry	None.
Chittenango creek	19 miles	1,500 B. T.+
6 (Butternut creek)	No. 14 to Apulia dam, 13 miles	1,500 B. T.+
	Apulia dam to No. 39 and pond, polluted	None.
	No. 39 to source, 2 miles	360 S. T.+
2 (Limestone creek)	18 miles	2,000 B. T.+
8	4 miles	800 B. T.+
8	4.5 miles	140 B. T.+
1	1 mile	70 B. T.+
2–6 and tributaries	Small or dry	None.
1–7, 9–14, and tributaries.	Dry, small or warm	None.
9–33	Dry, small or warm	None.
34	Mouth to Delphi, polluted	None.
	Delphi to source, 1.5 miles	90 S. T.+
5	0.5 mile	70 S. T.+
1–4, 6, 7, and tributaries	Small, dry or warm	None.
37	4 miles	1,500 B. T.+
1	2 miles	150 B. T.+
41	0.5 mile	130 B. T.+
35, 36, 38–40, 42–44 and tributaries	Dry, small and warm.	None.

Appendix VIII—Continued

Stream and tributary number	Mileage available for stocking	Stocking policy per mile
Chittenango creek — (*Cont'd*)		
6 Butternut creek — (*Cont'd*)		
14	0.5 mile	125 B. T.+
1	Small	None.
15	Lower 2 miles	250 B. T.+
1	1 mile	270 B. T.+
1	Small	None.
2	Lower 0.4 mile	250 B. T.+
1	Small	None.
3–4	Small	None.
Jamesville reservoir	0.52 square miles	Lm. B., Bg. S.
16–18	Dry	None.
19	1 mile	180 B. T.+
20	Dry	None.
21	2 miles	360 B. T.+
1	1 mile	180 B. T.+
1	Small	None.
2	Small	None.
22	Small	None.
23	1 mile	270 B. T.+
24 and tributaries	Warm	None.
25	Lower 0.4 mile	720 B. T.+
26–28 and tributaries	small or warm	None.
29	0.5 mile	125 B. T.+
1	Small	None.
30–34 and tributaries	Dry or small	None.
35	1 mile	180 B. T.+
1	Small	None.
36	1.5 miles	360 B. T.+
1–2	Small	None.
37–38	Dry or small	None.
Pond	Polluted	None.
39	1.5 miles	90 S. T.+
40	Small	None.
41	0.3 mile	90 S. T.+
25–28	Dry	None.
29 (Munger brook)	3 miles	500 S. T.+
1 and tributary	Dry	None.
2	1.5 miles	190 S. T.+
1–2	Small	None.
3	0.5 mile	90 S. T.+
4	0.5 mile	235 S. T.+
5	Small	None.
3	0.2 mile	120 S. T.+
30 and tributary	Small	None.
31	2 miles	270 S. T.+
1–3	Small	None.
32–33	Dry or small	None.
34	1 mile	180 B. T.+
1–2	Small	None.
35	Warm	None.
Cazenovia lake	2 square miles	Sm. B., Pp., Y. P.
1–9 and tributaries	Dry or small	None.
36	1.5 miles	270 S. T.
1	0.5 mile	180 S. T.+
37–46 and tributaries	Dry, small or warm	None

Appendix VIII—Continued

Stream and tributary number	Mileage available for stocking	Stocking policy per mile
Chittenango creek — (*Cont'd*)		
47	2.5 miles	1,300 S. T.+
1	Small	None.
2	2 miles	450 S. T.+
1–3 and tributary	Small or dry	None.
3	Small	None.
4	0.5 mile	235 S. T.+
1	Small	None.
5 (Spring run)	0.5 mile	290 S. T.+
48 and tributary	Dry	None.
49	0.6 mile	180 B. T.+
50	0.5 mile	235 B. T.+
51	3 miles	360 B. T.+
1	1 mile	126 B. T.+
1	Small	None.
2 and tributary	Small	None.
3	0.5 mile	65 B. T.
4–5	Dry or small	None.
52, 53 and tributary	Small	None.
54	1 mile	125 B. T.+
1–2	Small	None.
55	1 mile	235 B. T.+
56	Small	None.
Onondaga creek	No. 8 to No. 26 15 miles	600 B. T.+
	No. 26 to source, 5 miles	320 S. T.+
1–8 and tributaries	Small or warm	None.
9	5 miles	216 B. T.+
1	0.5 mile	90 B. T.+
2–3 and tributary	Dry or small	None.
4	0.3 mile	65 B. T.+
5–7	Small	None.
8	0.4 mile	90 B. T.+
10	Dry	None.
11 (West branch)	8 miles	380 S. T.+
3	0.5 mile	125 S. T.+
Pond	1 acre	300 S. T.+
6	1 mile	100 S. T.+
1–2 and tributaries	Dry	None.
3	0.5 mile	190 S. T.+
1	Small	None.
4	0.5 mile	75 S. T.+
1	1 mile	235 S. T.+
2	Small	None.
5–8	Dry or small	None.
8	Lower 0.5 mile	142 S. T.+
1–2 and tributaries	Small	None.
1, 2, 4, 5, 7, 9, 10 and tributaries	Dry, small or warm	None.
12–13	Dry	None.
14	Lower 1 mile	450 B. T.+
15–17	Dry or small	None.
18	Lower 1 mile	450 B. T.+
1	Small	None.
19–24	Dry or warm	None.

Appendix VIII—Continued

Stream and tributary number	Mileage available for stocking	Stocking policy per mile
Chittenango creek — (*Cont'd*)		
Onondaga creek — (*Cont'd*)		
11 (West branch) — (*Cont'd*)		
25	1 mile	180 B. T.+
1	Small	None.
26	0.7 mile	180 S. T.+
27	Small	None.
28	0.6 mile	110 S. T.+
1	Small	None.
29–30	Dry	None.
31	0.3 mile	75 S. T.+
32	Dry	None.
33	0.6 mile	180 S. T.+
Ninemile creek	Warm	None.
2	Small	None.
Mud pond	About 3 acres	Lm. B., Bg. S.
6–15	Small and warm	None.
Mud pond	7 acres	Lm. B.. Bg. S., Y. P.
16–27	Dry, small or warm	None.
Otisco lake		
Pond	Tributary No. 3 Otisco, 80 acres	Lm. B., Bg. S.
4	Mouth to dam, 1.5 miles	400 R. T.+
	Dam to source, 2 miles	450 S. T.+
1–3 and tributaries	Small	None.
6	0.5 mile	180 R. T.+
14	Mouth to dam, 0.5 mile	270 R. T.+
	Dam to source, 1.5 miles	180 S. T.+
1	Small	None.
Spafford creek	6 miles	400 S. T.+. 300 R. T.+
1	0.3 mile	75 S. T.+
1–2 and tributaries	Small	None.
5	1 mile	65 S. T.+
8	0.6 mile	235 S. T.+
9	0.3 mile	65 S. T.+
2–4, 6, 7 and tributaries	Small	None.
1–3, 5, 7–13, 15–44 and tributaries	Dry, small or warm	None.
1 (tributary to Carpenter brook)	2 miles	360 S. T.+
Skaneateles outlet	Polluted	None.
3–5 and tributaries	Small and warm	None.
Skaneateles lake		
14	0.5 mile	180 R. T.+
Skaneateles inlet	2 miles	250 B. T.+, 200 R. T +
1	Small	None.
11	0.5 mile	180 B. T.+
1–13, 15–54, 55–71 and tributaries of 14	Dry, small or warm	None.

Appendix VIII—Continued

Stream and tributary number	Mileage available for stocking	Stocking policy per mile
Skaneateles Outlet — (*Cont'd*)		
Skaneateles Lake — (*Cont'd*)		
Bear Swamp creek	Mouth to New Hope, precipitous	None.
	New Hope to source, 4.5 miles	1,500 S. T.+
11	0.3 mile	300 S. T.+
13	0.6 mile	300 S. T.+
1–10, 12, 14	Dry	None.
72–91	Dry	None.
Putnam brook and tributaries	Small	None.
9 (tributary to No. 10 of North brook)	Small or warm	None.
Owasco lake		
Dutch Hollow brook	Mouth to No. 27, 9 miles	R. T.— natural spawning adequate.
	1 mile above No. 27	200 B. T.+
1–28	Dry or small	None.
4	1 mile	R. T.— natural spawning adequate.
1, 2, 3, 5–26 and tributaries	Dry or small	None.
Owasco inlet	Warm and sluggish	None.
1–2 and tributaries	Dry	None.
1 (Decker brook, tributary to No. 17)	3 miles	820 S. T.+
1	2 miles	720 B. T.+
1–3	Small	None.
2	1.5 miles	350 S. T.+
1	1.5 miles	180 S. T.+
2	Small	None.
6	0.4 mile	120 S. T.+
3–5, 7–10	Small, warm or dry	None.
1, 2, 3, 5–26, 27, 28 and tributaries	Dry, small or warm	None.

Appendix IX

Stocking List to Accompany Map 5

Naples, Penn Yan, Ovid, Genoa, Moravia and Cortland quadrangles

Stream and tributary number	Mileage available for stocking	Stocking policy per mile
Skaneateles inlet	4.5 miles	200 B. T.+, 350 R. T.+
Spring run	0.3 mile	90 R. T.+
(2–10)	Dry or small	None.
Bear Swamp creek	1 mile	1,000 S. T.+
Owasco inlet	19 miles	1,000 B. T.+, 1,500 R. T.+
3–16	Dry	None.
17 (Dresserville creek)	1.5 miles (mouth to Montville)	900 B. T.+, 1,000 R. T.+
	3 miles (Montville to Dresserville)	1,200 B. T.+
	3 miles, middle (posted)	None.
	Dresserville to source, warm	None.
1 (Decker brook)	1.5 miles (mouth to No. 1)	2,000 B. T.+
	1.5 miles (No. 1 to 0.5 mile above No. 2)	1,000 S. T.+
1	1.5 miles	450 B. T.+
Spring run	0.3 mile	300 S. T.+
2	2 miles	350 S. T.+
2–10	Dry or small	None.
11 (Butler brook)	1.3 miles (below dam)	1,300 B. T.+
	1 mile (above dam)	350 S. T.+
	0.5 mile (lower and middle), posted	None.
1	0.5 mile	235 S. T.+
1	Small	None.
12	0.5 mile, lower (posted)	None.
	1 mile (above posting)	350 B. T.+
1–2	Small	None.
13	0.5 mile	235 B. T.+
14	0.3 mile (lower)	120 B. T.+
15–18	Dry or small	None.
Pond on 18	4 acres	Lm. B., Bg. S.
18–28	Dry or small	None.
29 (Hemlock creek)	5 miles	1,200 S. T.+
2 (Hollow brook)	4.5 miles	900 S. T.+
1–6	Dry, warm or small	None.
(1, 3–10 and tributaries)	Dry, warm or small	None.
30–42	Dry or small	None.
43 (Sears brook)	0.5 mile	125 B. T.+
44 (Peg Mill)	3 miles	540 S. T.+
1 (Cogshall brook)	1 mile	180 S. T.+
2 (North brook)	2 miles	360 S. T.+
3 (Middle brook)	2 miles	360 S. T.+
4 (Lane brook)	1.5 miles	270 S. T.+

Appendix IX—Continued

Stream and tributary number	Mileage available for stocking	Stocking policy per mile
(5 and tributaries of 1, 2, 4)	Small	None.
45 (Weaver brook)	1 mile	270 B. T.+
1	Small	None.
46	Small	None.
47 (Booth brook)	1 mile	125 B. T.+
48 (Bosard brook)	0.5 mile	70 B. T.+
49	Small	None.
50 (Hart brook)	2 miles	350 B. T.+
1	1 mile	235 B. T.+
2–3	Small	None.
51–52	Small	None.
53 (Carey brook)	1 mile	270 S. T.+
54 (Dick brook)	1 mile	125 B. T.+
55 (Stoddard brook)	1.5 miles	90 B. T.+
56 (Peruville creek)	6 miles	540 B. T.+
4	1 mile	90 B. T.+
(1, 2, 3, 5, 6, 7)	Small	None.
57	0.6 mile	90 B. T.+
58	0.5 mile	90 B. T.+
59 (Spring brook)	1.5 miles	470 S. T.+
60 and tributary	Small	None.
Cayuga lake		
22–51 and tributaries	Dry or small	None.
Salmon creek	17 miles	300 B. T.+, 200 R. T.+
1–7	Dry or small	None.
8 (Gulph creek)	4 miles	200 B. T.+, 100 R. T.+
1–11	Dry or small	None.
9–23	Dry or small	None.
24	2 miles	180 B. T.+
1	1.5 miles	90 B. T.+
1	Small	None.
25–38	Dry, warm or small	None.
52–57	Dry or small	None.
Fall creek	8.5 miles (No. 15 to McLean)	Natural spawning of Sm. B. adequate.
	5 miles (McLean to Groton City pond)	2,000 B. T.+
	6 miles (Groton City pond to source)	1,500 S. T.+
8	Small	None.
16 (Virgil creek)	2.5 miles	1,300 B. T.+
15	0.5 mile (lower)	270 B. T.+
	Upper, dry	None.
1	1.5 miles	180 B. T.+
2	Dry	None.
(2, 4, 11, 13, 16–20 and tributaries)	Dry	None.
Spring run	0.3 mile	180 B. T.+
17–18 and tributaries	Dry or warm	None.
19 (Mud creek)	2 miles	585 S. T.+
1–4 and tributaries	Dry or small	None.
20–21 and tributaries	Dry	None.

Appendix IX—Continued

Stream and tributary number	Mileage available for stocking	Stocking policy per mile
Fall creek (*Cont'd*)		
22	3.5 miles	1,400 S. T.+
1	1 mile	180 S. T.+
2	0.5 mile	117 S. T.+
3	0.5 mile	360 S. T.+
4	1 mile	90 S. T.+
5	1.5 miles	270 S. T.+
1	0.5 mile	90 S. T.+
23	Small	None.
24 (Hart brook)	1 mile	350 B. T.+
25	0.4 mile	470 B. T.+
26 (Jones brook)	1.5 miles	350 B. T.+
1	Small	None.
27 (Blanchard brook)	0.5 mile	432 B. T.+
1	Small	None.
28	Small	None.
29	1 mile	575 B. T.+
1	0.3 mile	150 B. T.+
30 (Webster brook)	2 miles (lower)	900 B. T.+
	Upper, warm	None.
1 (Wilson's brook)	1.5 miles	190 B. T.+
2–7	Dry or small	None.
31	0.5 mile	235 B. T.+
1	Small	None.
32	0.6 mile	290 S. T.+
33 and tributaries	Warm	None.
Spring run	0.3 mile	235 S. T.+
34	0.3 mile	575 S. T.+
35	Small	None.
36	1.5 miles	575 S. T.+
37–38	Dry or small	None.
39	5 miles	935 S. T.+
1	2 miles	235 S. T.+
1	Small	None.
2–8	Dry or small	None.
9	0.3 mile	120 S. T.+
10	Small	None.
40–41	Dry	None.
Lake Como	0.12 square miles	20,000 R. T.+, Sm. B.
73–82	Dry or small	None.
Taghanic creek	0.8 mile (mouth to falls)	1,000 R. T.+
	6 miles (falls to No. 3)	800 B. T.+
6 (Reynoldsville creek)	1.5 miles	1,200 B. T.+
(1, 2, 3, 4, 5, 7 and tributaries of 6)	Dry, small or warm	None.
83–121 and tributaries	Dry, small or warm	None.
Seneca lake (6–33, 77–94, Big Stream and all tributaries)	Dry or small	None.
Keuka lake outlet	0.3 mile (mouth to Cascade Falls)	3,000 R. T.+
	Cascade Falls to source, polluted	None.
1–14	Dry or small	None.

Appendix IX—Continued

Stream and tributary number	Mileage available for stocking	Stocking policy per mile
Keuka lake outlet — (*Cont'd*)		
Keuka lake		
61	9 miles	200 S. T.+, 300 R. T.+
(1–25, 43–60, 62–68 and tributaries of 61)	Dry, small or warm	None.
95–106	Dry	None.
Kashong creek and tributaries	Dry	None.
Flint creek (tributary of Canandaigua outlet)	12 miles (Potter to source)	600 B. T.+
	5 miles (14 to Potter)	Lm. B., Pp.
26 (Nettle Valley creek)	5 miles	270 B. T.+
38	1 mile	125 B. T.+
39	3 miles	315 B. T.+
40	0.25 mile	180 B. T.+
(13–25, 27–37 and tributaries of 26 and 39)	Dry, small or warm	None.
Canandaigua lake		
15–31	Dry or small	None.
West river	4 miles (lower)	Sm. B., Pp.
	6 miles (upper)	190 R. T.+
1	Dry	None.
2 (Naples creek)	4 miles (lower)	1,000 B. T.+, 1,000 R. T.+
	5 miles, upper (Eelpot creek)	450 S. T.+
1–2	Dry	None.
3	2 miles	180 B. T.+
4–7	Dry	None.
8 (Grimes creek)	2 miles (below falls)	800 B. T.+
	6 miles (above falls)	500 S. T.+
1	Small	None.
2	2 miles (lower 0.5 mile posted)	350 B. T.+
(1–2 and tributaries)	Small	None.
3	Dry	None.
4	1.25 miles	270 S. T.+
5 and tributaries	Warm	None.
6	1 mile	125 S. T.+
7–10	Dry or small	None.
9 (Tannery creek)	1 mile (below dam)	600 B. T.+
	4 miles (above dam)	500 S. T.+
1–5	Dry or small	None.
10 (Reservoir creek)	1 mile (below dam)	360 B. T.+
	2.5 miles (above reservoir)	360 S. T.+
1	Small	None.
2	2 miles	360 B. T.+
3	2 miles	500 R. T.+
1–4 and tributaries	Small	None.
11	Small	None.
12	1.5 miles	360 B. T +
1–4	Small	None.

Appendix IX—Continued

Stream and tributary number	Mileage available for stocking	Stocking policy per mile
West river—(*Cont'd*)		
2 (Naples creek)—(*Cont'd*)		
13 and tributaries	Small and dry	None.
14	1.5 miles	270 S. T.+
15	1 mile	235 S. T.+
16	Small	None.
17	0.5 mile	180 S. T.+
18	1 mile	125 S. T.+
19	1 mile	125 S. T.+
Mud creek (and tributaries 77–80)	Dry, small or warm	None.

Appendix X

STOCKING LIST TO ACCOMPANY MAP 6

Bath, Hammondsport, Watkins, Ithaca, Dryden and Harford quadrangles

Stream and tributary number	Mileage available for stocking	Stocking policy per mile
Cayuga lake		
57–64	Dry	None.
Fall creek	10 miles	Natural spawning of Sm. B. adequate.
1–15	Dry, small or warm	None.
16 (Virgil creek)	8 miles	1,350 B. T.+
1–4	Dry	None.
5	Sulphurous	None.
6–7 and tributaries	Dry or warm	None.
8	0.5 mile	Natural spawning of S. T. adequate.
9	Dry	None.
10	0.3 mile	200 B. T.+
11 and tributary	Dry	None.
12	0.4 mile	300 S. T.+
13	Dry	None.
14	1 mile, lower	180 B. T.+
	1 mile, warm (upper)	None.
1	0.6 mile	100 B. T.+
1	0.2 mile	200 B. T.+
Cayuga inlet	Mouth to Fair Grounds, polluted	None.
	Fair Grounds to Nina, 6 miles	600 B. T.+, 600 R. T.+
	Nina to Stratton, 2 miles	720 R. T.+
1–2	Small	None.
3 (Cascadilla creek)	Mouth to 7, warm	None.
	7 to source, 2.5 miles.	720 B. T.+
1–7	Dry	None.
8	0.5 mile, lower	250 B. T.+
1–2	Small	None.
Spring runs between 8–9	Small (posted)	None.
9	Dry	None.
10 (Ringwood brook)	2 miles	270 B. T.+
1	0.3 mile	150 B. T.+
Tributaries and 11–13	Small or dry	None.
4	Dry	None.
5 (Sixmile creek)	Mouth to Potters Falls dam, 1 mile	1,000 R. T.+
	Potters Falls dam to 37, 7.5 miles	1,000 R. T.+, 800 B. T.+
	37 to falls at 49, 5.5 miles	1,600 B. T.+
	49 to source, 2 miles	1,200 S. T.+
1–38 and tributaries	Dry warm or small	None.

Appendix X—Continued

Stream and tributary number	Mileage available for stocking	Stocking policy per mile
Cayuga lake — *(Cont'd)*		
Cayuga inlet — *(Cont'd)*		
5 (Sixmile creek) — *(Cont'd)*		
Potters Falls reservoir	192 acres	50,000 R. T.+
39 (Mulks brook)	2 miles	180 B. T.+
Tributaries and 40–41	Dry	None.
42 (Bull brook)	1 mile	200 B. T.+
1	0.5 mile	100 B. T.+
2	0.4 mile	70 B. T.+
Bull pond	(Posted)	None.
43–44	Small or dry	None.
45 (Trout brook)	1 mile	300 S. T.+
Tributaries and 46–47	Small or dry	None.
48 (Dusenbury brook)	2.5 miles	1,200 S. T.+
Tributaries and 49–59	Small or dry	None.
6–7 and tributaries	Dry or small	None.
Burrts Spring run	0.2 mile	300 B. T.+
8–9 and tributaries	Dry or small	None.
10 (Buttermilk creek) and 11–15	Dry, small or warm	None.
Jennings pond	28 acres	Lm.B., Bg. S., Co.
16 (Butternut creek)	Mouth to falls, 2 miles	800 R. T.+, 800 B. T.+
	Falls to 15, 2 miles	700 B. T.+
	15 to source, dry	None.
1–3	Dry	None.
4 (Enfield creek or Fivemile)	3 miles, lower	1,000 B. T.+
	Upper, dry	None.
1–19 and tributaries	Dry, small or warm	None.
5–17 and tributaries and 18–24	Dry, small or warm	None.
25 (Newfield brook)	Mouth to falls, 0.8 mile	1,200 R. T.+
	Falls to Newfield dam, 1 mile	1,000 B. T.+
	Dam to source, 3.5 miles	1,000 S. T.+
1–5 and tributaries	Dry, small or warm	None.
6	0.8 mile	180 S. T.+
7–10 and tributaries	Dry, small or warm	None.
11–13	0.3 mile each	275 S. T.+
26	Dry	None.
27	1.5 miles	180 B. T.+
1–2	Dry or small	None.
28 (Robinsons Spring brook)	1.5 miles	180 B. T.+
Tributaries and 29–30	Small or dry	None.
31 (Stratton brook)	1.3 miles	360 B. T.+
Tributaries and 32–48 and tributaries	Dry, warm or small	None.
Williams brook — 73	Dry, small or warm	None.
81	Small	None.
Taghanic creek	7 to 15, 7 miles	700 B. T.+
	15 to source, Small	None.
5	Dry	None.

Appendix X—Continued

Stream and tributary number	Mileage available for stocking	Stocking policy per mile
Cayuga lake — (*Cont'd*)		
Taghanic creek — (*Cont'd*)		
6 (Reynoldsville creek)	3 to Reynoldsville, 4 miles	700 B. T.+
	Reynoldsville to source, dry or small.	None.
3 (Allen brook)	1 mile, lower	500 B. T.+
Tributaries and 4–15	Small, dry or warm	None.
7–14	Dry, small or warm	None.
15	1.5 miles	75 B. T.+
Tributaries and 16–19	Small	None.
Seneca lake		
Sawmill creek	Mouth to falls, 0.3 mile	450 R. T.+
	Falls to source, small	None.
34–43 and tributaries	Dry or small	None.
44	Mouth to Burdett, precipitous	None.
	Burdett to source, 5 miles	700 B. T.+
1–3	Dry or small	None.
4 (Texas Hollow brook)	3 miles	450 B. T.+
1	Dry	None.
2	0.5 mile	120 B. T.+
3–4	Small	None.
5–7	Small	None.
8	0.5 mile	270 B. T.+
9–11	Small	None.
45 — Excelsior Glen brook	Dry	None.
Catharine creek	10 miles	1,000 R. T.+
1–4 and tributaries	Dry or small	None.
5 (Catlin Mills creek)	Mouth to falls, 0.8 mile	1,000 R. T.+
	Odessa to 4, 2 miles	120 B. T.+
	4 to source, small	None.
1	Dry	None.
2 (Cranberry creek)	3 miles	125 B. T.+
1	Small	None.
3	0.5 mile	180 B. T.+
4–11 and tributaries	Dry or small	None.
6 (Havana Glen brook)	Below falls, 0.5 mile	1,000 R. T.+
	Above falls, warm	None.
Tributaries and 7–8 and tributaries	Dry or small	None.
9	Below falls, 0.5 mile	180 R. T.+
	Above falls, small	None.
Tributaries and 10–22 and tributaries	Dry or small	None.
Watkins Glen creek	Small	None.
46–75 and tributaries	Dry, small or warm	None.
Big Stream creek and tributaries.	Dry, small or warm	None.

Appendix X—Continued

Stream and tributary number	Mileage available for stocking	Stocking policy per mile
Keuka lake		
26–35	Dry, small or warm	None.
Keuka inlet	Mouth to dam at 5, 2 miles	2,000 R. T.+
	5 to State Hatchery, 1.5 miles	1,000 B. T.+
	Hatchery to source, 0.5 mile	300 B. T.
1 and tributaries	Dry	None.
2	1 mile, lower	235 R. T.+
	Upper, small	None.
1	Dry	None.
Spring run	0.2 mile	200 R. T.
3–8 and tributaries	Dry or small	None.
37–42	Dry or small	None.

Appendix XI

STOCKING LIST TO ACCOMPANY MAP 7

Elmira quadrangle

Stream and tributary number	Mileage available for stocking	Stocking policy per mile
Catharine creek	3 miles	1,000 R. T.+, 1,000 B. T.+
23–26	Small, dry or warm	None.
27 (Chemung canal)	3 miles	1,000 S. T.+
1	Dry	None.
2	0.5 mile, lower	200 S. T.+
1–2	Small or dry	None.

Appendix XII

Vegetation of Cayuga and Seneca Lakes

W. C. MUENSCHER

The plant life of a lake is limited to that part of the water which is penetrated by the sunlight. Aquatic vegetation consists of two general types of plants: (1). The attached plants consisting of the larger "pondweeds" which often form extensive weed beds. (2). The microscopic free-floating plants (phytoplankton) usually unobserved unless they are present in enormous numbers when they produce the so-called "water bloom."

The attached plants occur in shallow lakes or in the shoal waters of deeper lakes often forming extensive weed beds. The most common kind of weed beds in Cayuga and Seneca lakes consist of large submerged plants that are rooted on the bottom, such as "pondweed," *Potamogetons* sp. and eel-grass, *Vallisneria* sp. etc. Among these larger plants smaller plants are often so abundant that the weed bed consists of a very dense tangled mass of vegetation which may or may not reach the surface of the water. Attached to the stems and leaves of these larger plants are innumerable smaller plants, algae and diatoms, many of which are seasonal. Sometimes they completely cover the larger plants. In Cayuga and Seneca lakes these weed beds are practically limited to the water which is between 5–15 feet in depth. Another type of weed bed common in Cayuga and Seneca lakes consists of stoneworts or "grass," species of *Chara* and *Nitella*, covering sometimes extensive areas of almost pure stands. In the shallow water these plants usually have numerous diatoms and small algae, or even larger filamentous algae, attached to them. The beds of *Chara* occur in water from a few feet deep to a depth of about 20 feet. *Nitella* was observed only rarely in water less than 10 feet deep but more commonly in water from 15 to 25 feet deep. In a few places, notably at the north end of Cayuga lake, at Canoga marshes, and to a less extent at the south end of Cayuga lake and Seneca lake cat-tail marshes occur in which the predominating species is *Typha angustifolia*. Along the outer margin of the cat-tail marshes other emersed plants such as rushes. *Scirpus acutus* and *S. americanus*, may extend over considerable areas of shallow water.

The attached plants, and the smaller plants such as diatoms and algae growing among them, form one of the principal primary sources of food for fish and other animals living in a lake. Some of the larger plants may furnish food or shelter for certain fish or other animals that are eaten by fish. Some of the algae are eaten directly by fish and other animals. Most of the larger plants act as supports on which myriads of smaller plants, algae and diatoms, and also many smaller animals may grow to furnish food for other organisms. When the weeds die they decompose and add to the organic matter in the water or the ooze on the bottom. Some of the products of this decomposition, at least to some extent, are used as a source of food by other organisms.

Cayuga and Seneca lakes are both long narrow deep lakes with very steep sides except at a few points where streams enter. The areas of these lakes that are shallow enough for attached plants are therefore very limited except in the shoal water at or near their ends. The shallow area, and therefore the area covered by weed beds, is much greater in Cayuga lake than in Seneca lake. A list of the principal weed beds in Cayuga and Seneca lakes together with the approximate areas covered by them is given at the end of this chapter. A list of all the species of larger plants observed in the two lakes, indicating the predominating species, is also included.

Because the time available for the study of the attached plants of Cayuga and Seneca lakes was limited, only very general statements can be made regarding the distribution, abundance and relative importance of the various species of plants. Much more intensive work is needed to determine the rôle played by the several species in contributing either directly or indirectly to the food supply of fish. Probably of greater importance than the larger weeds themselves are the algae that grow attached to them, among them, or on the rocks along the shores. It is generally assumed that each kind of "pondweed" produces a single crop. More information is desirable regarding the rate of growth and the conditions under which growth takes place before very accurate quantitative estimates can be made regarding the productivity of a given species.

On the other hand it is known that several attached algae will produce a crop, disappear, and produce another crop. This may be repeated three or four times in one year. In some cases different species may be concerned. It is evident that it is not possible to estimate the amount of food contributed by a given species unless it is known how rapidly or under what conditions it continues to grow or reproduce or how many crops are produced in a season or year. The significant fact is not the amount of plant material that is present, in a given area or lake, at a given time, but how much can be produced in one season or one year and what the most important conditions are affecting this production. To obtain such information it will be necessary to make an intensive study of each species and the conditions under which it thrives.

The principal weed beds in Cayuga lake.—The largest weed beds in Cayuga lake occur near its north end. From Union Springs to the north end the bottom is mostly less than 25 feet deep. Probably about one-half of this area of approximately 10 square miles is covered with weed beds. In some places even where the water is less than 15 feet deep rather extensive barren areas occur. The most prolific beds of larger weeds occur from the railroad trestle at Cayuga village to the north end, and north of Cayuga Park and about Canoga marshes on the west shore. These beds consist largely of species of pondweeds, *Potamogeton Richardsonii*, *P. pectinatus, P. Robbinsonii, P. compressus* and *P. amplifolius*, eel-grass, *Vallisneria americana*, hornwort, *Ceratophyllum demersum, Najas flexilis, Elodea canadensis*, mud plantain, *Heteranthera dubia*, water marigold, *Bidens Beckii*, and a number of less common species. *Ruppia maritima* and *Najas marina*, two brackish water plants, were found only at the north end of Cayuga lake. Both were rather common at Cayuga Park and the latter was also found at Canoga marshes. From Canoga northward, weed beds were observed almost to the middle of the lake in several places. The vegetation in the deeper water sometimes consisted entirely of *Chara* or *Nitella* or both growing together. *Potamogeton gramineus* var. *graminifolius* was frequently found associated with *Chara*.

The bottom at the south end of the lake is rather shallow and sandy near the shore, but somewhat muddy near the 15-25 foot depth which marks the limits of rooted aquatics. Except for some barren sandy places near the southeast corner and the deeper bottom near the middle of the lake, most of the bottom of the area between the south end of the lake and a point one-half mile to the north is covered by rather dense weed beds. The total area occupied by these weed beds is probably less than one square mile. The densest of these beds are located between the lighthouse and the west shore and off the east shore, extending for some distance in each direction from the Remington Salt Works. The predominating species in the southwest corner were *Potamogeton pectinatus, P. Richardsonii, P. crispus, Elodea canadensis, Najas flexilis*, and in deeper water, *Zannichellia palustris* and *Nitella* were abundant. Along the east shore *Potamogeton Richardsonii* and *P. Friesii* were the predominating species.

Along the east shore small areas of weed beds occur in the little bays to the north and south of Myers point, in Aurora bay and to the north and south of Farley's point. At the first two places the predominating species were *Potamogeton Richardsonii* and *P. pectinatus* and in deeper water also *P. gramineus* var. *graminifolius*. At Farley's point the vegetation was very dense and consisted of representatives of most of the species found in Cayuga lake. Along the rest of the shore only scattered and very narrow weed beds occur. These beds are usually less than 100 feet in width and seldom extend for more than 100 yards from shore except on each side of the larger points.

Weed beds in Seneca lake.—There are but two localities in Seneca lake where extensive weed beds occur. The largest and most productive weed beds are at the north end, especially in the northwest corner, covering a total area of probably less than one square mile. In the shallow water near the shore the vegetation was very dense and consisted of numerous species among which Potamogetons predominated. In deeper water *Chara* and *Nitella* were the predominating plants, usually alone or sometimes associated with *Potamogeton gramineus* var. *graminifolius*. The only other weed beds of any extent occur between Dresden and Long point on the west shore of the lake. Here occurred several fairly dense beds of Potamogeton with minor species intermingled, but they are mostly near the shore and only in a few places extend more than 300 yards from shore. The total area of these beds is probably less than one-half square mile. Only a very few small weed beds were noted at the south end of Seneca lake. These occur near the inlet in the southeast corner. In Seneca lake, as in Cayuga lake, only occasional narrow scattered weed beds were found along the east and west shores.

A rough estimate of the areas covered by weed beds would be about six square miles in Cayuga lake and about two square miles in Seneca lake.

A List of the Larger Plants in Cayuga and Seneca Lakes[1]

C = observed in Cayuga lake.
S = observed in Seneca lake.
* = predominating species.

ALGAE

The following genera of the larger algae were represented by one or more species which were abundant in at least one or more localities in both lakes: * Chara, Chaetophora, * Cladophora, Drapernaldia, Hydrodictyon, * Mougeotia, * Nitella, Oedogonium, Oscillatoria, Phormidium, Rivularia, Spirogyra, Ulothrix, Vaucheria, Zygnema.

MARSILEACEAE

C Marsilea quadrifolia L. Water clover, Pepperwort.

EQUISETACEAE

C Equisetum limosum L. (Piper)

TYPHACEAE

C S Typha angustifolia L. Narrow-leaved Cat-tail.
C S Typha angustifolia L. var. elongata (Dudley) Wiegand.

SPARGANIACEAE

C S Sparganium eurycarpum Engelm. Giant Bur-reed.
C S Sparganium americanum Nutt. Bur-reed.

NAJADACEAE

C S Potamogeton natans L. Pondweeds
C S Potamogeton amplifolius Tuckerm.
C S Potamogeton americanus C. & S. var. novaeboracensis (Morong) Benn.
C S *Potamogeton gramineus L. var. graminifolius Fries.
C S Potamogeton angustifolius Birch & Presl.

[1] NOTE: Specimens of nearly all of these plants are preserved in the herbarium of Cornell University.

C S Potamogeton lucens L.
C S *Potamogeton Richardsonii (Benn.) Rydb.
C S Potamogeton bupleuroides Fernald.
C S Potamogeton crispus L.
C Potamogeton epihydrus Raf. var. cayugensis (Wiegand) Benn.
C S Potamogeton compressus L.
C S *Potamogeton Friesii Rupr.
C S Potamogeton pusillus L.
C S Potamogeton vaginatus Turcz.
C S Potamogeton filiformis Pers. var. borealis.
C S *Potamogeton pectinatus L.
C Potamogeton Robbinsii Oakes.
C Ruppia maritima L. var. longipes Hags. Sea- or Ditch-grass.
C S *Zannichellia palustris L. var. major (Boen.) Koch. Horned Pondweed.
C Najas marina L. Large Naiad.
C S *Najas flexilis (Willd.) Rostk. & Schmidt. Naiad.

Alismaceae

C S Sagittaria latifolia Willd. Arrow-head.
C S Sagittaria heterophylla Pursh. Arrow-head.

Hydrocharitaceae

C S *Elodea canadensis Michx. Water-weed.
C S *Vallisneria americana Michx. Eel-grass.

Cyperaceae

C S Scirpus americanus Pers. Rush.
C S Scirpus validus Vahl. Bulrush.
C S Scirpus acutus Muhl. Bulrush.

Araceae

C S Peltandra virginica (L.) Kunth. Arrow Arum.

Lemnaceae

C S Spirodela polyrhiza (L.) Schleid. Duckweed.
C S Lemna trisulca L. Duckweed.
C S Lemna minor L. Duckweed.
C Wolffia columbiana Karst.

Pontederiaceae

C S Pontederia cordata L. Pickerel weed.
C S Heteranthera dubia (Jacq.) MacM. Mud plantain.

Ceratophyllaceae

C S *Ceratophyllum demersum L. Hornwort.

Nymphaeaceae

C S Nymphozanthus advena (Ait.) Fernald. Yellow water-lily.
C Nymphaea odorata Ait. Sweet white water-lily.
C S Nymphaea tuberosa Paine. White water-lily.
C Nelumbo lutea (Willd.) Pers. Yellow nelumbo or lotus.

RANUNCULACEAE

C S Ranunculus longirostris Godr. White water buttercup.
C Rannunculus aquatilis L. var. capillaceus D. C. White water buttercup.

HALORAGIDACEAE

C S *Myriophyllum exalbescens Fernald. Water milfoil.

LENTIBULARIACEAE

C Utricularia vulgaris L. var. americana Gray. Great bladderwort.

ACANTHACEAE

C Dianthera americana L. Water willow.

COMPOSITAE

C S Bidens Beckii Torr. Water marigold.

Key map of Oswego watershed showing the principal water areas and their connections. Outlines in red indicate the boundaries of the U. S. G. S. quadrangles

Map 1.—Highmarket and Port Leyden quadrangles

[illegible]

Map 2.—Oswego, Fulton, Mexico, Kasoag, Taberg and Boonville quadrangles

Map 3A.—Macedon, Palmyra, Clyde and Weedsport quadrangles

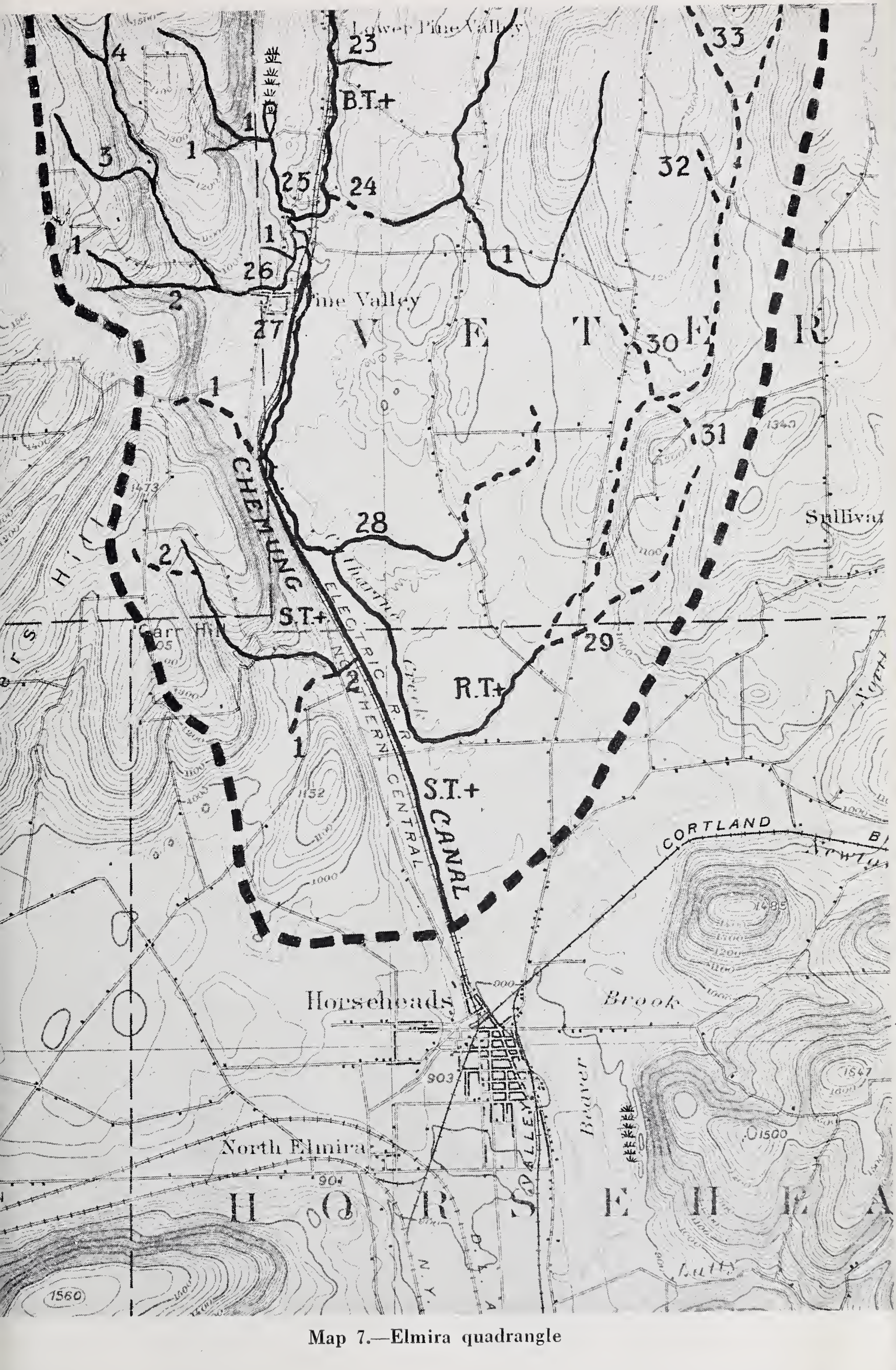
Map 3B.—Baldwinsville, Syracuse, Chittenango, Oneida and Oriskany quadrangles

Map 4A.—Canandaigua, Phelps, Geneva and Auburn quadrangles


N E L S O N

Map 5.—Naples, Penn Yan, Ovid, Genoa, Moravia and Cortland quadrangles

Map 6.—Bath, Hammondsport, Watkins, Ithaca, Dryden and Harford quadrangles



Map 7.—Elmira quadrangle