STATE OF NEW YORK

CONSERVATION DEPARTMENT

A BIOLOGICAL SURVEY OF THE ERIE-NIAGARA SYSTEM

Supplemental to Eighteenth
Annual Report, 1928

ALBANY
J. B. LYON COMPANY, PRINTERS
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Alexander Macdonald.............*Conservation Commissioner*
Francis X. Disney..........*Deputy Conservation Commissioner*
Herbert F. Prescott.............................*Secretary*

Division of Fish and Game

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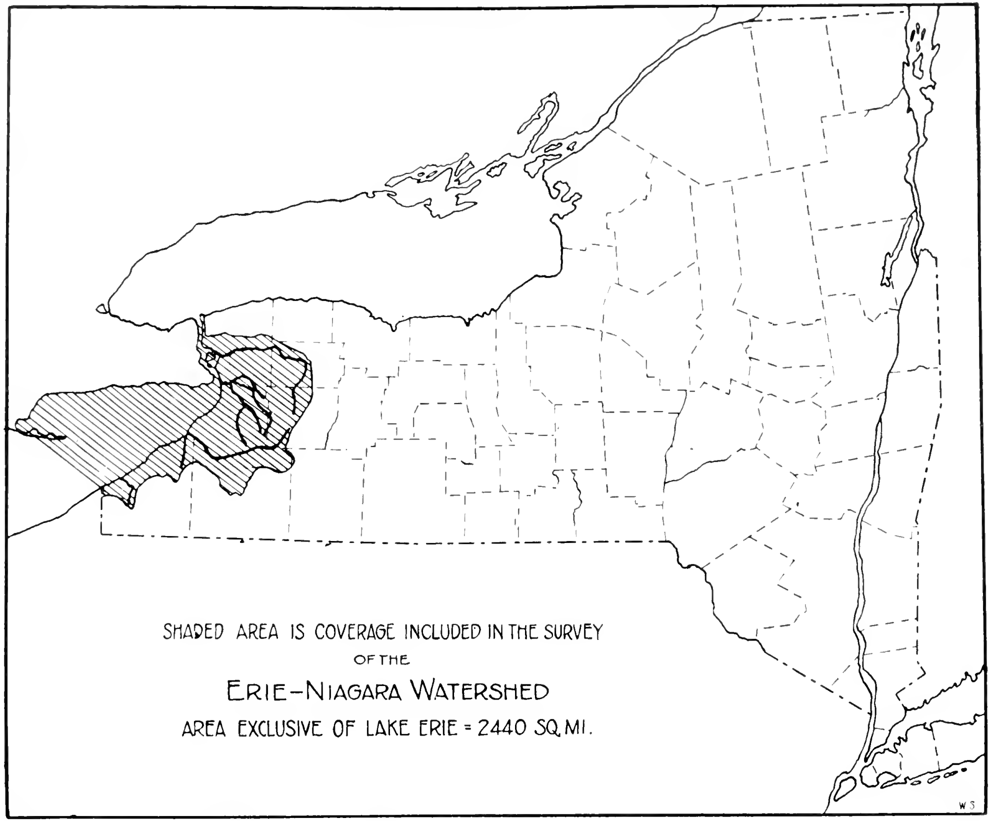
SHADED AREA IS COVERAGE INCLUDED IN THE SURVEY
OF THE
ERIE-NIAGARA WATERSHED
AREA EXCLUSIVE OF LAKE ERIE = 2440 SQ. MI.
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A BIOLOGICAL SURVEY OF THE ERIE-NIAGARA SYSTEM

Supplemental to the Eighteenth Annual Report, 1928

Introduction

By Emmeline Moore

Investigator in Fish Culture, in Charge of Survey

The report of the biological survey submitted herewith incorporates a series of papers bearing on the subject of the fisheries in the Erie-Niagara system. Three major lines of inquiry were pursued—the study of the deeper water at the eastern end of Lake Erie with special emphasis on factors limiting productivity; the investigation of the general shore conditions, including a study of the effects of pollution resulting from the highly industrialized centers on or near the water front; and an evaluation of the tributary streams and their headwaters in relation to a stocking policy.

The recent disastrous slump in the whitefish and herring industry in Lake Erie led Commissioner Alexander Macdonald to secure an adequate appropriation from the Conservation Fund in order that one subdivision of the survey might be conducted as a joint effort with the Federal Bureau of Fisheries following plans which developed at a conference called by the United States Fisheries Commissioner, Henry O'Malley, in February at Cleveland, Ohio. The Federal Bureau agreed upon a plan of cooperation which would detail the government boat "Shearwater" to the uses of the New York State Conservation Department for its Erie-Niagara survey. Subsequently the Province of Ontario detailed its representative to join the survey staff.

This initial effort in analyzing the Lake Erie problem should be the forerunner of more effective coordination of all agencies interested in the Great Lakes fishery.

Area of Survey.— The coverage included in the Erie-Niagara survey is shown in the accompanying map. In respect of the fisheries, the area presents aspects of widely varying interest and importance, the more significant and striking of which are briefly these: the Lake Erie shore line of approximately 70 miles stretching from the Pennsylvania border to Buffalo represents a "fishing outlook" of great economic interest and of primary concern to the commercial fishermen. In the frontage of 37 miles of the Niagara river lies another major interest in that the upper and lower stretches of the river represent adjuncts of Lakes Erie and Ontario as sources for the replenishment of the lake supply. The tributaries and headwaters of the watershed spread over six counties—Erie county entire, Niagara, Genesee, Wyoming, Cattaraugus and Chautauqua. Three of the largest stream systems, Cattaraugus, Tonawanda and Buffalo creeks, have their sources in the plateau section at the eastern and southern ends of the waters and at an elevation from 1,000 to 1,900 feet above sea level. In these headwaters are the chief trout waters of the region while in their lower reaches are the common "pan fish" species. A vast assemblage of lesser streams entering Lake Erie offer contributions of importance in the economy of the lake by supplying suitable spawning or feeding grounds for migrating lake species.

The stream length including that of all large and lesser streams together with their tributaries totals for the watershed about 3,300 miles. Of this number about 527 miles are worthy of stocking; and of this mileage 370 are suitable for trout. The acreage in small lakes and ponds is 491 and that of reservoirs 276½ acres. Barge canal waters total approximately 25 miles.

Authorization of Survey.— From the Conservation Fund there was appropriated as a part of the appropriation bill from this source the sum of $65,000 for the "Biological Survey including Fish Protection." In pursuance of this provision, this survey, the third of the series, was undertaken in the Erie-Niagara watershed including also the eastern end of Lake Erie undertaken by the State as a joint effort with the Federal Bureau of Fisheries and with participation by the Province of Ontario, Canada. Reports of the two preceding surveys of watersheds, the Genesee and Oswego systems, have been distributed to the public.

The Watershed as the Unit.— The New York plan of surveys is based on the watershed as the unit. There are 19 watersheds lying wholly or in part within the boundaries of the State. The plan is "a watershed a year." By doubling some of the smaller ones, it will be possible to finish the survey of all the State waters in about eight more years. The watershed as the unit area has been adopted because of the nature of certain major problems impinging upon that of a stocking policy, such as, pollution, basic problems in fish population and distribution, the impounding of waters in hydro-electric development, municipal water supplies, the influence of canals, problems in commercial fishing and the like —in all of which greater continuity and comprehensiveness are attained by attacking the watershed as a unit.

Statistics.—According to the records of the Conservation Department, the plantings of fish in the Erie-Niagara system total for the ten-year period, 1918–1927, 612,777,930 young fish. The plantings by species and the water into which they are placed are shown in table 1.

TABLE 1.—PLANTINGS OF FISH IN THE ERIE-NIAGARA WATERSHED, 1918-1927

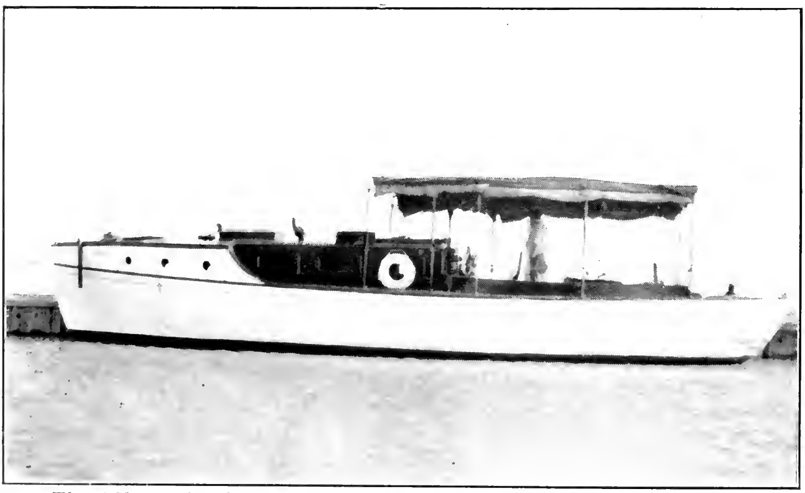
WATER	Lake trout	Trout species	Whitefish	Cisco	Pike-perch	Yellow perch	Small-mouthed bass	Miscel-laneous	Total
Lake Erie	48,000		35,966,000	556,536,000	450,000		5,000		593,005,000
Lower Niagara river			1,000,000	1,000,000	600,000				2,600,000
Barge Canal							1,400		1,400
Small lakes and ponds		7,090			2,435,000	16,200	8,600	300 (bullhead)	2,467,190
Trout streams		1,405,990							1,405,990
Warm streams					11,215,000	65,250	453,100	1,565,000 (muska-longe)	13,298,350
Total	48,000	1,413,080	36,966,000	557,536,000	14,700,000	81,450	468,100	1,565,300	612,777,930

By reference to the table it is seen that the total trout plantings for the ten-year period in this watershed represent an average annual plant of approximately 140,519 fingerlings. Compared with the suggested stocking policy, this number is about 10,000 less than has been recommended as a result of the survey. Obviously the survey would disclose that some streams may profitably be more heavily stocked than in the past, others less so according to their capacity to absorb them. Unfortunately no data are at hand on the catch in these trout streams. Such information is of special interest to the angler and of importance in administration. In time it will be forthcoming but only when local sentiment rises to the occasion.

Program of Erie-Niagara Survey.—Nature does not repeat herself even in watersheds. Hence, the program requirements of the different areas often demand a shift of emphasis or a broadening in scope to meet the exigencies of the situation. In the first place, the Erie-Niagara watershed, as in the two preceding river systems already surveyed, presented the usual problems of stream study with the direct bearing on the development of a stocking policy. Such are the studies that assist in evaluating the streams in terms of the kinds of fish best adapted to the waters and the numbers of young fish which may be planted annually in order to utilize fully the natural food resources. Secondly, the shore front of lake and river approximating 110 miles from the Pennsylvania border to Lake Ontario introduced a variety and complexity of objectives which tie into studies of both lake and stream. This is the receiving area of contributions from the numerous inflowing streams which influence its character physically and biologically. It is also the zone of aquatic plants with the attendant population of insect and other animal life including the vast numbers of minnows and other fishes adapted to this region and which serve as a source of food supply to many species of lake fishes.

Thirdly, the extension of the State's interest beyond the limits of the tributary systems and the lake frontage to the problems of the open lake where the maintenance of the commercial fishery is of dominant importance placed emphasis on a new aspect of survey programs, that of cooperative effort of all interested agencies—State, Federal and Canadian. The gradual decline of the lake fishery during the last two decades and especially the recent, drastic slump in the herring catch pointed the way to this joint effort in promoting a unified program of scientific study. Cooperative effort has for years been urged to secure greater uniformity in fishing laws and in methods of recording statistics. Some results along this line have been accomplished but in the matter of scientific inquiry of conditions in the lake related to its productivity, there has been little unanimity of action. The slump in the herring catch, therefore, provided the impetus for a combined attack with the Federal Bureau, Canada and New York State participating. Thus the program of the survey resolved into activities pertinent to each of the following subdivisions of the area—the streams, the shallow shore waters and the eastern end of the open lake.

Organization of Staff.—An essential feature in the organization of the biological surveys is the trained personnel recruited



The "Navette" of the Conservation Department in the service of the Erie-Niagara survey

mainly from the educational institutions of the State which during the past three years have cooperated with the Department in its survey work. The protective force located within the area as well as sportsmen, anglers and conservationists make important contributions in the way of experience and local statistics.

In the conduct of the present survey the different agencies interested brought into effective cooperation an unusual representation in the personnel. The Federal Bureau of Fisheries and the Province of Ontario each detailed a biologist. The Conservation Department placed 30 scientists including several specialists in the field. The Buffalo City Health Laboratories contributed the services of two of its staff members. The Buffalo Museum of Science, also, made contributions to the personnel of the survey. The crew of the U. S. Steamer Shearwater and the Conservation Department boat Navette brought the total number engaged upon the project to 41 members. Nearly all were in the field from about the middle of June to the middle of September.

The staff was organized in four major groups or units with a field director for each group and with plans coordinated to bear directly upon the practical problems of the fisheries in the area. These units comprised a lake unit, shore and stream units and a chemical unit. In addition the several specialists were occupied with various technical aspects of the problem in hand.

The field staff is organized and equipped that it may function as a mobile unit with adequate transportation facilities and with apparatus and devices for the conduct of its technical problems. This requires weeks of planning and preparation in advance of the intensive drive for facts which goes on in the field mainly from June to September. Many of the problems for their complete elucidation require all the facilities of a well equipped laboratory. This year, as heretofore, the staff has been provided generously with such facilities in the City of Buffalo at the Buffalo Museum of Sciences, at the City Water Laboratory and in the City Health Laboratories. The office of the Niagara Frontier Planning Board also placed at the disposal of the staff its facilities for map work.

Continuation Studies.— Our plan provides for follow-up work so that on the completion of the initial survey of a watershed there may be continuous, intensive study of one or more problems which the survey discloses is important for the future welfare of the fishery in that watershed. A continuation study originating in last season's survey has been going on this year in the carp control studies in Oneida lake and in the interconnecting canal and streams. Those aspects of the problem that are being stressed this year relate to the interference of carp with game and other food fish in the spawning areas, their food and schooling habits, their seasonal and local migrations and the methods of seining in lakes, streams and canals.

The carp problem is a troublesome one both on account of the usurpation of desirable angling waters by this prolific species and because of the general prejudice which prevails against the use of seines in these waters. Scientific study of the problem provides the basis of intelligent action.

Another continuation study is directly correlated with the practical problem of bass culture. It deals with experimental studies of control of the bass cestode (*Proteocephalus ambloplitis*)* whose ravages in advance cases greatly impair or completely inhibit the

* See page 198.

spawning function of the bass. The disease is endemic in Lake Erie and other waters of the St. Lawrence drainage system. It is also showing up elsewhere in and out of the State. In small lakes and ponds, such, for example, as are publicly or privately stocked and in hatchery ponds, the organism when established becomes particularly menacing and for this reason, emphasis is placed on continuing the study along lines of remedial measures. The life history of this organism is now fairly well established. This is shown pictorially on page 200. The picture will be complete and cures effected, when certain of the remaining problems are solved,—in the first place when the maximum period of life in each of the intermediate hosts and the definitive hosts is determined; secondly, when it can be determined how to break successfully the life cycle, rendering the parasite controllable at least in hatchery ponds.

A third project in the follow-up group refers to quantitative studies of the natural fish food supply using selected streams in the watersheds covered. Both naturally stocked and hatchery stocked streams are studied so that the results should aid not only in determining the productive capacity of streams but in assisting in the elucidation of some of our post-hatchery problems.

Conditions of Pollution in Erie-Niagara Watershed.— Intensive and collaborative studies have been conducted to present as adequately as possible the situation regarding conditions of pollution in the watershed. Chemist, biologist, physiologist and ichthyologist have furnished data helpful to the understanding of these conditions.

The chemists have shown that the relatively shallow shore waters only receive the contributory influences of the inflowing streams and the effects of the municipalities and industrial concerns sewering into them. The graph (Fig. 2)* depicts the conditions of the oxygen supply at distances of 500 and 2,000 feet from the lake shore and 100 feet from shore in the Niagara river. The bad condition in the harbor does not exist outside where the great volume of water assimilates the wastes and the oxygen supply is good. On the Niagara river below Buffalo where pollution is carried along the river front, the oxygen sag is conspicuous. The characteristic up-swing in the curve is possible because of the remarkable, natural endowment of this river in its volume of water and in the rapids and falls which provide the most stupendous, natural aerating system in the world.

Special studies of local areas and profiles of the more grossly polluted streams are given in the full report.

The biologist by examining dredge samples where a low oxygen content is indicated adds most impressively to the data supplied by the chemist. This is especially true because of the greater stability and permanence of conditions at the bottom. The deposits of foul sludges and their accompanying foul water organisms are thus a fruitful if not an agreeable aspect of the study of existing condi-

* See page 113.

tions and contribute a requisite type of data to a proper understanding of conditions.

The full report of the biologist includes a description of the bottom conditions prevailing along the shore, in the harbors and in the Niagara river. A tabulation of pollution conditions in the streams of 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 streams noticeably affected by the polluting wastes is estimated at about 54 miles, 49 of which would be suitable for fishing streams.

One of the foremost difficulties confronting one in the investigation of polluting conditions is to establish proof of the effects of pollution on the fish themselves. These difficulties require methods which can be translated into means for detecting these effects. The physiologist in his investigations during the survey has given emphasis to new considerations in the study of pollution by using the blood of fish as a test of the effects of pollution. These studies of the blood furnish new clues of such injury. The studies this season have made important contributions to our knowledge of normal blood values in fish and the effects of weak acid solution.

Pollution damage to either young or adult fish cannot be always estimated adequately by the usual means of a minnow test. The emphasis, therefore, on the blood test enables us to change our strategy by placing more reliance on methods showing why the fish die rather than on how long it takes them to die.

Stocking Lists and Maps.—A key map of the watershed 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 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 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.

Certain species, such as, bluegill sunfish and crappie, which have not hitherto been planted in the watershed are recommended for suitable waters. These additions should improve basically the fishing for "pan fish," giving greater diversity to this activity.

The Colored Plates.— The reproductions in color (Plates Nos. 1–8) command attention in one or more directions according as they

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* See maps following App. III.

Niagara Falls—the stupendous aerating system of the Niagara River facilitate acquaintance with the species of local interest or serve to give emphasis to problems of basic importance in the fishery.

The colored plate of the cisco, or common lake herring (Plate No. 1) is an aid in the difficult task of identification of other closely allied members of the herring group whose decline during the past few years has occasioned concern in the commercial fishery. The whitefish (Plate No. 2) choice commercial fish of the lake, has declined to an inconspicuous place in the fishery. A vast array of facts must be sought bearing on the interrelations of the lake population before progress can be made constructively in rehabilitating this fishery.

The gold carp (Plate No. 3) is an alien in these waters, having been introduced from Europe. It is of questionable value economically. It multiplies with great rapidity in the shallows, usurping space of less prolific but more important species in the economy of the lake. It requires serious study. The fat-head (Plate No. 4) is a minnow with fish cultural possibilities because of its non-competitive food habits and its great prolificity in reservoirs and ponds where reproduction continues throughout the summer season.

The stonecat (Plate No. 5) is a troublesome member because of its poisonous spines. For this reason it is not marketed though its flesh is excellent.

The perches, illustrated in Plates Nos. 6–8, make a notable contribution to the fishery of Lake Erie. The sauger and yellow pike, often called wall-eye or pike-perch, of the more shallow waters in the lake, are of interest chiefly to the angler while the blue pike, a deep water species of this group, affords large catches to the commercial fishermen.

The annotated list* summarizes important data of each of the species illustrated as well as others which have been found in the drainage area.

Results of the Survey.— Proper survey technique combines two steps,—the acquisition and analysis of the facts and their use in the development of a program of intelligent action. Many so-called practical studies have not led anywhere because they lacked a scientific basis. It is true also that many scientific investigations have not led to anything practical. It is the object of the survey to relate more closely scientific study to our practical problems.

The question may well be asked,—how is the biological survey working out in practice? With our stint of "a watershed a year," it is manifestly impossible to cover all problems thoroughly in a single season even with a large force in the field,—hence, the importance of follow-up studies. However, we are accomplishing our main objectives by putting into operation as we proceed with the surveys a more intelligent stocking policy. We are accumulating valuable "by-products" in the way of useful data such as information of the underlying factors of productivity of the fish-

* See page 166.

ing streams, lakes and ponds, the reaction of fishes to pollution, the distribution of the various species within and outside the limits of the watersheds, the contribution to educational work of the colored plates of fishes and relevant data which will be compiled eventually in a volume entitled "Fishes of New York State."

One most important result is the establishment of cooperative relationships with educational institutions in the State, a most helpful relationship in adapting science to practice.

It is hopefully expected the surveys will cover eventually the 19 watersheds in the State. Each presents its own more or less peculiar and technical problems, some of which must be studied in the follow-up program intensively a long time.

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

(1) Stocking policy for the Erie-Niagara system.

(2) A preliminary report on the joint survey of Lake Erie.

(3) Chemical investigation of the Erie-Niagara watershed.

(4) The biological investigations of pollution.

(5) Studies upon the fish blood and its relation to water pollution.

(6) Fishes of the Erie-Niagara watershed.

(7) The food of certain fishes of the Lake Erie drainage basin.

(8) Vegetation of the Niagara river and the eastern end of Lake Erie.

(9) Further experimental studies on the bass tapeworm, *Proteocephalus ambloplitis* (Leidy).

(10) Carp control studies in the Barge canal.

(11) Quantitative studies of the fish food supply in selected areas.

I. STOCKING POLICY FOR THE STREAMS, LAKES AND PONDS OF THE ERIE-NIAGARA WATERSHED, EXCLUSIVE OF LAKE ERIE

BY G. C. EMBODY

Professor of Aquiculture, Cornell University

In the present survey the same methods have been used as heretofore described for the Genesee and Oswego watersheds. The field blank (App. I), when properly filled out, contains the information upon which the stocking policy is based. The duty of collecting this information has fallen principally upon the following persons:—Messrs. A. S. Hazzard, R. P. Hunter, R. A. Laubengayer, Dr. Thomas Smyth and the writer.

The shorter streams have generally been followed throughout their courses but in the case of longer ones which could not be so fully covered, it has been the practice to take a full set of readings at several stations in the headwaters, the middle and lower sections and especially at every road crossing.

Dr. F. E. Wagner determined the oxygen, carbon dioxide content and the alkalinity for waters which gave any indication of unsuitability for the maintenance of fishes. Mr. J. R. Greeley and Dr. D. J. Leffingwell likewise supplied additional information in regard to the distribution of fishes in waters difficult of observation. Acknowledgment must be made also of courtesies extended by game protectors, fishermen and owners of property adjacent to streams and ponds, who supplied information of great value in the conduct of the work.

During the summers of 1920 and 1921, T. L. Hankinson and others collected fishes in Erie County streams and in the report (Hankinson, 1924[1]) certain recommendations were made for stocking. These have been examined and compared with the information secured during the past summer.

The stocking policy as recommended includes the names of fishes for which the waters seem best suited, the length of stream or the area of pond over which suitability was established and the calculated number of 3-inch fingerling trout per mile which would seem necessary to fulfill the annual stocking requiremnts. The specific recommendations for each stream will be found in the Stocking List (App. III).

A discussion of the factors involved in the development of a stocking policy has already been given in the reports on the Genesee and Oswego surveys. There are certain points relative to the determination of the stocking number per mile of stream which will bear repetition since the recommendations have not always been understood by those applying for trout.

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[1] Hankinson, T. L., 1924. A preliminary report on a fish survey in western New York. Bull. Buffalo Soc. Nat. Sci. XIII, No. 3, p. 57.

The number of pounds of fish a unit of stream length will produce depends upon the average width of the stream, the amount of food it contains and the number and condition of pools.

The average width of one mile of stream is a rough measure of the area covered by that length of stream and within certain limits, the larger the area, the greater the production. Hence a stream, say 10 feet wide, should be able to produce approximately twice as much as one 5 feet wide, because the area is twice as great. Consequently in order to keep up the stock, twice as many fish must be planted in the larger as in the smaller stream.

Likewise streams differ greatly in nutritive richness and the greater the amount of food the greater will be the production of fish per unit area. It is not possible to determine quickly all degrees of food richness but with a little experience it is a comparatively easy matter to place streams into three classes:—very rich, average richness and those poor in food. The very rich stream according to our calculations would be expected to produce on the average three times as much fish flesh as one poor in food and consequently would receive three times as many fingerlings. In this connection one should consult the paper presented in this volume by Dr. Paul R. Needham.*

In much the same manner the streams are placed into three categories with respect to pool conditions:—highest, average and poorest.

Finally values are given for all possible combinations of these three factors, as shown in Table 1.

TABLE 1.— PLANTING TABLE FOR TROUT STREAMS: NUMBER OF 3-INCH FINGERLINGS PER MILE

WIDTH 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

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%

* See page 220.

In the extreme left hand column (Table 1) one will find various stream widths from 1 to 10; in the other columns, numbers indicating the number of 3-inch fingerlings recommended for the various stream widths. These latter are based upon various combinations of pool values designated by the capital letters A, B and C, and food values, by 1, 2 and 3. Thus (A1) indicates the very best pool conditions and the highest degree of nutritive richness. Should this combination occur in a stream whose average width is 5 feet, one would recommend an annual planting of 720, 3-inch fingerlings per mile.

Temperature in Relation to the Distribution of Trout.— One of the most difficult problems a stream surveyor has to meet, is the interpretation of water temperatures in relation to the suitability of streams for trout. We know from observations on central New York streams and from careful experiments conducted in the hatchery that 75° F., is just below the highest temperature that the native brook trout may endure. This of course presupposes that waters of that temperature are free from deleterious substances and that the gaseous content is satisfactory. It has been learned also that 80° F., is pretty close to the limit for brown and rainbow trout and of the two species, the rainbows seem to stand a slightly higher temperature than the browns. It therefore becomes a very important matter to know whether a stream on the hottest summer days will show temperatures exceeding these limits.

If one were studying a very few streams, it might be possible to ascertain this without difficulty by visiting them on the few days that maximum air temperatures prevail. In a survey of a large area, this is not possible, because our hottest days are not numerous. It becomes necessary therefore to estimate maximum water temperatures from records made on moderately warm days.

For this purpose Tables, 2 and 3, taken from the Oswego survey, were used, the first for regions below 1,000 feet elevation in which summer air temperatures may reach 96° and 98° F., and the other for elevations upward to about 1,900 feet where the maximum air temperatures range from 88° to 90° F., since the streams of the Erie-Niagara watershed were found at various elevations from 573 up to about 1,900 feet, both tables were very useful.

TABLE 2.— RELATION OF AIR AND WATER TEMPERATURES IN TROUT STREAMS LOCATED IN OPEN COUNTRY UP TO 1,000 FEET ELEVATION

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

TABLE 3.— PROBABLE RELATION OF MAXIMUM AIR AND WATER TEMPERATURES IN NORTH BRANCH FISH CREEK, LEWIS CO., LOCATED IN A FORESTED COUNTRY, 1,600 TO 1,900 FEET ELEVATION

Max. air temperature	80	82	84	86	88	90
Max. water temperature, brook trout	71	72	73	74	75	76

Certain corrections were made for densely shaded streams and also for the hour a reading was taken. In the former case, the water temperatures are held down on hottest days much more than on days of average temperature. For example, on a day showing an air temperture of 80° F., the corresponding water temperature might be two or three degrees higher than given in the tables and yet not exceed the critical point on the hottest days.

With reference to the hour of recording water temperatures, it may be said in general, that the water temperature lags behind a rising air temperature. Hence in the morning, it may not necessarily bear the same relation to the air temperature as in the afternoon. Just how much of a correction must be made for this factor, cannot be tabulated at the present time. It is to be hoped that an opportunity may come another year for securing a large series of hourly temperatures from some of the warmer streams in which trout are known to thrive.

During the past summer one occasion presented itself for obtaining such data in the Wiscoy creek and two of its tributaries, all of which are noteworthy fishing streams. The records are presented in Table 4, more for the purpose of future comparison than for immediate interpretation.

TABLE 4.— COMPARISON OF AIR AND WATER TEMPERATURES IN THREE TROUT STREAMS, ALTITUDE 1,594 TO 1,734 FEET. MAXIMUM AIR TEMPERATURE FOR THIS REGION RANGES FROM ABOUT 88° TO 92° F.

Brown Trout and Brook Trout Present						Brook Trout Absent; Brown Trout Present					
North Branch Wiscoy, August 3, 1928			Trout Brook August 4, 1928			Wiscoy at Bliss August 3, 1928			Wiscoy at Pike August 4, 1928		
Hour	Air temperature	Water temperature	Hour	Air temperature	Water temperature	Hour	Air temperature	Water temperature	Hour	Air temperature	Water temperature
10:45	81.5	67	10:35	81	68	10:30	79	71	....	.....	......
11:00	82	67	11:05	81	68	11:00	81	72	11:00	81	74
12:00	79*	69.5	12:00	83	70	12:00	83	74.5	12:10	83	76
1:00	83	72	1:00	85	72	1:00	84	76.5	1:06	85	78.5
2:00	84	72.5	2:00	87	74	2:00	85	77	2:06	87	80
3:00	86	75	3:00	87	75	3:00	85	79	3:06	87	81
4:00	84.5	75.5	4:00	87	75	4:00	86	79	4:06	87	80
5:00	84	74	5:00	86	74	5:00	83	78.5	5:08	86	79
5:30	83	73	....	.....	.....	5:30	83	78	....	.....	......

* Air temperature dropped 3° due to clouds and a 10 minute shower. Duration of shower too short to influence water temperature.

The temperatures recorded in Table 4 were taken at the following places:

North Branch Wiscoy just above railroad crossing near the village of Bliss. This must have been close to the lower limit of distribution of brook trout but brown trout ranged a much greater distance downstream.

Trout brook, just above highway bridge at Pike Five Corners. Both brook and brown trout were present here.

Wiscoy, main stream immediately below Bliss. Brook trout were not seen at this point but brown trout were very abundant.

Wiscoy, main stream at Pike Five Corners a distance of approximately 4.5 miles below Bliss. Brown trout were found here but were more numerous at Bliss.

In all three streams there was much colder water to be found above the points of observation, and it may be said that brook trout were more numerous in those sections having colder water. Nevertheless it is interesting to note that brook trout in some numbers remained in temperatures as high as 75.5° F., and that browns extended downstream into water having a still higher temperature, the highest observed in this case being 81° F.

The great difference between the upper Wiscoy and the Fish creek watersheds (Table 3) is to be found in the latitude and the forest conditions. The Wiscoy flows through an open cultivated region while the East Branch of Fish creek has its origin in an area of approximately 70 square miles nearly all of which is covered by forest and is a little farther to the north where the winters are more severe. The maximum summer temperatures range two or three degrees lower; the forest cover tends to keep the ground and the air immediately over the streams a little colder on hottest days and consequently the water temperatures are held down to a greater degree on such days than on moderately warm days.

A Quantitative Study of the Fish Population in Streams.— During the latter part of June, attempts were made to study the fish population of selected trout streams. The excessive rain, however, interfered with the plans to such an extent that it was possible to carry out the program in but one case, Peg Mill brook located near Groton, N. Y.

The object of this study was to throw light upon a number of questions, including the following:

1. Total quantity of fish per unit area of stream.
2. Ratio of trout to minnow population.
3. Relative number of individuals belonging to each age group represented.
4. Rate of growth of wild trout.

The procedure consisted in first measuring the stream, evaluating food and pool conditions and then, so far as possible, draining the section to be studied by diverting the water to another channel. Finally all fish were collected, weighed, measured and ages determined.

Only a very brief statement of results from the study of Peg Mill brook can be given at this time.

Average width of stream, 7.3 feet; length of drained section, 1002 feet. Area of drained section 7348 square feet or .168+ acres.

Total weight of all fish recovered, 7.7 lbs., or at the rate of 45.43 lbs. per acre. Minnows and suckers made up about 70 percent of the total weight while rainbow trout and brown trout constituted the remaining 30 percent. There were 1 yearling brown trout, 100 rainbow fingerlings of the 1928 hatch and 64 yearlings and two-year-olds. Sixty percent of the rainbows were small fingerlings about two months old; about 27 percent were yearlings and an estimated 13 percent, two-year-olds. All trout except three of the two-year-olds were under six inches long. Hence only three or slightly more than one percent of the trout population in nearly one-fifth of a mile of stream were at this time (June 20) available to fishermen.

Further explanation and discussion must await future studies. The work represents a comparatively new line of attack upon that big and practically untouched problem of stream production which is one of the most important considerations in developing a stocking policy.

A Change in Policy for Rainbow Trout.— In past surveys, it has been recommended that trout of this species be planted in certain of the larger streams and in others tributary to lakes and reservoirs; this because eastern rainbows some time before the third year, tend to migrate downstream into such bodies of water where they grow to sex maturity. If these particular conditions do not exist, they simply migrate out of the stream and are apparently lost. However in a great many streams too warm for either brook or brown trout and which do not flow into reservoirs, we have found rainbows varying in size from fingerlings up to 9 inches long. Those above 6 inches rise freely to the artificial fly and furnish good sport in streams which otherwise would not contain game fishes of any kind. A case in point is Elton creek which yielded several 2-year old rainbows in the section above Delevan, N. Y. Except for a short section near the source and one large pool containing a spring, the stream was found unfit for brook or brown trout by reason of the high water temperatures. If a normal stocking were made in a stream like this, it is believed that an unnecessarily large proportion of the fish would disappear which would mean a waste of valuable stock.

It is therefore recommended in such a case that small yearly plantings be made, a number just sufficient for local angling needs with the expectation that nearly all will have been caught before they are old enough to migrate. It must be understood that under these conditions that natural spawning would play no part in maintaining the supply and annual plantings would always be necessary. In the present survey we have indicated plantings of from one-eighth to one-tenth of the normal number for several streams of this character.

Competition Between Minnows and Trout.—Many species of brook minnows consume to a greater or lesser degree the same food organisms that are eaten by trout. Abundant proof of this assertion is to be found in the works of Forbes, Juday, Pearse, Needham, Greeley, Sibley and others. It is not necessarily true, however, that trout, except possibly small fingerlings and advanced fry, would suffer to any material extent by this competition. If it were, we might have to assume that minnows are superior to trout in their ability to observe and capture food; that they are livelier, more aggressive and able to protect themselves in combat with trout. It is of course conceivable that minnows might exist in such large numbers that there would be small chance of trout securing insect food but one must remember that minnows, in themselves, are good food for trout and if insects are not available, trout may help themselves to minnows.

Trout fishermen have furnished us some of the best proof that trout will eat minnows. They have found that the smaller sizes of minnows constitute one of the most successful baits not only for brown trout but likewise for brook and rainbow trout. A rather large proportion of the anglers in central New York are now using minnows for this purpose with great success.

When it comes to the smaller sizes of trout—advanced fry and small fingerlings—there is little doubt that competition with minnows may be severe. The excessive mortality among young trout may be due in a large measure to competition for food and to predatory habits of the larger minnows.

If a stream is otherwise suitable for trout, it is believed that a large population of minnows will not seriously interfere with the activities of trout of normal yearling size or above and we therefore see no reason to alter our usual stocking policy for such streams, that is, to plant the full quota of trout of the larger sizes in order to make the competition more severe for the minnows. In the writer's opinion this would seem to be the best corrective for minnow-infested trout streams, and in the surveys of the past three summers stocking recommendations have conformed to this principle.

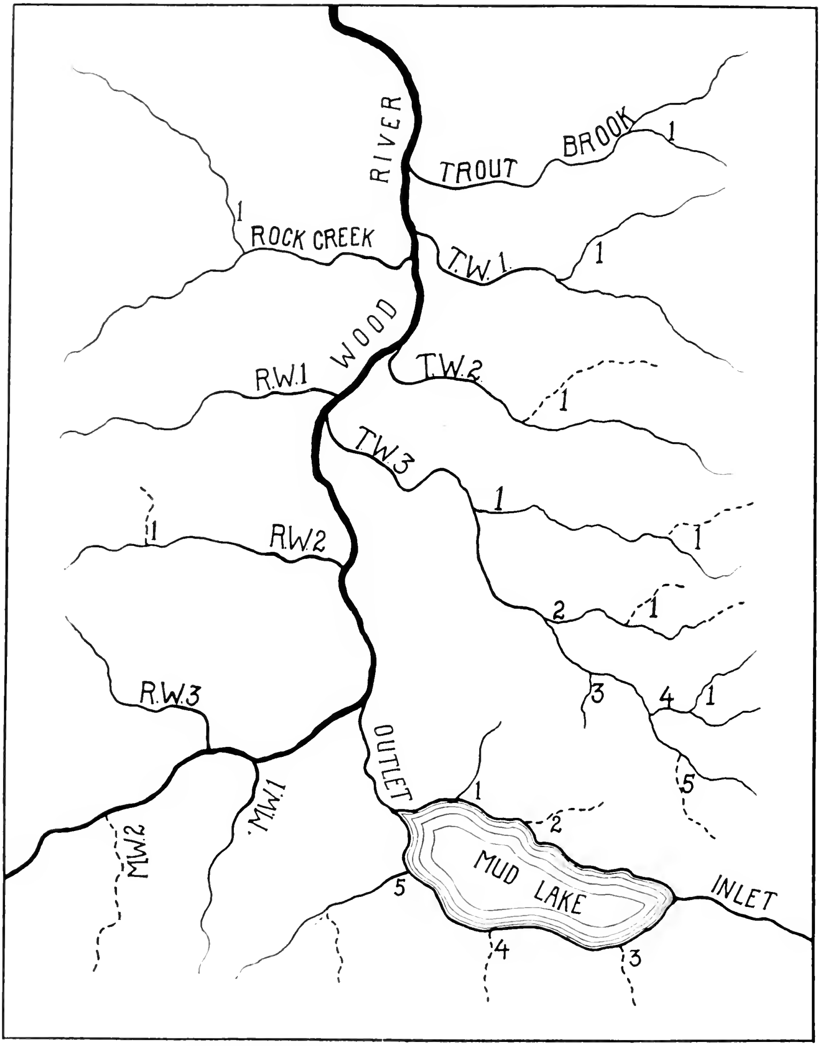

Diagram illustrating the method used in designating unnamed streams. Explanation of diagram:

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 inital 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.

Stream Mileage Suitable for Stocking.— The total stream mileage in the Erie-Niagara watershed (in New York State) is approximately 3,300. Of this only about 527 miles appear to be worthy of stocking. The remaining 2,773 are unworthy in one or several ways. They may become dry in summer, badly polluted, too warm for trout, too small for bass or posted. Dry streams and those too warm for trout and too small for bass are the more numerous. It is unfortunate that we do not have a food or game fish that will live in the permanent, small, warm, rapid brook which now harbors small bony suckers and minnows only.

Of the 527 miles worthy of stocking, approximately 370 are suitable for trout; 152 for small-mouthed bass and 5 for large-mouthed bass, pike-perch, pickerel, sunfish and bullheads.

The 370 miles of trout streams will support a total annual plant of about 138,462 fingerlings distributed among the three species as follows:—

Brook trout	62.2 miles with 28,053
Brown trout	209.35 miles with 93,409
Rainbow trout	99.00 miles with 17,000

In addition to this, there are 17 acres of ponds requiring an annual stocking of 2,900 brook trout and 108 acres for which 9,500 rainbows have been recommended.

The distribution of the trout stream mileage according to the main creek systems is shown in Table 5.

Table 5.— Distribution of Trout Stream Mileage

Stream	Brown Trout		Rainbow Trout		Brook Trout	
	Miles	Number	Miles	Number	Miles	Number
Tonawanda	46.0	18,970	10	1,600	0.5	175
Buffalo	31.3	8,699	17.5	2,350	17.3	6,529
Smoke	3.0	900	3.0	300	0.0	0
Eighteenmile	13.5	6,050	15.0	1,500	0.5	150
Sister	3.5	1,425	3.0	600	0.0	0
Delaware	0.0	0	6.0	1,800	0.0	0
Cattaraugus	77.4	47,946	28.0	5,400	42.9	20,999
Canadaway	1.0	400	1.5	450	0.0	0
Chautauqua	25.9	7,109	12.0	2,400	0.5	200
Bell	0.25	112	0.0	0	0.0	0
Twentymile	7.50	1,798	3.0	600	0.0	0

The trout streams are more numerous and of better quality in those regions situated in the headwaters of the principal Erie-Niagara tributaries, namely, the Tonawanda, Buffalo and Cattaraugus creeks, the last showing by far the highest mileage and the best streams. The trout streams are to be found chiefly in altitudes varying from about 1,200 to 1,900 feet. This is due largely to the lower maximum air temperatures and to the greater number of springs found here.

The More Successful Trout Streams and Ponds.— Niagara river, though not at present a trout stream, is mentioned here because it has possibilities. From Lake Erie to the Falls it is not suitable for trout. As it plunges over the escarpment and down through the rapids and gorge, it takes up oxygen to a point of supersaturation (10.3 p. p. m. at a temperature of 71.4° F.) and shows temperatures on hottest days somewhat below the critical point for rainbow and steelhead trout. There is a strong probability that a run of one or the other species could be established between the rapids and Lake Ontario. The lake would serve as a summer and winter habitat for the adults which would be expected to run up the river to some point above Lewiston and furnish the finest kind of fishing during April and a part of May. At the present time commercial fishing, though prohibited on the New York side, is permitted on the Canadian side. As long as this unfortunate condition of affairs exists, it would hardly seem wise to stock with trout.

Tonawanda Creek System: The main stream quite generally shows conditions unsuitable for any species of trout. A stretch of about 6 miles in the extreme headwaters above and below Southburg contained some brown trout. At a place three-fourths of a mile below this village certain pools showed temperatures low enough for brook trout. For example, in one the water temperature was 65° F., at 2 p.m., when the air was 83° F. Nevertheless above and below this section temperatures ranged considerably higher, and it is believed that a much longer stretch would be available for trout fishing, if plantings of brown trout were continued.

Ellicott creek (tributary 1 of Tonawanda) except for a short section below Williamsville showed temperatures too high for any trout. Hankinson[1] reported brown trout here. Various fishermen likewise have caught them. Hence a small planting has been recommended. Tributaries 8, 9 and 10 are rather small but 8 is large enough for some fishing. All flow into Ellicott creek in that section below Williamsville containing brown trout, and stocking with this species is suggested chiefly for the purpose of feeding the main stream. The pond at the head of tributary 8 is spring fed and very cold. Doctor Wagner's analysis[2] however shows a deficiency of oxygen which would make it unfit for trout. Just below this pond the stream picks up oxygen very quickly and is apparently suitable.

Ranson creek (6 of Tonawanda) with its tributary, Got creek, Ledge creek and the upper 4 miles of Little Tonawanda together with its tributary 8, all contain sections suitable for brown trout.

Ledge creek presents rather unusual conditions. In the past it has been heavily stocked with brook trout but so far as could

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[1] Loc. cit.

[2] See page 127.

be learned very few if any have been taken. Brown trout have been reported by a number of fishermen. Temperatures taken between 2:30 and 3 p. m., on August 8 ran as follows:

Station 1. Just below the mouth of Murder creek, air = 82; water = 76
Station 2. One mile above the mouth of Murder creek, air = 84; water = 68
Station 3. Just below tributary 2, air = 85; water = 65.5
Station 4. Just above tributary 2, air = 85; water = 80

The water temperature may be considered suitable for brook trout beginning a little above the mouth of Murder creek and extending upstream within two miles of source.

Attention is called to the drop in temperature between Stations 4 and 3. This was due to an inflowing cold stream, tributary 2*. It was found that much if not all of this water comes from pumps located at the gypsum mines. It was stated that while these pumps are running almost all of the time, they are occasionally stopped. Two things might then happen which would disturb the conditions we found in the main stream and in tributary 2. If the pumps were stopped on a hot summer day, the stream would change very quickly from a cold to a warm stream and tributary 2 would become very nearly dry.

Hankinson records brook trout, rock bass and small-mouthed bass among others and says that in the headwaters the stream is suitable for brook trout. He also indicates that the water farther down probably becomes too warm for brook trout and under present conditions recommends browns.

In order to find out more about conditions in this stream Doctor Wagner analyzed the water at approximately the places indicated above with the following results, Table 6:

TABLE 6.— ANALYSIS OF THE WATER IN LEDGE CREEK [1] THE CENTIGRADE DEGREES HAVE BEEN CHANGED TO FAHR.

STATION	Temperature		O_2 p.p.m.	CO_2 p.p.m.	Methyl, orange alkalinity p.p.m.	pH
	Air	Water				
1[2]	74	65.3	8.5	0.5	171	8.1
2	76	63.5	9.1	....	178	8.1
3	72	65 3	10.4	....	177	8.1
4	72	71.6	6.9	3.4	136	7.8

Since we have found brook trout in water containing as little as 4 p.p.m. of oxygen, it is evident that the content in this gas given at every station above is sufficient. The water is very hard but not more so than certain other trout waters which have been

* See Map 1B.
[1] Data furnished by Dr. F. E. Wagner.
[2] Station 1 located at first bridge above Murder creek. All others the same as referred to in text.

studied. The hydrogen ion concentration (pH), ranging from 7.8 to 8.1, is well within the limits suitable for trout.

The only reason that occurs to the writer as to why brook trout do not survive, is the possible sudden change in conditions, primarily temperature, brought about by the stoppage of pumps at the gypsum mines. It might be that even brown trout would not survive the change. However rather than to withhold all stocking from Ledge creek, we would favor giving it a trial with brown trout and since bass and pickerel occur within the area, we would suggest that yearling fish be used. It is also suggested that if the pumps referred to above were stopped during the colder weather of spring and fall, only, the effect on trout would not be so severe.

Since tributary 2 (Quarry Spring Run) is subject to changing conditions by reason of the mine pumps, stocking is not advised at the present time.

Crow brook, tributary 46 of Tonawanda,[1] in its extreme headwaters is suitable for a mile or more for brook trout. However, if brown trout were introduced, the fishing would be extended much farther downstream. It is largly a question as to which species the local fishermen prefer. Either brook trout or browns may be planted. More than one species however is not advised.

Brown trout have also been recommended for various other headwater tributaries the most important of which is the East Fork, 77.[2] This stream is generally too warm for trout. However the upper 2 miles is cooler and with a few spring holes scattered well downstream some good trout fishing might be afforded.

Buffalo Creek System: Except for the uppermost 5 miles above Dutchtown, the main stream is generally too warm for trout. However it is possible that if brown trout are planted here some of them will work downstream locating pools that are cooled to some extent by springs and seepage. Rainbows would not ordinarily be suggested for a stream like Buffalo creek without a lake or suitable reservoir in which they might grow to maturity. But in accordance with the change in policy already discussed, we have suggested about one-eighth of a normal planting. Fishermen may therefore expect to find brown trout restricted chiefly to the upper 5 miles and rainbows well scattered downstream a few miles farther.

Cazenovia creek is either polluted or too warm for trout throughout its length. A number of tributaries, though, furnish trout fishing. One of the most important is East Branch, 14,[3] known as Protection creek above Holland. Both browns and rainbows have been taken above Holland and this section is interesting from the fact that adult rainbows have been caught during the past season. In addition to brown trout we have accordingly recom-

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[1] See Map 2B.
[2] See Map 3B.
[3] Map 2A, 3B.

mended somewhat more than the usual number of rainbows believing that some of them may grow to sex maturity.

A few of the Cazenovia tributaries are cold enough for brook trout but with the exception of one, they are too small to be considered as fishing streams and since Cazenovia proper is not a trout stream, we have not indicated a stocking policy for the smallest cold tributaries. The exception to this is Spring brook, 7,[1] which is not only cold but large enough to support some fishing. Brook trout have thus been recommended.

Almost all of the other tributaries of Buffalo creek suitable for trout are small and comparatively short. There are two however, 55[2] (Beaver Meadow) and 58,[3] which afford several miles of fishing. In the former, Angel Falls about 30 feet high and located just above Java Village, divides the stream into a colder section above and a warmer one below. The upper part is spring fed and temperatures run well below the critical point for brook trout. On August 9 between 10:30 and 11:30 temperatures ran as follows: Station 1, air 80.5, water, 59; Station 2, air, 80, water 63.5. In the warmer part just below the falls the following temperatures were recorded at 4:30 p. m. on the same day: Air, 84.5, water, 75. Brook trout should be planted above the falls and brown trout always below.

Beaver Meadow creek is the outstanding brook trout stream in the Buffalo creek system, and is worthy of heavy and continuous stocking. Tributary 58 is considerably warmer and although certain pools now contain brook trout, it is believed to be better adapted to browns. Temperatures taken from 12:45 to 2:30 p. m. on August 9 ran as follows: Station (1) air, 83, water, 74.5; (2) air, 84, water, 76; (3) air, 84, water, 78.5.

Eighteenmile Creek System: There are about 7 miles from Boston to source in which both brown and rainbow trout were observed. Possibly the uppermost mile might be suitable for brook trout, but it would hardly seem wise to reserve so short a section for this species. The most important tributary is the South Branch, 4. Above New Oregon, it is well adapted to brown trout. Also in accordance with the new policy for rainbows, fingerlings of this species should be spread over the upper 8 miles. Tributary 29, however, which is large enough for fishing and much colder than the main stream, should be reserved for brook trout. Among the other tributaries of Eighteenmile creek, 14 showed temperatures just under the critical point for brook trout. Since it is too small for fishing and does not flow into a section of the main stream suitable even for brown trout, stocking is not advised. All other cold tributaries entering the main tream above Boston should receive brown trout. They are principally feeders for the main stream.

Sister Creek System: Here we found but a few miles in the headwaters and but one tributary, 14, in which brown trout conditions seemed to prevail. Hankinson records two specimens of

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[1] Map 2 A; [2], [3] Map 3B.

about $6\frac{1}{2}$ pounds each in that section just above North Collins. About a mile above this point near tributary 17 temperatures of 81 for air and 69 for water were recorded during the past summer, indicating suitability for brown trout. Opposite North Collins and at all points below temperatures were much too high for trout. A small plant of rainbows has been suggested. Were it not for the impassable dams shutting off all migration from Lake Erie, a run of rainbows might be established and a much larger plant would then be in order.

Delaware Creek System: The main stream flows into Lake Erie west of Angola. In 1921 Hankinson and others studied this stream in the region near Brant and reported that although it seemed ideal for brook trout, plantings had not been successful. During the past summer there was reported to us four unsuccessful attempts to establish this species. We therefore see no reason for continuing the experiment. There appears however to be a chance of establishing a run of rainbows and for that purpose a total annual plant of about 1,800 fingerlings has been recommended for the next four years.

Cattaraugus Creek System: This is by far the most promising system for trout in the whole watershed. It has the highest stream mileage suitable for trout and is worthy of heavier stocking than any other in the Lake Erie watershed. Except for the uppermost eleven miles, in which brown and rainbow trout were found, the main stream at present is of no value as a trout stream. But numerous tributaries in the upper half of the drainage area are of such a character as to appeal strongly to every trout fisherman. It is possible to mention only a few of them at this time. All, however, will be found in the Stocking List.

The upper part of North Branch of Clear creek, 6,[1] is dammed to form a reservoir about 1 mile long and 30 to 40 feet deep. Because of the low bottom temperatures, it was thought that trout might find conditions suitable therein. Dr. Wagner's analysis, however, while it indicated sufficient oxygen at the surface showed none at a depth of 15 feet and below. It is not believed that trout would survive in this reservoir.

South Branch, 20,[2] is too warm for trout as far upstream as East Otto, where cold pools begin to appear. Above this village it is known as East Otto creek. From tributary 15 to source, the water is entirely suitable for brown trout. A total annual plant of about 1,900 fingerlings should not only cover the requirements of the uppermost section but also those of the cold pools scattered downstream.

Mansfield creek (11[3] of South Branch) is one of the finest trout streams in the watershed. It is well supplied with spring water from source down to about tributary 3, is cold, clear and contains both brook and brown trout, possibly the latter in greater num-

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[1] See Map 3A.

[2], [3] See Map 4B, 4C.

bers. Judging from temperatures recorded and from the observed distribution of both species of trout, the upper 5.5 miles and tributaries 3 (Eddyville), 4 (Spring run), 6, 7 and 10 are suitable for brook trout. The lower 2 miles together with tributaries 1, 2 and 9 (Goodell) are generally too warm for brook trout and now contain browns. In fact brown trout range everywhere except possibly in the coldest spring tributaries. The two species are so thoroughly mixed that it is difficult to decide upon a proper stocking policy. We feel that the planting of both species in their respective sections will best meet the situation and this recommendation is founded on the belief that so far as possible, all parts of a stream or system should be fully utilized and that we should try to preserve brook trout in all fishing waters which show favorable conditions.

In tributary 4, brook trout are abundant while browns are scarce excepting in the last pool or two. The stream is supplied chiefly from a spring which flows an 8 inch pipe full of water having a temperature of 48.2° F. Temperatures near the mouth of the stream 2:10 p. m., August 28 were, air, 85.5 and water 64; one-half mile upstream at 2:30 p. m., air, 85.5, water 61. These are among the lowest stream temperatures observed for the corresponding air temperatures and indicate that this stream is much better adapted to brook trout than to browns.

Analysis of the water in the spring itself showed 4.2 p.p.m. of oxygen and 9.7 p.p.m. of carbon dioxide. These are well within the limits endured by trout but nevertheless cannot be considered highly favorable. Undoubtedly the water soon picks up enough oxygen and loses enough carbon dioxide to make it entirely favorable. It will support a relatively large number of brook trout and should appeal strongly to the fisherman who prefers this species.

A Proposed Artificial Lake for the Zoar Valley: Because of its bearing upon the stocking policy of certain streams tributary to the main Cattaraugus creek, it is well at this time to mention the proposed construction of a dam across the creek at a place just below tributary 2 (Watermans brook*). It is understood that this may exceed 150 feet in height raising the water level to the 1,100 foot contour thereby flooding the Zoar valley upstream to the Scoby bridge. A lake 8 to 9 miles long and in places a mile or more wide may thus be formed. Considerably more than one-half of this lake will exceed 100 feet in depth but there will be numerous shallow bays extending up the valleys of tributary streams. Immediately above the proposed lake at Scoby bridge there is now a 30-foot dam impassable to fish.

While it is impossible to predict just what conditions may prevail, it is reasonably safe to assume the following:

1. That the water below a depth of about 60 feet will be cold enough for trout.

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* See Map 4B.

2. The oxygen content at the bottom may or may not be sufficient for trout requirements. The presumption is that a large part of it will be suitable. Certainly there is likely to be a considerable area over which combinations of depth, water temperature and gaseous conditions favorable to adult rainbow and lake trout will prevail.

3. There will be extensive areas of shallow water with gravel bottom suitable for the spawning of small-mouthed black bass and lake trout.

4. While the 30 foot dam at Scoby bridge will constitute a barrier to the upstream migration of fish, particularly rainbow trout, there are various streams which will flow into the lake from the north and south, thus fulfilling the requirements of spawning rainbow trout.

We conclude from the above that the new lake would probably be suitable for small-mouthed bass, lake trout and rainbow trout.

The more important streams which the rainbows may use for spawning purposes are Watermans, Utley, Coon, Connoisarauley, Derby and Spooner, all of which would receive plantings of rainbows in addition to what has already been recommended. Of these Derby brook is at present one of the best brook trout streams while Connoisarauley above the falls is suitable for browns. Watermans, Utley, Coon and Spooner brooks appear to be a little too warm except possibly in the headwaters, and stocking is not recommended until the lake is completed when rainbows may be introduced.

There are a number of streams above the Zoar Valley region which furnish trout fishing. Chief among them are Spring brook, 32; Buttermilk, 33; Elton, 48, with its two tributaries Delevan and McKinstry; Sardinia, 50 and Clear creeks, 56.

Spring brook generally shows temperatures low enough for brook trout. It is polluted to some extent in the lower section and there is danger of further pollution as the town of Springville grows. For this reason stocking is recommended for the upper 3 miles only. The numerous ponds in this region are either posted or too warm for trout.

Elton creek has already been treated in connection with the new policy for rainbow trout. One of its tributaries, Delevan creek which is the outlet of Lime lake, is much more important from the fisherman's standpoint. It is one of the most popular brown trout streams in the Lake Erie watershed and is very heavily fished. The upper part is entirely suitable for brook trout but brown trout range throughout its course and stocking with this species has been so successful in the past that it might well be continued. The most important tributary, McKinistry creek, showed lower temperatures and contained many brook trout.

Sardinia brook, 32, is a fairly cold stream a part of which appears suitable for brook trout. Two specimens were taken above Sardinia. At present, however, brown trout are the more abundant and if this species is used in stocking, there should be fishing all the way downstream to mouth. Tributary 1, is a small cold spring-run possibly large enough, however, to support some fishing and should be reserved for brook trout.

Clear creek is another popular fishing stream and consequently much over-fished. In addition to this it has few good pools and is subject to high water. While it is productive at the present time it would be much more so, if pools could be established.

All three species of trout were taken but brown and rainbow trout were more abundant, especially so in the section between Sandusky and Arcade. Clear creek is another in which brown trout are confined chiefly to the main stream while the more important tributaries are colder and better adapted to brook trout.

Crystal lake is not suitable for trout but its outlet just below the lake receives much cold spring water and continues cold until it joins Clear creek. Moores pond is an enlargement of the outlet a short distance below the lake in which several good sized brook trout were observed.

Skim lake is spring fed and cold. According to Dr. Wagner's analysis, the water at the bottom showed a temperature of 48°F., with an oxygen content of 13.5 p.p.m., indicating suitability for brook trout. The lake also contains large-mouthed bass and sunfish. There is some question as to how well bass and trout will get along together in the same pond. We believe that the cold water is better suited to trout than to bass and hence have suggested an experimental planting of brook trout. If this lake is so stocked in 1929, fishermen should be on the lookout for them in 1930 and '31 and the future stocking policy should depend upon the success of this first plant.

Hayden brook, the outlet of Skim lake, also receives much spring water below the lake and continues cold all the way down to Clear creek. It should be reserved for brook trout.

Silver Creek System: The main stream on July 10 showed temperatures from 78 to 84 with corresponding air temperatures of 82 and 84, much too high for trout. Tributary 1, Walnut creek, was examined with more than usual care because it had been stocked apparently without success. The water temperatures on July 18 varied from 84 to 86 and the reason for the lack of success in stocking is evident.

The only trout water in the system will probably be found in the newly constructed reservoir situated in tributary 8. This will have a maximum depth of about 35 feet and will undoubtedly be large enough to hold mature rainbow trout. The streams above the reservoir appear to have favorable conditions for the spawning of this species.

Canadaway Creek System: Brown trout have been taken in two sections, near the head of the main stream and just below the falls at Laona. The former section shows temperatures low enough for brown trout but the latter is so warm that it is not believed any great number of trout could survive. The Fredonia reservoir on tributary 7, however, contains adult rainbows and the stream itself above appears large enough for natural spawning.

Chautauqua Creek System: Except for tributary 9 and an occasional spring-run altogether too small for fishing, there is no place suitable for brook trout. However, brown trout have been taken in several parts of the main stream and large rainbows have been reported in early spring. The only possible barrier to the upward migration of rainbows from Lake Erie is a falls of about 2½ feet situated in the lower section. It is believed that rainbows may successfully pass this falls and hence an attempt to establish a run has been suggested. Tributary 19, Clarks brook, is small but nevertheless large enough to provide some brook trout fishing and since it is the only stream in the watershed in which brook trout may be expected to survive, this species has been assigned. Should local fishermen however prefer to reserve this as a nursery stream for browns no serious objection should be made.

Twentymile Creek System: This system is much like the Chautauqua having water too warm for brook trout except an occassional spring fed tributary much too small for fishing. Brown and rainbow trout, however, occur at several points and there is a possibility of establishing a comparatively large run from Lake Erie. The only fall is a low one about 18 inches high situated in the lower section which could readily be passed by rainbows during the period of high water in April and May.

Bass Waters: *Streams:* Large or small mouthed bass have been recommended for all unpolluted streams over about 30 feet wide in which natural spawning is apparently inadequate. We have eliminated the lower sections of streams which may be entered by bass breeders from Lake Erie because, if entirely suitable, they should be fully populated with young from lake breeders. If they are not so populated, it is reasonable to presume that they are not suitable in which case, stocking would be unsuccessful. Two noteworthy examples are Buffalo and Cattaraugus creeks. At one time the latter as far upstream as Gowanda, must have been an enormous natural hatchery for Lake Erie bass. This is borne out by the statements of the older inhabitants of the region. The present polluted condition, though it may not wholly prevent bass from entering, must operate adversely upon eggs and young.

Streams under 30 feet in width, if they contain bass at all, usually are over populated with undersized fish, the result of natural spawning. It is evident that nothing would be gained by stocking them.

Small-mouthed bass have been recommended for streams with some current and having frequent gravel shoals; large-mouthed, for the more sluggish streams with mud bottom and an abundance of vegetation particularly water lilies and cattails.

The principal small-mouthed bass streams are:

Cayuga creek (Map 1A), lower 3 miles.
Tonawanda creek including Barge canal, 72 miles.
Buffalo creek, from tributary 6 to 30, 25 miles.
East Branch Cazenovia, 3 miles.
Eighteenmile creek, 1 mile.
Cattaraugus creek, Gowanda to tributary 48, 34 miles.
South Branch, Cattaraugus, lower 14 miles.

Large-mouthed bass have been recommended for but one stream, Ellicott creek. The lower 5 miles seem better adapted to this species than to small-mouthed bass, even though the latter may occur in places. It may be said that streams suitable for large-mouthed bass usually also have favorable conditions for bluegills, crappie, pike-perch, pickerel and bullheads and in many cases we have suggested one or more of them to be planted along with bass.

The More Important Bass Ponds and Lakes.— There are about 627.5 acres of ponds and lakes for which bass have been recommended. Of these 135.2 are suitable for small-mouthed, and 492 for large-mouthed bass. There are many other ponds in the watershed in which stocking is not advised. They fall into one or more of the following categories: posted, stocking not desired, too small or polluted.

With one exception, the small-mouthed bass ponds are small and unimportant. They are as follows:

Stevens reservoir	1.5 acres, Map 2B
Old Attica reservoir	4 acres, Map 2B
Gowanda state hospital reservoir	56 acres, Map 3A
Otto Pond	2 acres, Map 4B

The large-mouthed bass ponds are generally larger and more numerous. They are as follows:

Dead lake	2 acres, Map 1B
Railroad pond	2 acres, Map 2A
Reservoir (tributary 13 of Murder creek)	35 acres, Map 2B
Smith Mills pond	10 acres, Map 3A
Java lake	123 acres, Map 3B
North Wilson pond	4 acres, Map 3B
East Concord pond	5 acres, Map 3B
Beaver lake	15 acres, Map 4C
Crystal lake	40 acres, Map 4C
Lime lake	256 acres, Map 4C

The most important lakes from the fisherman's standpoint are Lime, Crystal and Java.

Lime lake is about 1.2 miles long and varies in width from about .25 to .5 of a mile. Soundings indicated a maximum depth of about 40 feet. The water temperature varies with depth and the location, the latter influenced chiefly by bottom springs which appear to constitute the sole water supply.

TABLE 7.— TEMPERATURES RECORDED IN LIME LAKE ON JULY 26. AIR REGISTERED 80 DEGREES F.

DEPTH IN FEET	Temperature, F
Surface	76
22.5 (East side)	72
31.0 (South end)	62
31.5 (N. E. of center)	58.5
32.5 (E. of center)	72
40.0 (N. of center)	52

The bottom is principally of mud and muck with only a very small area covered with gravel. There are great beds of submerged plants at each end and along the sides, while water lilies are abundant in the numerous bays.

Although the bottom temperatures are low enough for brook trout, the bottom water has a strong odor of hydrogen sulphide, an indication that it is deficient in oxygen. The lake now contains large-mouthed bass, pickerel, yellow perch, sunfish and bullheads for which it seems best adapted.

Crystal lake is only about .5 of a mile long and .15 of a mile wide. On its east shore is situated "Scouthaven", a summer camp for boy scouts. The greatest depth recorded was 27 feet. The bottom is composed principally of mud with only an occasional area of gravel. Pond lilies are abundant and large submerged meadows of pond weeds, water weeds and wild celery occur at each end. Although the lake has been repeatedly stocked with small-mouthed bass, the predominating form is the large-mouthed and this species together with bluegills and calico bass should be planted in the future.

Java lake has a minimum depth of about 25 feet and is fed principally by springs located in the northwest corner. The bottom temperatures were low ranging from 58.5 to 62. Mud bottom predominates everywhere except for a short stretch along the northwest shore. Submerged vegetation is dense and extensive while patches of pond lilies were found here and there in the shallows.

The bottom water is cold enough for trout but there is evidence of hydrogen sulphide which is an indication that the oxygen content is too low. Doctor Leffingwell seined the lake carefully and found the following species among others: yellow perch, bullhead, pike-perch, large-mouthed bass, northern pike and sunfish. It has been stocked with small-mouthed bass but none was seen and presumably the plant was not a success. The general conditions seem much better suited to a large-mouthed bass and associated forms.

II. A PRELIMINARY REPORT ON THE JOINT SURVEY OF LAKE ERIE

By CHARLES J. FISH

Director Buffalo Museum of Science

Introduction

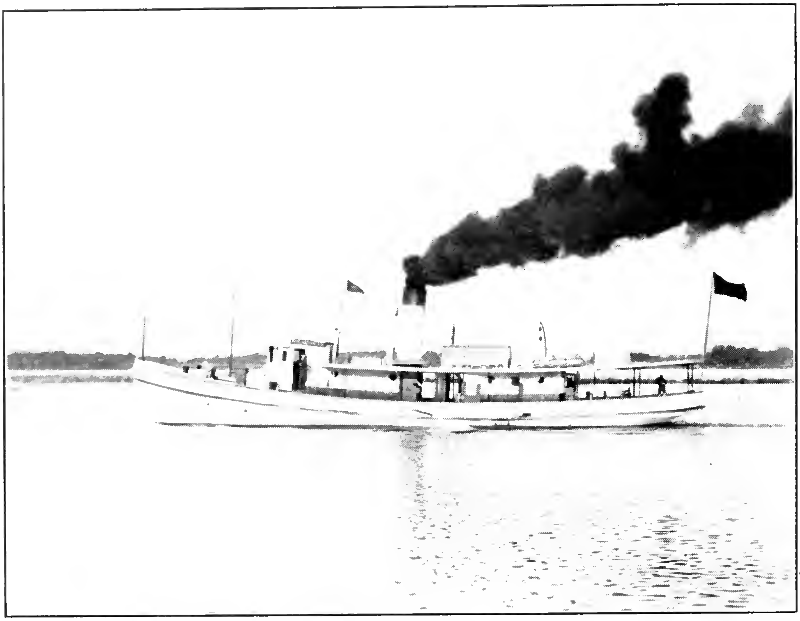
The present report contains a brief summary of some of the results of a three months' survey of eastern Lake Erie, carried on under the joint auspices of the United States Bureau of Fisheries, the New York State Conservation Department, the Ontario Department of Game and Fisheries, the Health Department of the City of Buffalo, and the Buffalo Society of Natural Sciences. The object of the investigation was to determine if possible the cause or causes for the decline in the fisheries of the lake.

The staff consisted of the following eleven investigators:

Charles J. Fish, Field Director, Buffalo Museum of Science, Buffalo, N. Y.
Richard Parmenter, Hydrographer, formerly with U. S. Bureau of Fisheries.
Marie Poland Fish, Biologist, Buffalo Museum of Science, Buffalo, N. Y.
Charles B. Wilson, Biologist, Westfield Normal School, Westfield, Mass.
Paul R. Burkholder, Botanist, Cornell University, Ithaca, N. Y.
Roger C. Williams, Chemist, City Health Department, Buffalo, N. Y.
Andrew N. Zillig, Bacteriologist, City Health Department, Buffalo, N. Y.
Albert E. Allin, Assistant Ichthyologist, University of Toronto, Toronto, Ontario
Willis L. Tressler, Assistant, University of Wisconsin, Madison, Wisconsin.
Elizabeth L. Saunders, Assistant, Brown University, Providence, R. I.
Vernon S. L. Pate, Assistant, Cornell University, Ithaca, N. Y.

Program and Itinerary.— The program was designed with two objects in view: first, a determination of the normal physical, chemical, and biological conditions in the lake and the natural requirements for successful production of fishes; second, a careful investigation to determine to what extent these natural requirements have been interfered with by man, to what extent the waters have been made impossible for fish life, what areas of the bottom have been rendered unfit for spawning, etc. By continuing the results of these two lines of study it should be possible to determine where the natural requirements have been most seriously affected and how conditions may best be improved.

In the area of 1701 square miles lying east of a line from the New York-Pennsylvania boundary to Long Point, 23 stations were located and plans made to visit each of these weekly from June 15 to September 15, using the U. S. Fisheries steamer, *Shearwater*, an 85 foot vessel of 95 gross tons. Before the arrival of the larger vessel, during the interval between June 15 and July 26, a modified program was carried out in the shallow area around the margin of the lake on the New York State gasoline launch, *Narette*.*



The federal steamer "Shearwater" of the Bureau of Fisheries detailed for service in the Lake Erie survey

TABLE I.— SHEARWATER STATIONS

Station	Depth in meters	Location		Remarks	Station	Depth in meters	Location		Remarks
		Latitude	Longitude				Latitude	Longitude	
1	6	42° 52′ 30″	78°-55′	Buffalo intake pier	14	39	42°-21′-30″	79°-50′	Mid lake
2	11	42° 48′	78°-56′	Seneca shoal	15	62	42°-29′	79°-58′	Deep hole.
3	9	42° 44′	78° 59′	Off 18-Mile creek.	17	29	42°-33′ 30″	80°-03′	Long Point.
4	22	42° 47′	79°-02′	Mid lake.	18	10	42° 36′	80° 10′	Bluff bar.
5	9	42° 50′ 30″	79°-05′	Pt. Abino.	19	10	42°-43′	80°-14′	Ryerse.
6	15	42°-51′	79° 15′	Port Colborne	20	35	42°-40′	79°-66′	Long Point bay
7A	22	42° 42′	79° 13′	Mid lake.	21	60	42°-33′	79°-43′	Mid lake
9	11	42° 34′	79°-10′	Silver creek.	22	37	42° 40′	79°-43′	Mid lake.
10	16	42° 33′	79°-15′	Beaver creek.	23	15	42°-46′-30″	79°-43′	Tecumseh reef.
11	18	42° 30′	79°-20′	Dunkirk.	24	15	42°-48′-30″	79°-36′	Port Maitland.
12	22	42° 23′	79° 34′	Westfield.	25	15	42°-49′ 30″	79° 25′	Sunken island bay.
13	16	42° 17′	79°-46′	State Line.	....	.....	....	....	....

* See illustration page 12.

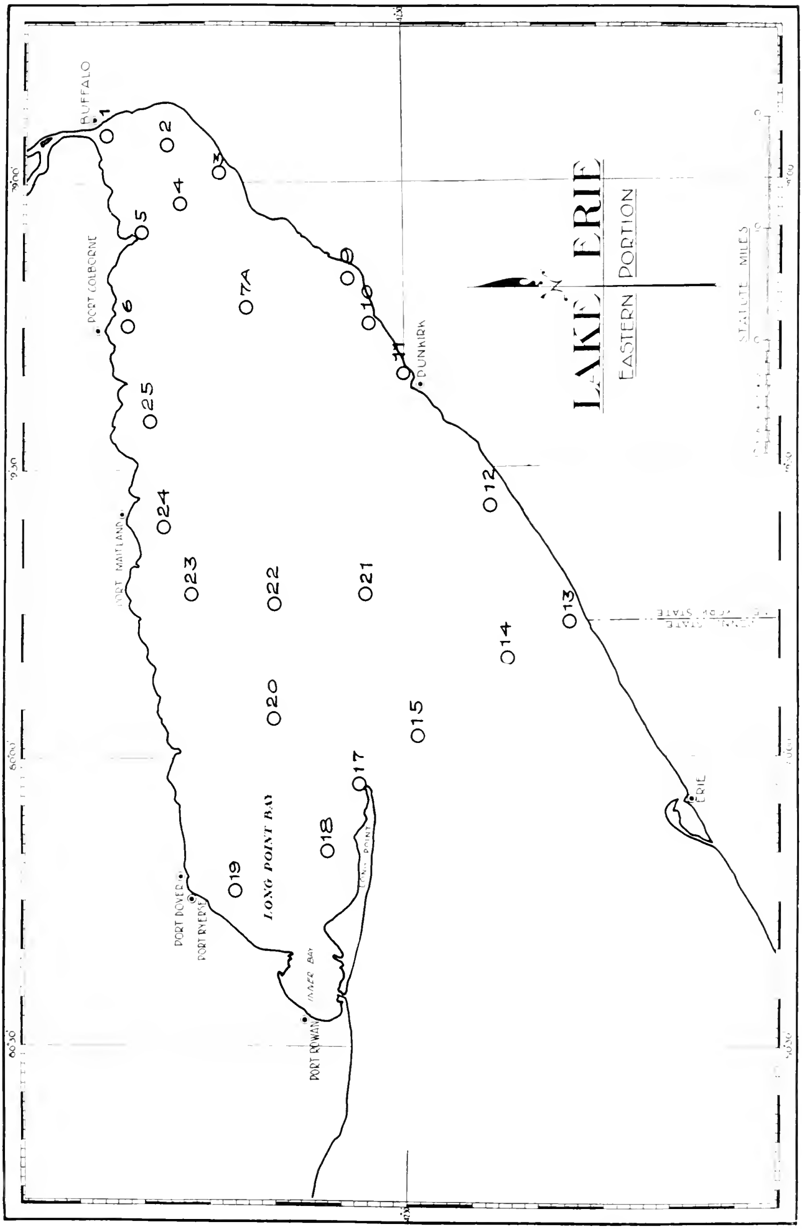


Fig. 1.—Key chart of the Shearwater stations

The field program consisted of:

Physical Observations:

1. Sounding for depth and bottom sample—to determine the character of bottom throughout the region and the distribution of silt deposits.
2. Temperature—horizontal and vertical range throughout the season; also diurnal fluctuations.
3. Currents—rate and direction of the movements in the water mass.
4. Transparency—degree of turbidity due to organic and inorganic matter in suspension.
5. Effect of storms on physical, chemical, and biological conditions in the eastern part of the lake.

**Chemical and Bacteriological Observations:*

1. Free ammonia, albuminoid ammonia, nitrates, dissolved oxygen, dissolved carbon dioxide, calcium carbonate, calcium bicarbonate, and hydrogen ion test to determine
   (a) Normal chemistry of the lake.
   (b) Extent and concentration of pollution.
2. Bacterial test to determine quantitative distribution of bacteria and of the *B. coli-aerogenes* group.

Biological Observations:

Limnological cruise—

*1. Liter samples from surface and bottom centrifuged for nannoplankton.

*2. Fifty liters from the surface and bottom taken with pump and filtered through No. 20 silk for quantitative distribution of phytoplankton.

3. Horizontal five-minute hauls at surface and near bottom with No. 20 silk foot net for a qualitative check on the pump collections.

4. Horizontal five-minute hauls at surface and near bottom with Michael Sars meter net of No. oxx and No. ooxx silk for quantitative and qualitative macroplankton and young fish collections. (Depth at which lower net fished was determined from the angle of the dredging wire and length of line out.)

Fishing Cruise—

1. Five-minute bottom hauls with a Helgoland trawl for demersal fish eggs, small fry, and the macroplankton community adjacent to the bottom.

*2. Fifteen-minute hauls with a Petersen young fish trawl (1/4 inch square mesh) fishing at all levels.

* Observations omitted on Navette stations.

Occasional shore seining with 150 foot seine to supplement the off-shore work.

In order to facilitate the work the field program was divided into two parts, the young fish collections (Petersen and Helgoland trawls) and the limnological collections being taken on alternate weeks. This allowed the laboratory staff two weeks to complete the more time-consuming work on the chemical, bacteriological, and plankton analyses.

TABLE II.— NAVETTE STATIONS

Station	Depth in meters	Location		Remarks	Station	Depth in meters	Location		Remarks
		Latitude	Longitude				Latitude	Longitude	
1A	9	42°-51′	78°-55′	Off Michigan gap.	21C	15	42°-51′-30″	79°-16′	Port Colborne.
2C	7	42°-48′	78°-58′	Waverly shoals.	22C	15	42°-50′	79°-36′	Port Maitland.
3A	10	42°-46′	78°-58′-30″	Seneca shoal.	23C	5	42°-46′	80°-12′-30″	Port Dover.
Z	7	42°-52′	78°-55′	Buffalo light.	24C	8	42°-44′	80°-15′	Ryerse.
4A	4	42°-46′	78°-54′	Athol Springs.	25C	14	42°-36′	80°-09′	Bluff bar.
6A	6	42°-43′-30″	78°-59′	18 Mile creek.	I Sp.	6	42°-52′-30″	78°-55′	Intake pipe.
7A	7	42°-42′-30″	79°-02′	Kellogg's dock.	26C	.....	42°-58′	78°-59′-30″	Sidway's — Grand isl'd.
8A	3	42°-39′	79°-05′	Boulder shoal.	27C	.....	42°-57′	78°-55′-30″	Strawberry island.
15C	7	42°-51′	78°-57′	Waverly sh. N.	14A	17	42°-30′	79°-20′	Dunkirk
16C	2	42°-53′	78°-57′	Rose's reef.	13A	6	42°-31′	79°-16′-30″	Beaver creek.
17C	4	42°-53′	79°-00′	Bertie bay.	12A	8	42°-33′	79°-13′	Havilah.
18C	4	42°-52′	79°-02′-30″	Thunder bay.	11A	6	42°-33′-30″	79°-11′	Silver creek.
19C	3	42°-51′-30″	79°-05′	Point Abino bay	10A	5	42°-34′	79°-09′	Cattaraugus creek.
20C	10	42°-51′	79°-07′	W. of Pt. Abino.	9A	12	42°-37′	79°-07′	Muddy creek.

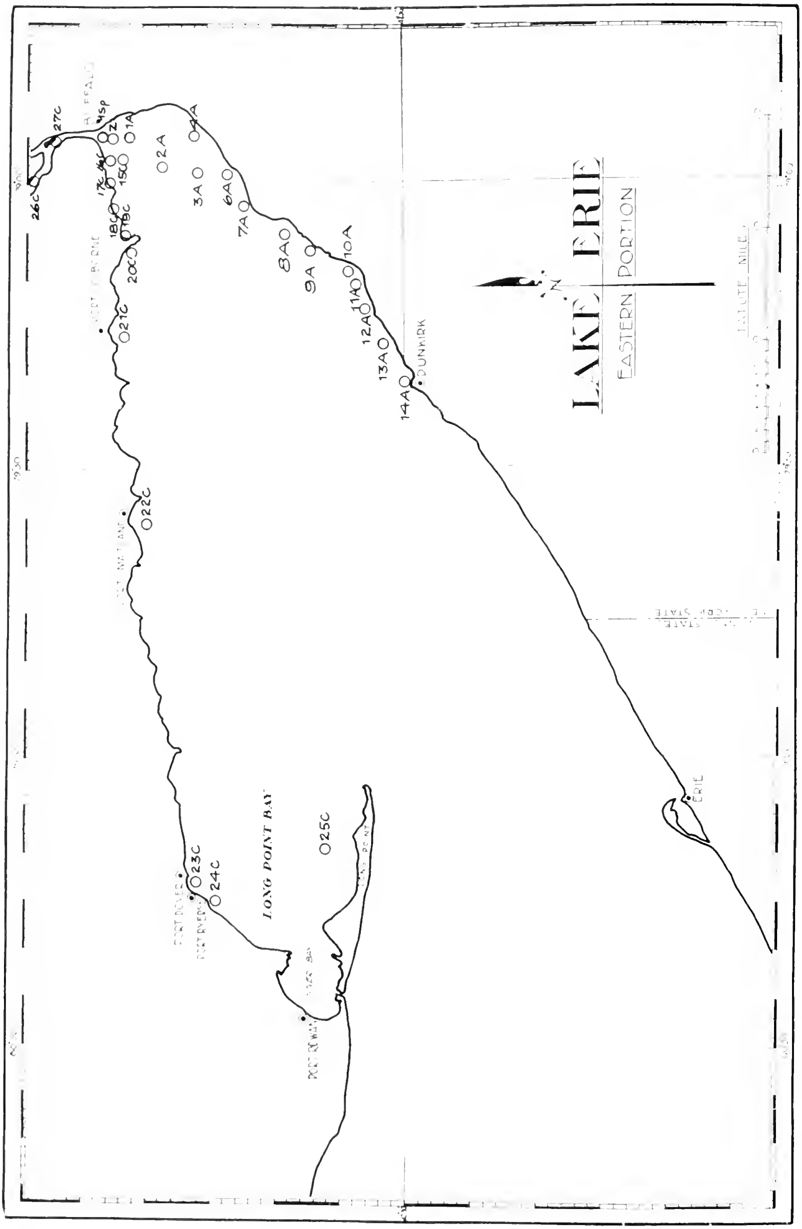


Fig. 2.—Key chart of the Navette stations

Discussion of Results

1.—Hydrography

By Richard Parmenter

Equipment.— All hydrographic apparatus was worked on a 1/4 inch galvanized iron wire attached to the barrel of a hand winch and passing over the standard form of meter wheel. The meter wheel was suspended from a small davit on the port quarter of the vessel. The thermometers, water-bottles, etc., could thus be easily controlled and lowered to the depth desired with a high degree of accuracy.

Greene—Bigelow water bottle with Richter reversing thermometer

Throughout this report all temperatures are given in the Centigrade scale and all depths are in meters.

Temperatures.*—For the determination of surface temperatures an ordinary laboratory thermometer reading to 1/5 of a degree Centigrade was used. For sub-surface work the conventional type of deep-sea thermometer manufactured by the firms of Negretti & Zambra and Richter & Weise were used. The Negretti instruments were graduated to fifths of a degree Centigrade and the Richter's to tenths in the same scale.

Transparency.— The Secchi disk, eight inches in diameter, was used for determining the transparency of the water. The transparency is expressed as the depth in meters at which the disk disappeared from view.

Currents.— Two meters were used in investigating the currents of the lake. For direction the Ekman type was used. In this small shot are released from a reservoir by the turning of the mechanism and after passing along a grooved compass needle fall into a compartmented box. For velocity the newest electric-acoustic type of meter manufactured by the Gurley Company was used. The results of the Ekman were not very satisfactory as the mechanism showed a tendency to stick. Due to deficiencies in the *Shearwater's* equipment she could be anchored in only the very calmest weather and current determinations were consequently limited to these times.

The shape of the lake bottom in the region investigated is clearly shown by the bathymetrical chart, (fig. 3), whereon contour lines are laid down at 10 meter intervals. The areas of the 10 meter levels and their percentage of the total surface area (1701 sq. mi.) are as follows:

TABLE 3.— TEN-METER INTERVALS SHOWING PERCENTAGE OF SURFACE AREA

LEVEL METERS	Area sq. mi.	%
0	1,701	100.0
10	1,399	82.2
20	940	55.2
30	616	36.2
40	338	19.8
50	122	7.2
60	29	1.7

Distribution of Temperature.—Although Lake Erie as a whole did not freeze over in the winter of 1927-1928, there was closely packed field ice extending westward from Buffalo as far as the eye could reach on May 15 and for several days thereafter. This ice had been in this region for some time and had come down there from the upper lakes. It is, therefore, probable that on this date the temperature of the lake as a whole and from top to bot-

* See page 55.

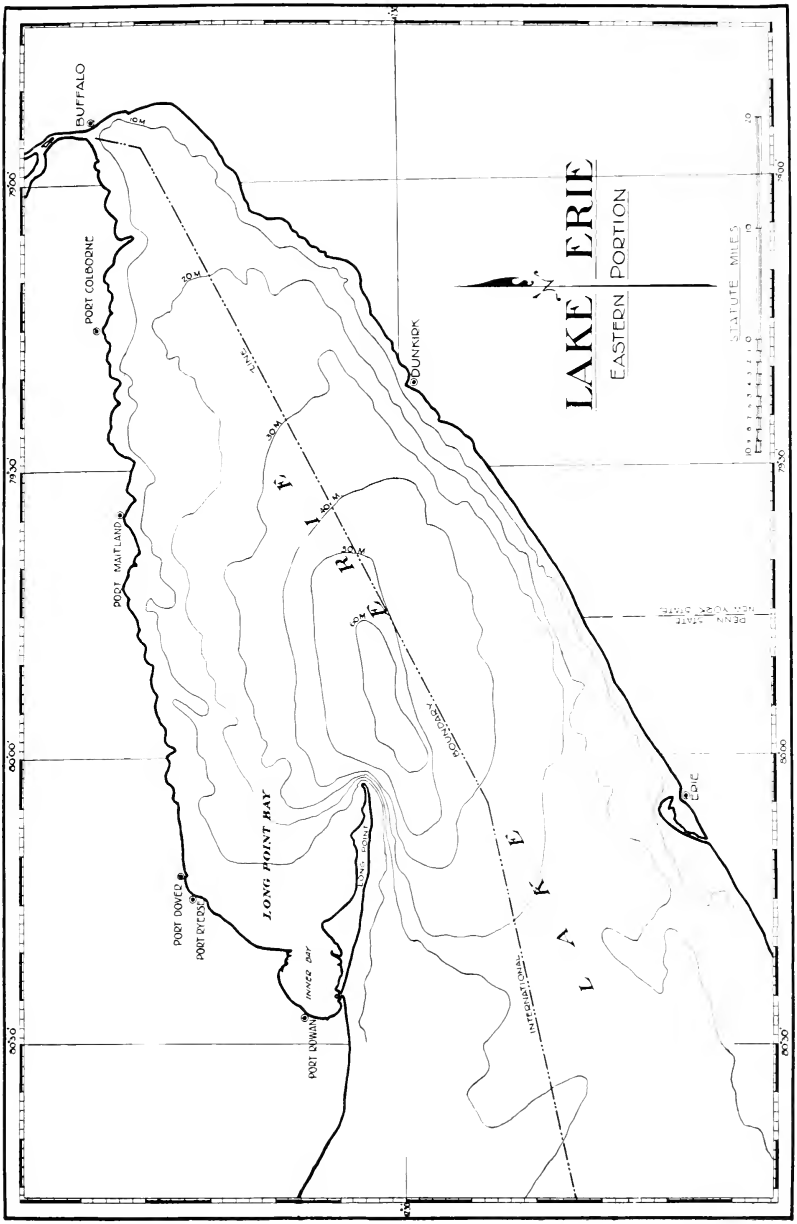


Fig. 3.—Bathymetric chart of eastern portion of Lake Erie

tom was somewhere around 4 degrees C, any warming which may have taken place during the earlier spring months having been obliterated by the arrival of this ice.

By May 25 all ice had disappeared and by the time of the first cruise which was made in the New York State Conservation Department's launch *Narette* on June 10, 11, and 12, a pronounced warming both of surface and bottom had taken place in this area.

The first *Narette* cruise covered the Buffalo region and extended in very shallow water along the American and Canadian shores. The extreme shallowness of these shore stations gave temperatures which could not be considered indicative of the lake surface as a whole nor permit of comparison with the later *Shearwater* stations. Consequently only the stations farthest out from land, 1A, 2C, 3A, and 15C have been used for estimating the probable average surface temperature in the Buffalo region. The mean of these four is 13.0°.

In the Buffalo region no noticeable vertical gradient existed, but farther west there was a pronounced differential. Thus at station 20 on the west side of Pt. Abino the surface temperature was 15.8° while the bottom in 10.5 m. was only 10.6°.

The second cruise took place a week later and included the region along the Canadian shore from Buffalo to Port Dover. The mean surface temperature of the three stations occupied on the first day was 13.6°. There was an even vertical gradient from top to bottom with no evidences of a thermocline as yet. The stations in Long Point Bay near Port Dover were thoroughly mixed but at the station off Bluff Bar a temperature of only 8.8° was found at the bottom in 14 m.

The third *Narette* cruise embraced the American shore between Dunkirk and Buffalo. It took place on July 11 and 12 and the surface was found to have warmed to a mean temperature of 23.5°. This high value is due to the fact that only the marginal zone of the lake figured in these stations and the figure does not represent the mean surface temperature of the lake as a whole in any sense. Vertical gradients were found to have disappeared in this shallow band along the edge.

With the arrival of the *Shearwater* at Buffalo late in July it became possible to take up the original program which consisted of occupying at weekly intervals a series of stations forming a net work over the area to be investigated. Their location is shown on the key chart. Due to certain limitations in the *Shearwater's* equipment work could only be carried on during the daylight hours and in order to complete the circuit of 23 stations three days were required. The first night was spent in Dunkirk, the second in Port Dover, while the third day was passed in the return to Buffalo with the stations that lay along this route. Consequently, stations 1 to 11 which were taken up on the first day between Buffalo and Dunkirk were always separated by a gap of at least twenty-four hours from stations 20 to 25 which were occupied on the last day's run. As happened on several occas-

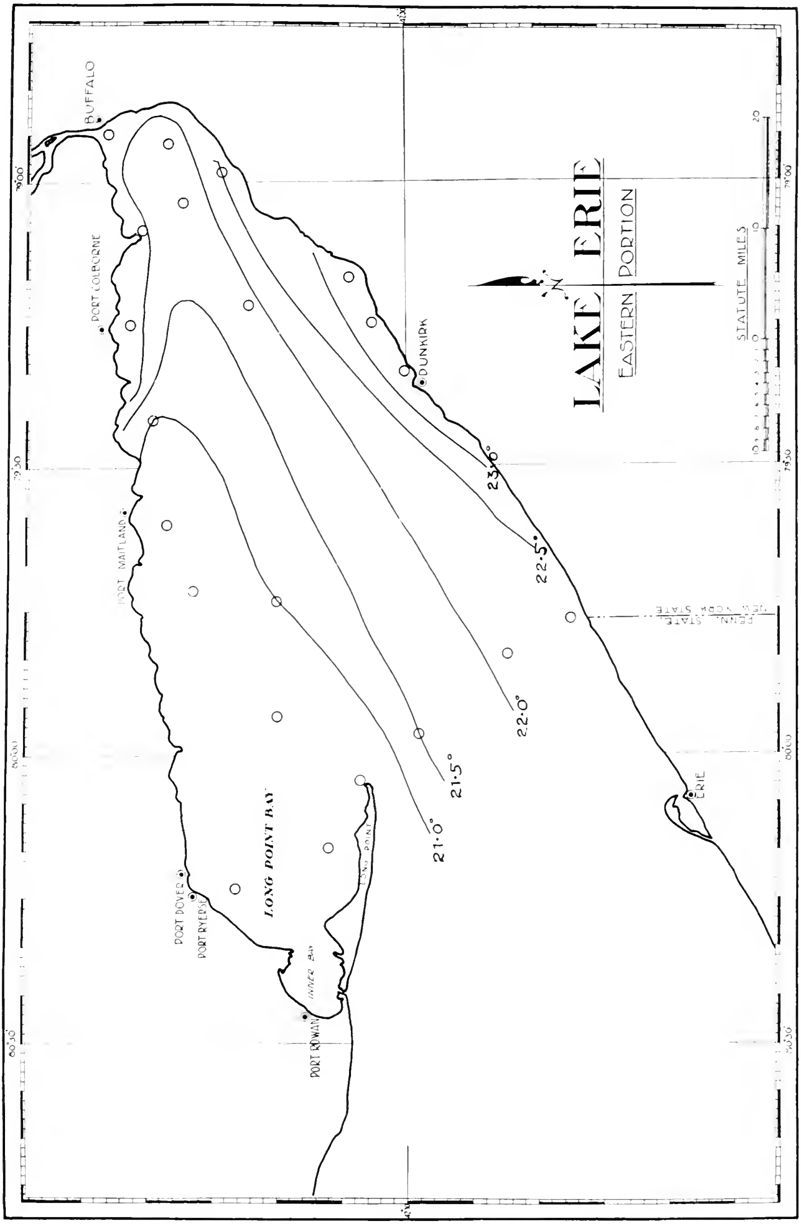


Fig. 4.—Distribution of surface temperature. First cruise

sions, bad weather interrupted the work at Dunkirk or Port Dover or both, and the interval between the first and last stations was correspondingly lengthened. The lake is so large, however, and its diurnal changes, even under the influence of a brisk wind are so small that mean temperatures can be discussed and contour lines of distribution drawn as safely as though it had been possible to occupy all of the stations within the same twenty-four hours.

Cruise 1 began on July 24 and continued, with interruptions due to bad weather, until July 31. The distribution of surface temperature was in accordance with Fig. 4. There was a pronounced piling up of warm water along the American shore and into the pocket at the Buffalo end of the lake. The Dunkirk region was warmest with water slightly above 23° while all the Long Point bay region was covered by water below 21°.

When station 14 was occupied the relatively feeble penetration of vernal warming was evident and the first evidence of a thermocline observed. There was a drop of 10° in the ten meters between the 10 m. and 20 m. levels and at the bottom in 36 m. water of 4.7° was encountered.

A stop of 18 hours was made at the next station, 15, the "deep hole". Here the temperature was taken every 5 m. down to the 30 m. level and then every 10 m. to the bottom in 60 m. True winter water of just above 4° was found in the bottom 10 m. and a marked discontinuity layer occurs between 25 and 35 meters. The finding of the 4.7° water at station 14 was now explained and a glance at Fig. 5 shows a rather widespread distribution of water below 5°. Rather surprising was the fact that this cold water seemed to be running up hill a little, for 4.7° occurs at a level 10 m. higher at station 14 than at station 15. But this inclination of the water layers occurs in a manner truly remarkable on the northern side of the "deep hole" where at station 17 where water fractionally above 5° is found at 15 m. although six miles away at station 15 it is 40 m. below the surface.

The most remarkable discovery at station 17 was the existence of a thermocline in which a change of 7.8° takes place in a vertical distance of only one meter—between 14 m. and 15 m. Such a condition has never been found before in a large and exposed body of water so far as I can find out; and in order to make certain of this phenomenon the readings were repeated three times with different thermometers. The region is one of strong currents and wave action. This cold water which climbs uphill against the force of gravity extended a certain distance "around the corner" into Long Point bay. But to the westward of the neighborhood of Bluff bar there was either no further intrusion or the sun's rays had penetrated the shallows sufficiently to make the water virtually uniform from top to bottom, there being a differential of only 0.5° at the station 18 and of 1.8° at station 19.

It may be considered that the top 10 meters of the lake were now pretty thoroughly mixed, the mean surface temperature being 21.8° and the mean for 10 m. being 20.9°. But this mixing did not

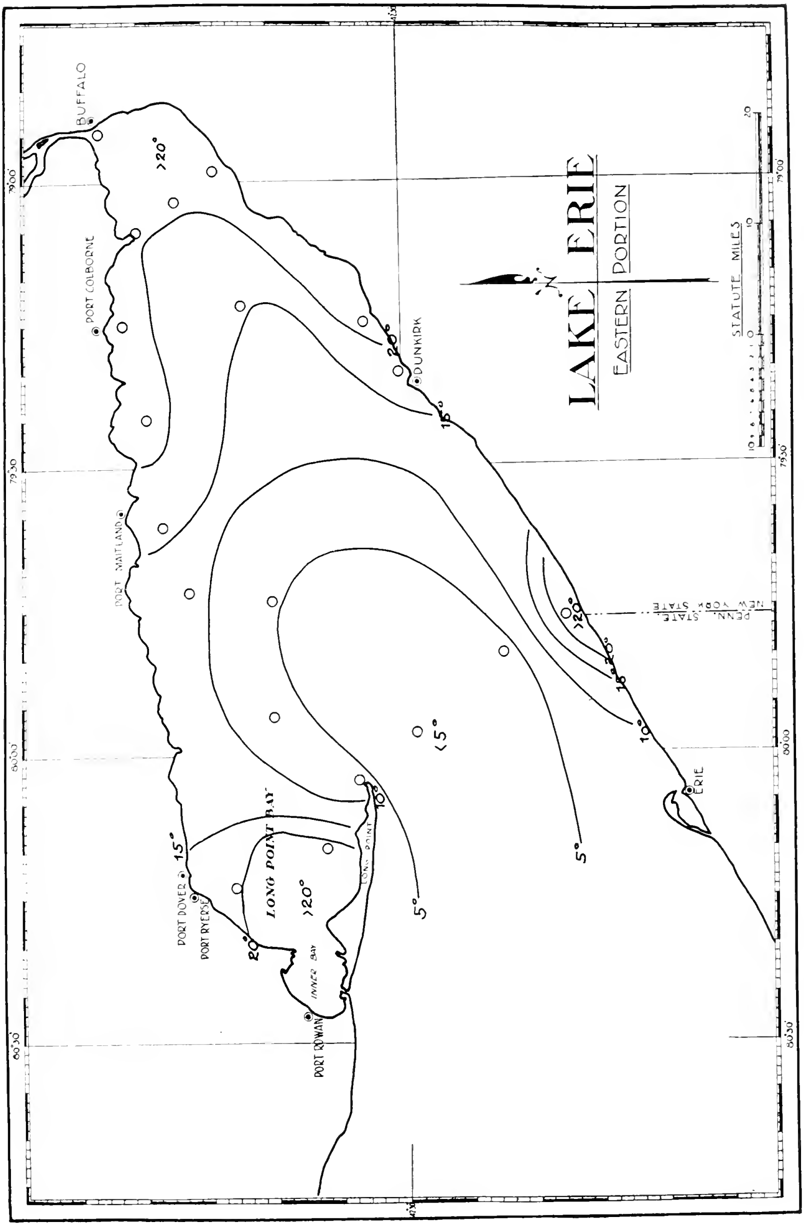


Fig. 5.—Distribution of bottom temperature. First cruise

extend far below the upper 10 m. for in general the temperature dropped off sharply below this point, the exceptions occurring in the eastern end of the lake and along the American shore—both regions of "pile up" due to the prevailing southwest winds.

The water in the trench off Long Point was apparently true winter water still practically at minimum temperature and maximum density and the occasional storms which had blown across the surface above it since the water began to warm up in the spring had not been strong enough to overcome the steadily increasing stability of equilibrium into which the warm weather was putting the water.

The second cruise of the *Shearwater* was given over to fishing with the trawls, but on the third cruise, August 15, 16 and 17 the mean surface temperature had risen to 22.9° and the mean temperature of the 10 m. level to 21.3° showing the water to be thoroughly mixed in the upper ten meters.

But the most remarkable feature of the lake at this time was the very low temperature found at the bottom at stations 3 to 10, caused by a great spreading out to the eastward of the water which had previously been confined to the trench off Long Point. Hampered as we are when dealing with fresh water by the absence of salinity values as identifiers, the complete absence on the first cruise of any water below 20° to the eastward of the line of stations 3-4-5 is proof positive that the water below 15° now found at these stations could have come there only from the west, that is from the deep hole.

Something had set this cold mass in movement and against the action of gravity it was rising over the slopes which surround its place of origin and creeping under the lighter surface water until it encountered some obstacle to its progress. In the region of Dunkirk where it had been halted by the shore its presence was manifested in the low surface temperature as well as the bottom for in these shallows the water was thoroughly mixed from top to bottom. It had not apparently extended far enough to the eastward to make itself felt at stations 1 and 2 nor had it gone around the corner into Long Point bay as far as station 18, but it had affected the bottom temperatures of practically all the other stations.

The question at once presented itself whether this creeping of cold water to the eastward was a normal flow of the entire lake water toward Buffalo—a flow which would presently drain the deep hole of cold water and replace it with warmer water from the western end of the lake—or whether it was an oscillatory movement of the nature of a submarine seiche.

A theory can be advanced which accords fairly well with the computed "normal lake movement" (to be discussed later) which would explain why cold water had not appeared off Point Abino earlier in the season and yet did appear now; but it was recognized that a seiche movement was far more likely to furnish the explanation, and temperatures taken from station 1 to station 9 on the

4th cruise showed conclusively that this was the case. For at this time all trace of the cold bottom water at these eastern stations had disappeared.

To return to the third cruise: At stations outside of the Buffalo region and Long Point bay the creeping in of this cold bottom water had set up strong density gradients and consequently retarded mixing. Nevertheless it was fractionally warmer at the bottom at stations 14 and 17 than it had been two weeks earlier. At station 17 the existence of the surprising thermocline was again noted. This time the discontinuity layer lay between 17 and 18 meters instead of between 14 and 15 meters as earlier. The top 15 meters of water were quite thoroughly mixed. The temperature at 15 m. was 20.5°; at 17 m. it was 12.9°; and at 18 m. only 6.4°. The finding of this phenomenon again removed any doubt as to the accuracy of the previous readings.

It is interesting to note that while the surface density gradient had been reversed over what its direction was on the first cruise, the forces which were holding the water layers inclined at so sharp an angle to the horizontal on the south side of Long Point had changed apparently neither in magnitude nor in direction. Water of low temperature was still found at station 17 many meters higher than was water of the same temperature at the adjacent station 15.

Cruise 4 which took place on August 22, 23, and 24 was a fishing trip and temperatures were taken only at stations 1 to 9 in order to check up on the movement of the bottom water.

The fifth cruise began on August 28 and lasted, with interruptions due to strong winds, until September 3. The mean surface temperature was 21.6° at the 19 stations which were occupied and the individual divergences from this mean so small that no chart has been prepared.

The surface had cooled slightly since the third cruise and was now about the temperature of a month earlier. Nor was the maximum temperature, 22.8° at station 11, as high as the maximum of cruise 3. Evidently the peak of the summer warming was reached some time between the 15th of August and the 1st of September and with the increasing declination of the sun and the greater intensity and frequency of strong winds which now began, surface cooling went on faster and faster. Already water in unstable equilibrium had appeared. On the morning of September 1 which was raw and cold an inverted temperature gradient was observed at station 13 extending from top to bottom and at station 14 between the top and 20 meters. Convectional overturning must have been going on rapidly at these stations.

The upper 20 meters was now thoroughly mixed and at station 15 the same reading 21.3° was obtained at 0, 10, and 20 metres. Just below 20 meters, however, a pronounced thermocline was evident in all stations having depths exceeding this figure and while time would not permit of more detailed investigation at station 17, evidences of the former concentrated discontinuity layer—somewhat attenuated—were found even though the water at 18 meters was several degrees warmer than it was two weeks before.

Also, as the westward extension of the 50 meters level was found to be only about 8 miles beyond station 15, it seems probable that the normal net movement toward the lake outlet at Buffalo was concentrated solely in these upper strata, else the cold water here would by now have been replaced by water from the shallower parts of the lake to the west and could have been easily identified by its much higher temperature.

Yet the water in the deep hole was neither chemically nor physically stagnant as such a condition of apparent insulation from surrounding waters might lead one to expect. Chemical analyses showed an abundance of oxygen in the lower levels in spite of incessant consumption by the animal members of the community, although this oxygen could not have been brought there by transference from the aerated regions near the surface. There is apparently light enough here for the plants of these waters to carry on photo-synthesis. Nor is there physical stagnation here, for current meters operated on the first and fourth cruises revealed the presence of considerable velocities even in the lowermost levels. More temperature data in the region lying to the west of the deep hole is urgently needed if the movements of the cold water are to be understood.

The sixth and last cruise began about a week later on September 12 and, as it covered only the region between Buffalo and Dunkirk with the addition of station 22, a very detailed discussion of temperature distribution cannot be undertaken. The surface water now had a mean temperature of 20.9° with approximately 20.6° at the ten meter level. Mixing had been so complete down to 20 meters that all bottom water to the east of the Port Colborne—Silver creek line was over 20°.

The only indications we had of the condition of the bottom water in other regions was furnished by the value 9.4° in 33 meters at station 22. The water from the deep hole was apparently not in movement—to the eastward at any rate.

A Taylor self-recording thermometer was set up aboard the *Shearwater* at her dock at the foot of Porter Avenue in order to gain some idea of the magnitude of the diurnal changes taking place in the surface waters. The instrument was set in such a position that the capillary bulb extended about six inches below the surface and on the seaward side of the vessel. The water at this point was in continuous gentle movement due to a small current and while exposed fully to wind action was protected from high waves by the presence of the inner breakwall a few hundred yards away. Readings were taken continuously from noon of September 7 to noon of September 11, and the values never rose above 70°F. (21°C.) nor fell below 67°F. (19.5°C.) and this extreme difference occurred all on the day September 7–8, the diurnal changes on the other days being less than 1°F.

Currents.— Current measurements were taken at Station 15 — the deep hole on the first and fourth *Shearwater* cruises. A maximum surface current of 0.92 ft/sec. (about 0.63 mi/hr.) was encountered at 8 p. m. on July 30, the maximum bottom reading of this set of measurements, which lasted 12 hours, being 0.44 ft/sec, occuring at 4 a.m. on the 31st.

The velocities encountered during the fourth cruise were not as large and hence the high currents reported by the fishermen who claim that their nets and gear are damaged thereby must still remain a matter of hearsay, although it is probable that they do not exist.

In the complete report, to be published elsewhere, it is shown that the currents of Lake Erie cannot be due to the "normal flow" of the water from the western to the eastern end; and that these currents must be brought about by winds, barometric pressure, the distribution of density, or combinations of these factors. In this fuller discussion, a theory to account for the movement of the cold water noted in the pages above is advanced and fully discussed. The suggestion is offered that data supplied by the weather bureaus of the lake cities may ultimately permit the location of this cold water to be forecasted day by day. Since several of the commercial species of fish follow this cold water closely, the economic value of such forecasting is evident.

Transparency.— The transparency of Lake Erie as a whole is low. The maximum reading of the Secchi disk was only 10.5 meters with a minimum reading of 2 m. The average was between 5 and 6 meters.

The plotted distribution of the data showed no particular geographical effect, the near shore stations being about as high in value as the off shore. The roughness of the sea decreased the transparency and the angle of the sun had some effect for the highest values occurred on sunny quiet days within a few hours of noon. The abundance of living organisms probably played the most important part in varying the transparency, and mean value (5–6m.) which we found in the eastern part of the lake is about what might be expected in a "green" sea. Harvey* gives the transparency average for the Deutschland Expedition's tests in "green" sea water as 9 m.

CONVERSION TABLE FROM FAHRENHEIT TO CENTIGRADE

°F.	°C.	°F.	°C.	°F.	°C.	°F.	°C.
33.8	1.00	46.4	8.00	59.0	15.00	71.6	22.00
34.7	1.50	47.3	8.50	59.9	15.50	72.5	22.50
35.6	2.00	48.2	9.00	60.8	16.00	73.4	23.00
36.5	2.50	49.1	9.50	61.7	16.50	74.3	23.50
37.4	3.00	50.0	10.00	62.6	17.00	75.2	24.00
38.3	3.50	50.9	10.50	63.5	17.50	76.1	24.50
39.2	4.00	51.8	11.00	64.4	18.00	77.0	25.00
40.1	4.50	52.7	11.50	65.3	18.50	77.9	25.50
41.0	5.00	53.6	12.00	66.2	19.00	78.8	26.00
41.9	5.50	54.5	12.50	67.1	19.50		
42.8	6.00	55.4	13.00	68.0	20.00		
43.7	6.50	56.3	13.50	68.9	20.50		
44.6	7.00	57.2	14.00	69.8	21.00		
45.5	7.50	58.1	14.50	70.7	21.50		

* Harvey, H. W. Biological Chemistry and Physics of Sea Water, table 43. p. 157, 1928.

2.—*Bacterial Studies of Lake Erie*

By Andrew M. Zillig

This report represents the sanitary condition of the water at the points collected in the eastern part of Lake Erie during the months of July and August, including methods and results obtained, with interpretations. Standard Methods for Water Analysis, as approved by the American Public Health and the American Water Works Association, were employed.

Bacteria sampler for subsurface collections

The bacterial count, as obtained by Standard Methods, does not reveal the actual number of bacteria present in the amount of water tested, but should be interpreted as an index of the bacterial content. The average bacterial count obtained on 94 samples examined was 34, the lowest 1, and the highest count 210 bacteria per cubic centimeter of water tested. *B. Coli* or *aerogenes* were not found in one-tenth or one cubic centimeter amounts of any of the samples tested. Members of *B. Coli-aerogenes* group were present in 20 of 470 of ten cubic centimeter amounts.

The bacteriological condition of Lake Erie is never constant but subject to fluctuations due not only to seasonal changes, but following heavy storms at any time during the year, particularly when preceded by heavy rains, the records showing that such disturbances have occurred as late as the month of December. However, in the light of available evidence, the lake is remarkably free from pollution and from the bacteriological standpoint, in the

Preparing cultures on Shearwater

area investigated, is not a factor in the destruction of either young or adult fish.

Regarding adult fish, there is no evidence to suspect bacterial infection of an epidemiological nature in Lake Erie. Such a condition, if extensive enough to affect their abundance, would be observed in the inspection of thousands of pounds caught yearly by the commercial interests for marketing purposes. Storms may produce mechanical injury to a small percentage of fish in shallow water, one of the principal effects being sand in the gills, which prevents the function of breathing, or injury to the issue after removing protective substances, subjecting the fish to bacterial and fungus infection.

3.—*Chemical Studies of Lake Erie*

By Roger C. Williams

The chemical investigation of Lake Erie was undertaken chiefly for the purpose of ascertaining the amount and extent of pollution from sewage and industrial wastes. Something of the normal chemical conditions in the lake was also determined as being of biological significance.

In order to carry out the chemical program the following analyses were made: Determination of free ammonia, albuminoid ammonia, and nitrates, free carbon dioxide, bicarbonate, carbonate, dissolved oxygen, hydrogen ion concentration and temperature.

Three chemical trips were made on the U. S. F. S., *Shearwater*, in July, August and September for the purpose of visiting the stations chosen as representative of that eastern portion of the lake included in the survey. For the exact location of these stations see fig. 1.

Methods.— For the nitrogen analyses a one-liter sample of water was collected from the middle depth of each station in July, and from both the surface and bottom in August and September. The collection was accomplished by lowering a one-liter glass stoppered bottle in a special frame to the desired depth. It was then filled by working a double tripping device which opened and closed the bottle in situ. The samples were kept in these bottles on ice until analysis could be made in the laboratory.

Water samples for all other analyses were taken in a Greene-Bigelow water sampler, using proper precautions so as not to change the chemical properties of the water. The titrations for carbon dioxide, oxygen, and the pH determinations were made immediately in the field laboratory on board the *Shearwater*.

Wherever analyses were made temperature readings were also taken at the same depths. For this purpose reversing thermometers of the Negretti-Zambra and Richter types were used.

In executing the chemical determinations standard methods were employed as recommended by the American Public Health Association, "Standard Methods of Water Analysis" for 1925.

The answer to the problem of pollution in the lake proper may be discussed briefly in the light of the chemical analyses. It must

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The City of Buffalo, through the co-operation of Dr Francis E. Fronczak, Health Commissioner, and Dr Charles A. Bentz, Director, Division of Communicabie Diseases Laboratories, contributed the services of the City Chemist and a Bacterlologist to assist in Lake Erie survey work.

be borne in mind that this discussion applies only to the lake conditions as determined at points one-half mile or more from shore. The pollution problem in shallow water close to shore is handled elsewhere in the State report.[1]

When sewage and other organic wastes are added to a body of water decomposition soon sets to work. By the normal processes of "oxidation" large quantities of oxygen may be removed from the water and used in breaking down the complex organic compounds into simpler form. It may readily be realized that where this goes on to any considerable extent the normal amount of oxygen dissolved in water may be depleted in a marked degree. Hence oxygen depletion is often taken as an indication of pollution.

Oxygen depletion as a criterion of pollution must, however, be used with consideration of other factors. Replenishment of the supply of dissolved oxygen from the atmosphere and from the photosynthetic process of green organisms in sunlight may serve to maintain a relatively high percentage of saturation even in the presence of pollution. This condition of plenty of free oxygen will be found wherever large growths of algae furnish oxygen in excess of the demands of oxidation reactions. Because of the interaction of various factors judgment must be used in weighing the value of the analyses for the interpretation of pollution condition.

The minimum degree of oxygen saturation found in the lake during the period of the survey was about 50% and the greatest 95%. A certain amount of oxygen depletion is normal for such a body of water, because of the animal forms which use oxygen in their respiration and to a greater extent because of the decomposition of the bodies of dead organisms whose natural environment is the lake. An average oxygen content in Lake Erie of approximately only 25% below the saturation point is due to the normal respiration of the lake and is not indicative of pollution.

The relative abundance of certain nitrogenous compounds is used as an index to the amount of organic pollution. All of the analyses showed that the several kinds of nitrogen determined were present in quantities—signifying no objectionable pollution.

The amount of free ammonia present never reached more than .038 parts per million of nitrogen and on the average it occurred as only about .016 parts per million. These figures are comparatively low.

The analyses for albuminoid ammonia showed a minimum figure of .06 and a maximum of .12 with an average of .08 parts per million for the entire eastern end of the lake. And these figures are comparatively low.

The nitrate analyses indicate the presence of moderate amounts of nitrogen in its completely oxidized state. The largest quantity was determined in July at .20 parts per million; the smallest occurred in August as .08 parts. Nitrates averaged .14 parts per million.

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[1] See report of Dr. F. E. Wagner, et al.

These analyses taken all together show that the lake contains only a normal amount of nitrogenous substances which are very essential to the successful production of micro-organisms and fish in the lake.

As regards industrial pollution, whether acid or alkali, the reaction of the water to phenolphthalein and methyl-orange and the pH showed no indication of any such pollution. The limits of variability found may all be interpreted as normal phenomena.

It is well known that wastes are being emptied into the lake from various sources. Why, then, does the lake not show indications of this pollution? In answer it may be stated that the process of dilution is operative in vast measure in a body of water the size of Lake Erie. Any concentrated source of pollution is made very dilute by mixing with an enormous quantity of water. In the open water normal oxidation processes change the suspended organic stuffs into soluble form. In the Buffalo region these wastes are being poured down the Niagara river in tremendous quantities.

In conclusion, let it be stated that the analyses made and the conclusions drawn from the assembled data *do not* apply to conditions that may exist in shallow water near shore. As regards the open lake water the analyses warrant the conclusion that the lake proper is normal and free from objectionable pollution.

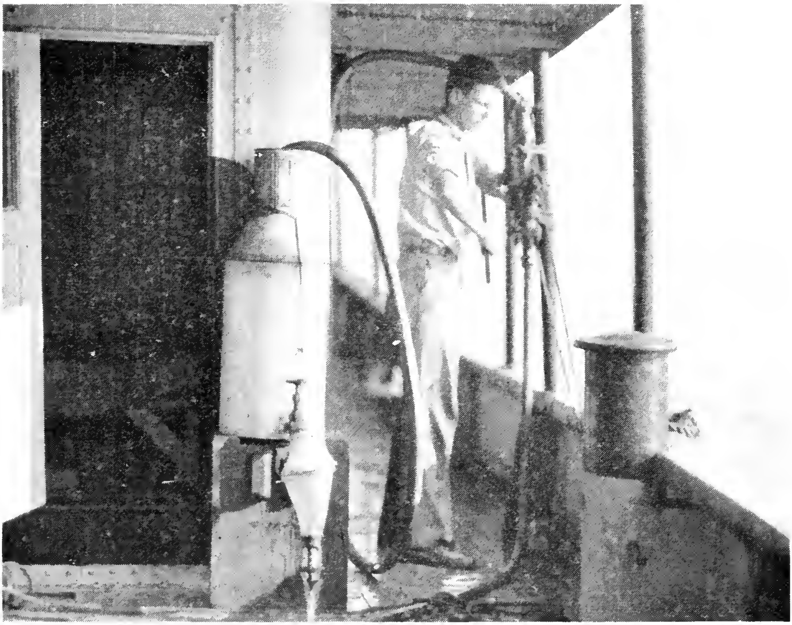
4.—Microplankton Studies of Lake Erie

By Paul R. Burkholder

Studies of the microplankton life of Lake Erie were undertaken as part of the general biological survey during the summer of 1928. The objects of this particular phase of the work were the following: 1. To study the kinds and quantity of micro-organisms existent in the lake, and 2. To determine something of their significance in the economy of the lake, more particularly as regards their bearing on the problem of fish production.

In order to secure representative samples it was necessary to establish a number of stations at various points on the eastern portion of the lake included in this survey. Those stations were chosen which were deemed either biologically significant, i.e., near sources of pollution, outwash from streams, etc., or were significant on account of the depth of the water or their geographical location.

Field Methods.— Quantitative samples of microplankton were secured by the following method: Water was drawn from the various stations and depths by using a double action hand pump and rubber hose. This method of securing water samples is deemed adequate for the microplankton, though not for the rapid swimming macroplankton forms which manage to evade the pump suction stream. The hose, attached to a cable running from a hand winch, was let down to the proper depth as determined by reading the meter wheel. After the hose had been thoroughly pumped out so as to remove the organisms that might be foreign to the particular station or depth, a 50-liter sample of water was pumped into a galvanized iron can made for this purpose. From the pet-cock at the bottom of the can, the water sample was allowed to run through No. 20 silk strainer with bucket. The organisms retained in the bucket were then washed into a 4 oz. bottle and enough formaldehyde added to preserve.



Pump arrangement for net plankton

To obtain a sample of the organisms that were so small as to go through the meshes of the No. 20 silk strainer a one-liter sample of water was collected immediately after the 50-liter sample had been taken. To this 1-liter sample was then added sufficient formaldehyde to preserve until it could be centrifuged in the laboratory.

In addition to the above quantitative collections, at each station qualitative collections were made by towing a No. 20 silk bolting cloth net, one foot in diameter, for 5 minutes at the surface and one also at the bottom. The depth at which the bottom net was straining was determined from the angle and length of line out. These townet collections were preserved with formaldehyde and used in the laboratory for identification and as a supplement to the quantitative catches.

Laboratory Method.—The organisms strained from the 50-liter water samples were brought into the laboratory in the 4 oz. bottles. The excess water was siphoned off with a bent glass tube over the end of which a No. 20 piece of silk bolting cloth had been firmly attached with a rubber band. Then the suspension was made up with distilled water and formaldehyde as a preservative to stand-

Liter water sampler for nannoplankton

ard volume, 10 cc. in all cases. These 10 cc. samples were put into homopathic vials and used for the counts.

The one-liter samples of water were run at uniform speed through a Foerst No. 14 centrifuge. The organisms were thus obtained in a small volume of water to which was added sufficient distilled water and formaldehyde to make the volume of suspension 10 cc. in all cases.

Enumeration of the organisms in both "net" and "centrifuge" plankton was accomplished as follows: The 10 cc. sample was thoroughly shaken and with a "Stempel" pipette 1 cc. was transferred to a Sedgwick-Rafter cell. The standard method of 10 random counts was used and the number of organisms or colonies per liter of lake water computed.

Several interesting things were noted in making a comparison of the "centrifuge" and "net" plankton results. It was discovered that the so-called "nannoplankton" forms were comparatively scarce. Assembled data showed that for the most abundant organisms occurring in both net and centrifuge catches there was a difference in the computed results as to number per liter. On an average the figures obtained from the centrifuge method ran 3.9 times higher than the net catch figures. This may mean that the net used was inefficient in straining. Also, it is pointed out that the probable error involved in the random count method of dealing with so small a sample as 1 liter is very great.

Therefore, let it be stated that too much faith should not be placed in the actual numbers obtained for the various kinds of organisms. The value rather lies in recognizing that the data were gathered by a standard method througout the investigation and as such warrant certain comparisons and the deductions of certain conclusions that are to follow.

The Genera and Species of Microplankton.*—Isokontae. Of the green algae, *Sphaerocystis Schroeteri* was the most abundant species in the lake. It occurred throughout the summer in comparatively large quantites and increased in number in September. In early summer the colonies were compact and with large cells; as the season advanced micro colonies became very abundant. *Oocystis* was another very prevalent genus which diminished somewhat in midsummer and again increased in September. *O. elliptica* and *O. crassa* were the most common species. *Staurastrum longiradiatum* was the most common desmid found. *Pediastrum* was represented by three species: *P. simplex, P. duplex and P. Boryanum*, the last named being the most abundant, though at no time very conspicuous. Other genera of green algæ were never abundant and were obtained only occasionally at the various stations.

Heterokantæ. *Botryococcus Braunii* occurred in the surface tows and less frequently at the bottom. It was never common in the counts except at Station 09 on September 12, when the number reached 500 per liter.

Chrysophyceae. Two species of *Dinobryon* occurred in the plankton, *D. stipitatum* and *D. divergens.* On September 1 the number was at its maximum of 244 of the combined species per liter, just six times the number for August 15. *Mallomonas* and *Synura* were extremely rare in occurrence.

Bacillariales. Diatoms formed a very considerable part of the life in the lake. The most conspicuous genera were *Asterionella, Fragilaria, Melosira, Stephanodiscus* and *Tabellaria*. *Tabellaria* seemed to be the most prominent throughout the summer, increasing to a maximum number of 882 per liter at station 05 on Septem-

* For a comprehensive list of plankton algae of Lake Erie see "The Plankton Algae of Lake Erie" by J. Snow, Bull. of U. S. Fish Commission, Vol. 22, 1902.

ber 12. *Asterionella* and *Fragilaria* gradually increased through the season until on September 12 at station 05 the former reached 1575 per liter and the latter 1640 per liter. *Stephanodiscus* and *Melosira* were about equal in numbers, both occurring to a lesser degree than did the other three important genera of diatoms. *Gyrosigma*, *Surirella* and *Cymatopleura* were infrequently found in small number. The centrifuge recovered considerable quantities of *Synedra* throughout the summer as well as minor amounts of *Navicula*, *Nitzschia* and *Cocconeis*. The relatively small number of nannoplankton species in the lake was very noticeable throughout the summer.

Dinophyceae. *Ceratium hirundinella* was important during the entire season and showed a gradual increase in September. *Peridinium* was very rare in occurrence.

Eugleninae. A few specimens of *Euglena* were taken in the middle of August, but this genus was not found in the plankton at any other time.

Myxophyceae. Nine genera represented this group of algae. Of these *Anabaena* was abundant in early summer falling down considerably in August but increasing again in September. In late August and September *Aphanothece* made itself known in fair quantity where it had occurred only as scattered traces in July. *Aphanizomenon* was found in abundance at several stations in early July but during August and September it had all but disappeared. Small quantities of *Nostoc* appeared in September. During August *Microcystis* flourished in a moderate way, occurring abundantly in the foot net tows at stations 05 and 23 and not at all at stations 01, 02, 7A, 09. *Coelosphaerium*, *Lyngbya* and *Aphanocapsa* were irregular and sparse in occurrence.

Protozoa. *Vorticella* was the chief member of this group, occurring in large quantities attached to *Anabaena* colonies. In September there was a decline. *Difflugia* and *Amoeba* occasionally appeared in small amounts. An unidentified Helizoan occurred in both the net and centrifuge collections more abundantly during August than at any other time.

Rotifera. *Polyarthra* was most frequently found. It was gradually on the increase at the end of the season. During July *Anuraea cochlearis* was rather frequent but in September none was found. *Conochilus unicornis* was very common at several shallow water stations in early July. It was never again found commonly. *Ploesoma*, *Trochosphaera*, *Asplanchna*, *Anapus* and *Asplanchnopus* were taken in shallow water early in July but not later in any of the deeper stations.

The Quantity of Microplankton.— In order to adequately present the data from the standpoint of distribution, both vertically and horizontally, and to show the effects of seasonal variation would require more space than can be allotted to this discussion. Hence a brief presentation of the quantitative data will be given here, leaving certain additional features for the more complete treatise to be published elsewhere.

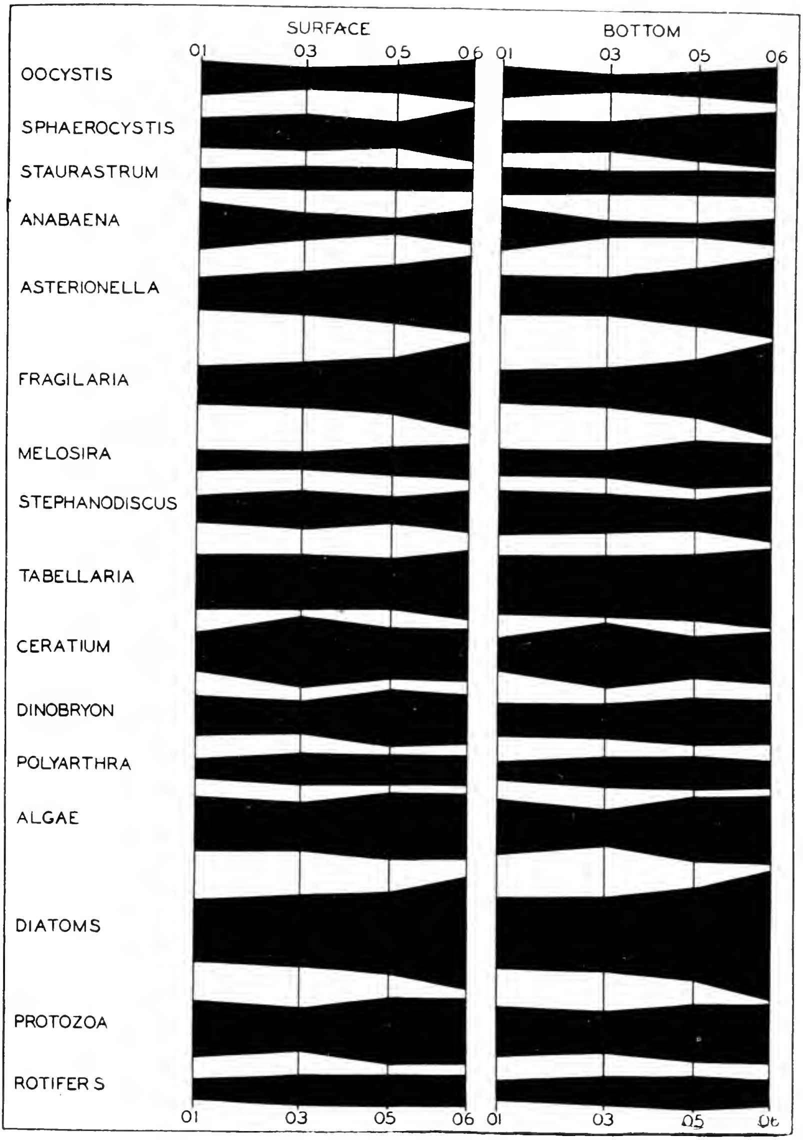


Fig. 6.—Relative abundance and seasonal variation (at the surface and bottom) for dominant genera and large groups of microplankton. The number of organisms is plotted against time. The trips are of the dates: 01, July 30-Aug. 1; 03, Aug. 15-17; 05, Aug. 28-Sept. 3; 06, Sept. 12-14; 28.

In order to show graphically the relative abundance of the constituent genera and groups fig. 6 was constructed for the net plankton. An average for each dominant genus or group for the lake as a whole was computed from all the stations and the number of organisms or colonies per liter was plotted for each of the four trips.

The graphical method of expressing results is that used by Lohmann and also by Birge and Juday.[1] Time is plotted along the abscissa and the quantity of organisms as ordinates. The trips and dates are as follows: 01, July 30–August 1; 03, August 13–17; 05, August 28–September 1; 06, September 12–14. The width of the black band for any genus or group at any time represents the diameter of a sphere whose volume is the number of organisms per liter. $R=\sqrt[3]{\frac{V}{4.19}}$ where R is the radius of of the sphere whose volume is V. V in this case is the number of organisms per liter. The width of the black band in the chart is equal to 2R, i. e., the diameter of the sphere. The scale employed in making the graphs is R=1=.25 cm. To solve the graph for the average number of organisms present in the lake at any given time the following formula may be applied:

$V=4.19(5D)^3$ where V=number of organisms per liter; D=width of the band in centimeters.

It must be borne in mind that the width of the bands is a function of the cube root of the actual number per liter and hence the increase in width becomes proportionately less with the increase in number of organisms represented.

Upon examining the chart, several things appear outstanding. With the exception of the rotifers, there is an increase in the number of organisms in autumn. This is especially true of the diatoms, which in September are rapidly approaching their autumnal maximum. A concept of the relative abundance of the constituent genera at any time during the summer may be formed by looking at the chart of the crop. It might be pointed out that any given organism is not always present in constant numbers nor is it necessarily true that one or several organisms maintain a dominant position in the environment at all times. This is due to fluctuations in the physical and chemical factors of the lake environment and to the action of predatory rotifers and crustaceans. These latter are in large measure dependent upon the smallest micro-organisms for food and in turn are themselves eaten by fish.

In view of these various factors operative in the formation of plankton as basic fish food, it is very evident that further study is necessary in interpreting the none too simple problem of lake production. It is hoped, however that these studies may contribute a little more knowledge as to the kinds of microplankton in Lake Erie and something of their significance in the economy of the lake.

[1] Wisconsin Geol. & Nat. Hist. Survey Bull. No. 64. Scientific Series No. 13.

5.—*The Macroplankton of Lake Erie*

By Charles B. Wilson

Apparatus and Methods.— In the present survey the macroplankton was collected by two meter nets, one drawn along the surface and the other just above the bottom, and by a Helgoland trawl drawn along the bottom. Foot-nets were used for the microplankton, and their contents were examined also for crustacea to make sure that none of the smaller species escaped. The only thing they really added to the contents of the large nets was a greater abundance of developmental stages, nauplii and metanauplii.

Importance of the Macroplankton.— The number of fish any lake will produce depends almost entirely upon the amount of suitable food which the water of the lake is capable of furnishing. Artificial feeding, especially in a body of water the size of Lake Erie, is absolutely impossible. The food must be a natural production of the lake itself, and must exist in sufficient abundance not only to carry the fish through the earlier and more critical period of their existence, just after they are hatched from the egg, but also to keep them well fed as long as they live. It must be, therefore, of such a nature that it can reproduce itself and thus furnish a new supply as fast as the old is used up. The plankton crustacea fully meet these requirements by reproducing in great numbers throughout the entire year, but especially at the time when the newly hatched fish fry most need them. These fry almost without exception feed practically exclusively upon the crustacea, and the latter also serve as food for those other organisms, which make up the diet of larger fishes, such as insect larvae, smelts, minnows and the like. Some fish, like the ciscoes, smelts, minnows and darters, continue to feed more or less largely upon these small crustacea as long as they live. Hence the plankton crustacea occupy a critical and most important position in the economy of fish propagation.

Its Relation to the Microplankton.— Obviously if the crustacea are to multiply in sufficient numbers to feed the fish they themselves must have an abundance of nourishing food. This they obtain from the microscopic plants in the plankton, especially the diatoms, and their mouth parts as well as their habits of life are admirably suited for just this kind of food. By eating and digesting these tiny plants the crustacea convert vegetable substances into animal tissues which are not only more palatable to the great majority of fishes, but also are vastly more nourishing. Fortunately the diatoms and other microscopic plants in their turn are able to manufacture their own food synthetically out of the soluble inorganic substances and gases in solution in the lake water. We thus find a complete cycle of interdependence from the dissolved substances in the water up to the large adult fishes, and failure on the part of any single factor of this cycle will result in disaster to fish propagation. Each must be present in the required amount and each must be continuously renewed if the whole is to operate constantly and smoothly toward the desired result.

Its Components and Amount.—The bulk of the lake macroplankton is made up of 6 copepods, 6 cladocerans, 1 amphipod, 1 mysidacean, and a few insect larvae. The copepods include 2 species of Cyclops, 2 of Diaptomus and 1 each of Epischura and Limnocalanus. The cladocerans include 3 species of Daphnia and 1 each of Bosmina, Leptodora and Sida. The other species, which are recorded farther on, do not occur in sufficient numbers to form an appreciable percentage of the total bulk. Among the crustacea in this lake the cladocera are of more value as fish food than the copepods because they are both larger in size and occur in much greater numbers.

Some investigators determine the amount of plankton entirely by weighing, others depend largely upon volumetric determinations, while a third group make actual enumerations of the individuals of each separate species. In the present survey a combination of the last two methods has been employed. The total bulk of each catch was measured in cubic centimeters and the percentage of each species was computed by an actual count of the number of individuals present in a measured sample of the catch.

These methods have conclusively proved two facts with reference to the total amount of plankton. First the crustacea are not uniformly distributed throughout the water of the lake; on the contrary the amounts obtained at different localities showed the greatest inequality. Of the two hauls, made at adjacent stations at a very brief interval of time and under almost identical conditions, it repeatedly happened that one yielded a total bulk too small to be measured, while the other produced from 500 to 2,000 cubic centimeters. Indeed, the chief characteristic of the amount of plankton obtained in the various hauls was its exceptional disparity. In view of this fact it does not seem rational to make any computation of the amount of plankton per cubic liter of water or per square meter of the surface of the lake. But the second fact is just as conclusive, namely, that the lake as a whole contains an amount of plankton amply sufficient to feed many times the number of fish it contains. When the investigation first started each haul of the meter net lasted 15 minutes, but it was quickly manifest that the total bulk of plankton thus obtained was far greater than could be adequately handled, and the haul was reduced to 5 minutes. Even after this reduction the amount of plankton in a single haul often reached 1,000 cubic centimeters.

This means that the amount of fish food in the water of the lake is so great that it could be stocked with a very large number of fish fry without danger of depletion. The various hatcheries around the shores of the lake can all be pushed to the limit of their production, and the resultant fry can be put into the lake with the certainty that they will find an abundance of good food.

Its Horizontal Distribution.—The present survey began the middle of June and lasted until the middle of September, and hence the distribution here given is for the summer season only. In the horizontal distribution of the plankton crustacea 3 zones may be distinguished with considerable accuracy. Of course, it is understood that along the margins where two of these zones come together there is more or less overlapping of species, and migration back and forth from one zone into the other. But in general the limits seem fairly well drawn and each zone has its own characteristic species as well as those common to other zones.

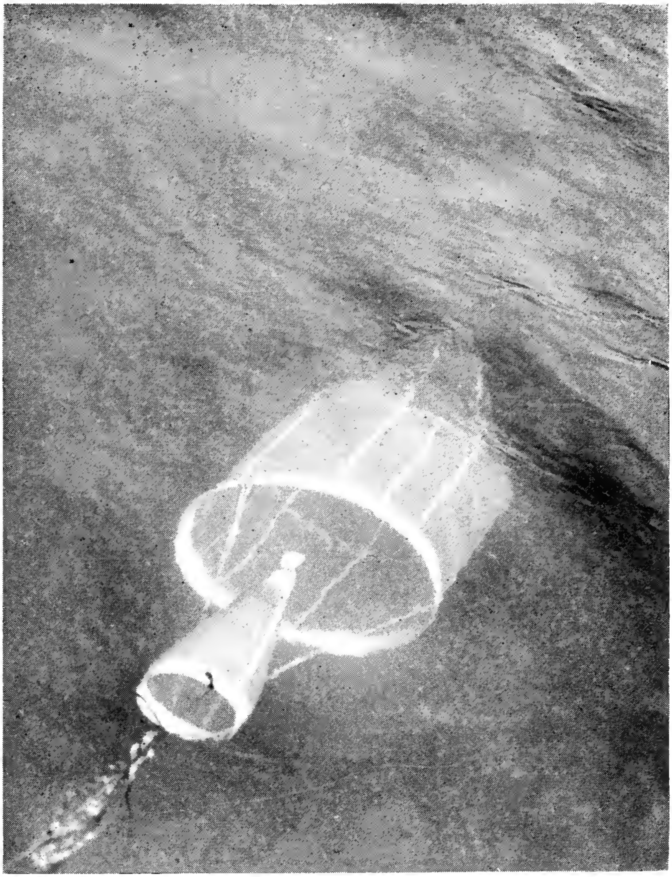
The marginal zone: This includes the shallow water along the shores of the lake up to a meter in depth and also in the mouths of the tributary creeks. This zone can be most conveniently examined by wading from the shore and by washing out the sand and mud in a few inches of water. In this zone also may be properly included the small ponds adjacent to the lake and others at a greater or less distance from the lake but draining into the tributary creeks of the latter. In proof of this may be mentioned the fact that practically every species of crustacean found in these ponds, including even 3 Harpactids, have been identified in the stomach contents of fishes seined near the mouths of the creeks or along the shores of the lake. At the depth of a meter the plankton begins to change rapidly into that of the second zone, and here many species are common to both zones. Among these a quite unexpected discovery was the presence of Leptodora in considerable abundance; this curious cladoceran can even be washed out of flocculent mud in two or three inches of water among the water plants. Of crustacea peculiar to this zone and not found in deeper portions of the lake were 2 copepods and 8 cladocerans.

Owing to unavoidable circumstances this zone received but little attention during the present season, but the results obtained were very suggestive. The number of genera and species of crustacea far surpasses that of both the other zones combined. And this fact assumes considerable economic importance when we remember that the newly hatched fry of many lake fish congregate in shallow water close to the shore and in the mouths of the various creeks. These first few weeks of the fish's life are a critical period of its existence during which it needs plenty of good food. That each of these crustacea contribute toward that end is abundantly proved by finding them in the stomachs of young fish. Every species of copepod and cladoceran is one more possible addition to the daily menu of some fish, and although it may not be as large and toothsome as some of the others, it may yet contribute materially to the fish's nourishment. On the basis of such consideration this zone may well lay claim to a more careful and extended examination another season.

The littoral zone: This includes the shallow water from 1 to 10 meters in depth and of necessity shows more or less overlapping in two directions, toward the shore and toward the deeper portions of the lake. The examination of this zone can be best conducted from the lake itself, and with a smaller boat that can enter quite shallow water. During the present survey this zone was covered by the *Navette* belonging to New York State, and trips were made along both the American and Canadian shores, one trip with the meter nets and another with the Helgoland trawl. Several curious facts with reference to the distribution of the various crustacean species came to light when the results of the *Navette* hauls were tabulated. There were 14 stations along the American shore from Buffalo to Dunkirk, and 14 along the Canadian shore from Long Point to the Niagara River, the last two in the river itself. In the meter net hauls 2 copepods and 2 cladocerans constituted practically the entire bulk of the plankton, with 3 other copepods and 4 cladocerans appearing usually in very small percentages. The copepods were very much in excess of the cladocerans along the Canadian side, except at the two river stations, while the cladocerans were equally predominant on the American side. One of the cladocerans, *Daphnia pulex,* averaged 61 percent of the total bulk of plankton at the 14 American stations, but was wholly lacking at 6 of the Canadian stations. At the two stations in the Niagara river, however, it was present in such numbers as to constitute practically 100 percent of the catch. It is the second in size of the lake cladocerans and the first in abundance of the entire plankton. In chemical composition also it is one of the very best of fish foods, and this rare combination of superiority in size, quantity and quality gives it exceptional value. The other of the two prevailing cladocera, *Daphnia retrocurva,* was present in varying amounts at all but two of the American stations, but not a single specimen was found along the Canadian shore. A third cladoceran, the curious form known as *Leptodora kindtii*, was also much more abundant on the American side of the lake. It is the largest cladoceran known and is usually regarded as a surface form, but in this littoral zone it proved to be much more abundant at the bottom during the daytime. In fact at two of the stations near Dunkirk it was present in such numbers in the hauls made with the Helgoland trawl as to constitute practically 100 percent of the total bulk.

The predominance of the copepods at the Canadian stations, as stated above, is due more to the diminution in numbers and frequent absence of the cladocerans than to any marked increase in the copepods themselves. The two prevailing copepods, *Diaptomus sicilis* and Epischura, were present at every station on both sides of the lake. The percentages of Diaptomus averaged larger on the Canadian side, but those of Epischura were about even. But a third copepod, Limnocalanus, showed a marked increase on the Canadian side, and as it is the largest copepod in the lake it compensates for the lack of the Daphnias. In the plankton collected with the Helgoland trawl there were two copepods and one cladoceran which were not found in the meter net hauls. Three copepods and three cladocerans are largely confined to this zone, one of the copepods, *Diaptomus sicilis,* being very abundant, while the other two and all three cladocerans are quite rare.

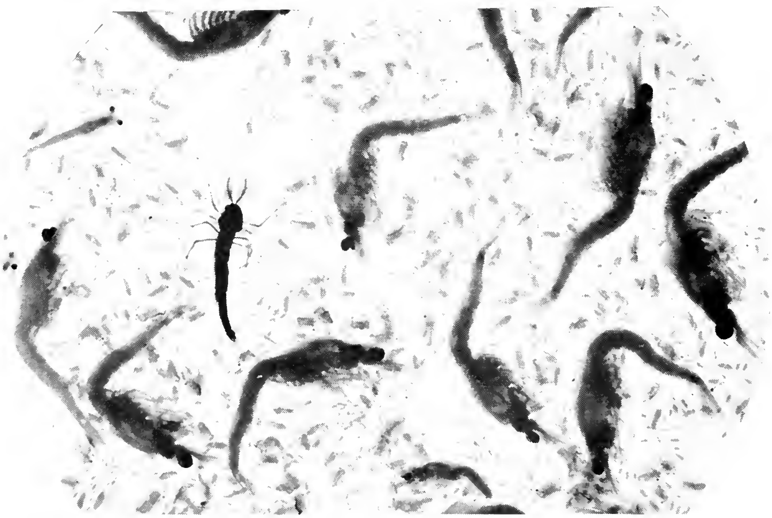
The lacustric zone: This includes the deeper portions of the lake, which at this eastern end vary from 10 to 62 meters in depth. Positively this zone is characterized by a single species, the cladoceran *Latona setifera* which was captured in the Helgoland trawl and is not found anywhere in the shallower water. Negatively it is characterized by the entire absence of most of the species peculiar to the other zones. The numerical proportions of the various species are also very different from those which prevail in the other zones. During the present survey this zone was covered by the *Shearwater*, belonging to the U. S. Bureau



Surface meter and foot plankton nets

of Fisheries, which made 6 trips in August and September, 4 with the meter nets and 2 with the Helgoland trawl. As previously stated the bulk of the plankton in the littoral zone is made up of 2 copepods and 2 cladocerans, but in the present zone at least 5 copepods and 5 cladocerans have a considerable share in the total bulk. As would be naturally expected there is also here a much greater difference in the hauls made at the surface and those near the bottom. This is chiefly due to an active migration by many of the crustacea from the surface toward the bottom, or in the opposite direction. As a result the species which has a large percentage at the surface has a conversely low one near the bottom, and vice versa.

Again, since this zone is located in what may be termed the middle of the lake there is but little contrast between the American and Canadian sides. Among the copepods, however, Limnocalanus still shows considerable preference for the Canadian side, while Daphnia is somewhat more abundant on the American side. On the bottom in this zone is the mysidacean, *Mysis relicta*, which is much larger than any of the plankton crustacea and is freely eaten by some of the larger fishes. Here also are found the amphipods and the insect larvae, neither of which were found at



Typical lacustrine zone plankton community in the deepest part of the lake. Station 04.15, 62 meters. *Limnocalanus macrurus*, abundant; *Daphnia long. galeata*, rare; *Daphnia pulex*, common; *Sida crystallina*, rare; *Mysis relicta*, abundant; *Pontoporeia hoyi*, common.

more than one or two stations, but both of which constitute excellent fish food where they do occur. The most noticeable thing about the plankton in this lacustrine zone was its exceptional abundance; a 5 minute haul of the meter net rarely yielded less than 250 cubic centimeters of plankton, it often reached 1000 and twice went to 2000. The few small catches were all at the surface and were offset in every instance by a large catch made simultaneously near the bottom. In fact, the chief production of the plankton crustacea appears to start early in the season over the deeper water in the central portion of the lake. It then gradually expands until it covers the whole of the lacustrine and much of the littoral zones, reaching the peak of production at the height of the summer temperature.

Summary.— 1. The present survey gives an excellent idea of the kind and amount of macroplankton in Lake Erie and its horizontal distribution, with important suggestions as to its vertical and seasonal distribution. The last two factors, however, require additional investigation before they can reach an equality with the first three.

2. The amount of animal plankton in the lake is amply sufficient, not only for the fish it now contains, but also for all the fry with which it can be stocked from the hatcheries situated around its shores. And this fish food is as exceptional in quality and size as it is in quantity.

3. The marginal zone, since it is the place to which many of the newly hatched fish fry resort, is worthy of more careful examination than could be given to it during the present survey. It can be most conveniently reached by automobile trips around the lake shores.

4. We should also know the rate of reproduction of the 4 or 5 more important species, the average length of their life, and their seasonal distribution. This is especially true of the two largest copepods, Epischura and Limnocalanus, with reference to which no data are available.

5. Insect larvae probably form an important food factor in the marginal zone, and should be included with the plankton crustacea in any further study of that zone.

6. Whatever depth may be considered as forming the boundary line between shallow and deep lakes, Lake Erie with its maximum depth of 62 meters would fall in the latter class. But the deep area is so small compared with that of the entire lake, and there is so much shallow water that the plankton is decidedly intermediate in character, especially in its cladoceran species.

7. Not merely the animal but also the vegetable plankton is very unevenly distributed throughout the lake both horizontally and vertically. And this is as true of the separate species which combine to make up the plankton as it is of the total bulk of the latter.

8. In the horizontal distribution three zones may be accurately distinguished, which may be designated as marginal, littoral and lacustric. In each zone the macroplankton differs from that of the other two zones in the kind and number of its constituent species, as well as in their numerical proportions.

9. During the present survey there were identified 19 copepods, 29 cladocera, 1 amphipod, and 1 mysidacean, a total of 50 species. Of these, 5 copepods and 7 cladocera were found in all three zones, 1 copepod and 1 cladoceran were present in two zones, 2 copepods were parasitic upon fish and hence cannot be assigned to any zone, while the remaining 34 species were confined to a single zone.

10. Through the cooperation of other members of the working staff, especially Dr. Sibley, it has been possible to designate in the following list of species the kinds of fish for which each crustacea serves as food. This makes the value of the macroplankton for fish food specific rather than general, and adds greatly to the usefulness of the present report.

List of Species

Copepoda

Achtheres ambloplitis.—Parasitic on the gills of the small-mouthed black bass; only one infected fish found during the entire season.

Canthocamptus illinoiensis.—In small pond draining into Cattaraugus creek; found in stomach of carp sucker seined on the lake shore.

Canthocamptus staphylinoides.—In small pond draining into Cayuga creek; found in stomach of small carp seined on the lake shore.

Canthocamptus staphylinus.—In small pond draining into Canadaway creek; found in stomach of carp seined near mouth of Canadaway creek.

Cyclops bicuspidatus.—In all 3 lake zones, most abundant in littoral zone; eaten by the cisco, the carp sucker and the Cayuga shiner.

Cyclops robustus.—A bottom form of the littoral zone; eaten by the carp and the carp sucker.

Cyclops vulgaris.—In mud washing, Tonawanda creek and in old Erie canal; eaten by red-horse sucker, white-nosed sucker, carp sucker, white sucker, carp, bullhead, straw-colored minnow, the trout perch, the white bass and the yellow perch.

Diaptomus ashlandi.—In all 3 lake zones, most abundant in lacustric zone; eaten by the silversides and the Cayuga shiners.

Diaptomus oregonensis.—In small pond draining into Cayuga creek; eaten by carp sucker and yellow perch.

Diaptomus sicilis.—In all 3 lake zones, most abundant in littoral zone; eaten by green-backed shiner, spot-tailed shiner, trout perch and yellow perch.

Epischura lacustris.—In all 3 lake zones, most abundant in littoral zone; eaten by green-backed shiner and yellow perch.

Ergasilus centrarchidarum.—Parastic on the gills of pike-perch and the small-mouthed black bass; very few fish infested.

Eucyclops agilis.—Widely distributed, but confined to marginal zone; eaten by bullhead, straw-colored minnow, Cayuga shiner, red-horse sucker, carp and stone-roller.

Limnocalanus macrurus.—In littoral and lacustric zones, more common in the latter; eaten by cisco.

Macrocyclops annulicornis.—Found only in the marginal zone; eaten by bullheads and yellow perch.

Macrocyclops signatus.—Found only in marginal zone; eaten by yellow perch.

Mesocyclops obsoletus.—In all 3 lake zones, most abundant in lacustric zone; eaten by cisco and mud minnow.

Paracyclops phaleratus.—Found only in marginal zone; eaten by carp.

Platycyclops fimbriatus.—Only in marginal zone; eaten by yellow perch.

Cladocera

Acroperus harpae.—In small pond draining into Cayuga creek; found in stomach of unidentified fish captured in the Helgoland trawl.

Alona rectangula.—In mud washing, marginal zone; eaten by yellow perch, carp, stone-roller, red-horse sucker, carp sucker, Cayuga minnow, bullhead, goldfish and white-nosed sucker.

Bosmina longirostris.—In marginal and littoral zones, more abundant in the latter; eaten by goldfish, green-backed shiner, Cayuga shiner.

Bosmina longispina.—In littoral zone only and very scarce.

Camptocercus rectirostris.—In marginal zone only; eaten by red-horse sucker and the picconou.

Ceriodaphnia pulchella.—In marginal zone only; eaten by yellow perch.

Ceriodaphnia reticulata.—In marginal zone only; eaten by carp.

Chydorus gibbus.—In mud washing marginal zone; eaten by bullhead.

Chydorus sphaericus.—In sand washing, Crystal Beach; eaten by red-horse sucker, carp sucker and bullhead.

Daphnia longispina galeata.—In all 3 lake zones, most abundant in lacustric zone; eaten by cisco and yellow perch.

Daphnia longispina mendotae.—In all 3 lake zones, most abundant in lacustric zone; eaten by cisco and yellow perch.

Daphnia longispina typica.—In all 3 lake zones, most abundant in littoral zone; eaten by cisco.

Daphnia pulex.—Abundant in all 3 lake zones, but showing a decided preference for the American shore in littoral zone; eaten by cisco, yellow perch, carp, carp sucker, lake herring, green-backed shiner, trout perch, Cayuga shiner, white bass, log perch, lake sheepshead.

Daphnia retrocurva.—In all 3 lake zones, most abundant in littoral zone; eaten by cisco.

Eurycercus lamellatus.—A bottom form in littoral zone; eaten by carp sucker and yellow perch.

Holopedium gibberum.—Very rare in littoral zone; eaten by cisco.

Ilyocryptus sordidus.—Mud washings, marginal zone; eaten by carp.

Ilyocryptus spinifer.—Mud washings, marginal zone; eaten by carp.

Latona setifera.—Bottom form, lacustric zone.

Leptodora kindtii.—In all 3 lake zones, even in mud washings, marginal zone; eaten by cisco and lake herring.

Leydigia quadrangularis.—In pond draining into Cattaraugus creek; eaten by bullhead and carp.

Macrothrix laticornis.—In marginal zone only; eaten by carp sucker and red-horse sucker.

Moina rectirostris.—Mud washings, marginal zone; eaten by carp.

Pleuroxus aduncus.—In pond draining into Cattaraugus creek; eaten by carp and carp sucker.

Pleuroxus denticulatus.—In pond draining into Cattaraugus creek.

Pleuroxus striatus.—In marginal zone only; eaten by carp sucker.

Sida crystallina.—In all 3 lake zones, most abundant in lacustric zone; eaten by cisco and yellow perch.

Simocephalus serrulatus.—In marginal zone only; eaten by bullhead and carp.

Simocephalus vetulus.—In marginal zone only; eaten by bullhead and carp.

OTHER CRUSTACEA

Mysis relicta.—Bottom form in lacustric zone; recorded in other lakes as eaten by some of the larger fish.

Pontoporeia hoyi.—Bottom form in lacustric zone; eaten by the cisco.

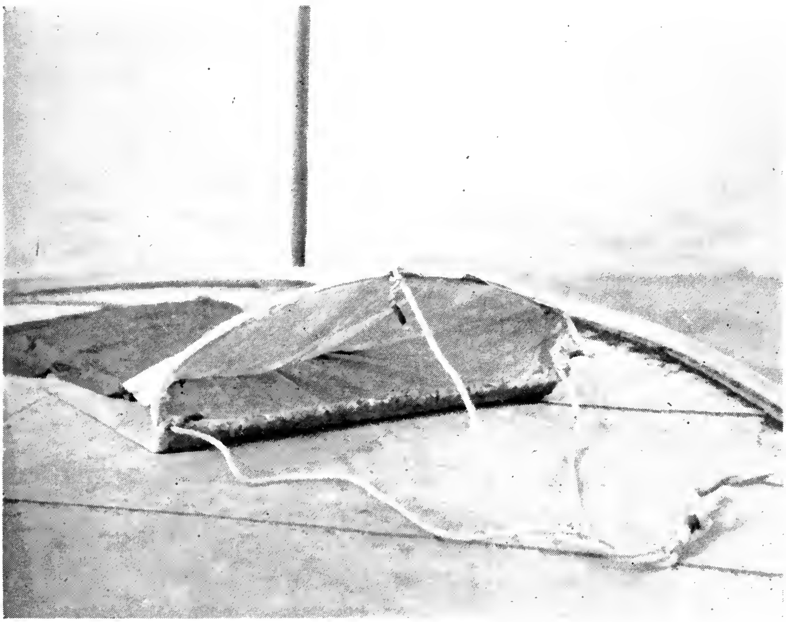
6.—*Contributions to the Early Life Histories of Lake Erie Fishes*

BY MARIE POLAND FISH

Problem.—That nature has provided for most fishes to spawn thousands or even millions of eggs annually without an apparent increase and sometimes with an alarming decrease in the number of individuals reaching maturity, evidences a most hazardous career for the young, and points to the necessity for studying early life histories. So unlike the known adults are they, and so little clue to their identification do the larval forms give, that the first and most difficult phase of the problem is their identification at various stages. When once these developmental series have been worked out, further investigations are considerably simplified. The young of only a few fresh water fishes had been previously studied, so that practically all of those which came up in our nets during the past summer were unknown stages, and the determination of each one presented a new and often perplexing puzzle. That the majority of specimens were less than half an inch in length, lacking finrays and other diagnostic adult characters, indicates the complexity of the problem. Upon the ability, however, to recognize these species at all stages rests the successful pursuit of studies on abundance and rate of growth, the mapping of distribution, the understanding of where in the life history of each species great destruction occurs, and other questions which we are striving to answer.

Methods.—Petersen young fish trawls at all depths, Helgoland trawls on the bottom, and meter nets at the surface and deeper levels were used throughout the survey for the collection of young fish material. The first step toward identifying the unknown larvae thus captured was by making vertebral counts, this being the only character which remains comparatively constant throughout the lifetime of the individual. Shape, pigment marking, and other peculiarities make each species easily distinguishable subsequently, but counting the vertebrae offers the best original guide. This information together with knowledge of the fish fauna of the locality permits us to narrow down the possibilities and very often to spot the species immediately. In some small specimens strong light is sufficient to reveal the spinal column, but usually it is necessary to use stain and in larger fishes to bisect. Every stage was described in detail, and it is hoped that eventually a series of keys for the identification of all lake fishes at different stages may be published.

The adult fish is usually so different in coloration, body proportions, and general characters from the very young that existing adult descriptions are of no assistance in work of this kind.



Helgoland young fish trawl

It seemed wise to attempt a collection of postlarvae and young adults which might form a connecting link between the tiny specimens caught in our nets and the older known adults. The Stream Survey staff* gave valuable co-operation, bringing in 37 species

* I am indebted also to Dr. John Van Oosten for a very large and complete series of young whitefish; E. L. Wickliff for whitefish eggs and young, pike perch, herring, and yellow perch; J. L. Hart for whitefish, herring, perch, pike perch, and muskalonge; J. P. Snyder for herring, whitefish, lake trout, black bass, and brook trout; Dr. Emmeline Moore for muskalonge eggs and larvae; Miss Ida Mellen for brook trout eggs; F. B. Voegele for whitefish and lake trout eggs; and A. P. Miller for muskalonge larvae. Mr. Vernon S. L. Pate made the drawings for this report. Miss Elizabeth L. Saunders was general laboratory aide.

of small fishes. We adopted a special form of description and card-cataloged all species in this way. Thus such additional data were recorded as the myomere count and chromatophore marking previous to the appearance of scales which is invaluable for work on the earlier developmental stages.

The most satisfactory way to identify a young fish with the adult is, of course, to secure a ripe female and male, artificially fertilize the eggs, and study the resultant developmental stages in the laboratory. Splendid cooperation was met with from other fisheries' workers who kindly offered all available hatchery material and promised more complete series next season.

Summary of Results.— The *Shearwater* and *Navette* plankton net and young fish trawls yielded 1049 specimens, representing 18 species. Supplementary collections from hatcheries, streams, and along shore numbered about 49 more, making a total of at least 67 species for which descriptions of young forms have been made. Records of distribution and descriptions of developmental stages of 25 species, most of them illustrated by camera lucida drawings, are ready for publication, but the limited space of the present report allows the inclusion of only a few of the more commercially important. A trail has been blazed and further work on the lake, especially if it can be started early in the spring, will doubtless fill some of the gaps in the life histories of partially known species and add data on those at present unknown.

TABLE 4.— RECORD OF SPECIES OF YOUNG FISHES TAKEN BY *Shearwater* AND *Navette*

SPECIES	Number of specimens	Length of specimens	Record of Capture			
			Depth	Station	Net	Date
Lepisosteus osseus........	1	41 mm........	0 m.	*Navette* dock Buffalo	Dip	July 12
Catostomus commersonii...	2	15 mm........	6 m.	6A.........	Meter......	Je. 12
	1	15 mm........	3 m.	8A.........	Meter......	Je. 12
	30	14–21 mm.....	0 m.	Sturgeon Pt.	Dip........	Je. 13
	11	20.5 mm......	0 m.	Navette Dk.	Dip........	Jul. 9
	42	24.5 mm......	0 m.	Grand Is...	Seine......	Jul. 9
Moxostoma aureolum.....	1	8 mm.........	6 m.	13A........	Meter......	Jul. 11
Notropis hudsonius......	Many	Ripe adults....	0 m.	Sturgeon Pt.	Dip........	Je. 13
	1	5.2 mm.......	5 m.	4A.........	Helgoland..	Jul. 12
Notropis atherinoides....	1	6.4 mm.......	60 m.	01.15......	Meter......	Jul. 30
	1	6.5 mm.......	17 m.	01.17......	Meter......	Jul. 31
	2	4.6–5.5 mm...	9 m.	01.18......	Meter......	Jul. 31
	2	6.7–9.0 mm...	10 m.	01.19......	Meter......	Jul. 31
	1	16.5 mm......	23 m.	05.12......	Meter......	Sept. 1
	2	16–17 mm.....	0 m.	05.15......	Dip........	Sept. 1
Fundulus diaphanus menona.	Many	5.5–12.5 mm..	4 m.	4A.........	Meter......	Je. 12
	14	6.5–13 mm....	4 m.	4A.........	Helgoland..	Je. 12
	23	6–11 mm......	6 m.	6A.........	Meter......	Je. 12
	6	6–12 mm......	3 m.	8A.........	Meter......	Je. 12
	1	9.2 mm.......	3 m.	8A.........	Helgoland..	Je. 12
	2	6.5–9.6 mm...	4 m.	17C........	Meter......	Je. 13
	2	7–8 mm.......	6 m.	11A........	Helgoland..	Jul. 11
Percopsis omisco-maycus..	6	7.5 mm.......	7 m.	7A.........	Helgoland..	Je. 12
	3	6.3–6.5 mm...	3 m.	8A.........	Helgoland..	Je. 12
	1	6 mm.........	3 m.	8A.........	Meter......	Je. 12
	1	6.3 mm.......	6 m.	11A........	Helgoland..	Jul. 11
	1	9.7 mm.......	14 m.	01.05......	Meter......	Jul. 26
	1	6.5 mm.......	60 m.	01.15......	Meter......	Jul. 30
	7	17–25 mm.....	20 m.	02.04......	Petersen....	Aug. 8
	1	16 mm........	20 m.	02.13......	Helgoland..	Aug. 9
	1	35 mm........	50 m.	02.21......	Meter......	Aug. 10
Perca flavescens.........	631	c. 40 mm......	8 m.	02.02......	Petersen....	Aug. 8
	212	c. 40 mm......	20 m.	02.04......	Petersen....	Aug. 8
Stizostedion canadense griseum.	1	15.2 mm......	60 m.	01.15......	Meter......	Jul. 30
Boleosoma nigrum nigrum.	Eggs	1.4–1.5 mm...	0 m.	Sturgeon Pt.	Dip........	Je. 11
	1	5.5 mm.......	17 m.	14A........	Helgoland..	Jul. 11
	3	35 mm........	7 m.	7A.........	Helgoland..	Je. 12
	1	14.5..........	25 m.	02.04......	Helgoland..	Aug. 8
	6	7.5–15.5 mm..	16 m.	02.09......	Helgoland..	Aug. 8
Percina caprodes........	1	62 mm........	15 m.	02.05......	Petersen....	Aug. 8
	1	25.5 mm......	8 m.	02.11......	Petersen....	Aug. 9
	1	25.5 mm......	40 m.	02.17......	Helgoland..	Aug. 9
Micropterus dolomieu.....	6	9.5–10 mm....	6 m.	11A........	Helgoland..	Jul. 11
Aplodinotus grunniens....	1	13.3 mm......	17 m.	03.24......	Meter......	Aug. 16
Cottus bairdii kumlieni...	1	9.7 mm.......	10.5 m.	3A.........	Helgoland..	Je. 11
Cottus cognatus..........	2	21–21.5 mm...	20 m.	02.04......	Petersen....	Aug. 8
	1	20 mm........	23 m.	02.23......	Helgoland..	Aug. 10
	1	33.5 mm......	20 m.	04.11......	Helgoland..	Aug. 22
	1	22 mm........	20 m.	04.12......	Helgoland..	Aug. 23
	1	35 mm........	20 m.	04.13......	Helgoland..	Aug. 23
	1	18.5 mm......	16 m.	04.25......	Helgoland..	Aug. 25

TABLE 4.— RECORD OF SPECIES OF YOUNG FISHES TAKEN BY *Shearwater* AND *Navette* — (*Concluded*)

SPECIES	Number of specimens	Length of specimens	Record of Capture			
			Depth	Station	Net	Date
Cottus ricei	1	27.5 mm	22 m.	04.23	Helgoland	Aug. 25
Triglopsis thompsoni	1	12.5–27.5 mm.	60 m.	01.15	Meter	Jul. 30
	1	16 mm	20 m.	02.13	Helgoland	Aug. 9
	2	12.5–14 mm	38 m.	02.20	Helgoland	Aug. 10
	1	14 mm	33 m.	02.22	Helgoland	Aug. 10
Lota maculosa	1	5.8 mm	6 m.	6A	Meter	Je. 12
	3	3–7.1 mm	15 m.	22C	Meter	Je. 18
	1	6.2 mm	5 m.	23C	Meter	Je. 19
	2	6–7 mm	14 m.	25C	Meter	Je. 20
	14	7–14 mm	60 m.	01.15	Meter	Jul. 30
	1	10.5 mm	32 m.	01.20	Meter	Aug. 1
	4	11.5–15 mm	34 m.	01.22	Meter	Aug. 1
	1	11.5 mm	50 m.	02.15	Meter	Aug. 9
	4	30.5 mm	.....	Long Pt. bay	Seine	Aug. 22

TABLE 5.— STATION RECORD OF YOUNG FISHES TAKEN BY *Shearwater* AND *Navette*

STATION	Net	Species	Number	Length
3A	Helgoland	*Cottus bairdii kumlieni*	1	9.7 mm.
4A	Meter	*Fundulus diaphanus menona*	36	5.5–12.5 mm.
4A	Helgoland	*Fundulus diaphanud menona*	14	6.5–13 mm.
6A	Meter	*Fundulus diaphanus menona* *Lota maculosa* *Catostomus commersonii* *Notropis atherinoides*	17 1 2 1	6–11 mm. 5.8 mm. 15 mm. 34 mm.
7A	Helgoland	*Percopsis omisco-maycus* *Boleosoma nigrum nigrum*	6 3	7.5 mm. Ripe adults
8A	Meter	*Fundulus diaphanus menona* *Percopsis omisco-maycus* *Notropis atherinoides* *Catostomus commersonii*	6 1 11 1	6–12 mm. 6 mm. Young adults up to 34 mm. 15 mm.
8A	Helgoland	*Percopsis omisco-maycus* *Fundulus diaphanus menona*	3 1	6.3–6.5 mm. 9.2 mm.
17C	Meter	*Fundulus diaphanus menona*	2	6.5–9.6 mm.
Sturgeon Point	Dip	*Catostomus commersonii* *Notropis hudsonius* *Notropis atherinoides*	30 Many Many	14–21 mm. Ripe adults. Adults.
Buffalo harbor	Dip	*Notropis atherinoides*	Many	Adults.
Crystal Beach	Dip	*Notropis atherinoides*	Few	Adults.
22C	Meter	*Lota maculosa*	3	3–7.1 mm.
23C	Meter	*Lota maculosa* *Fundulus diaphanus menona*	1 3	6.2 mm. 5.3–6.2 mm.
25C	Meter	*Lota maculosa* *Fundulus diaphanus menona*	2 1	6–7 mm. 8.8 mm.
4A (July 12)	Helgoland	*Notropis hudsonius*,	1	5.2 mm.
11A	Helgoland	*Fundulus diaphanus menona* *Percopsis omisco-maycus* *Micropterus dolomieu* *Egg No. a*	2 1 6 2	7–8 mm. 6.3 mm. 9.5–10 mm. 1.55–1.6 mm.
13A	Meter	*Moxostoma aureolum*	1	8 mm.
14A	Helgoland	*Boleosoma nigrum nigrum*	1	5.5 mm.
01.05	Meter	*Percopsis omisco-maycus*	1	9.7 mm.
01.15	Meter. Depth Om Depth 60 m	 *Notropis atherinoides* *Stizostedion canadense griseum* *Triglopsis thompsoni* *Percopsis omisco-maycus* *Lota maculosa*	 1 1 1 1 14	 6.4 mm. 15.2 mm. 13 mm. 6.5 mm. 7–14 mm.
01.17	Meter	*Notropis atherinoides*	1	6.5 mm.
01.18	Meter	*Notropis atherinoides*	2	4.6–5.5 mm.
01.19	Meter	*Notropis atherinoides*	2	6.7–9 mm.
01.20	Meter	*Lota maculosa*	1	10.5 mm.
01.22	Meter	*Lota maculosa*	4	11.5–15 mm.
02.02	Petersen	*Perca flavescens*	631	c. 40 mm.

TABLE 5.—STATION RECORD OF YOUNG FISHES TAKEN BY SHEARWATER AND NAVETTE—(*Concluded*)

STATION	Net	Species	Number	Length
02.04	Petersen	*Perca flavescens* *Notropis atherinoides* *Cottus cognatus* *Percopsis omisco-maycus*	212 7 2 7	c. 40 mm. 47 mm. 17 mm. 18 mm.
02.04	Helgoland	*Boleosoma nigrum nigrum*	1	14.5 mm.
02.05	Petersen	*Percina caprodes*	1	62 mm.
02.09	Helgoland	*Boleosoma nigrum nigrum*	6	7.5–15.5 mm.
02.11	Petersen	*Percina caprodes*	1	c. 25 mm.
02.13	Helgoland	*Percopsis omisco-maycus* *Triglopsis thompsoni* *Egg No. b*	1 1 4	16 mm. 16 mm. 2.1–2.3 mm.
02.15	Meter	*Lota maculosa*	1	11.5 mm.
02.17	Helgoland	*Percina caprodes*	1	25.5 mm.
02.20	Helgoland	*Triglopsis thompsoni*	2	12.5–14 mm.
02.21	Meter	*Percopsis omisco-maycus*	1	35 mm.
02.22	Helgoland	*Triglopsis thompsoni*	1	14 mm.
02.23	Meter	*Cottus cognatus*	1	20 mm.
03.24	Meter	*Aplodinotus grunniens*	1	13.3 mm.
04.11	Helgoland	*Cottus cognatus*	1	33.5 mm.
04.12	Helgoland	*Cottus cognatus*	1	22 m.
04.13	Helgoland	*Lota maculosa* *Cottus cognatus*	1 1	19 mm. 35 mm.
04.23	Helgoland	*Cottus ricei*	1	27.5 mm.
04.25	Helgoland	*Cottus cognatus*	1	18.5 mm.
05.12	Meter	*Notropis atherinoides*	1	16.5 mm.
05.15	Dip	*Notropis atherinoides*	2	16–17 mm.

FAMILY COREGONIDAE

Leucichthys artedi Le Sueur—Lake herring; tullibee; cisco

Record of Capture.—No young herring were taken by the survey during the past summer. By the time that our collecting trips started the herring had grown to a stage where they were able to successfully escape the trawls used. Consequently it was necessary to rely upon rather scanty hatchery material for a study of this species. Arrangements have been made to obtain a very complete series of eggs and young next year, so that the following short account of a few stages will serve only as preliminary data toward a complete developmental history to be made later.

Description.—*Egg.* Diameter of hatchery specimens examined varying from 2.0 mm. to 2.5 mm., mostly 2.25 mm. The earliest stage obtained measuring 2.25 mm., diameter of yolk 1.8 mm., with a colorless early embryo reaching halfway around the yolk. Very opaque from preservation but c. 20 rather large oil globules apparent, deep amber in color on the yellowish yolk. In a later stage with the embryo reaching more than once and a half around yolk and apparently ready to hatch, top of head heavily pigmented and dorsal and ventral brown stripes, characteristic of the newly hatched larva, prominent. Yolk sac still deep yellow, its anterior part filled with a large oil globule, and dark thickly distributed chromatophores making their appearance on the underside posteriorly. Eyes dark, and center of head behind eyes covered by a diamond-shaped patch of small chromatophores. Chromatophores continuing, small and stellate, to form the double dorsal series to end of body, with a similar ventral series behind the vent. Myomeres faintly discernible.

8.5—9.8 mm. stage. Newly hatched. Much like following stage figured but yolk sac larger and body proportionately more slender. Pigment identical.

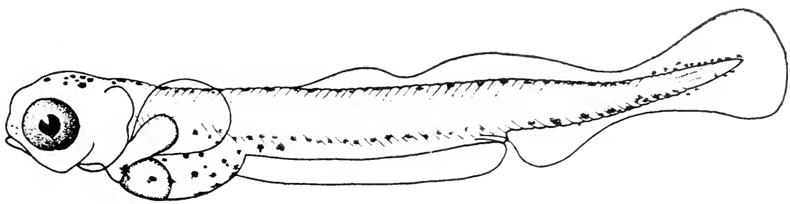


Fig. 7.—*Leucichthys artedi*, 10.25 millimeters

10.25 mm. stage. Fig. 7. Age about 2 days. Total length 10.25 mm; length to vent 6.8 mm; greatest depth behind yolk sac 0.85 mm; diameter of eye 0.9 mm; myomeres, 38 to vent, 19 behind. Embryonic marginal fin complete, starting over seventeenth myomere, rising, then notching over twenty-ninth myomere, rising again and notching at peduncle; ventrally starting beneath yolk sac, breaking completely at vent, and notching at peduncle; caudal lophocercal; pectorals large, rounded. Head very blunt, its highest point over posterior part of eye; mouth subinferior, jaws equal. Opaque white in color, differing from *Coregonus clupeaformis* in the restriction of yellow color to the yolk, whereas in the latter this color is diffused in subsurface streaks about the head, above stomach, and in some specimens over the whole body. In the specimen figured, 2 round areas of chromatophores on head followed by a double series of 18 along dorsal aspect to a point opposite vent, thence 24 to tip of tail. These two lines not even, being sometimes alternate and differing in size and number, thus distinguishing the species from *Coregonus clupeaformis* in which the dorsal series usually perfectly symmetrical. Lateral and ventral aspects of head colorless; 1 very large stellate spot over pericardiac region at the beginning of yolk sac; behind this, 2 more or less definite lines extending across sac, and a few chromatophores arranged longitudinally on underside of sac, very linear in shape. Starting just before end of yolk sac, series of c. 20 large stellate chromatophores over intestine, and behind vent an uneven double line of c. 12 intersprinkled with smaller ones to tip of tail.

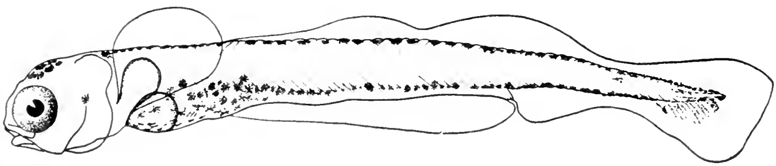


Fig. 8.—*Leucichthys artedi,* 12.5 millimeters

12.5 mm. stage. Fig. 8. Total length 12.5 mm; length to vent 8.5 mm; greatest depth 1.6 mm; diameter of eye 1.0 mm; myomeres 38 to vent, 19 behind. Immediately after preceding stage yolk beginning to shrink, and at this stage represented by only a fragment showing yellowish through the body wall. Embryonic marginal fin unchanged; pectorals enlarged; notochord turning upward very slightly. The linear chromatophores on underside of yolk sac now more numerous, giving a "pin feather" effect, and those on sides of sac increased greatly in size and remarkably stellate; others unchanged. Head less blunt than before; lower jaw slightly shorter. All specimens examined thus far with heavy dorsal pigment on head and beginning of dorsal ridge, then a break until shortly before vent during which chromatophores are quite sparsely distributed, thence closer together, more numerous, and forming a very distinct band.

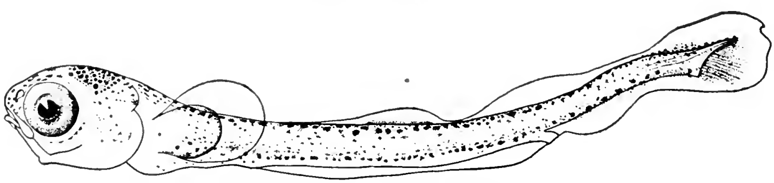


Fig. 9.—*Leucichthys artedi,* 14.5 millimeters

14.5 mm. stage. Fig. 9. Total length 14.5 mm; length to vent 10.6 mm; length of head 2.5 mm; greatest depth (head) 1.92 mm; diameter of eye 1.25 mm; maxillary 1.1 mm. Embryonic marginal fin broken dorsally at former notch and well separated from posterior portion; no rays evident but some concentration in the anterior portion indicating later position of basal elements; ventrally marginal fin much reduced; caudal becoming heterocercal by dorsal extension of notochord, outer contour very slightly notched, and few rays suggested ventrally; no ventrals in this specimen although beginning in another specimen only 13.2 mm. long. Head more pointed; maxillary to middle of pupil. Chromatophores increasing greatly on top of head; double dorsal series with 3 or 4 lines of smaller ones between; more on sides of body and on dorsal surface of intestine, both surface and subsurface; few extending on to caudal.

16.5 mm. stage. Total length 16.5 mm; standard length 15.25 mm; length to vent 11.9 mm; length of head 3.5 mm; length of maxillary 1.4 mm; diameter of eye 1.5 mm; greatest depth (head) 2.2 mm; depth at stomach 1.9 mm; greatest depth behind vent 0.82 mm. Nine dorsal elements and short rays; no anal rays; caudal rays developing; small ventrals apparent directly beneath dorsal rays. Vent still ending away from body at margin of embryonic fin. Body somewhat heavier than preceding; pigmentation unchanged.

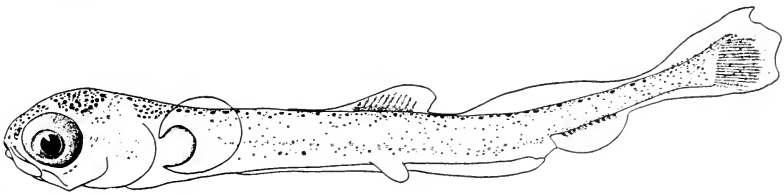


Fig. 10.—*Leucichthys artedi*, 17.5 millimeters

17.5 mm. stage. Fig 10. Total length 17.5 mm; length to vent 12.3 mm; length of head 3.6 mm; length of maxillary 1.4 mm; greatest depth (head) 2.3 mm; diameter of eye 1.5 mm. Elements complete and 10 dorsal rays visible; 10 anal elements but no rays; ventrals larger but not rayed.

Breeding.— The lake herring spawns in November and early December, coming into shallow water in vast schools for the purpose. The eggs incubate on the bottom during the long winter months, hatching the following spring, the exact date dependent upon the temperature of the water.

Coregonus clupeaformis Mitchill—Whitefish

Record of Capture.—As in the case of the lake herring, the late start of our collecting trips during the past summer prevented the capture of eggs and early young of this species. The following notes are based on a series of eggs obtained from E. L. Wickliff at Put-in-Bay, Ohio, and young from 7 days to 109 days from Dr. John Van Oosten, raised at the New York Aquarium. The later stages described were loaned by J. L. Hart.

Description.— *Egg.* Fig. 11. Diameter mostly 2.8 to 3.0 mm; perfectly spherical, yolk yellowish or amber with half its surface covered by varying sized oil globules closely crowded together. Immediatey after fertilization yolk entirely fills egg, with no perivitelline space apparent except at one pole. At 6 hours average diameter 3.0 mm, yolk diameter 2.6 mm, with widened perivitelline space and the first concentration of germinal matter to form the blastodisc at center of oil globule mass. Blastodisc continuing to form until the beginning of cleavage at 24 hours, 2, 4, and 8 cell stages being apparent at this time. Blastodisc lenticular by 5th day with oil globules congregated below. On

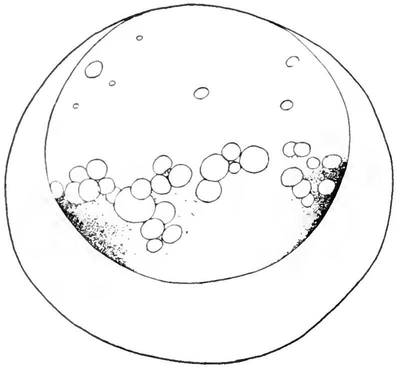


Fig. 11.—*Coregonus clupeaformis* egg immediately after fertilization

26th day an early embryo, reaching halfway around egg, showing well developed optic vesicles slightly pigmented on inner and upper margins and oil globules coalescing to form usually about 2 very large bubbles with many small ones remaining. At 40 days embryo completely around egg; head much higher and more rounded, eye larger and black; 1 large oil globule on yolk and only a few smaller ones. First evidence of dorsal and ventral marginal pigmentation evident at 54 days.

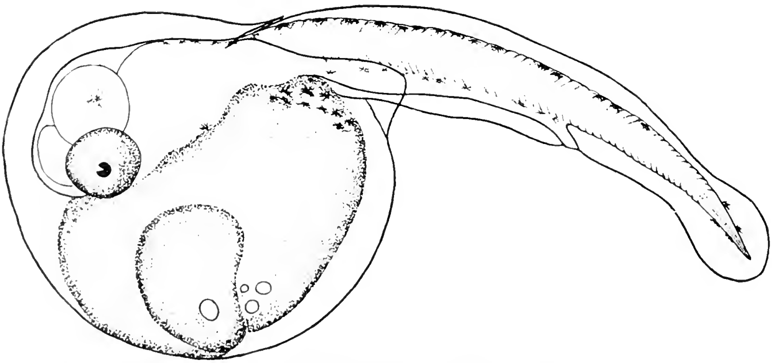


Fig. 12. *Coregonus clupeaformis* egg with larva emerging

Fig. 12 shows the embryo in process of hatching on the 61st day. Mouth is not open; vent at a distance from body, at edge of fin; embryonic marginal fin completely encircling fish from behind head around lophocercal tail to yolk sac; yolk sac very large, deep yellowish in color, with 1 large oil globule and other smaller ones. Myomeres completely formed. Double series of brown chromatophores on both dorsal and ventral aspects; yolk sac also pigmented posteriorly, near the body. Other eggs in collection not yet hatched at 131 days.

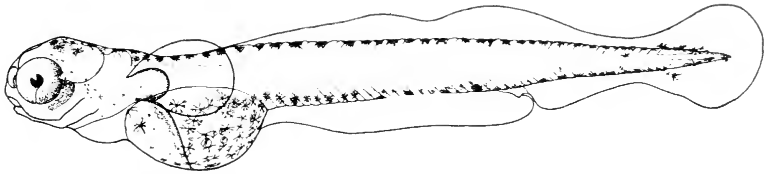


Fig. 13.—*Coregonus clupeaformis* less than 1 week old, 12 millimeters

12.0 mm. stage. Fig. 13. Less than 1 week old. Total length 12.0 mm; length to vent 7.0 mm; greatest depth behind yolk sac 1.1 mm; diameter of eye 0.8 mm. Characterized by large, very yellow yolk sac, and much yellow diffused in subsurface streaks about the head, above the stomach, and in some specimens over the whole body, thus differentiating it from *Leucichthys artedi* in which this color is less intense and limited to the yolk sac. Body much heavier, the greatest depth behind yolk sac being 10.9 in total length, while in a herring of equal development it is 12. Embryonic marginal fin resembling herring, originating over middle of yolk sac, notching somewhat about 11 myomeres before the vent, rising again to highest point over vent, notching on either side of peduncle, and breaking entirely at vent. Pigmentation essentially as the herring, but chromatophores generally much larger, darker, more regularly arranged, consisting of few large black stellate spots on top of head and a few very small ones on sides, running into an unbroken double line of c. 52 on dorsal aspect, very large, squarely stellate; on the ventral side chromatophores under head, continued in a line across yolk sac and on dorsal aspect of intestine to vent, c. 28 on each side; few others spread over yolk sac; double ventral series of c. 17, similar to dorsal, behind vent.

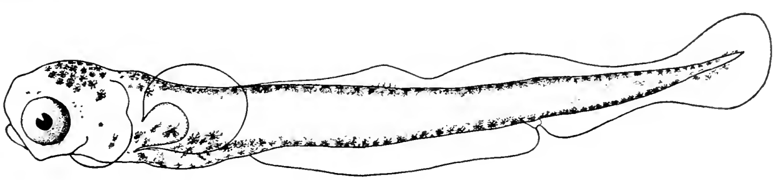


Fig. 14.—*Coregonus clupeaformis* about 1 week old, 13.5 millimeters

13.5 mm. stage. Fig. 14. About 1 week old. Total length 13.5 mm; length to vent 10.0 mm; greatest depth 1.6 mm; diameter of eye 1.25 mm. Embryonic marginal fin unchanged in shape, but slight suggestions of 5 dorsal finrays in anterior part, pectorals very large. Still much yellow over yolk region which is almost completely reduced, and whole head tinged with yellowish. Chromatophores same in number and arrangement but size increased until they overlap in marginal series.

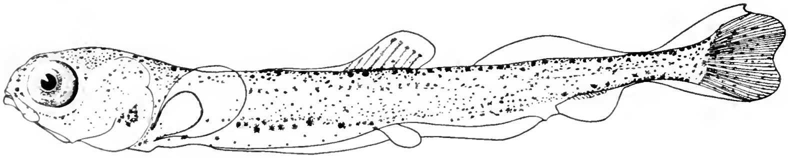


Fig. 15.—*Coregonus clupeaformis* postlarva, 18.5 millimeters

18.5 mm. stage. Fig. 15. Age unknown but similar to specimens 61 days old. Total length 18.5 mm; standard length 17.0 mm; length to vent 13.25 mm; length of head 4.0 mm; depth of head 2.25 mm; greatest depth behind head 2.0 mm; diameter of eye 1.6 mm. Dorsal rays fairly well developed; embryonic marginal starting again after wide space behind dorsal, continuing to caudal, complete on ventral side, with basal elements of anal fin developed but no rays; caudal slightly notched dorsally at end of notochord, lower portion becoming forked and rays well formed; ventrals prominent. Dorsal and ventral series of chromatophores still important but many smaller ones scattered over sides of head, body and caudal.

22.0 mm. stage. 65 days old. All fins fully developed with exception of adipose, in which region a large fragment of the embryonic marginal remains.

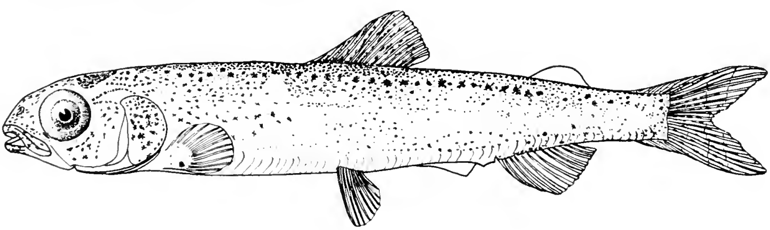


Fig. 16.—*Coregonus clupeaformis* young fish, 31.5 millimeters

31.5 mm. stage. Fig. 16. Age unknown but similar to specimens 95 to 109 days old. Total length 31.5 mm; standard length 27.0 mm; length of head 6.75 mm; greatest depth of body 4.5 mm; diameter of eye 2.0 mm. Assuming shape of adult. Pigmentation essentially as in younger specimens but more diffused with dorsal and ventral ridges of body from head to caudal still most deeply pigmented; black, stellate dorsal chromatophores continuing down the sides to lateral line becoming gradually smaller and wider apart; lateral line marked by closely distributed small black spots; few chromatophores on ventral aspect of stomach but none beneath intestine; large areas of chromatophores behind eye still noticeable, and many more, lighter in color, between and before the eyes becoming darker at mouth; dorsal and caudal speckled with black, following lines of rays. Body, and especially head, silvery at this stage.

By further development, body becomes deeper, head smaller, and proportions more like the adult. Tiny chromatophores increase greatly in number from dorsal aspect to lateral line, and ventral half of body noticeably light colored with pigment spots sparsely distributed. At 53 mm. the anal is speckled with black. Space allows only measurements of the following later stages.

53.0 mm. stage. Total length 53.0 mm; standard length 47.0 mm; length to vent 35.0 mm; length of head 11.8 mm; greatest depth 11.25 mm; diameter of eye 3.75 mm.

68.0 mm. stage. Total length 68.0 mm; standard length 58.0 mm; length to vent 43.5 mm; length of head 14.5 mm; depth at origin of dorsal 13.15 mm; diameter of eye 4.0 mm; length to origin of dorsal 28.0 mm.

83.0 mm. stage. Yearling. Total length 83.0 mm; standard length 70.5 mm; length of head 18.5 mm; depth of head 11.5 mm; length to dorsal 35.5 mm; greatest length of dorsal rays 14.25 mm; depth at dorsal 15.0 mm; length to ventrals 36.5 mm; greatest length of ventral rays 12.0 mm; length to vent 52.2 mm; greatest length of anal rays 9.5 mm; length to pectorals 17.5 mm; greatest length of pectoral rays 12.0 mm; length of maxillary 7.0 mm; interorbital width 6.0 mm; diameter of eye 5.7 mm. Fully scaled as adult. Greenish gray above; very silvery on sides and below; area of light amber extending from just behind pectorals to lateral line and about half that width; eye blue, edged in black.

The larval stages of *Coregonus clupeaformis* and *Leucichthys artedi* are easily confused, and the very small number of herring obtainable this summer prevented us from formulating any rules of identification. It will be necessary to study many more specimens before we can be sure that these differences are constant.

I have pointed out a few outstanding characters in the above descriptions, especially the diffusion of yellow color in the whitefish throughout the yolk region, head, and sometimes over the whole body, as contrasted in the herring with the restriction of this pigment to the yolk sac. Furthermore, the double dorsal series of chromatophores in the whitefish is symmetrical, even, and continuous from behind head to tip of tail, while in the herring it becomes broken and uneven from shortly behind head often to a point more than halfway to vent. Although this character is certainly a valuable indication of the species, it cannot be depended upon, for in our large collection of whitefish there were quite a number in which the dorsal series is thin and sometimes quite uneven in this region, while among the dozen hatchery specimens of young herring studied, one had a perfectly continuous line indistinguishable from that of the whitefish. In all our herring specimens the pigment over the intestine was very much less noticeable than in the whitefish.

In those specimens which we have studied, the body of the whitefish was deeper than that of a herring of like size, and usually the latter species was somewhat more advanced in development at the same length. The more elongate body of the herring may be found to be a constant factor when the two species are raised together, subjected to the same temperature and environmental conditions, but only when this is done can we put complete faith in proportional differences, so great is individual variation within the species. As an example may I quote Ada Hall (1925) concerning the whitefish: "Fry hatching at 1, 2, and 4 months after spawning differ in size of body but not in size of yolk; those hatching at 4 months are 4 to 6 mm. longer than those hatching earlier."

With the large number of hatchery herring promised for next year we hope to sift out of the present possibilities whatever differences are constant.

Breeding.—The whitefish spawns in November and early December, as does the herring, the eggs hatching the following spring. The period of incubation is dependent upon temperature.

FAMILY *Percidae*

Perca flavescens Mitchill—Perch, yellow perch, ring perch

Record of Capture.— The youngest specimens were hatched at Put-in-Bay June 6, 1928. The older stage figured was captured by a night haul at Shakespeare Island Lake, Lake Nipigon, Ontario. The only specimens taken in Lake Erie this summer were quantities of young adults averaging 40.0 mm. in length, 631 in a Petersen trawl at 8 meters off Seneca Shoals on August 8, and 212 on the same day in a Petersen trawl at 20 meters in midlake, between Point Abino and Sturgeon Point.

Description.— *Egg.* Masses spawned at a temperature of 44° to 50° F. in early spring; eggs held together in a single layer forming hollow strings several inches wide, folded like the bellows of an accordian, but reaching 3 to 7 feet in length when drawn out; not attached to objects on the bottom. Wide variation in size of eggs (Ryder 1885); usually about 3.5 mm. in diameter, with 1.75 mm. vitellus, and large oil globule; light colored semi-transparent, complex egg membrane. Incubation period c. 27 days at mean temperature of 47° F; egg sac absorbed in c. 5 days (Leach 1927).

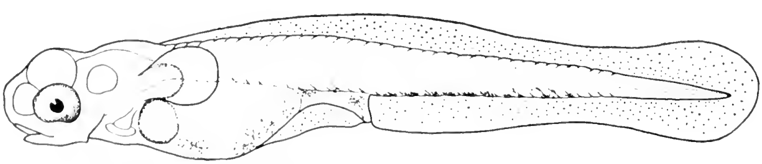


Fig. 17.—*Perca flavescens* immediately after hatching, 5.5 millimeters

Newly hatched larva. Fig. 17. Total length 5.5 mm; length to vent 2.7 mm; greatest depth 0.83 mm; diameter of eye 0.36 mm;

diameter of oil globule 0.4 mm; length to end of yolk sac 2.2 mm; myomeres, c. 18 before vent, c. 18 behind (incomplete). Characterized by large oil globule occupying anterior part of very large yolk sac; embryonic marginal fin granular in texture originating dorsally at base of brain and ventrally at middle of yolk sac, moderate in height without pronounced elevation; pectorals well developed. Very dark eye; sparsely distributed, large light-colored stellate chromatophores on bottom of yolk sac; usually 1 or more on dorsal and ventral aspects of intestine; uneven series of very small unequal ones ventrally behind vent, with divisions of myomeres (few or all depending on individual) marked by black line running from ventral edge to lateral line.

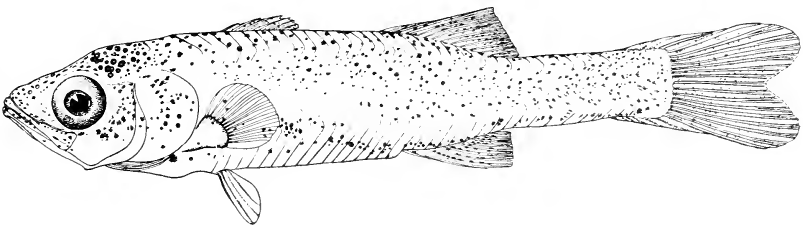


Fig. 18.—*Perca flavescens*, 20.5 millimeters

Postlarva. 20.5 mm. stage. Fig. 18. D. III to VII, II, 9 to 12 (very incomplete); A. II, 6 to 8; C. shallowly forked; V. developed, below P. Total length 20.5 mm; standard length 17.25 mm; length to vent 10.5 mm; length to first dorsal 5.95 mm; length of maxillary 2.0 mm; greatest depth 3.6 mm; diameter of eye 1.5 mm; myomeres c. 18 before vent, 18 behind. Body greatly compressed, more elongate than adult yellow perch but decidedly deeper than pike perch of this length; mouth large, with very small sharp teeth discernible but no canines, maxillary reaching to middle of eye; pelvic fins very close together. Round and stellate chromatophores on head and double line dorsally to end of body; scattered also over sides of head and more or less evenly over sides of body; many specimens with dark subsurface area over stomach region; rather indistinct ventral row of large stellate chromatophores to vent and irregular double series from vent to caudal, darkest at base of anal; dorsals, anal, and caudal speckled; banded coloration of the adult not evident in these preserved specimens.

Adult. Specimens of 40 mm. fully developed, definitely banded.

Stizostedion sp.—Pike-perch

Record of Capture.— These small pike-perch were hatched at Thurlow hatchery, Ontario, May 7, 1927, but in the absence of other data we cannot determine the species.

Description.— *Newly hatched larva.* Fig. 19. Total length 7.75 mm; length to vent 3.7 mm; greatest depth 1.5 mm; diameter of eye 0.5 mm; myomeres 15 to vent, 26 behind (incomplete). Inferior mouth and vent open; yolk very large, bright yellow in color and covered completely by large, light-colored, very stellate

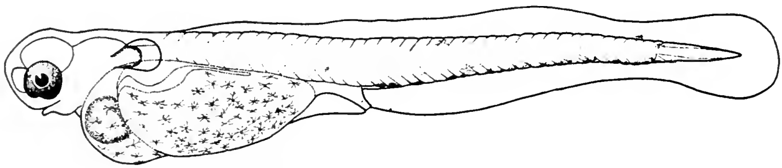


Fig. 19.—*Stizostedion sp.*, **7.75 millimeters**

chromatophores, which extend over the heart and the large clear yellow oil globule. Eye large, blue-black in color. Embryonic marginal fin complete; small pectorals developed. Only dorsal pigmentation consisting of about 2 large chromatophores between vent and caudal; a well defined line of dark brown spreading chromatophores, almost interlocking, from vent to caudal.

Older specimens in the same collection have yolk absorbed. In these the large stellate yolk chromatophores persist on yellow stomach region, and last quarter of dorsal aspect has c. 6 others arranged alternately on the two sides.

Stizostedion canadense griseum DeKay—Sauger; sand pike; gray pike

Record of Capture.— Two specimens, 13.1 mm. in length, were obtained from the Put-in-Bay hatchery. The 14.5 mm. stage, described and figured below, was caught in a meter net towed at 60 meters in the deep hole off Long Point Bay.

Description.— *Developmental stages, 13.1 mm.* Total length 13.1 mm; standard length 12.2 mm; length of head 3.4 mm; length to vent 7.6 mm; greatest depth 2.8 mm; diameter of eye 1.0 mm; myomeres 20 to vent, c. 21 behind (incomplete). Embryonic marginal originating just before vent and becoming abruptly elevated immediately behind, over the basal elements and suggestions of c. 17 rays; persisting ventrally with basal elements and suggestions of c. 11 rays; no ventrals; pectorals moderate; caudal truncate at this stage. Body rather slender, not much compressed; small canines in both jaws; maxillary reaching to hind margin of pupil; large simple air bladder; intestine coiled; vent open, intestine ending at a distance from body, at edge of marginal fin. Pigmentation consisting of large stellate chromatophores on jaws and over top and sides of head with angle and posterior margin of preopercle dark; single series on dorsal aspect, double around fin; lateral line with irregular series of large stellate chromatophores, and myomere divisions above and below marked with irregular black lines; few on sides of stomach region, and very dark subsurface patch over air bladder and along dorsal surface of intestine; ventral ridge with many branching chromatophores, especially at base of anal; caudal somewhat marked; eye very black. All chromatophores grayish, rather light-colored.

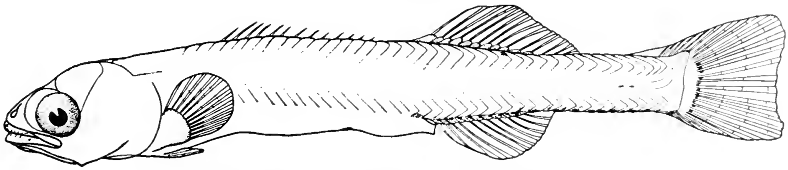


Fig. 20.—*Stizostedion canadense griseum*, 14.6 millimeters

14.6 mm. stage. Fig. 20. D. XIII, 15 (incomplete); A. I, 10 (incomplete); P. rather small; V. small, below P; C. emarginate. Total length 14.6 mm; standard length 12.6 mm; length to vent 7.7 mm; greatest depth 2.0 mm; diameter of eye 1.0 mm; myomeres, 21 to vent, 21 behind. Body elongate, dorsal contour slightly depressed before soft dorsal and anal, and somewhat depressed just behind head; head pointed, sides quite parallel, eyes directed sideward; mouth terminal; large curved teeth in both jaws; maxillary reaching to posterior margin of pupil. First dorsal, consisting of 13 slender spines, originating just behind ventrals. Mostly opaque white. One large chromatophore on dorsal side of intestine at vent, and a double ventral series of c. 25 small, uneven, inconspicuous pigment spots (12 of them around anal) from vent to end of body; few in thoracic region and near posterior limit of lateral line.

Breeding.—The sauger spawns in early spring on shallow gravelly or sandy bars, often running up rivers. With the beginning of warm weather it is reported to work its way down stream again and off into deep water. Whether the postlarval stages are common, also, in deep water, or whether this specimen was an exception, cannot be determined on our scanty evidence.

FAMILY *Centrarchidae*

Micropterus dolomieu Lacépède—Small-mouthed black bass

Record of Capture.—Six specimens 9.5 to 10.0 mm. long were taken in a Helgoland trawl at 6 meters near Dunkirk on July 11, 1928. The 8.8 mm. stage is hatchery material. The largest specimen figured below came from the mouth of Eighteenmile creek on July 18.

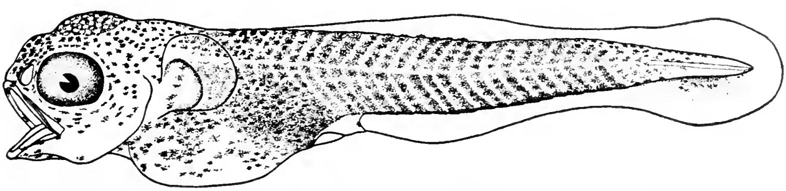


Fig. 21.—*Micropterus dolomieu*, 8.8 millimeters. Hatchery specimen

Description.—*8.8 mm. stage.* Fig. 21. Total length 8.8 mm; length to vent 4.0 mm; greatest depth 1.8 mm; diameter of eye 0.85 mm; myomeres, 10 before vent, 19 behind (very incomplete). Embryonic marginal fin originating over end of yolk region, rising to slight elevation at position of later soft dorsal, similar on ventral side; caudal lophocereal; pectorals rounded. Head and yolk region robust, body compressed behind vent; eye large; mouth large, oblique, with maxillary extending to middle of pupil; intestine ending at edge of marginal fin. Whole larva darkly pigmented; many large stellate chromatophores massed over bulbous head; fewer on sides of head and around jaws; yolk region well covered except on ventral aspect; myomeres with lines of large very spreading chromatophores (c. 2 wide on each myomere before vent, 1 wide behind) giving an almost even appearance of brown color in the preserved specimens, chromatophores extend on to base of pectorals, and slightly into caudal, otherwise fins colorless; eye dark.

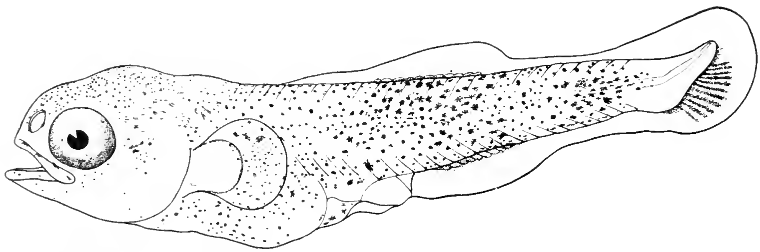


Fig. 22.—***Micropterus dolomieu*, 10 millimeters. Lake specimen with contracted chromatophores**

10.0 mm. stage. Fig. 22. Total length 10.0 mm; length to vent 5.25 mm; greatest depth 2.17 mm; diameter of eye 1.0 mm; myomeres 10 before vent, 18-20 behind (incomplete). Proportions and general appearance as hatchery stock, but differing mostly in light color, resulting from contracted chromatophores which in other specimens were much expanded (contraction constant for lake specimens); however, number and arrangement of chromatophores identical in the two stocks.

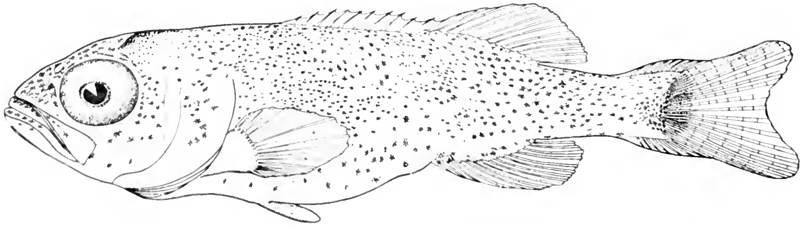


Fig. 23. *Micropterus dolomieu*, 19 millimeters. Lake specimen

19.0 mm. stage. Fig. 23. D.X, 14; A. III, 12; V. and P. well developed; C. forked. Total length 19.0 mm; standard length 15.0 mm; length to vent 9.6 mm; length of head 5.4 mm; greatest depth 4.3 mm; diameter of eye 1.5 mm. Mouth very large, oblique, lower jaw projecting, maxillary ending about middle of pupil. Pigmentation essentially as in younger stages, sides of body being closely covered with stellate and round chromatophores of varying sizes; 3 longitudinal rows on either side of dorsal ridge, and single line either side of ventral ridge behind vent; peritoneum black; head less pigmented than body, and underside of stomach much lighter than rest of body; fins colorless.

7.—*Seining Records and Food of the Intermediate Stages of Lake Erie Fishes*

By A. E. Allin

Although the biological part of the summer's work consisted largely of plankton analyses and a study of the early life history of the fishes of Lake Erie, due record was made of any later stages observed or taken in the nets. Occasionally a larger specimen was taken in the meter net or the Helgoland trawl, but such occurrences were uncommon. Such gear rarely captures any fishes longer than 25 mm. in the daytime due to the limited straining ability of the fine mesh. For stages between 25 mm. and 60 mm. offshore the Petersen trawl has proven most effective, and is quite as applicable to large lakes as to the sea.

The efficiency of the net is indicated by the catches of 631 and 212 specimens respectively taken at stations 2 and 4 on the second trip. In view of the small number of specimens obtained at most of the other stations it would appear that there were few fishes between the lengths of 25 and 60 mm. offshore during the period of the investigation. The yearlings of the fall spawners (of 1927) were too large and active to be taken, and many, perhaps the majority of the early spring spawners, would most likely have been found in the shallower waters about the margin of the lake. The young of those species spawning in the early summer were taken in the fine mesh nets. It may be noted that the greater number of intermediate stages was found at the eastern end of the area studied.

On July 9, 1928 three hauls were made at the mouth of a small stream on the west side of Grand Island with a one hundred fifty foot seine for the purpose of determining what food was being taken by the fish of the region. The natural lake food supply was supplemented by outwash from the land as well as backwash from the Niagara river.

Although the number is too small to give an adequate idea of the food of the fish in the lake, excepting at one or two individual stations, it is interesting to observe that those fish, taken in the seine hauls, vividly show a balance of nature even in so restricted an area. There are those fish feeding on algae and diatoms, those living practically on crustaceans or larvae of aquatic insects, and finally those feeding on smaller fish and fish eggs. In the first class may be included the Cyprinidae and Catostomidae; in the second, the smaller Percidae and Centrarchidae; in the third, the larger Percidae, Esocidae, and Catostomidae (fish eggs).

TABLE 6.—PERCENTAGE OF ORGANISMS IN STOMACH CONTENTS

SPECIES, STATION AND DATE	T. L. mm	Bacillariaceae	Chlorophyceae	Rotifera	Daphnia sp.	Copepoda	Ostracoda	Cambarus sp.	Tricoptera	Chironomus	Baetis sp.	Gyrinidae	Frag. adult Insects	Fish eggs	Fish	Remarks
Common sucker (*C. commersonii*), Grand island, 7-9-28.	73				10				5	60		25				
	51	t	80		8				2	10						
	75	t	15							50		35				
	71				4	8			38	50						
	85									40			10	50		
	85		10		40								50			
Hog sucker (*H. nigricans*), Grand island, 7-9-28.	62		3	t		12				70		5	10			
	90	2	70	t		10				20						
	73	t	10									90				
	88									92		6				Coptotomus 1-2%
	81		t			1			2	97						
	90		33						34	33						
Red-fin sucker (*M. lesueurii*), Grand island, 7-9-28.	68		5	t	18	12			5	60						
	69				2	8				90						
	69		10		10					80						
Spot-tailed minnow (*N. hudsonius*), Grand island, 7-9-28.																6 sp. Av. L. 115 mm 100% Crustacean debris.
Sturgeon Pt., 7-6-28.															100	
			100													
			50													Crustacean debris 50
			50													Crustacean debris 50
			50											50		
			100													
			3													
			100													
			90													
			50													Crustacean debris 50

Common shiner (*N. cornutus frontalis*), Grand island, 7–9–28.	95															Crustacean debris 100
	90		4										96			
	76		50										50			
	85												10		90	
	103		2										98			
	95		100													
	73		100													
	73		100													
	75												100			
	84		96										4			
Emerald minnow (*N. atherinoides*), Sturgeon Pt., 7–6–28.	48		2										2			Crustacean debris 96
	65				55								45			
	39												4			Crustacean debris 96
	47												100			
	35		40										50			Crustacean debris 10
	38		100													
	35		100													
	33															Crustacean debris 100
Pickerel (*E. lucius*), Grand island, 7–9–28.	450														100	
Barred killifish (*F. diaphanus menona*). Grand island, 7–9–28.	72					100										
	67		100													
	65				100											
	51		20		80											
	46		10			90										
	46					100										
Yellow perch (*P. flavescens*), Grand island, 7–9–28.	84				100											
	73										100					
	82														100	
	107														100	
	59					10					15		75			
	65									60	20					Palpomyia sp. 20%
	76				50										50	
	78				33					17					50	
	89												50		50	
	94				100											
Station 02.02, 7–9–28	46				10	90										
	47				85	15										
	41				35	65										*Daphnia sp.* 100
	46				5	95										Cop. 100% *Disptomus ashlandi*
	47				10	90										
	50				10	90										
	41				60	40										

TABLE 6.— PERCENTAGE OF ORGANISMS IN STOMACH CONTENTS — (*Concluded*)

SPECIES, STATION AND DATE	T. L. mm	Bacillariaceae	Chlorophyceae	Rotifera	Daphnia sp.	Copepoda	Ostracoda	Cambarus sp.	Tricoptera	Chironomus	Baetis sp.	Gyrinidae	Frag. adult Insects	Fish eggs	Fish	Remarks
Yellow perch — (*Conclude*)	43					100										
	43					100										
	50				50	50										
	47				60	40										
	42				1	99										
	41				25	75										Cop. 100% D. *ashlandi*
	44				40	60										*Daphnia pulex* mainly
	40				15	85										
	43				10	90										
	37				15	85										
	42				10	90										
	45				10	90										
Brook stickleback (*E. inconstans*), Grand island, 7-9-28.	39					100										
	40					96				4						
	35					47	6			47						
	31				5	20				75						
	37				28	47				25						
	36					67				33						
	38				20	5				75						
	32					8	2			90						
	35				2	2				95						Amphipod 1
Rock bass (*A. rupestris*), Grand island, 7-9-28.	44										100					
	47										100					
	45							4		10	85					
Small-mouthed bass (*M. dolomieu*), Silver creek, 7-11-28.	330							100								
	330							100								
	260							55							45	
	380														100	

Log perch, (*P. caprodes zebra*), Grand island, 7-9-28.	70	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	100	.....	.....
	62	.....	.....	.....	.....	.....	.....	.....	.....	75	20	.....	5	.....	.....
	65	.....	.....	.....	.....	.....	.....	.....	.....	45	55	.....	.....	.....	.....
	73	.....	.....	.....	.....	.....	.....	.....	.....	100	.....	.....	.....	.....	.....
	59	.....	.....	.....	.....	.....	.....	.....	.....	100	.....	.....	.....	.....	.....
Johnny darter (*B. nigrum*), 7-12-28.....	38	.....	.....	.....	.....	.....	.....	.....	.....	100	.....	.....	.....	.....	.....
Grand island 7-9-28..............	57	.....	.....	1	1	.....	.....	.....	.....	98	.....	.....	.....	.....	.....
	51	.....	.....	.....	.....	.....	.....	.....	.....	100	.....	.....	.....	.....	.....
	61	.....	.....	.....	.....	.....	.....	.....	.....	100	.....	.....	.....	.....	.....
	62	.....	.....	.....	.....	40	.....	.....	.....	60	.....	.....	.....	.....	.....
	48	.....	.....	.....	.....	.....	.....	.....	.....	100	.....	.....	.....	.....	.....
	50	.....	.....	.....	.....	.....	.....	.....	.....	100	.....	.....	.....	.....	.....
	47	.....	.....	.....	.....	.....	.....	.....	.....	80	20	.....	.....	.....	.....
	43	.....	.....	.....	.....	.....	10	.....	.....	90	.....	.....	.....	.....	.....

Summary and Conclusions

In considering the results of the summer's work the various branches of the subject will be summarized individually first and later considered in terms of the objects of the survey. As stated in the introduction, the problem can not be interpreted in terms of chemistry, bacteriology, microplankton, macroplankton, or any one of the subjects treated in the present report. They are all so inter-related that any one must be discussed in the light of the others and only from the combined results of all may we look for the answers to the problems on the economy of the lake which formed the object of the present investigation.

Although many data of purely scientific value were obtained, in order to avoid confusion these have been but briefly touched upon, the bulk of the discussion being devoted to those findings applicable to the immediate problems. Special subjects will be treated in later publications.

Physical Hydrography.—In cross section Lake Erie is on either side bounded by sandy beaches or limestone cliffs sloping gradually into coarse sand and finally beyond the influence of land outwash into the basic smooth shale, honey-combed shale, or faulted rock bottom, covered with almost no sediment of any sort except for short distances off the mouths of the larger rivers. It is this "clean bottom" that such economically important species as the whitefish select for spawning grounds and which has been reported to contain in places heavy silt deposits. The central basin contains a thick deposit of clay mud considered by some to be of glacial origin, by others to be outwash from the land. In the area included in the present survey this deposit is quite free from industrial waste or sewage silt and is populated by a rich bottom fauna which offers an excellent source of food for fishes seeking a deep-water habitat.

Regarding the water mass, it has been said that Lake Erie in storms is churned from top to bottom, the nets of the fishermen torn, and in all probability great numbers of young fish and fish food destroyed. Were this true one would expect to find in summer almost uniform temperatures from surface to bottom, but this was not the case, at least during the period of the present investigation. Descending from the surface the temperature was found to decline gradually until in late August a level beyond the influence of summer heating was encountered at about 20 meters. Over a considerable area this cold layer of bottom water of 4 to 5 degrees Centigrade covered the floor of the basin. At times it oscillated back and forth. One week it was found to have advanced thirty miles toward Buffalo, and by the next cruise it had retreated again even beyond its former position. The cause of this movement has not been fully determined as yet, although there appears to be a close correlation between the wind and the movement of the water mass, the advance of the cold mass taking place in the readjustment process of the lake after the termination of the wind.

Fish seeking the cold water in summer apparently follow the bottom layer as it penetrates new areas. Fishermen at Port Dover complained that this summer they had found the fish widely dispersed and were forced to set their nets over a much greater area than usual. This would indicate that during the seasons when the lake warms more gradually than usual the cold bottom water is limited to a relatively small area. The summer heating of the present season was rapid, and the surface layer rapidly reaching a high temperature resulted in a stratification of the water mass, thus preventing vertical mixing. This fact was further indicated in the case of storms. Summer storms were found to penetrate to the bottom only in shallow depths. In greater depths during the past season they did not reach below the thermocline. During the bad wind storms of late August and early September the bottom water remained unchanged. Even at the shallower stations the bottom temperatures were unaffected and the plankton of the lower levels remained stratified in its usual manner, although the slightest churning, as for instance in the Emerald channel where the lake empties into the Niagara river, is sufficient to distribute it throughout the water mass. Everywhere else it was found even during the worst storms concentrated during the day near the bottom. Thus we may conclude that except in shallow water storms probably do not destroy eggs and helpless fry. During the winter months a coating of ice keeps the water mass intact and protects the incubating eggs of the whitefish and herring and during the summer the warm light surface water acts in a similar capacity. In years when the ice is particularly late in forming and the winds are unusually severe it is possible that large numbers of the eggs of fall spawning fishes in shallow water may be destroyed. It is not improbable that further investigations may show that the fluctuations in year classes may be found to be at least partially explainable on this basis, although the very poor production years more likely result from a combination of factors. However, the decline in the fish supply of Lake Erie cannot be attributed to storms, for the weather of the present day is no more severe than that of former times when the lake abounded with fish.

Subsurface currents of considerable force were found, not always corresponding to those at the surface. Following storms or barometric irregularities the lake level readjusts itself and in doing this subsurface currents are formed. In eighteen hours in the deep hole the current in the intermediate levels showed a wide fluctuation in rate and direction. It may be that the damage to the fishing gear in deep water is caused by these movements. However violent in force there is not the churning action found in surface water, and, although no doubt an important factor in transporting eggs and young fry from one place to another, they probably exert little or no destructive action.

Bacteriology and Chemistry.—As a result of the analyses made by the Buffalo City Chemist and Bacteriologist from samples taken at the surface, mid-depth, and bottom throughout the area it is possible to safely say that the lake as a whole is remarkably free from pollution. In harbors and along the shore in places the water is often badly polluted, but these are purely local problems and effect in no way the lake as a whole. The churning action in the shallow water about the margin of Lake Erie, which is choppy most of the time, aerates the water and in the presence of sunlight dilutes and quickly eliminates waste products. At Dunkirk the area within the breakwater was badly polluted,* the bacterial count being almost beyond computation, and the water absolutely devoid of oxygen. However, a quarter of a mile off the mouth of the harbor the water contained an abundance of oxygen and was without a trace of pollution of any sort. The oft repeated statement that industrial waste from the Detroit river and the cities at the western end of the lake is invading the eastern area and destroying the fishing is without foundation. Nowhere in the open lake was abjectionable pollution of any kind found in the water or silt deposits located on the bottom. The lake survey did not extend into the Niagara river, for once the water passes from the lake it never returns, and thus did not form a part of the problem. The New York State Conservation Department included this area in its survey of the streams and along shore waters and its findings are given in another part of the report.

Biology.— The various objects of the biological investigations I have already mentioned, and although space will not permit me to describe all of the results I shall mention a few of the most significant ones.

Starting with the production of food materials, as a shallow lake, Erie should offer the greatest possibilities for rich animal and plant life, and our results indicate that those possibilities have apparently in no respect been diminished. The chemistry was found to be normal chemistry of lake water, and the plankton occurred in almost unbelievable abundance. I can best describe it, perhaps, by making a comparison with the ocean. One of the richest areas of plankton life in the western Atlantic is the Gulf Stream, and yet hauls made during the same week in July with the same size and type of net in Lake Erie and in the Gulf Stream off New York City yielded the following results: in five minutes ten times the amount of plankton was obtained in the lake as in a two-hour haul in the ocean. When one considers the abundance of life which the ocean plankton supports it can be seen that certainly food is not a problem in the lake. The fish supply has diminished, but their food has not, and at the present time Lake Erie could support several times the number of fish now existing there.

A striking characteristic of both the microplankton and macroplankton was the inequality in horizontal distribution quantitatively and qualitatively. Production of both plants and animals

* See report of F. E. Wagner, page 121.

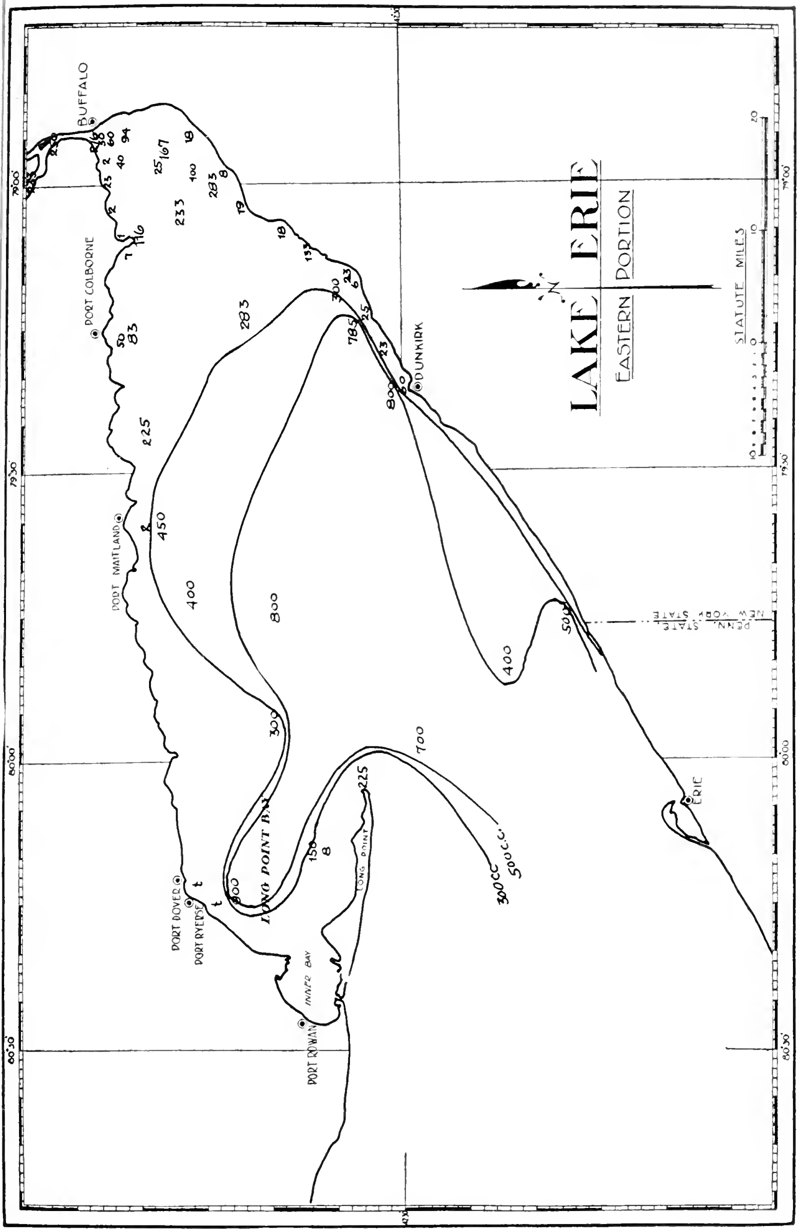


Fig. 24.—Quantitative distribution of macroplankton at the bottom. Navette and first Shearwater cruises. Total volume in cubic centimeters

increased during the summer, the highest zooplankton production centering in the deeper part of the lake and expanding laterally until as indicated in fig. 25 almost the entire offshore area was included within the 300 cc. curve (300 cc. taken in a five-minute meter net haul). Figures 24 and 25 illustrate the expansion from the deeper area at two times during the season. The highest production of zooplankton, as shown in the following table, was found on the third cruise in the middle of August when the surface temperature was highest. Later it declined in volume as the microplankton increased, the latter becoming increasingly abundant with the approach of the autumnal maximum at the end of the season.

TABLE 7.— SEASONAL VARIATION IN TOTAL VOLUME OF MACROPLANKTON

CRUISE	Number of stations	Total volume cc.	Adjusted volume cc.	Average volume per station cc.	Factor	Average temperature surface °C	Average temperature 10 meter °C
I	21	8,316	7,128	396	1.0	21.8	20.9
III	21	13,075	11,207	622	1.57	22.9	21.3
V	18	8,984	8,984	499	1.26	21.6	21.2
VI	11	3,894	6,372	354	0.89	20.9	20.6

It has been said that perhaps as the fishes declined their enemies increased and now are destroying most of the eggs and young of commercial species. Enemies of fish have always been present in the lake and are abundant today, but no evidence has been found to indicate that they have increased in number or are more important than in the past. Like the storms this factor has always been present and probably is no more alarming as a destructive agent than it was in the days when the lake abounded with fish. We must look elsewhere for the real cause of the decline.

Before it was possible to identify the various fry appearing in the nets the early life histories of each species had to be worked out, and this proved an important part of the summer's work. The young upon hatching in no way resemble the adult, or in fact the later stages of the same species. But one character remains reasonably constant, the number of vertebrae of the back bone, and it is upon counts of the body segments that the work had to be based. Of the seventy-five odd species reported from the lake, the young of very few had been described. This year sixty-seven species were taken, identified, and the developmental stages of twenty-five figured and described by Mrs. Fish.* Next year it is planned to continue these studies. In the course of the work the young of two species of sculpins not previously reported from Lake Erie appeared in collections from the bottom of the deep hole. They inhabit the bottom in deep water, and it is not surprising that they have heretofore escaped notice.

*See page 76.

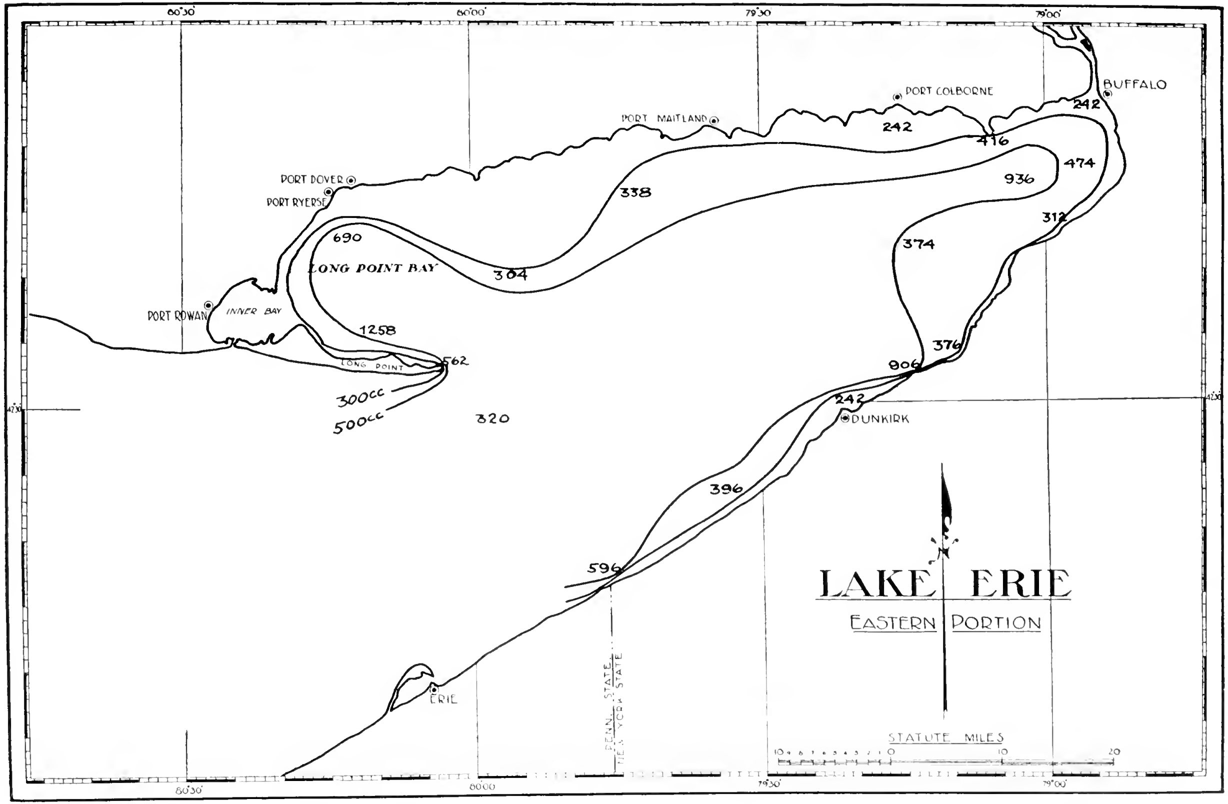


Fig. 25—Quantitative distribution of macroplankton at the bottom. Fifth Shearwater cruise. Total volume in cubic centimeters

As the survey of the lake proper did not begin until July 26 it was not possible to determine the production centers of those economically important species which incubate during the winter months and hatch when the ice breaks up in the spring. By July the herring and whitefish had dispersed from the spawning grounds and had become sufficiently large to escape the gear designed for earlier stages. However, those species which spawn in spring and early summer were taken, and next year it is hoped that by starting in May this part of the problem can be completed.

General Discussion.— Considering the general results of the survey, it can safely be stated that Lake Erie is capable of supporting a few large fauna of open lake fishes. There are no dangerous silt deposits affecting the spawning beds, the open lake water is not polluted, and there is food in abundance. Only those species which enter the stream mouths to spawn are to date in danger of depletion, from chemical or sewage pollution. The depletion appears to have resulted from over-fishing and unwise fishing. At least these seem to be the only important factors that have not been tentatively eliminated in the course of the investigations. By protecting the spawning grounds during the breeding season, by increasing the number of hatcheries, by reducing the number of under-sized fish destroyed in the nets, and, if necessary, by limiting the catch, one may hope for improvement. However, before action by those legislative bodies having jurisdiction over the lakes can be wisely taken to protect the spawning grounds, these production centers must be located, evaluated, and the breeding seasons carefully determined. Before perfect stocking methods can be devised the natural requirements for successful production and development must be ascertained. If the greatest mortality is found to take place during the early weeks after hatching, it will be desirable to carry those species over the critical period before liberating them. Through extensive collecting and plotting of the distribution of different stages the source and migrations of the young fish may be traced and those areas most worthy of protection located. The improvement of the fishing methods forms a part of the program of the Federal Bureau of Fisheries.

Although the present investigations indicate that Lake Erie is capable of *supporting* a very much larger fish fauna than now exists, what in its present depleted condition it is capable of *producing* has not yet been determined. In the light of the present findings the greatly reduced parent fish stock is apparently the only serious limiting factor at this time and every possible effort should be made to protect the fish during the spawning season and to find means of decreasing the mortality among incubating eggs and developing young. The work of the survey to date has been largely one of elimination, eliminating theories advanced to explain the decline in the fishery. There remains the task of establishing a basis for improvement.

III. CHEMICAL INVESTIGATION OF THE ERIE-NIAGARA WATERSHED

By Frederick E. Wagner

Lately fellow, Rensselaer Polytechnic Institute

Had the selection of watersheds to be studied been made with that object in view, it would hardly have been possible to select three which differ more decidedly and radically than those covered in the present and in the preceding two years.

In the present instance we were confronted not as in the case of the Genesee survey with a single river system, not as in the Oswego survey with a distinctly unique series of lakes, great and small, whose outlets are finally combined into a common stream, but with a series of streams varying from a few miles up to nearly one hundred miles in length, each making its independent way to a huge body of fresh water and there losing its identity. Tonawanda creek is a notable exception to this classification, since its flow is reversed during the last few miles of its course by the Barge canal, which, usurping the creek's bed from the Niagara river to Pendleton flows thence to Lockport and supplements Tonowanda's insufficient volume by additional water drawn from Niagara.

Many of the streams have offered individual problems in the past, while the depletion of Lake Erie fishing has caused much discussion and conjecture regarding the possible contributory influences of the tributary streams, municipalities and industrial concerns which sewer into it. And so in the formulation of the chemical policy to be pursued it was decided that particular emphasis would be given to those streams of past concern, and to that part of Erie which might be affected by the influences mentioned.

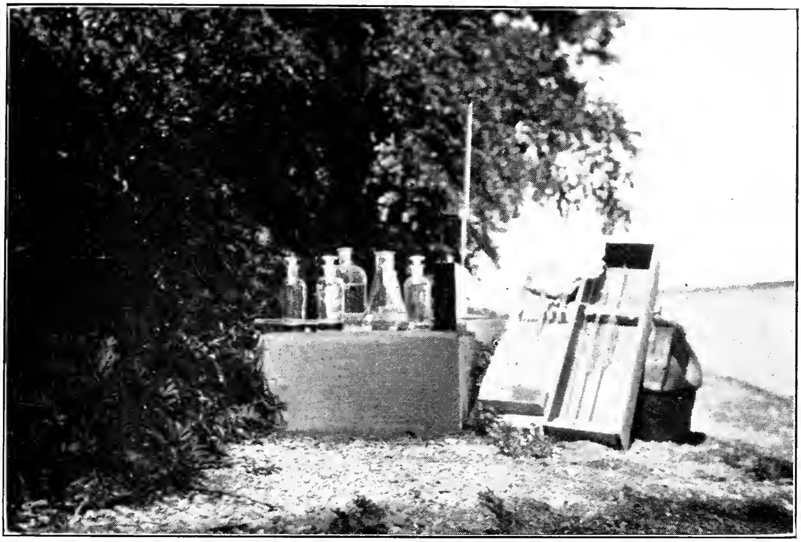
Types of Pollution.— Without regard to the particular water influenced and arranged approximately in order of their prominence, the list of polluting substances includes municipal sewage, wastes from iron and steel works, textile, glue, tanning and chemical industries, canneries, milk plants, laundries, garbage and other wastes of lesser importance.

Methods Employed.— Limited space makes it inadvisable to discuss at length the effects of various types of pollution, which information the interested reader may find by referring to the corresponding reports of the past two years. In practically all instances gaseous relationships were determined in the field with a portable outfit, a part of which is shown in the illustration. In addition, the facilities of the Buffalo Bureau of Water Laboratory which was generously placed at our disposal made it possible to

The headquarters of the chemical unit in the Buffalo Bureau of Water Laboratory conduct such additional determinations as biochemical oxygen demand, nitrogen ratios, and non-carbonate hardness when desirable.

Analytical methods followed were essentially as outlined in "Standard Methods of Water Analysis", 6th edition, 1925, American Public Health Association. Ten day biochemical oxygen demand was determined by incubation at 20° C. with dilution where necessary. All values for percentage saturation of dissolved oxygen have been adjusted in accordance with the barometric pressures of the regions. *The heavy horizontal lines across the graphs represent 100 per cent of saturation.*

Dr. Peter R. Kosting, assistant chemist, United States Fixed Nitrogen Research Laboratory, was associated with the writer throughout the summer's work.



A portable outfit for field work in pollution studies

All data are listed in the accompanying tables, while a few series have been selected for graphical representation. Alkalinity values are expressed as parts per million of calcium carbonate in all cases. The phenolphthalein end point having been accepted as the dividing line between free and fully bound or fixed carbon dioxide, the latter content, or as otherwise expressed content of normal carbonate is given by twice the phenolphthalein alkalinity. Total alkalinity as determined with methyl orange, minus twice the phenolphthalein alkalinity gives the bicarbonate (half bound carbon dioxide) expressed again as calcium carbonate. Such values may be converted into terms of bicarbonate by multiplying with the factor 1.62.

Classification of Data.— Their interlinkage and interdependence have made it impractical to draw a sharp line of separation or classification of the waters for purpose of discussion, though in the tabulation such division has been more rigorously adhered to. Thus all of Lake Erie data have been incorporated into Series I, all of Niagara river data into Series II, while all other streams with the exception of Cattaraugus creek have been placed in Series III. A separate series (IV) has been devoted to Cattaraugus because of its past importance, and because of the more intensive and collaborative studies made thereon.

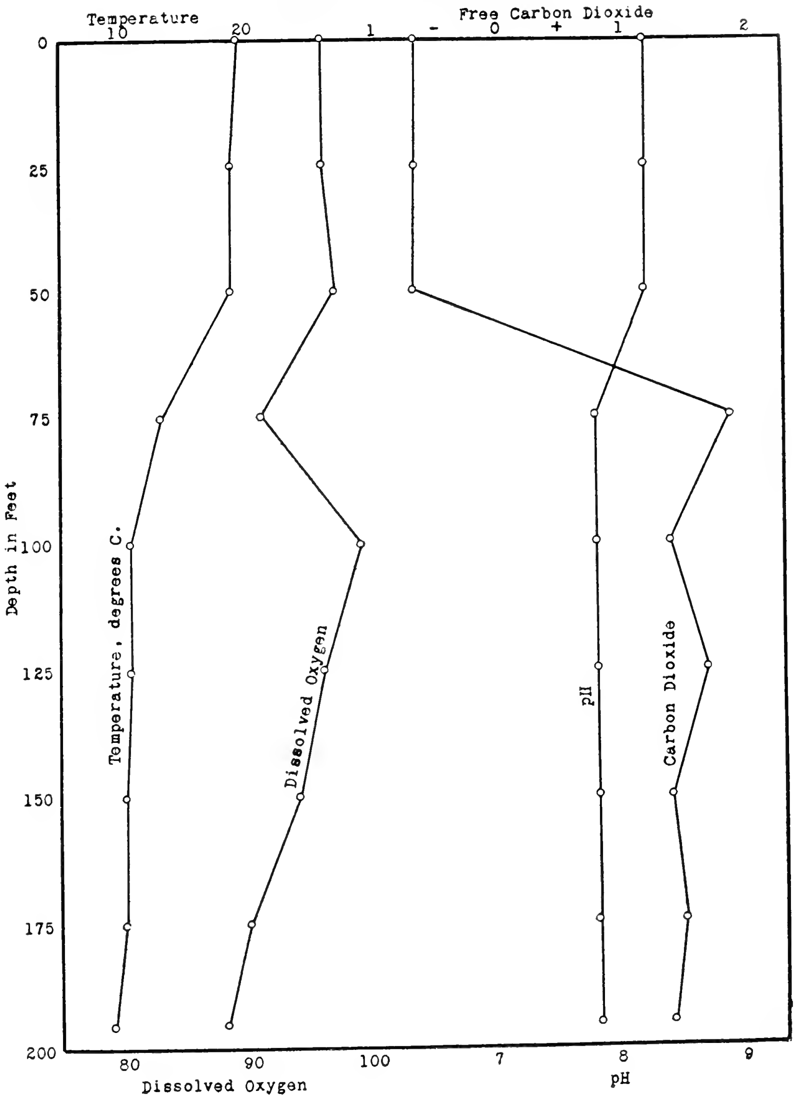
Lake Erie Studies.— In contemplating how the investigation of the lake waters could most intelligently and fruitfully be conducted it seemed probable that the effects of shore washings, sewers and tributary streams would be limited to a comparatively narrow stretch of shore waters, and here only would pollution be a factor, since in so far as fish life is concerned contributions to the main lake body as from passing boats would be infinitesimal and negligible. Such a zone is indicated when streams have been roiled and swollen by rains which have not greatly disturbed the smoothness of the lake. But such relatively shallow waters are of paramount importance during the spawning period and early life history of the fish. Hence the question which arises is how far out into the lake do shore factors exert their influence.

A preliminary cruise was made as far as the New York-Pennsylvania State line toward the end of June, samples being taken at pertinent stations, near the surface and bottom at each point and at varying distances from shore. On this and on subsequent cruises the Conservation Department cabin cruiser, *Navette*, was used as a base, a small boat with outboard motor facilitating the actual collection of samples. As a result of the preliminary findings it was decided to repeat the determinations at monthly intervals, and to take samples at each station approximately 500 and 2000 feet from shore. Because of the small likelihood of any sudden changes in the nature of the lake bottom, Mr. N. L. Cutler accompanied only the first and last cruises, dredging samples at each station for biological examination and collaboration.

An additional desideratum was the sampling of the water at intervals between the surface and bottom at Erie's approximately greatest depth, about six miles southeast of Long point, and this was taken care of on the last cruise. The data will be found in Series I of the tables. Dissolved oxygen from a percentage of saturation consideration exhibited but a slight diminution toward the bottom. An interesting thermocline was found between the fifty and seventy-five feet levels, where also the free carbon dioxide of the lower regions gave place to the fixed carbon dioxide of the upper strata, pH values changing from 7.8 to 8.2. These features are graphically represented in Fig. 1.

Fig. 1

ANALYSES OF LAKE ERIE WATER



The shore studies showed that there are points where entering pollution exerts appreciable effects upon localized areas about the points of entry, but that it is soon assimilated by the great volume of lake water. In places such as Dunkirk harbor the exuberant weed beds doubtless aid greatly in the assimilation, and directly outside the harbor no effect of pollution could be detected. Between the New York-Pennsylvania State line and the city of Lackawanna the two most noteworthy entries are Cattaraugus and Rush creeks. The former discharges a load of unassimilated organic matter into the lake, but it is the effect upon the stream itself rather than the lake which is the occasion for greatest concern.

Rush creek discharges into the lake wastes from the iron and steel works just above. On two occasions the stream was found to have an acidity of about .03 normal, or roughly about three times as strongly acid as the reagent which we use in determining a water's alkalinity. This stream carries a load of iron which it holds in solution by virtue of its acidity, but when neutralized by the alkalinity of the lake water the solution becomes a suspension, reddish brown in color because of the oxide of iron which separates out. And so on occasions the adjoining shore waters present a study in color shades, the reddish brown at the edge fading to a lighter hue streaked with clearer lake water as the eye travels outward, until finally the last trace disappears. Such a condition should not be permitted to exist, the more since it might easily be corrected.

The most easterly point which may be listed as lake proper was inside the breakwater opposite Michigan slip, and on all three cruises was found to be little affected by pollution. Luxurious weed beds late in the summer brought the dissolved oxygen content above the normal saturation point.

To show how remarkably free the lake proper is from fluctuations due to shore conditions, the profiles in Fig. 2 depict the averages of dissolved oxygen determinations made at the 500 and 2000 feet stations throughout the season. The graphs have been extended to include the data on Niagara river, so that all told the picture covers upwards of one hundred and ten miles of shore distance. Because of the character of river flow as opposed to lake, the nearest to shore samples in the case of the former were taken at a distance of 100 instead of 500 feet.

Niagara River.— The water which sweeps down the main channel of the river to the foot of Squaw island is, under normal conditions, little different chemically from that in the lake itself. Inside the ship channel however the effect of sewage is severe, and just above the international railroad bridge the oxygen content was found at one time to average 3 parts per million, while the ten day biochemical demand showed a value of more than twice this figure.

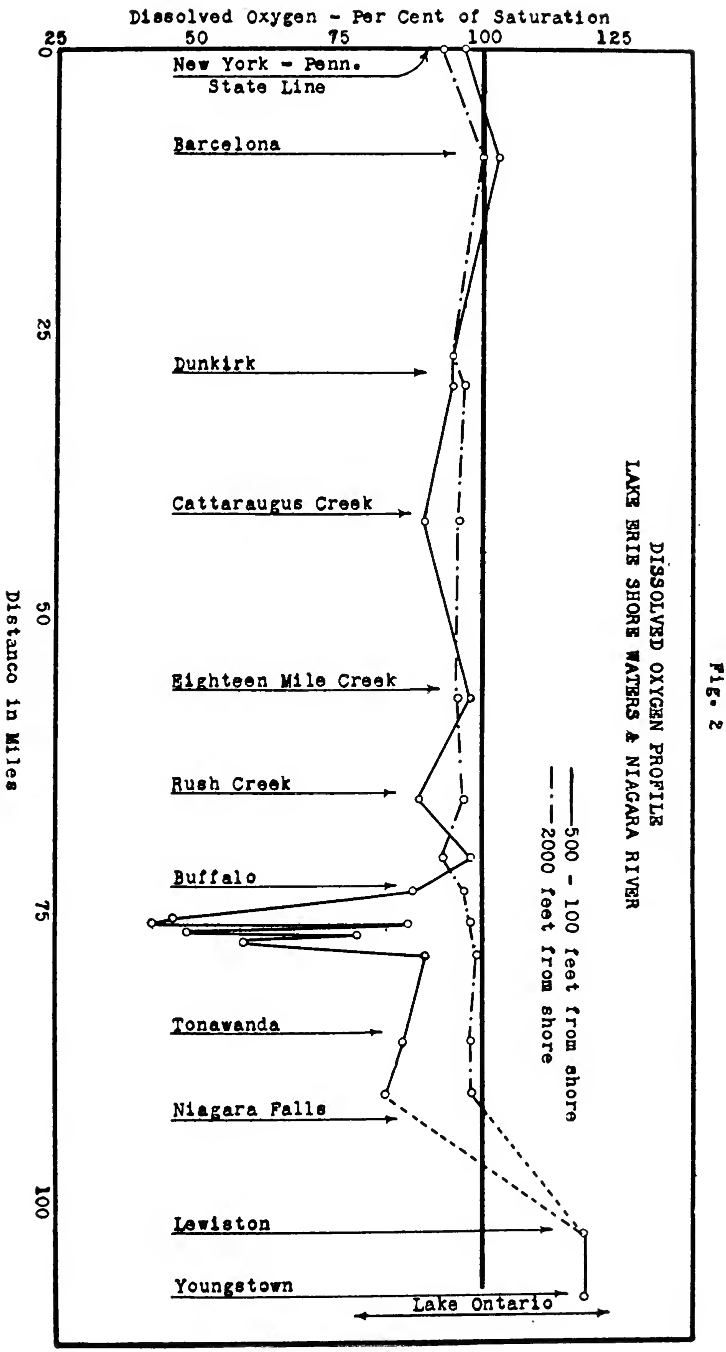


Fig. 2
DISSOLVED OXYGEN PROFILE
LAKE ERIE SHORE WATERS & NIAGARA RIVER

Below the Federal lock and sheltered from the river's current even greater depletion was observed. A short distance below, a great sewer bursts into the river through the old canal wall, and less than a mile farther a virulent and odorous textile effluent adds its quota. Results of determinations at these points are listed in Series II, and the serrated portion of the graph (Fig. 2) illustrates their intensity. But the assimilative capacity of Niagara with its normal flow of more than 200,000 cubic feet per second is enormous, and the mighty current rushes with its cargo to the falls and rapids below, there to be subjected to unparalleled opportunity for aeration and assimilation. Eddy currents soon dissipate the virulence of pollution at any point, though the near shore curve shows a steady decline to the foot of Grand island: the water in the channel however is not appreciably affected. And finally the water reaches the comparatively quiet level past Lewiston and Youngstown to Lake Ontario, with oxygen content far beyond its normal saturation capacity.

Other Streams.— It has been emphasized in the past reports that data can give a picture of conditions only at the time of observation, and that one may judge through experience what results are liable to be misleading, and formulate conclusions accordingly. As an instance, Cayuga creek was analyzed above and below pollution entrance from Lancaster on two separate occasions more than two months apart. As listed in Series III, where pollution at the earlier date had been indicated by a reduction of dissolved oxygen to 85 per cent of saturation and presence of 2.4 parts per million of free carbon dioxide, the later examination revealed an oxygen reduction to 23 per cent and carbon dioxide content of 12.1. Farther downstream the comparable oxygen figures were 98 and 7. Cayuga creek is thus practically ruined for fish life below Lancaster and Depew.

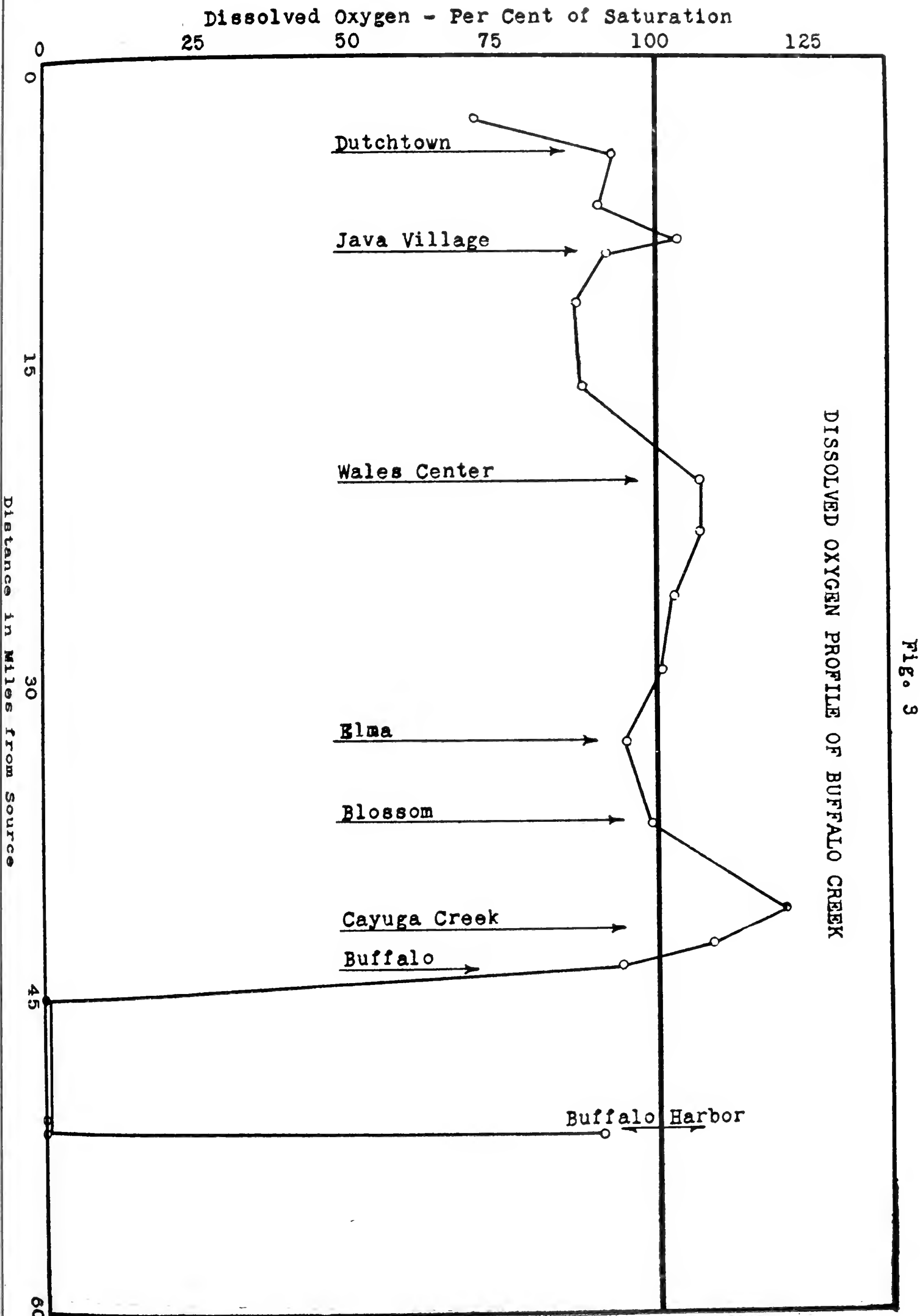
Ellicott creek is polluted by creamery wastes at Bowmansville, and the effects though not very serious are detectable for a couple of miles.

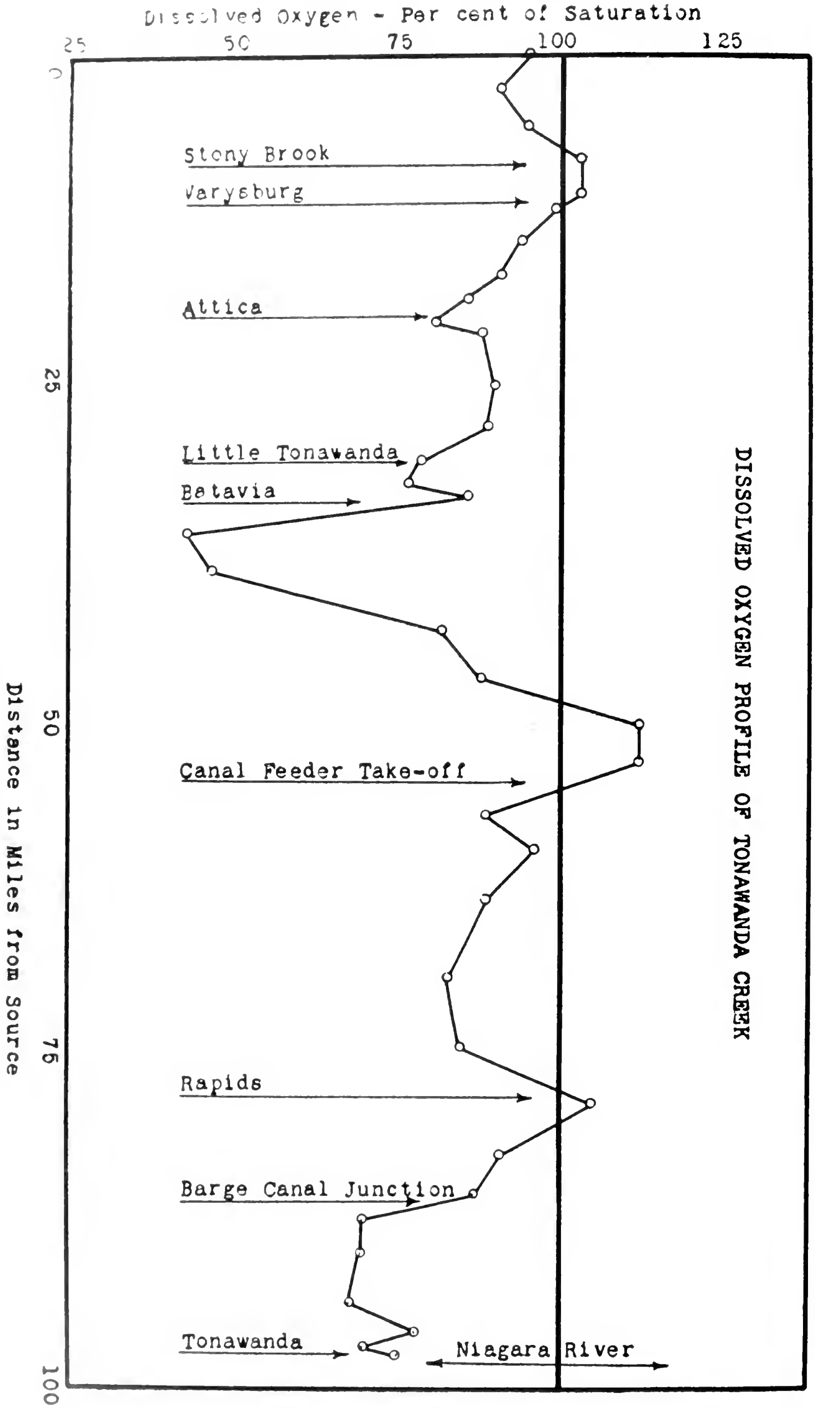
Pollution to Lime lake outlet by milk wastes is considerable, and a promising trout stream thereby endangered.

The evidence would indicate that Elton creek is not seriously affected by dairy wastes at Delevan. Potential possibilities must not be disregarded.

Spring brook receives cannery wastes just above the pond into which a part of Springville sewers. The pollution, while probably not fatal to at least the hardier forms of fish, produces a most undesirable condition in the pond, detached patches of blue-green algae flecking its surface.

Effect of the milk shipping station at East Otto upon South Branch Cattaraugus was found to be inappreciable at time of investigation.


Dissolved Oxygen - Per Cent of Saturation
0
25
50
75
100
125
Dutchtown
Java Village
Wales Center
Elma
Blossom
Cayuga Creek
Buffalo
Buffalo Harbor
0
15
30
45
60
Distance in Miles from Source
DISSOLVED OXYGEN PROFILE OF BUFFALO CREEK
Fig. 3



Dissolved Oxygen - Per cent of Saturation
25
50
75
100
125
0
25
50
75
100
Stony Brook
Varysburg
Attica
Little Tonawanda
Batavia
Canal Feeder Take-off
Rapids
Barge Canal Junction
Tonawanda
Niagara River
DISSOLVED OXYGEN PROFILE OF TONAWANDA CREEK
Distance in Miles from Source

Fig. 4

Tributary 7 of South Branch is seriously abused by the town of Cattaraugus, but is probably of little value in itself and recovers before reaching the main stream.

Rush creek has already been discussed under Lake Studies. Its neighbor, Smoke creek, also enters the lake in poor shape, with depleted oxygen and high content of free carbon dioxide.

The town of Silver Creek badly pollutes the stream of the same name, but being so near it is practically equivalent to sewering directly into the lake.

Canadaway creek was found to be in a vile state below entrance of Fredonia sewage, a condition which it is expected will be corrected by the disposal plant soon to be in operation.

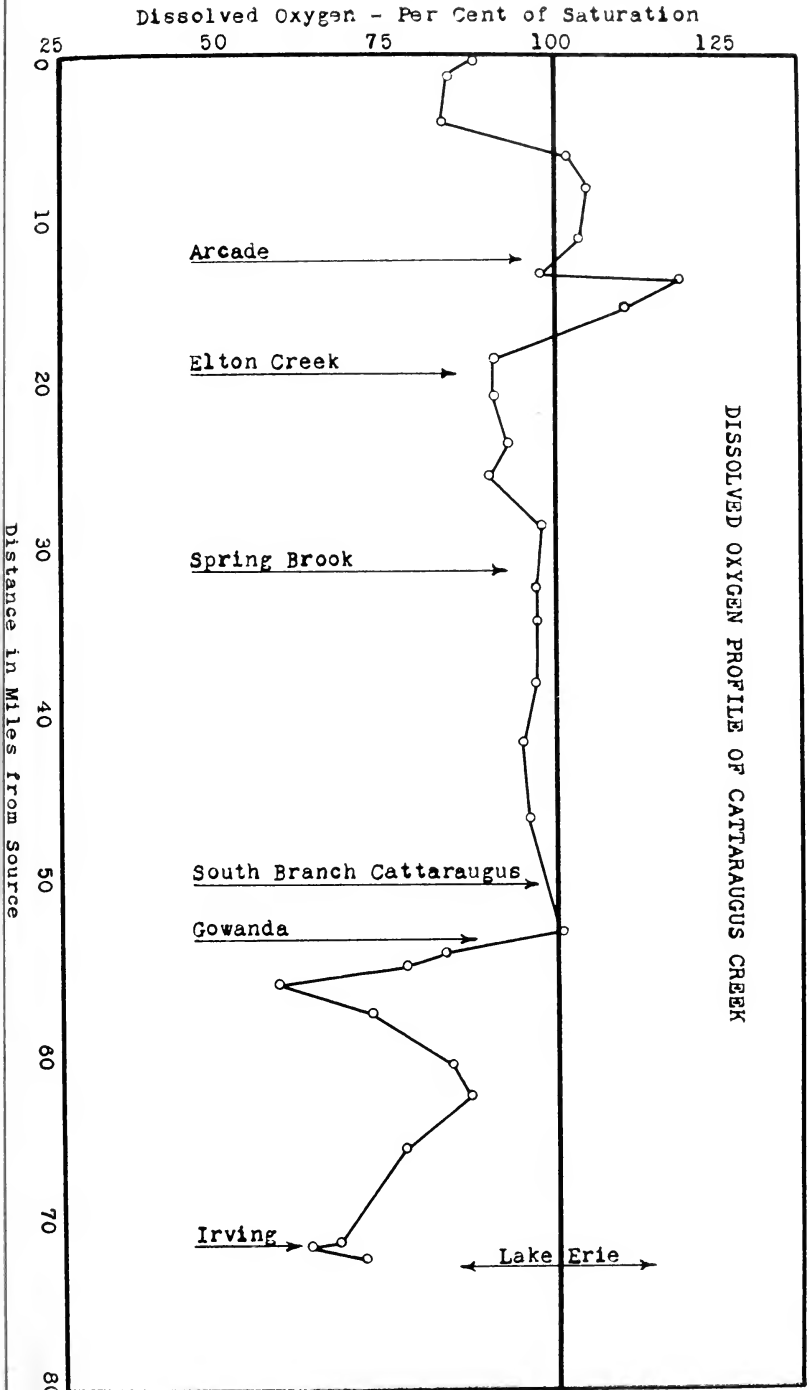
Eighteenmile creek appeared to be inappreciably affected by pollution from Hamburg, through its tiny tributary 5.

Buffalo creek receives no pollution of a serious nature until it reaches the city of Buffalo, and here for about 6 miles it is converted into a septic basin, absolutely devoid of dissolved oxygen, highly charged with carbon dioxide, and forming an effective barrier to fish. The dissolved oxygen profile is given in Fig. 3.

Tonawanda creek as has already been indicated is dredged throughout the last dozen miles of its course before entry into Niagara river, and because of this reversed flow such determinations as alkalinity correspond with those of the river. The dissolved oxygen throughout this area is considerably reduced because of opportunity for decomposition of foreign matter in the comparatively quiet water. The very bad condition of the stream as it leaves Batavia is surprising in view of the supposed operation of a complete disposal plant. There is abundant evidence of heavy pollution. Fig. 4 is a picture of conditions found.

Cattaraugus Creek.— Pollution to Cattaraugus creek by glue and tannery wastes at Gowanda has long been a cause of concern. This situation was investigated in collaboration with Mr. Cutler studying the biological aspects, and Mr. Greeley the fish species, to whose reports the reader is referred. The chemical data are listed in Series IV, while Fig. 5 shows a part of the same graphically. Some idea of the load of decomposable material which is thrust upon the stream may be obtained by reference to the values for ten day biochemical oxygen demand. The content of dissolved oxygen though greatly reduced was probably at no place insufficient for fish life. Nitrogen ratios show a mighty increase in both free and albuminoid ammonia, nitrite and organic nitrogen, while the high alkalinity of the wastes gives the water just below its entrance a high content of normal carbonate. The stream is obviously unable to assimilate the pollution which is somewhat resistant to decomposition, and so a large part is discharged into the lake, with the additional wastes from the cannery at Irving. Throughout the entire distance, deposits of sludge were found in the quiet places of diminished flow. Arcade is the only town of noteworthy size in the upper stretches of the stream, and its effects though appreciable were not serious.

It will be apparent from what has gone before that several streams which were probably at one time hereditary spawning grounds for lake fish have been entirely destroyed or at least greatly impaired for such purpose.



DISSOLVED OXYGEN PROFILE OF CATTARAUGUS CREEK

Fig. 5

SERIES I: CHEMICAL ANALYSES — SHORE WATERS OF LAKE ERIE

LOCATION AND REMARKS	Date	Depth in Feet		Temperature Degrees Centigrade*		Dissolved Oxygen		Alkalinity Calculated as p.p.m. Calcium Carbonate		Free carbon dioxide p.p.m.	pH	Ten day biochemical oxygen demand p.p.m.
		Total	Sample	Air	Water	Parts per million	Per cent saturation	Phenolphthalein	Methyl orange			
N. Y.-Pennsylvania State line:												
500 feet from shore	June 22	18	Surface	21.5	21.0	9.1	103	0.5	93	Nil	8.0	Undetermined.
500 " " "	"	18	Bottom	21.5	17.8	9.3	99	1.7	91	"	8.0	"
2,000 " " "	"	21	Surface	21.5	20.0	9.1	102	1.4	97	"	8.0	"
2,000 " " "	"	21	Bottom	21.5	15.0	9.4	95	Nil	95	1.0	7.9	"
500 " " "	July 26	5	2.5	23.8	24.4	8.2	99	0.7	97	Nil	8.1	0.9
2,000 " " "	"	20	Surface	25.0	24.1	8.3	100	1.2	97	"	8.2	Undetermined.
2,000 " " "	"	20	Bottom	25.0	22.4	8.7	102	1.2	98	"	8.2	"
500 " " "	Sept. 6	10	5	21.0	20.0	8.2	92	1.6	97	"	8.2	"
2,000 " " "	"	22	Surface	20.5	20.0	8.2	91	1.4	97	"	8.2	"
2,000 " " "	"	22	Bottom	20.5	20.0	8.1	90	1.5	97	"	8.2	"
East of Barcelona, one-half mile:												
500 feet from shore	June 22	6	Surface	23.0	21.0	9.2	104	1.6	97	"	8.0	Undetermined.
500 " " "	"	6	Bottom	23.0	19.0	9.8	108	2.5	99	"	8.1	"
2,000 " " "	"	12	Surface	23.0	20.0	9.3	104	1.5	95	"	8.1	"
2,000 " " "	"	12	Bottom	23.0	17.8	9.5	102	1.1	95	"	8.1	"
500 " " "	July 26	3	1.5	24.8	25.0	8.3	101	1.8	98	"	8.2	1.1
2,000 " " "	"	10	Surface	24.5	23.0	8.3	98	2.5	97	"	8.2	Undetermined.
2,000 " " "	"	10	Bottom	24.5	24.3	8.5	102	1.8	98	"	8.2	"
500 " " "	Sept. 6	6	3	20.0	20.0	9.0	101	2.0	96	"	8.2	"
2,000 " " "	"	20	Surface	20.0	20.0	8.6	96	2.0	95	"	8.2	"
2,000 " " "	"	20	Bottom	20.0	20.0	8.7	97	2.0	95	"	8.2	"
West of Dunkirk light, 0.5 mile:												
500 feet from shore	July 27	9	4.5	22.8	22.0	8.2	95	0.6	96	"	8.1	0.6
2,000 " " "	"	23	Surface	23.0	21.8	8.4	97	1.0	98	"	8.1	Undetermined.
2,000 " " "	"	23	Bottom	23.0	22.0	8.3	96	1.0	97	"	8.1	"
500 " " "	Sept. 7	14	7	18.5	19.5	8.5	94	2.2	97	"	8.2	"
2,000 " " "	"	30	Surface	18.3	20.0	8.5	94	1.5	97	"	8.2	"
2,000 " " "	"	30	Bottom	18.3	20.0	8.4	94	2.0	97	"	8.2	"

Dunkirk harbor:												
West end, entering channel........	July 25	15	7.5	23.0	23.2	8.2	98	1.8	98	Nil	8.2	Undetermined
End of Central Ave. pier..........	"	16	8.0	23.7	23.2	7.7	91	Nil	99	"	8.1	"
Off east side of pier, midway.......	"	16	8.0	24.0	23.8	7.3	88	0.6	98	"	8.1	"
South-east of U. S. breakwater.....	"	8	8.0	22.7	23.4	7.9	94	1.2	99	"	8.2	"
Battery Pt., 0.5 mile E. of Dunkirk:												
500 feet from shore (water roily from heavy rains)............	June 24	6	Surface	24.0	21.5	7.0	81	Nil	62	3.9	7.4	"
500 feet from shore...........	"	6	Bottom	24.0	19.5	7.7	85	"	75	1.9	7.6	"
2,000 feet from shore...........	"	16	Surface	24.0	17.0	9.5	100	1.8	98	Nil	8.2	"
2,000 feet from shore...........	"	16	Bottom	24.0	17.0	9.5	100	1.2	97	"	8.1	"
500 feet from shore.............	July 27	6	3	26.0	22.8	8.8	104	1.8	98	"	8.2	0.8
2,000 " " "	"	15	Surface	26.0	22.8	8.3	98	1.5	97	"	8.2	Undetermined
2,000 " " "	"	15	Bottom	26.0	22.4	8.2	96	1.2	98	"	8.2	"
500 " " "	Sept. 7	10	5	19.0	19.8	8.7	97	1.5	98	"	8.2	"
2,000 " " "	"	32	Surface	19.0	20.0	8.5	94	2.0	96	"	8.2	"
2,000 " " "	"	32	Bottom	19.0	19.5	8.5	94	1.8	97	"	8.2	"
East of Cattaraugus creek, 0.5 mile:												
500 feet from shore.............	June 24	5	Surface	19.0	18.5	8.8	96	Nil	86	1.4	7.9	"
500 " " "	"	5	Bottom	19.0	17.8	7.0	75	"	90	1.6	7.9	"
2,000 " " "	"	19	Surface	19.0	17.0	9.7	102	1.2	101	Nil	8.2	"
2,000 " " "	"	19	Bottom	19.0	17.8	8.5	91	Nil	87	2.3	7.9	"
500 " " "	July 27	5	2.5	24.0	24.5	7.3	85	"	118	0.7	7.9	2.7
2,000 " " "	"	12	Surface	25.4	23.8	7.4	88	0.6	103	Nil	8.1	Undetermined
2,000 " " "	"	12	Bottom	25.4	23.2	8.6	101	0.6	99	"	8.1	"
500 " " "	Sept. 7	5	2.5	21.0	20.5	8.8	99	2.0	97	"	8.2	"
2,000 " " "	"	23	Surface	20.0	20.3	8.7	97	2.5	97	"	8.2	"
2,000 " " "	"	23	Bottom	20.0	19.8	8.7	96	1.8	96	"	8.2	"
East of Eighteenmile creek:												
500 feet from shore, 0.5 mile.....	June 25	7	Surface	21.0	17.0	9.0	95	0.5	87	"	7.9	"
500 " " "	"	7	Bottom	21.0	17.2	9.1	96	0.6	89	"	7.9	"
2,000 " " "	"	25	Surface	21.0	16.8	9.4	98	0.6	93	"	8.0	"
2,000 " " "	"	25	Bottom	21.0	16.0	9.3	95	0.9	91	"	7.9	"
500 " " "	Aug. 14	10	Surface	24.5	23.4	8.1	97	3.0	98	"	8.2	"
500 " " "	"	10	Bottom	24.5	23.4	8.1	96	2.5	96	"	8.2	1.0
2,000 " " "	"	23	Surface	24.7	23.4	8.1	97	3.0	96	"	8.2	Undetermined
2,000 " " "	"	23	Bottom	24.4	22.3	8.2	96	3.0	96	"	8.2	"
500 " " "	Sept. 7	5	2.5	20.5	21.0	9.0	102	2.5	96	"	8.2	"
2,000 " " "	"	29	Surface	20.0	20.5	8.7	98	1.7	98	"	8.3	"
2,000 " " "	"	29	Bottom	20.0	20.0	8.5	95	2.5	98	"	8.2	"

SERIES I: CHEMICAL ANALYSES — SHORE WATERS OF LAKE ERIE — (*Concluded*)

LOCATION AND REMARKS	Date	Depth in Feet		Temperature Degrees Centigrade*		Dissolved Oxygen		Alkalinity Calculated as p.p.m. Calcium Carbonate		Free carbon dioxide p.p.m.	pH	Ten day biochemical oxygen demand p.p.m.
		Total	Sample	Air	Water	Parts per million	Per cent saturation	Phenolphthalein	Methyl orange			
West of Lackawanna, one mile; east of Rush creek, 0.5 mile:												
500 feet from shore	June 25	5	Surface	24.0	19.0	9.0	96	0.9	89	Nil	7.9	Undetermined
500 " " "	"	5	Bottom	24.0	18.8	8.7	95	1.0	88	"	7.9	"
2,000 " " "	"	12	Surface	24.0	19.0	9.0	99	1.2	93	"	7.9	"
2,000 " " "	"	12	Bottom	24.0	17.8	8.8	94	0.6	88	"	7.9	"
500 " " "	Aug. 14	15	Surface	24.5	22.6	7.9	93	2.5	97	"	8.2	"
500 " " "	"	15	Bottom	24.5	22.5	8.2	96	0.1	93	"	8.0	1.0
2,000 " " "	"	22	Surface	23.5	22.4	7.7	90	2.7	96	"	8.0	Undetermined
2,000 " " "	"	22	Bottom	23.5	22.0	7.7	89	2.5	98	"	8.2	"
100 " " " (water brown, see text)	Sept. 8	3	1.5	19.5	19.0	7.2	79	Nil	66	**25.0	6.9	"
500 feet from shore	"	8	4.0	19.5	19.5	8.4	104	"	90	**1.4	7.6	"
2,000 feet from shore	"	17	8.5	19.5	19.5	8.6	106	1.5	94	Nil	8.2	"
Michigan gap — upper Buffalo harbor:												
500 feet from shore	June 25	6	Surface	22.0	18.5	8.6	94	0.6	92	"	7.9	"
500 " " "	"	6	Bottom	22.0	18.4	8.6	93	0.7	92	"	7.9	"
2,000 " " "	"	20	Surface	22.0	18.0	8.6	93	0.8	91	"	7.9	"
2,000 " " "	"	20	Bottom	22.0	17.8	8.7	94	1.2	91	"	7.9	"
500 " " "	July 28	10	Surface	22.5	22.7	8.3	98	2.3	95	"	8.2	"
500 " " "	"	10	Bottom	22.5	22.6	7.9	93	2.0	97	"	8.3	0.4
2,000 " " "	"	20	Surface	22.5	22.6	7.9	93	0.7	97	"	8.1	Undetermined
2,000 " " "	"	20	Bottom	22.5	22.7	7.9	93	0.6	96	"	8.1	"
500 " " " (luxurious plant growth)	Sept. 8	10	5	19.5	19.8	9.5	105	2.4	93	"	8.3	"
2,000 feet from shore	"	27	Surface	19.5	20.0	8.4	93	1.8	96	"	8.2	"
2,000 feet from shore	"	27	Bottom	19.5	19.8	8.3	92	2.0	96	"	8.2	"

Erie's deepest part: About six miles south-east of Long point.	Sept. 6	195	Surface	18.5	19.2	8.7	96	1.5	98	Nil	8.2	. . . .
	"	195	25	18.5	18.5	8.9	96	1.5	99	"	8.2	. . . .
	"	195	50	18.5	18.6	9.0	97	1.5	99	"	8.2	. . . .
	"	195	75	18.5	13.0	9.4	91	Nil	98	1.9	7.8	. . . .
	"	195	100	18.5	10.4	10.9	99	"	98	1.4	7.8	. . . .
	"	195	125	18.5	10.5	10.5	96	"	99	1.7	7.8	. . . .
	"	195	150	18.5	10.0	10.4	94	"	99	1.4	7.8	. . . .
	"	195	175	18.5	10.0	10.0	90	"	102	1.5	7.8	. . . .
	"	195	Bottom	18.5	9.0	10.0	88	"	100	1.4	7.8	. . . .

* To change degrees Centigrade to degrees Fahrenheit, multiply by 9/5 and then add 32; e.g. (21.5 x 9/5) + 32 = 70.7 (degrees Fahr.).
** Acidity calculated as parts per million sulphuric acid.

SERIES II: CHEMICAL ANALYSES — WATERS OF NIAGARA RIVER

LOCATION AND REMARKS	Date	Depth in Feet: Total	Depth in Feet: Sample	Temperature Degrees Centigrade: Air	Temperature Degrees Centigrade: Water	Dissolved Oxygen: Parts per million	Dissolved Oxygen: Per cent saturation	Alkalinity Calculated as p.p.m. Calcium Carbonate: Phenolphthalein	Alkalinity Calculated as p.p.m. Calcium Carbonate: Methyl orange	Free carbon dioxide p.p.m.	pH	Ten day biochemical oxygen demand p.p.m.
Above Peace bridge, one-half mile:												
1,000 feet from Canadian shore....	July 6	14	Surface	23.0	18.7	9.0	98	1.4	94	Nil	8.2	....
1,000 " " " " ..	"	14	Bottom	23.0	19.0	9.0	99	1.1	95	"	8.2	1.5
500 feet from U. S. breakwater...	"	14	Surface	22.8	19.5	8.7	96	1.2	96	"	8.1	....
500 " " " " ...	"	14	Bottom	22.8	19.8	8.7	96	0.7	95	"	8.1	1.1
Inside breakwater — lower harbor..	"	18	Surface	22.8	20.5	7.7	87	0.6	97	"	8.0	....
" " " " " ..	"	18	Bottom	22.8	20.5	7.9	89	2.0	98	"	8.0	3.3
1,000 feet from Canadian shore....	Aug. 3	15	Surface	26.5	22.0	8.2	96	1.8	99	"	8.2	....
1,000 " " " "	"	15	Bottom	26.5	22.0	8.2	95	1.6	97	"	8.2	0.4
500 feet from U. S. breakwater ..	Aug. 6	14	Surface	24.0	23.0	8.1	96	2.2	100	"	8.3	2.0
Inside breakwater — lower harbor..	Aug. 3	20	Surface	27.5	23.5	7.3	87	0.7	100	"	8.0	....
" " " " " ..	"	20	Bottom	27.5	23.5	7.3	87	2.5	99	"	8.2	2.3
Above International R. R. bridge, 500 feet — lower harbor. Gas bubbles arising..........................	July 6	22	Surface	24.5	22.3	2.3	27	Nil	102	10.7	7.4	....
	"	22	Bottom	24.5	21.0	3.7	42	"	103	7.4	7.6	7.7
	Aug. 1	15	Surface	25.3	22.8	4.9	57	"	103	4.4	7.5	....
	"	15	Bottom	25.3	23.2	4.7	55	"	105	3.4	7.6	9.0
Foot of Squaw island:												
In channel outside breakwater.....	July 6	14	Surface	23.5	19.5	9.1	101	1.1	94	Nil	8.2	....
" " " "	"	14	Bottom	23.5	19.5	9.2	102	1.4	96	"	8.2	1.6
Below Federal lock..............	"	22	Surface	23.8	22.5	4.1	48	Nil	110	6.9	7.6	....
" " "	"	22	Bottom	23.8	20.5	5.3	60	"	97	4.3	7.6	3.7
In channel outside breakwater.....	Aug. 1	18	Surface	23.2	21.2	8.3	95	2.1	97	Nil	8.2	....
" " " "	"	18	Bottom	23.2	21.5	8.2	95	2.5	97	"	8.3	0.7
Below Federal lock..............	"	18	Surface	23.8	22.4	2.7	32	Nil	101	3.9	7.4	....
" " "	"	18	Bottom	23.8	22.5	2.6	30	"	106	3.4	7.6	1.5
Riverside sewer entrance, about three-quarters mile below Federal lock:												
Above sewer, ¼ mile, 100 feet from shore..........................	Aug. 22	22	11	22.5	22.5	7.4	87	2.0	95	Nil	8.2	....

At sewer, 100 feet from shore	"	22	11	24.5	22.5	4.1	48	Nil	100	3.0	7.6	3.8
Below sewer, $\frac{1}{4}$ mile, 100 feet from shore	"	15	7	22.5	22.5	6.7	78	0.5	95	Nil	8.0	3.5
Textile effluent, about one and one-half miles below Federal lock:												
Above sewer, $\frac{1}{4}$ mile, 100 feet from shore	Aug. 22	11	5	24.5	22.5	6.6	77	1.0	95	"	8.2	3.7
Below sewer 100 feet, 150 feet from shore	"	15	7	19.5	22.5	4.9	58	Nil	60	†13.0	<5.2	20.0
Below sewer, $\frac{1}{4}$ mile, 150 feet from shore	"	26	Surface	21.7	22.0	5.7	66	"	95	†1.4	7.6	
Below sewer, $\frac{1}{4}$ mile, 150 feet from shore	"	26	Bottom	21.7	22.2	5.6	66	"	95	†1.4	7.6	
Head of Grand island:												
Off U. S. shore 100 feet	July 5	22	Surface	20.0	20.5	7.8	88	0.1	98	Nil	8.0	
" " " " "	"	22	Bottom	20.0	20.7	7.9	90	Nil	97	0.4	8.0	5.1
East of Grand island 100 feet	"	10	Surface	20.0	19.5	8.8	97	1.4	98	Nil	8.1	
" " " " "	"	10	Bottom	20.0	19.5	8.8	97	1.4	97	"	8.1	3.4
West of Grand Island in channel	July 12	20	Surface	22.0	22.0	8.5	99	2.5	94	"	8.2	
" " " " " "	"	20	Bottom	22.0	22.0	8.5	99	2.5	94	"	8.2	4.4
Off U. S. shore 100 feet	Aug. 16	26	Surface	27.0	22.7	7.7	90	1.7	98	"	8.2	
" " " " "	"	26	Bottom	27.0	22.7	7.6	90	1.8	100	"	8.2	1.6
East of Grand island 100 feet	"	22	Surface	29.8	23.0	8.8	103	3.5	99	"	8.2	
" " " " " "	"	22	Bottom	29.8	23.0	8.5	100	2.5	98	"	8.2	0.5
West of Grand island in channel	"	18	Surface	25.2	22.6	8.3	97	2.5	97	"	8.2	
" " " " " "	"	18	Bottom	25.2	22.5	8.3	97	3.0	96	"	8.2	0.6
North Tonawanda:												
In the channel	July 12	11	Surface	27.0	22.0	8.3	96	1.8	95	"	8.2	
" " "	"	11	Bottom	27.0	22.0	8.7	101	2.5	94	"	8.2	2.7
Off U. S. shore 100 feet	"	17	Surface	26.0	23.0	7.5	88	0.6	95	"	8.1	
" " " " "	"	17	Bottom	26.0	23.0	7.4	87	0.6	95	"	8.1	2.7
In the channel	Aug. 17	18	Surface	25.6	22.5	8.3	97	2.2	96	"	8.2	
" " "	"	18	Bottom	25.4	22.5	8.2	96	2.0	97	"	8.2	0.4
Off U. S. shore 100 feet	"	25	Surface	25.0	22.6	7.1	93	1.5	98	"	8.2	
" " " " "	"	25	Bottom	25.0	22.6	7.3	86	1.0	97	"	8.1	1.6
Foot of Grand island:												
Off U. S. shore 100 feet (off Cayuga island)	July 5	10	Surface	22.5	21.3	7.1	81	Nil	95	1.0	7.9	
Off U. S. shore 100 feet (off Cayuga island)	"	10	Bottom	22.5	21.5	7.1	81	1.1	97	Nil	8.0	3.3
Off Buckhorn island 100 feet	"	10	Surface	21.5	20.2	8.9	100	0.7	98	"	8.0	
" " " " "	"	10	Bottom	21.5	20.2	8.8	99	1.4	100	"	8.2	3.4
West of Grand island in channel	July 12	18	Surface	23.0	22.0	8.1	93	2.5	95	"	8.2	
" " " " " "	"	18	Bottom	23.0	22.0	8.3	96	2.5	94	"	8.2	1.1

SERIES II: CHEMICAL ANALYSES — WATERS OF NIAGARA RIVER — (*Concluded*)

LOCATION AND REMARKS	Date	DEPTH IN FEET		TEMPERATURE DEGREES CENTIGRADE		DISSOLVED OXYGEN		ALKALINITY CALCULATED AS P.P.M. CALCIUM CARBONATE		Free carbon dioxide p.p.m.	pH	Ten day biochemical oxygen demand p.p.m.
		Total	Sample	Air	Water	Parts per million	Per cent saturation	Phenolphthalein	Methyl orange			
Foot of Grand island — (*Concluded*):												
Off U. S. shore 100 feet (off Cayuga island)	Aug. 20	15	Surface	25.5	22.4	7.3	85	1.0	98	Nil	8.2	....
Off U. S. shore 100 feet (off Cayuga island)	"	15	Bottom	25.5	22.7	7.3	86	2.3	99	"	8.2	1.9
Off Buckhorn island 100 feet	"	16	Surface	25.5	22.3	8.3	97	3.2	98	"	8.2	....
" " " " "	"	16	Bottom	25.5	22.4	8.3	97	2.7	98	"	8.2	0.9
West of Grand island in channel	"	17	Surface	23.8	20.8	8.0	91	1.4	99	"	8.2	....
" " " " " "	"	17	Bottom	23.8	21.0	8.0	92	2.0	98	"	8.2	0.8
At Lewiston:												
U. S. side of river	July 13	23	Surface	21.0	22.0	10.3	119	1.2	97	"	8.2	....
" " " " "	"	23	Bottom	21.0	21.8	10.3	119	1.2	97	"	8.2	....
Canadian side of river	"	23	Surface	21.0	22.0	10.3	118	1.2	97	"	8.2	....
" " " "	"	23	Bottom	21.0	21.6	10.3	118	1.2	96	"	8.2	....
At Youngstown, one mile above Lake Ontario	"	46	Surface	21.0	22.0	10.2	118	1.2	97	"	8.2	....
In mid-channel	"	46	Bottom	21.0	21.6	10.3	118	1.2	97	"	8.2	....

† Parts per million of hydrogen sulphide.
< Indicates "less than".

SERIES III: Chemical Analyses — Streams of the Erie-Niagara Watershed

Place sampled and remarks	Date	Temperature Degrees Centigrade		Dissolved Oxygen		Alkalinity Calculated as p.p.m. Calcium Carbonate		Free carbon dioxide p.p.m.	pH	Ten day biochemical oxygen demand p.p.m.
		Air	Water	Parts per million	Per cent saturation	Phenolphthalein	Methyl orange			
Cayuga creek, tributary No. 2 of Buffalo:										
0.9 mile above Lake Komo (Lancaster)	July 2	26.8	23.5	8.4	100	0.2	107	Nil	7.9	....
500 feet below Lake Komo	“	24.5	21.0	8.1	93	Nil	107	0.8	7.9	....
500 “ “ “ “	Sept. 12	28.0	24.0	8.3	114	1.5	125	Nil	8.2	....
1.5 miles below Komo; Lancaster pollution	July 2	26.7	22.5	7.2	85	Nil	118	2.4	7.7	....
“ “ “ “ “ “	Sept. 12	28.0	24.5	1.9	23	“	125	12.1	7.4	....
2.8 miles below Komo; Depew sewer just below	July 2	26.0	23.5	8.2	98	“	111	0.4	7.9	....
“ “ “ “ “ “ “	Sept 12	27.0	24.5	0.6	7	“	145	4.4	7.6	....
500 feet below Depew sewer	Sept. 13	23.5	21.0	0.1	1	“	147	14.1	7.4	....
At Bellevue, 2.5 miles below Depew sewer	“	23.5	22.0	3.2	37	“	128	8.5	7.4	....
4 miles below sewer, 500 feet below tributary 2	“	22.5	22.5	7.6	89	“	127	0.6	7.9	....
Ellicott creek, tributary No. 1. of Tonawanda — Pollution: Creamery wastes at Bowmansville:										
50 feet above creamery effluent	July 9	29.8	28.0	10.9	141	3.7	180	Nil	8.4	....
400 feet below; worst point	“	28.0	26.0	5.8	73	Nil	190	2.9	7.9	....
0.7 mile below	“	29.2	26.0	5.9	74	“	180	2.4	7.9	....
2.0 miles below, ponded	“	28.0	27.5	5.9	76	“	180	2.9	7.9	....
3.2 miles below, frequent riffles, mayflies	“	27.8	28.3	8.4	110	3.7	180	Nil	8.2	....
New York State Hospital reservoir — North Branch of Clear creek, below tributary No. 10:										
Surface sample	Aug. 10	27.0	26.5	7.5	100	Nil	37	1.0	7.7	....
At depth of 15 feet	“	27.0	21.5	Nil	....	“	40	13.0	6.8	....
At depth of 27 feet, bottom	“	27.0	15.5	“	....	“	58	20.2	6.8	....
Report of plugged gas wells in bottom.										
Lime lake outlet — Pollution: Wastes from milk plant:										
Waters leaving lake	Aug. 14	27.5	24.8	7.9	99	2.5	86	Nil	8.4	....
300 feet below milk plant, considerable fungi	“	26.0	23.3	6.5	80	Nil	87	0.5	7.9	....
0.5 mile below; heavy growth of water plants	“	25.8	21.0	6.1	72	“	101	1.5	7.9	....
1.5 miles below; mayflies in abundance	“	25.5	20.0	7.6	88	“	113	Nil	8.1	....
At confluence with Elton creek	Aug. 15	27.5	19.3	8.9	100	2.5	120	“	8.3	....

SERIES III: CHEMICAL ANALYSES — STREAMS OF THE ERIE-NIAGARA WATERSHED — (*Continued*)

PLACE SAMPLED AND REMARKS	Date	TEMPERATURE DEGREES CENTIGRADE		DISSOLVED OXYGEN		ALKALINITY CALCULATED AS P.P.M. CALCIUM CARBONATE		Free carbon dioxide p.p.m.	pH	Ten day biochemical oxygen demand p.p.m.
		Air	Water	Parts per million	Per cent saturation	Phenolphthalein	Methyl orange			
Elton creek — Pollution: Milk wastes at Delevan:										
50 feet above pollution entrance	Aug. 15	24.2	20.0	9.0	104	2.5	125	Nil	8.3	...
600 feet below; slight fungus growth	"	25.5	21.0	8.7	102	1.8	128	"	8.2	...
At confluence with Lime lake outlet	"	27.0	23.0	9.8	119	4.3	123	"	8.5	...
Spring brook, tributary No. 31 of Cattaraugus — Pollution: Cannery wastes and sewage at Springville:										
50 feet above cannery effluent	"	26.0	22.0	8.2	98	1.2	160	Nil	8.2	...
50 feet below; gray fungus growth	"	27.8	21.4	7.4	87	Nil	165	1.0	7.9	...
At crest of power house overflow, Springville	"	30.0	22.5	5.3	64	"	172	2.9	7.8	...
At confluence with tributary No. 1	Aug. 16	22.0	18.0	8.7	95	"	181	1.0	8.0	...
At confluence with Cattaraugus; very turbid	"	24.5	18.5	8.8	98	1.8	183	Nil	8.2	...
South Branch Cattaraugus creek — Pollution: Milk wastes at East Otto:										
50 feet above shipping station effluent	"	25.8	22.0	8.6	103	Nil	93	0.8	7.9	...
300 feet below effluent	"	27.0	22.0	8.7	104	"	100	0.8	7.9	...
Tributary No. 7 of South Branch Cattaraugus — Pollution: Milk wastes and rubbish from town of Cattaraugus, via tributary No. 1:										
1 mile above confluence with tributary No. 1	"	30.0	25.0	9.1	114	3.1	111	Nil	8.3	...
500 feet below confluence with tributary No. 1	"	29.5	30.0	5.9	81	Nil	139	1.0	7.9	...
0.5 mile below tributary No. 1	"	30.5	30.5	6.8	94	1.8	139	Nil	8.2	...
At confluence with South Branch; very turbid	"	29.5	30.0	7.6	104	3.1	140	"	8.3	...
Springs on Burdick farm, vicinity of Maples:										
Combined spring run on north side of Mansfield	Aug. 17	20.5	12.5	8.9	87	Nil	100	2.4	7.6	...
Spring hole, 10 feet in diameter, filling 8-inch drain pipe, south side of Mansfield creek	"	20.5	9.0	4.2	38	"	75	9.7	7.1	...
Rush creek — Pollution: Wastes from iron and steel works:										
1.5 miles above steel works	Aug. 25	19.3	19.8	9.0	98	1.0	156	Nil	8.1	...
0.3 mile below steel works	"	20.5	31.5	...	...	Nil	Nil	‡0.06	...	...
500 feet above Lake Erie	"	20.5	25.0	...	...	"	"	‡0.03	...	...
500 " " " "	Sept. 10	24.5	26.0	0.1	1	"	"	‡0.03	...	...

Tonawanda creek:										
0.5 mile from source; marshy	Aug. 31	16.3	17.5	8.6	95	Nil	125	2.4	7.8	....
2.6 miles from source	"	17.8	16.2	8.6	91	2.0	125	Nil	8.2	....
5.5 " " "	"	17.2	16.5	8.9	95	1.0	150	"	8.2	....
8.0 " " "	"	16.8	19.8	9.1	103	3.0	152	"	8.3	....
10.6 " " ", below Johnsonburg	"	17.0	19.2	9.2	103	2.0	160	"	8.3	....
11.7 " " ", at Varysburg, turbid	"	17.3	18.8	8.9	99	2.5	158	"	8.3	....
14.1 " " ", at Earls	"	18.5	18.5	8.6	94	Nil	156	1.0	8.1	....
16.6 " " ", at Sierks	"	16.5	19.0	8.2	91	"	158	0.8	8.1	....
18.7 " " "	"	17.0	18.2	7.9	86	"	168	1.0	8.1	....
20.2 " " ", entering Attica	Aug. 30	22.5	23.8	6.8	81	"	170	1.4	8.0	....
21.1 " " ", leaving Attica	"	23.5	24.5	7.2	88	"	157	Nil	8.1	....
25.0 " " ", at Alexander	"	24.0	24.0	7.4	90	"	173	0.5	8.1	....
28.0 " " ", at North Alexander	"	25.5	24.0	7.3	89	"	178	1.0	8.1	....
30.6 " " "	"	24.8	23.0	6.7	79	"	189	2.4	7.9	....
32.1 " " "	"	26.5	22.6	6.5	77	"	185	2.4	7.9	....
33.4 " " ", entering Batavia	Aug. 29	25.2	24.2	7.1	86	"	186	2.4	8.0	....
Leaving Batavia, water dirty and oily	"	25.0	25.0	3.5	43	"	186	6.3	7.7	....
At dam at Bushville	"	25.5	25.5	3.8	47	"	167	5.8	7.6	....
At dam at East Pembroke	"	25.5	24.5	6.7	82	"	167	3.0	7.8	....
At dam at North Pembroke	"	25.5	25.0	7.2	88	"	170	1.2	8.1	....
50.2 miles from source, at Indian Falls	"	24.5	24.0	9.3	112	2.5	158	Nil	8.4	....
53.0 " " "	"	24.0	22.8	9.5	112	1.0	160	"	8.3	....
Below canal feeder take-off	"	22.5	23.0	7.5	89	Nil	143	1.2	8.1	....
59.7 miles from source	Aug. 28	27.0	24.5	7.9	96	2.0	127	Nil	8.2	....
63.3 " " "	"	29.5	24.5	7.4	89	Nil	138	0.5	8.1	....
69.0 " " "	"	28.5	23.0	7.1	83	"	142	1.4	8.0	....
74.4 " " "	"	28.8	23.0	7.2	85	"	141	1.0	8.0	....
78.5 " " ", at Rapids	"	29.3	23.3	8.8	105	1.5	149	Nil	8.2	....
82.4 " " "	"	28.0	22.8	7.8	91	1.0	171	"	8.2	....
85.3 " " ", at Pendleton	Aug. 27	25.5	22.0	7.5	87	Nil	150	1.0	8.0	....
Canalized creek, 1.5 miles below canal take-off	"	26.0	22.8	5.9	70	"	§101	1.4	7.8	....
At Picard bridge	"	29.0	22.3	6.0	70	"	98	1.4	7.8	....
4.0 miles from Niagara river	"	26.0	22.3	5.8	68	"	98	1.4	7.8	....
1.5 " " " "	"	23.8	22.0	6.8	78	"	97	1.3	7.9	....
Entering Tonawanda, 0.6 miles from Niagara	"	23.5	21.5	6.1	70	"	97	1.7	7.8	....
At confluence with Niagara, surface	"	21.0	21.0	6.6	75	"	97	0.8	7.9	....
" " " ", bottom (17 ft. deep)	"	21.0	21.0	6.7	76	"	97	0.8	7.9	....
Buffalo creek:										
3.1 miles from source	Aug. 29	26.0	21.0	6.1	71	Nil	149	4.0	7.6	....
4.9 " " ", at Dutchtown	"	24.5	24.5	7.5	93	3.2	145	Nil	8.2	0.6
7.4 " " ", at Holland road	"	22.0	25.0	7.3	91	4.9	155	"	8.3	0.5
500 feet below stream from Java Center	"	27.5	27.5	8.0	104	5.2	147	"	8.3	....
9.7 miles from source, at Java Village	Aug. 28	28.0	26.0	7.3	92	3.0	141	"	8.3	1.0
200 feet below creamery stream, Strykersville	Aug. 29	23.5	22.0	7.4	87	0.5	155	"	8.2	0.6

‡ Figures express the acidity of the stream in terms of normality.
§ Canal reverses the normal direction of flow of Tonawanda creek, drawing water inland from Niagara.

4

SERIES III: CHEMICAL ANALYSES — STREAMS OF THE ERIE-NIAGARA WATERSHED — (*Concluded*)

PLACE SAMPLED AND REMARKS	Date	TEMPERATURE DEGREES CENTIGRADE		DISSOLVED OXYGEN		ALKALINITY CALCULATED AS P.P.M. CALCIUM CARBONATE		Free carbon dioxide p.p.m.	pH	Ten day biochemical oxygen demand p.p.m.
		Air	Water	Parts per million	Per cent saturation	Phenolphthalein	Methyl orange			
Buffalo creek — (*continued*)										
15.9 miles from source, at Wales Hollow	Aug. 29	24.0	24.0	7.2	88	2.0	157	Nil	8.2	....
20.4 " " " , at Wales Center	"	25.0	26.0	8.5	107	3.0	149	"	8.2	....
22.9 " " " , at Porterville	Aug. 28	30.0	29.2	8.0	107	4.2	133	"	8.3	....
26.0 " " " , at East Elma	"	29.0	26.5	8.1	103	3.0	133	"	8.2	1.2
29.4 " " "	Aug. 27	29.0	27.5	7.8	101	3.8	135	"	8.3	0.6
32.9 " " " , at Elma	Aug. 25	23.2	23.2	8.0	95	3.5	135	"	8.2	1.3
36.6 " " " , at Blossom	"	23.8	22.2	8.5	99	2.0	124	"	8.2	1.1
40.8 " " " , at Gardenville	Aug. 27	27.5	27.5	9.5	121	4.0	124	"	8.3	....
Below confluence with Cayuga creek	Sept. 13	22.5	24.0	9.1	109	1.8	126	"	8.2	....
At South Ogden Street bridge, Buffalo	Aug. 23	27.0	23.0	8.0	94	1.5	132	"	8.1	7.6
Below Bailey Ave. bridge, water 11 feet deep	"	28.2	25.0	Nil	....	Nil	100	24.0	6.7	18.0
One-quarter mile from lake	Aug. 2	25.5	24.2	"	....	"	135	17.4	7.1	6.3
500 feet from lake, surface	"	25.5	24.0	"	....	"	117	15.1	7.1	....
500 " " " , bottom, water 12 feet deep	"	25.5	24.0	"	....	"	121	16.4	7.1	8.6
At lake between pier ends, sampled at 10 feet	Aug. 23	26.0	22.5	7.8	91	0.6	98	Nil	8.0	5.2
Silver creek:										
Entering town of Silver Creek	Sept. 10	28.0	22.0	9.4	109	0.5	94	"	8.1	....
Tributary No. 1 (Walnutcreek) entering town	"	28.0	22.2	9.2	107	2.0	106	"	8.2	....
Entering Lake Erie	"	27.3	19.3	5.1	56	Nil	116	4.3	7.6	....
Smoke creek:										
2 miles from Lake Erie, garbage littering stream	"	26.5	19.5	7.7	86	"	131	1.4	7.9	....
Below Lackawanna disposal plant effluent	"	26.5	20.2	5.6	63	"	146	12.5	7.4	....
200 feet from lake	"	26.0	31.0	2.9	40	"	118	10.6	7.2	....
Tributary E-36, (Crooked brook):										
2 miles from Lake Erie, above Dunkirk	"	27.0	23.0	7.7	90	"	83	0.7	7.9	....
1.2 " " " " , at Dunkirk	"	27.0	24.0	7.4	89	"	85	2.4	7.7	....
0.5 " " " "	"	27.0	21.8	8.6	100	"	90	1.4	7.8	....
Canadaway creek:										
Entering Fredonia	Sept. 11	27.3	20.5	8.6	97	1.5	114	Nil	8.2	....
Leaving Fredonia	"	22.0	18.5	8.1	88	Nil	127	0.7	7.9	....
0.5 mile below sewage entrance	"	22.0	18.8	3.3	36	"	140	8.8	7.4	....
Above entrance of tributary No. 2 (Beaver creek)	"	23.6	20.2	2.6	29	"	153	7.2	7.6	....
500 feet from lake, minnows and mayflies present	"	24.0	20.5	7.9	89	"	147	1.0	7.9	....

Eighteenmile creek — Pollution: From Hamburg, through tributary No. 5:										
Tributary No. 5 at Hamburg its source	"	25.0	17.0	0.4	4	"	420	38.6	7.0	....
Tributary No. 5, 0.5 mile from Eighteenmile	"	25.0	18.5	7.9	85	"	164	3.1	7.9	....
500 feet above entrance of tributary No. 5	"	26.0	24.5	8.8	107	4.2	116	Nil	8.2	....
500 feet below " " " " "	"	26.0	23.0	8.8	101	2.0	148	"	7.9	....
Tributary No. 13 of Sister creek — Pollution: Canneries at North Collins:										
200 feet above tributary No. 2	"	27.0	24.0	7.9	96	Nil	96	1.0	7.6	Non-carbonate hardness as calcium sulphate p.p.m.
200 feet below tributary No. 2	"	26.0	24.0	5.8	70	"	122	5.5	7.5	
Entering Sister creek	"	23.5	22.0	6.8	79	"	78	4.2	7.4	
Ledge creek, tributary No. 11 of Tonawanda creek:										
1 mile from Tonawanda creek, above Murder creek	Sept. 13	23.5	18.5	8.5	92	"	171	0.5	8.1	....
2.5 miles " "	"	24.5	17.5	9.1	97	"	178	Nil	8.1	....
2.5 miles from source	"	22.5	18.5	10.4	113	"	177	"	8.1	....
1.0 " " "	"	22.8	22.0	6.9	80	"	136	3.4	7.8	123
Water from gypsum mines entering creek about 2 miles from source	"	22.8	10.5	....	....	....	....	....	...	124
Springs at source of tributary No. 8, Ellicott creek:										
At uppermost spring hole	Sept. 17	18.8	9.0	0.4	4	Nil	182	13.5	7.4	115
At bridge, 300 feet below	"	16.5	10.5	4.2	38	"	180	7.7	7.6	....
Skim lake:										
Surface sample	Sept. 19	14.5	17.0	8.9	97	3.5	77	Nil	8.5	....
Bottom sample at depth of 5 to 6 feet	"	14.5	12.7	13.5	133	2.5	110	"	8.3	....

SERIES IV: CHEMICAL ANALYSES — CATTARAUGUS CREEK

PLACE SAMPLED AND REMARKS	Date	Temperature Degrees Centigrade		Dissolved Oxygen		Alkalinity Calculated as p.p.m. Calcium Carbonate		Free carbon dioxide p.p.m.	pH	Ten day biochemical oxygen demand p.p.m.
		Air	Water	Parts per million	Per cent saturation	Phenolphthalein	Methyl orange			
0.5 mile from source, tiny riffly stream	Aug. 1	21.0	18.4	7.8	88	Nil	95	2.4	7.6	....
1.6 miles " " , two combined streams	"	19.5	16.6	7.8	84	"	120	1.4	7.8	....
0.5 mile below Java lake, brownish water	"	22.6	20.0	7.3	83	"	88	2.4	7.8	....
6.9 miles from source	"	25.0	19.0	9.0	102	0.9	121	Nil	8.1	....
8.2 " " " , at East Arcade	"	25.0	19.0	9.3	105	1.2	126	"	8.1	....
11.2 " " " , at Arcade Center	"	25.2	22.8	8.6	104	1.8	121	"	8.2	....
At Arcade, garbage in stream, private sewers	"	23.5	25.0	7.8	98	1.8	124	"	8.2	....
13.8 miles from source, leaving Arcade	Aug. 2	24.8	20.8	10.2	119	2.5	124	"	8.3	....
15.3 " " "	"	26.9	21.2	9.5	111	3.1	124	"	8.5	....
18.5 " " "	"	24.5	23.6	7.4	91	1.8	127	"	8.2	....
20.7 " " "	"	23.8	23.5	7.5	91	1.8	130	"	8.2	....
23.5 " " "	"	23.5	24.0	7.5	93	1.2	134	"	8.2	....
25.4 " " " , stream turbid henceforth	Aug. 3	24.0	20.0	7.9	90	Nil	139	0.5	8.1	....
28.4 " " "	"	25.5	22.0	8.3	98	0.6	138	Nil	8.2	....
32.0 " " " , just below Spring brook	"	26.0	22.4	8.1	97	0.6	138	"	8.2	....
34.0 " " "	"	29.5	23.0	8.0	97	0.6	136	"	8.2	....
37.8 " " "	"	28.8	25.0	7.8	97	1.2	135	"	8.2	....
41.2 " " "	"	30.0	26.8	7.4	95	1.2	133	"	8.2	....
45.9 " " "	Aug. 10	23.5	26.0	7.6	96	3.1	136	"	8.3	....
Entering Gowanda *(No. 1)	July 18	29.2	26.0	8.0	101	2.0	125	"	8.3	1.0
" " (No. 2)	Aug. 7	27.5	25.0	8.0	99	3.1	129	"	8.3	0.9
At crest of dam in Gowanda (No. 3)	July 18	29.5	27.1	6.0	77	11.4	131	"	8.7	20.0
" " " " " " (No. 4)	Aug. 7	25.8	26.0	6.6	83	18.5	143	"	9.0	14.6
Leaving Gowanda, 500 feet below bridge (No. 5)	July 18	28.5	26.5	5.8	73	6.2	127	"	8.6	11.0
" " " " " (No. 6)	Aug. 7	25.5	26.3	6.4	81	7.4	135	"	8.7	10.0
1 mile below Gowanda (No. 7)	July 18	30.0	27.0	4.5	58	4.3	129	"	8.3	10.0
3 miles " "	Aug. 7	26.0	27.0	5.6	72	3.7	145	"	8.5	10.4
At Versailles (No. 8)	"	25.0	27.0	6.6	84	4.3	132	"	8.3	14.6
9.7 miles from Lake Erie	Aug. 8	28.0	28.3	6.7	87	0.6	138	"	8.1	....
6.7 " " " "	"	27.5	24.8	6.3	77	Nil	139	0.7	8.1	....
At Irving, 500 feet above cannery effluent	"	25.0	23.2	5.6	67	"	138	1.4	7.8	....
At Irving, 500 feet below cannery effluent	"	25.5	23.2	5.3	63	"	138	2.4	7.8	....
2,000 feet from lake, about six feet deep	July 27	25.2	24.8	5.8	71	"	149	1.5	7.9	5.2

*** Figures identify samples used for nitrogen determinations; all values expressed in parts per million.**

Nitrogen Analyses

Sample No.	Ammonia		Nitrite nitrogen	Nitrate nitrogen	Organic nitrogen
	Free	Albuminoid			
1	0.012	0.052	0.003	0.25	....
2	0.014	0.104	0.006	0.20	0.38
3	1.04	1.92	0.012	0.20	....
4	1.30	2.18	0.017	0.18	....
5	1.22	1.43	0.007	0.25	....
6	1.08	2.15	0.012	0.19	0.96
7	1.25	1.66	0.009	0.20	....
8	1.11	1.57	0.014	0.22	....

IV. THE BIOLOGICAL INVESTIGATIONS OF POLLUTION IN THE ERIE-NIAGARA WATERSHED

By N. L. CUTLER

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The biological investigations of the conditions of pollution in the Erie-Niagara watershed were divided into, (1) Lake Erie and Niagara river, and (2) streams. In a biological study of a lake bottom it is harder to define the three characteristic pollution zones that are usually found in stream studies, i.e. (a) zone of recent pollution, (b) septic zone, (c) zone of recovery. In an open body of water such as Lake Erie a septic zone is never developed due to the rapid dispersion of the polluting substances though areas confined, as by a breakwater, may approach this condition.

Methods.— The methods and apparatus employed in examining a stream or lake bottom depend on the conditions encountered. In shallow streams the stones may be turned over by hand and specimens examined or the "Needham dredge", a screen-like scoop with a handle attached, may be used to catch the forms loosened by stirring up the bottom. In deeper water the Ekman or the Petersen bottom sampler are used. These consist essentially of two jaws which are lowered in the "open" position and then when closed on the bottom scoop up a certain definite area of bottom material. The Petersen sampler weighing 35 lbs. was used exclusively on Lake Erie and the Niagara river. The contents of the sampler when brought to the surface were sifted through screen bottom pans to strain out organisms, which were then preserved for further study.

Lake Erie and Niagara River.—Lake Erie shore: An attempt was made to get bottom samples at all points along the Lake Erie shore where chemical samples were taken*. This was not always possible because of the shale rock formation. Samples were satisfactorily obtained with the Petersen sampler at the New York-Pennsylvania border, Dunkirk harbor, Cattaraugus creek, Eighteenmile creek and Rush creek.

At the New York-Pennsylvania border and at Eighteenmile creek the samples taken showed no evidences of pollution.

Dunkirk harbor had heavy sludge deposits, luxuriant weed beds, and an abundance of foul water organisms, particularly west of the government dock. East of the dock the sewage was readily dispelled into the lake. This condition of the harbor, it is expected, will be corrected shortly when the new disposal plant is installed.

Cattaraugus creek carries down a heavy load of pollution from Gowanda which is somewhat augmented at Irving and washes

* See Series 1, page 120.

out into the lake, the sludge deposits get into the nets of the fishermen and cause considerable annoyance.

Rush creek, as may be seen by referring to the tabulated report of pollution, carries steel mill wastes into the lake. The effect on the lake bottom was to cause an almost total absence of any form of plant or animal life.

Buffalo harbor and Niagara river: From the Lackawanna plant of the Bethlehem Steel Co., where the water takes on a murky red colour, from the steel plant wastes, one may follow the pollution of deposits along the American shore almost to Niagara Falls. The sewage and industrial waste from Lackawanna has hardly started to dispel itself before being augmented by the influx of the turbid, sluggishly flowing Buffalo creek, carrying the industrial effluents and raw sewage of a great part of Buffalo. Through the harbor and ship canal one sewer after another adds its burden causing the bottom to be covered with foul-smelling sludge and furnishing ideal surroundings for the growth of such foul-water organisms as Tubifex, pollution forms of blue-green algae, etc. Below the government lock additional sewage from Buffalo, wastes from textile plants, paper mills, etc., and, farther down, the sewage from the Tonawandas, empty into the river causing heavy sludge deposits near their point of entrance. Out in the swifter part of the river the bottom is swept more or less clean by the current and samples were more difficult to obtain, but it is doubtful if conditions are as bad where the full force of the river is evidenced as in the slower parts along the shore. This fact is well shown in the chemical analyses.[1] The profusion of weed beds with their plentiful supply of snails, (Physa, Planorbis) etc., adhering to them, growing along the shores would indicate that the great powers of assimilation of the river kept it for the most part in a stage of recovery.

Previous investigations[2] indicated that pollution was confined more or less to the American shore on the upper river. This was borne out in the present investigation as many fresh water insects such as mayflies and caddisflies, fresh water mollusks such as Campeloma and Sphaerium, and many green algae were plentiful on the Canadian side of Grand island.

In the lower river conditions were much improved due to aeration by the falls but abundant weed beds still attested to the rich organic content of the water.

Streams.— Sewage and Industrial Pollution: Depew and Lancaster situated one below the other on Cayuga creek maintain in this stream conditions of heavy pollution until it becomes a part of Buffalo creek. This latter stream, in its lower 6 miles to the lake as indicated above serves as the carrier for a great part of Buffalo's sewage and industrial effluents. It receives an almost unbelievable burden of such wastes, which keep it in a strongly septic and highly toxic state throughout. Smoke creek, though

[1] See reports of A. Zillig, page 56, R. Williams, p. 58, and F. E. Wagner, p. 107

[2] International Joint Commission on the pollution of boundary waters.

much smaller, is almost as bad as it approaches the lake. The sewage disposal plant of Batavia is only partly effective and pollutes Tonawanda creek for a distance of 4 miles. East Aurora, with a sprinkling filter disposal plant, a type considered one of the most effective when properly operated, by-passes most of its sewage directly into tributary 14 of Cazenovia creek. A case that is, unfortunately, not without its parallels in other watersheds studied. Canadaway creek, though showing evidences of its pollution from Fredonia at present, should be entirely restored following the installation of the disposal plant there. Of the 30 miles polluted by these wastes, 27 would be suitable for fishing streams.

Milk Pollution.— By referring to the table of pollution it will be seen that there are very few milk plants in this watershed. The milk plant at Cattaraugus has a 12-inch waste pipe emptying into tributary 7 of the south branch of Cattaraugus creek which it takes 1¾ miles to recover from. The milk plants at Lime lake and Delevan seriously pollute very desirable fishing streams. The plant of the Merrill-Soule Co. pollutes Cattaraugus creek slightly at Arcade. Their plant at Farmersville Station has one of the most effective milk waste treatment plants in operation—a lime, ferrous sulphate treatment which gives a clear, desirable effluent. Of the total of 10 miles polluted by milk waste all would be suitable as fishing streams.

Oil, Acid and Iron Pollution.— Rush creek deserves special mention as being an extreme case of this combination of pollution, which it receives from the Seneca Iron and Steel Co. In the upper stretches of the creek oil pollution predominates and kills off all forms of organic life with the exception of a fungus, which seems to flourish midst such strong pollution. Near the mouth of the creek an enormously rich growth of Euglena sp., which the high acidity appears to favor, flourishes over the sides and bottom. Such a rich growth of this form is rather rare.

Glue and Tannery Wastes.— Cattaraugus creek at Gowanda receives a load of waste materials from the glue and tanning factory located there which it is unable to assimilate until its waters are dissipated in Lake Erie. Above these two plants many fresh water forms abound such as mayflies (Chirotenetes, Caenis, Heptagenia), caddisflies (Hydropsyche), stoneflies (Acroneuria, Perla), etc. A few hundred yards farther downstream, after the effluents have entered, all fresh water forms have disappeared, 6 inches of fibrous sludge covers the bottom just above the power dam and a mat-like growth of fungus (Sphaerotilus) covers the stones in the riffles. From this point to the mouth of the creek conditions of severe, though somewhat diminished pollution exist. In the pools, sludge containing abundant Tubifex is found, blue-green algae (Oscillatoria, Merismopedia, etc.) abound, Chironomidae are plentiful, and none but the more tolerant fish life is present.[1] Not only is 12 miles of what might be a valuable bass stream destroyed, but the sludge deposits extend out into Lake Erie, there causing a clogging of the fishing nets and undoubtedly affecting the bottom life and fish food in that vicinity.

Some effort was put forth this past summer to obtain further information on the biological indicators of pollution. With this end in view several collections of bottom forms were made in Dunkirk and Buffalo harbors and the Niagara river and also in the streams in the watershed. The presence or absence of any particular plant or animal is not, ipso facto, an indication of the condition of a body of water. There must be some few foul water organisms present in fresh water before it becomes polluted or they would not be present to thrive in it after pollution. Thus the sludge worm, *Tubifex tubifex*, is present often in clean water but it *abounds* under conditions of severe pollution. It is the relative abundance of certain foul water organisms and the scarcity of fresh water loving forms that indicate the degree of pollution.

Seining a hole in polluted water

From 31 collections of diatoms, desmids and algae made in polluted waters, over 50 forms have been identified to the genus or species.[2] This number will be greatly increased when the difficult work of separating the many species is completed. From the data obtained the species which showed the greatest abundance throughout a particular type of pollution were selected to be included in the table of indicators given on p.—. Of the 12 different species of mollusks[3] collected 4 are considered as indicative of pollution.

Of the total of 54 miles of stream polluted in the watershed 49 miles would be suitable for fishing streams.

[1] See report of Mr. Greeley, p. 164.

[2] Identifications by P. R. Burkholder.

[3] Identifications by Mrs. I. C. Robertson, Conchologist, Buffalo Museum of Science.

TABULATION OF POLLUTION STUDIES IN ERIE-NIAGARA WATERSHED

TYPE OF POLLUTION	Quadrangle	Township or post office	Stream	Effect on stream and fish life	Miles of stream affected
Sewage and industrial waste	Buffalo	Lackawanna	Smoke creek	Septic condition	$2\frac{1}{4}$
Sewage and industrial waste	Buffalo	Buffalo	Buffalo creek	Septic condition	6
Sewage and industrial waste	Batavia	Batavia	Tonawanda creek	Fresh water life absent	4
Sewage and industrial waste	Depew	Lancaster, Depew	Cayuga creek	Foul water forms abundant	8
Sewage and cannery waste	Dunkirk	Fredonia	Canadaway creek	Moderate at time investigated	4
Sewage and cannery waste	Springville	Springville	Spring branch	Not a fishing stream	1
Sewage	Eden	Hamburg	Eighteenmile creek	Slight, due to small volume sewage	$\frac{1}{2}$
Sewage	Depew	East Aurora	Tributary 17, Cazenovia	Incoming streams greatly assist in recovery.	1
Sewage	Dunkirk	Dunkirk	E. 36	Not a fishing stream	2
Sewage	Silver creek	Silver creek	Silver creek	Severe for short distance to lake	1
Industrial waste	Buffalo	Blasdell	Rush creek	Not a fishing stream	2
Milk waste	Arcade	Java Center	2 of Tributary 58 of Buffalo creek.	Potential	......
Milk waste	Arcade	Arcade	Cattaraugus creek	Fresh water forms reduced	4
Milk waste	Franklinville	Farmersville Station	Elton creek	Potential	......
Milk waste	Franklinville	Lime Lake	Lime Lake outlet	Spoils 2 miles of one of best fishing streams in watershed.	2
Milk waste	Franklinville	Delavan	Elton creek	Fungus abundant, fresh water forms absent.	$1\frac{1}{2}$
Milk waste	Cattaraugus	Cattaraugus	Tributary 7, South branch, Cattaraugus.	Fresh water forms much reduced	$1\frac{1}{4}$
Milk waste	Ellicottville	East Otto	East Otto creek	Slight	$\frac{1}{2}$
Canning wastes	Eden	North Collins	Tributary 13, Sister creek.	Not a fishing stream	$\frac{1}{2}$
Canning wastes	Eden	Collins	Tributary 8, Clear creek.	Plant closed at time of inspection	......
Canning wastes	Cherry creek	Nashville	Tributary 8, Silver creek.	Plant closed at time of inspection	......
Glue and tanning factory wastes.	Cattaraugus	Gowanda	Cattaraugus creek	Severe pollution	12

Indicators Tolerant of Sewage Pollution as Found in the Erie-Niagara Watershed

Blue-Green Algae.
- Oscillatoria sp.
- Phormidium sp.

Green Algae
- Scenedesmus bijuga
- Scenedesmus dimorphus
- Scenedesmus acutiformis
- Scenedesmus quadricauda
- Scenedesmus abundans

Pediastrum Boryanum

Ankistrodesums sp.

Diatoms
- Navicula sp.

Fungus
- Sphaerotilus sp.

Large plants
- Potamogeton pectinatus
- Potamogeton Richardsonii
- Potamogeton natans
- Potamogeton compressus
- Potamogeton pusillus
- Vallisneria americana
- Najas flexilis

Insects
- Eristalis tenax
- Psychoda sp.

Roundworms
- Tubifex tubifex

Mollusca
- Planorbis trivolvis
- Physa Sayi
- Physa heterostropha
- Pisidium variable

V. STUDIES UPON FISH BLOOD AND ITS RELATION TO WATER POLLUTION

By C. M. McCay

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The Blood of Fish as a Reflection of External Environment. — Early physicians recognized the blood as a means of detecting disease. Few applications of diagnosis through the condition of the blood have been possible until the last thirty years, however, due to the tardiness of the chemist in the development of analytical techniques that can be applied to blood. These methods have been applied chiefly to the blood of man and the warm blooded animals, however. The neglect of the study of fish blood has been due to several causes. The first of these is probably the failure of the mass of men to realize that their welfare is closely interwoven with the condition of everything that lives. The second is that fish blood is very difficult to secure and to study due to its property of clotting almost immediately after it is withdrawn from the body.

The great value of a study of fish blood lies in its possibilities of revealing conditions within the body long before there is any outward manifestation. Since only a thin membrame, through which gases pass readily, separates the blood of the fish from the water in which it swims, every unfavorable change in this water must be reflected in the circulating medium. This relationship opens up a new field for consideration by those who are concerned with water pollution and with means of measuring the effects of polluting substances upon the fish life that should exist in every stream used for recreation.

In the next place the blood serves as the most convenient indicator of the condition of the animal body. Before we can proceed far in improving the rearing methods employed in trout hatcheries we must know much more about the fundamental physiology of trout. The blood affords one excellent place to attack. Malnutrition is frequently reflected immediately in the blood. In order to be sure that the fish with which we are stocking our streams are as strong as those with which they must compete under natural conditions every attempt should be made to determine the relative hardiness of hatchery reared trout. Such studies must ultimately check those huge losses which at times are suffered by even well managed hatcheries. The first class modern fish culturist has already awakened to the value of the chemist, physiologist and bacteriologist in his work. Inevitable improvement in methods must result in the course of the next few years.

Finally any advances which are made through the study of fish blood must inevitably further the progress of comparative physiology with an ultimate reaction for human welfare totally outside the purpose of the original work, namely, the improvement of streams and the quality of fish used for stocking.

Blood from natural fish can only be obtained in the field in cooperation with an effective collecting unit that is used to handling live specimens. Transfer to the field laboratory must be carefully made. In the portion of the paper devoted to the experimental work the effects upon the blood of some of the common accidents will be shown.

Experiments Upon Fish Blood.— Three methods are described in most German texts for obtaining samples of blood from fish, slipping the gill, cutting the end of the tail and bleeding from the heart. We have tried all methods and find only the last satisfactory, if one wishes to keep the fish alive and in good condition after the blood has been removed. To the layman this sounds paradoxical since he has been taught since childhood that if the heart of an animal is pierced, life is lost. This is a popular fallacy, however, since the removal of blood from the hearts of rabbits and guinea pigs has been a common practice in bacteriological laboratories for many years.[1] The same technique of taking blood samples from the hearts of dogs has been widely used by the Stanford physiologists.[2] We have extended this technique to rats and swine and used it very extensively during the past three years upon both these species and dogs. That the operation is totally painless is shown by the fact that both dogs and rats frequently rebel when the needle touches the skin but never move when the heart is pierced. Fish, likewise, object to being taken from the water and placed upon their backs but never seem to mind the withdrawal of blood from their hearts.

By cardiac puncture or "heart stabbing" we are thus able to obtain sufficiently large blood samples for many types of analyses. This opens unusual opportunities to the biochemist. This is of special importance since we can employ cold blooded animals whose physiology is somewhat simpler than the higher warm blooded species, to obtain fundamental information that may be applied to reactions among the higher vertebrates.

For the purpose of taking blood from fish we have employed ordinary hypodermic syringes of capacities ranging from two to thirty cubic centimeters, about one ounce. A small syringe is preferable. We have used various sizes of hypodermic needles ranging from 3/4″ in length to 1 1/4″. We prefer 19 gauge although larger needles can be used. In order to prevent clotting we have employed either mineral oil or one of the common salts as sodium citrate. When later analyses are not concerned with fat determinations upon the blood, mineral oil is the most satisfactory. Both the needles and syringe can be well coated with oil. After removal from the animal the blood is placed quickly into a graduated centrifuge tube, containing some crystals of oxalate or citrate. As

[1] Kolmer, *Injection, Immunity*, and *Biologic Therapy*.
[2] E. W. Schultz, Journ. Biol. Chem. (1924) lx 189.

soon as analytical samples have been taken the blood is centrifuged, to a constant cell volume. From the reading on the centrifuge tube the per cent of erythrocytes (red blood cells) by volume can be determined.

In order to obtain blood from fish the heart must first be located and the position of the ventricle must be determined. The ventricle is the safest place to puncture since its thick walls close immediately after the needle is removed. This prevents any hemorrhage after the operation. If several specimens of a given species are available it is best to dissect one and locate the heart accurately. If only one specimen is at hand and blood must be obtained, it is best to place it on its back and to pierce the ventral surface at the half-way point on a line drawn between the foremost points of attachment of the pectoral fins.

This general technique is applicable to all fish except those belonging to the species of catfishes (Ameiurus). For these we have usually opened the gill cover, pierced the membrane directly under the gills, and gone into the heart from the left side with the specimen lying on its right side. We have employed this technique when working upon all closely related species except the large specimen of lake catfish (*Villarius lacustris*). We have been able to obtain samples easily from this specimen by piercing the ventral surface in the manner used normally. The reason for the employment of this special technique in the case of the Ameiurus is the excellent protection of the heart by the pectoral girdle. Unless the specimen is unusually large, one is forced to injure the liver in getting into the ventricle of the heart of species of Ameiurus in this manner.

Varying amounts of blood have been withdrawn from fish. The greatest taken in the course of the experiments are thirty cubic centimeters (about one ounce) in a single bleeding from the 8 pound specimen of lake catfish (*Villarius lacustris*). More could undoubtedly have been obtained but none of our experiments required more than fifteen cubic centimeters. Fifteen cubic centimeter samples have frequently been taken from four and five pound carp without any apparent effect upon their activity or vigor. In contrast to the higher, warm blooded mammals, fish can stand much greater losses of blood. The rat or dog is endangered if more than a fourth of its blood is removed at any one bleeding and if the hemoglobin is reduced below forty to fifty per cent. In contrast, we are able to draw unusually large amounts at one time from a fish and it seldom shows ill effects. We have reduced the hemoglobin of the blood of carp below a value of ten per cent, leaving the healthy fish still able to swim and with normal reactions.

All hemoglobin determinations were made according to the method of Cohen and Smith.* In this method the amount of hemoglobin in the blood is determined by dissolving a carefully measured volume of the unknown blood in tenth normal hydro-

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* Cohen, B. and Smith, A., J. Biol. Chem. (1919) 39, 489.

chloric acid and comparing the depth of color developed with a standard whose hemoglobin content has been determined by the oxygen capacity method of VanSlyke. In staging our values we have placed them in the common terms in which 100 per cent hemoglobin means a blood whose oxygen capacity is 18.5 cc. per 100 cc. of blood. Such blood was originally termed a hundred per cent hemoglobin one because this was established as the average among British citizens. American values seem to be somewhat higher but this meaning is still quite generally used. When fish blood is said to have 60 per cent hemoglobin it may roughly be considered as having three-fifths the hemoglobin value of that of a normal man.

Erythrocyte counts have been made according to the standard procedure using Gower's solution for dilution. Differential stains for white cells have been made with Wright's stain and with the strains of Giemsa and Leischman.*

In the present report we are devoting no section to the differential work upon white cells not because we question its importance but because we have not prepared the adequate drawings and microphotographs which must be included to make any such discussion intelligible. At some future date we hope to present material upon this important and very neglected phase of fish blood. We are especially interested in developing this field in the hope that it may furnish new clues in both fish diseases and injuries to fish through water pollution. In regard to human blood, Todd and Sanford have stated in their text, "Clinical Diagnosis", that a differential count probably "yields more helpful information than any other single procedure in blood examinations".

Before any deviations from the normal can be determined, one must study the blood of a large number of sound fish from relatively pure waters. In Table 1 we have made a preliminary presentation of data upon some species collected in the Erie watershed. These data must not be accepted as standards until they have been verified by many more determinations upon each species.

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* To Drs. Lesch and William F. Jacobs we wish to express our appreciation for stains and assistance in applying staining methods to fish blood.

TABLE 1.— THE HEMOGLOBIN AND ERYTHROCYTE VALUES OF THE BLOOD OF NORMAL FISH

SPECIES	Hemoglobin per cent	Erythrocytes per cubic millimeter
Mooneye (*Hiodon tergisus*)	66	Lost
Yellow perch (*Perca flavescens*)	47	1,100,000
White bass (*Lepidema chrysops*)	73	3,100,000
Water dog (*Necturus maculosus*) [1]	53	56,000
Yellow pike (*Stizostedion vitreum*)	....	1,700,000
Horned dace (*Semotilus atromaculatus*)	94	2,100,000
Small-mouthed bass (*Micropterus dolomieu*)	62	2,200,000
Common shiner (*Notropis cornutus*)	44	1,900,000
White crappie (*Pomoxis annularis*)	....	1,860,000
Sucker (*Moxostoma aureolum*)	80	Lost
Channel cat (*Ictalurus punctatus*)	95	2,400,000
Carp (*Cyprinus carpio*)	66	1,600,000
Cyprinus carpio [2]	30	1,000,000
Ameiurus nebulosus [3]	40	640,000
Cyprinus carpio [4]	102	Lost
Moxostoma aureolum [5]	100	1,500,000

[1] Value furnished through the courtesy of Professor S. H. Gage.
[2] An injured fish.
[3] Fungus growth developed over entire body.
[4] Dying from unknown causes.
[5] Dying from unknown causes.

Table 1 augments the data of previous workers in showing that fish have a comparatively small number of red cells but that these cells contain a considerable amount of hemoglobin. For purposes of comparison it might be well to recall that the average man has about five million erythrocytes per cubic millimeter of blood with a hemoglobin value of slightly more than 100 per cent. The adult rat has 8–12 million erythrocytes with a hemoglobin value of 100–130 per cent. The average goat has 15–20 million erythrocytes with a hemoglobin value of only 80 per cent. In other words fish blood often has as much hemoglobin in two million cells as goat blood has in fifteen million.

In Table 1 a sample from the water dog, *Necturus maculosus*, has been included in order to show the large amount of hemoglobin contained in their cells.

At the bottom of Table 1 have been placed some typical data upon blood from sick or injured fish. These figures show the rapid response of the blood to injuries of the body. A starving animal will frequently show a marked concentration of the blood with increased hemoglobin while many types of malnutrition and diseases show the opposite effect. It is hoped that ultimately such indications can be employed in hatcheries to allow time to check diseases before the fish have started to die.

Effects of Weak Acid Solution upon Fish.—Since acids are among the most common polluting substances found in streams and also since they are frequently employed in trout hatcheries to check the spread of certain infections, studies with very weak acetic acid solutions were undertaken. The general method of the experiment consisted in placing twenty-two liters of water in each of two wooden buckets. Holes were bored in the close fitting tops to allow the passage of glass tubes. Through these tubes air was blown in a constant stream throughout the experiment. To the water in one bucket was added 6 cubic centimeters of glacial acetic acid. This renders the tap water in the bucket very faintly acid. The acid can hardly be tasted. Since these were merely initial experiments, the resulting hydrogen ion concentration was not measured. Fish were placed in aerated solutions of acid and tap water. After a definite period of time they were removed and hemoglobin determinations run upon the blood. Erythrocyte counts were also made at the same time. After the first few runs when it was found that the fish in the bucket of aerated water were unchanged and uninjured, only the acid experiments were continued. In all cases fish left in the acid for even a brief period, and in this very weak acid, showed a skin response in the form of a dense white coating of mucus over the entire body including the eyes. This leads one to wonder whether the much stronger acids in which trout are bathed during hatchery infections produce their effects due to direct action upon the organisms that are attacking the skin or due to the indirect action from the formation of a mucus coating.

Table 2 incorporates some of the preliminary data obtained in the experiments upon acids. Table 3 has been presented to show the number of red cells, erythrocytes, that are required in normal fish to furnish a hundred per cent hemoglobin. This is obtained by dividing the number of red cells formed by the hemoglobin per cent after the per cent is changed to a decimal.

Although the data of these tables are much too meagre to premit of any fair statistical treatment they suggest that the acid causes the number of red cells to diminish without changing the hemoglobin. Such an effect is shown when the number of red cells to contain one hundred per cent hemoglobin is calculated. Since there are some obvious exceptions in these data, nothing more than suggestions can be presented. These, however, afford definite opportunities for much more extensive experimental work.

TABLE 2.— THE EFFECTS UPON FISH BLOOD OF INCREASING THE HYDROGEN ION CONCENTRATION OF THE SURROUNDING WATER

Date	SPECIES	Time in acid	Hemoglobin per cent	Erythrocytes per cm.	Eryhtrocytes volume per cent	Erythrocytes to yield 100 per cent
8/10	Bullhead *Ameiurus nebulosus*).)….	2 hrs…	64	700,000	……	1,100,000
8/14	Bullhead (*Ameiurus nebulosus*)…..	3 hrs…	67	1,095,000	……	1,600,000
8/14	Pike (*Esox lucius*)…………….	1 hr….	57	1,460,000	20	2,600,000
8/29	Bullhead (*Ameiurus nebulosus*)…..	1 hr….	80	1,420,000	26	1,800,000
8/29	Goldfish (*Carassius auratus*)…….	1 hr….	47	690,000	27	1,500,000
8/30	Carp (*Cyprinus carpio*)…………	½ hr….	73	830,000	……	1,100,000
8/30	Carp (*Cyprinus carpio*)…………	½ hr….	100	710,000	……	700,000
9/7	Carp (*Cyrpinus carpio*)…………	1 hr….	65	1,790,000	35	2,700,000
9/7	Bullhead (*Ameiurus nebulosus*)…..	1 hr….	60	1,050,000	25	1,700,000
	CONTROL EXPERIMENTS IN WATER ONLY					
8/10	Bullhead (*Ameiurus nebulosus*)…..	2 hrs…	64	1,230,000	……	1,900,000
917	Bullhead (*Ameiurus nebulosus*)…..	1 hr….	80	1,410,000	30	1,800,000

In Tables 4, 5, 6, 7 and 8, we have included data to show the resistance of several species of fish to severe hemorrhage. This type of work opens up rich possibilites in several directions. In the first place it demonstrates the remarkable factors of safety presented in the blood. In Table 6 we have shown the results from constantly removing the blood from a carp. In spite of a reduction to 7 per cent hemoglobin and a respiratory pigment that occupied three per cent of the whole blood volume, this animal could live and swim normally. This factor of safety explains why fish can frequently enter very badly polluted areas with impunity. Although the oxygen of these areas may be very deficient, the fish can survive until it escapes.

In the next place it shows the possibilities of using the fish as a test animal for foodstuffs responsible for blood formation in the body. This is of special importance when we consider the huge tonnage of liver that is now being consumed daily by those suffering from various anemias. To speed up progress in locating foodstuffs that are as effective as liver it is essential that we have good test animals. If we can bleed an animal like a carp, then feed it a given diet and measure the rate of recovery of its red blood corpuscles, we have added one more valuable animal to those few now used for this important problem. An initial experiment in this direction is shown in Table 7. This specimen of *Ameiurus nebulosus*, the common bullhead, was able to effectively regenerate its blood because we fed it a diet of raw liver. A control, which was run at the same time and not fed, showed no regeneration. In Table 8 we have shown the effects of constantly bleeding a pike without permitting it to have feed.

TABLE 3.— NORMAL NUMBERS OF ERYTHROCYTES TO YIELD 100 PER CENT HEMOGLOBIN

SPECIES (Normal condition)	Erythrocytes per cm.	Hemo-globin	Erythrocytes per 100 per cent hemoglobin
Carp (*Cyprinus carpio*)	1,600,000	66	2,400,000
Carp (*Cyprinus carpio*)	1,400,000	80	1,800,000
Carp (*Cyprinus carpio*)	1,700,000	80	2,100,000
Carp (*Cyprinus carpio*)	1,500,000	67	2,300,000
Carp (*Cyprinus carpio*)	1,800,000	65	2,700,000
Bullhead (*Ameiurus nebulosus*)	2,800,000	96	2,900,000
Bullhead (*Ameiurus nebulosus*)	1,300,000	62	2,100,000
Bullhead (*Ameiurus nebulosus*)	1,300,000	80	1,600,000

All these tables and all our experiments thus far have shown one development for which we have no explanation. After the first removal of blood from a fish, the level of hemoglobin and red cell count sinks to about two-thirds the normal value. After this the reduction rate seems considerably slower. It seems as if the fish does not draw upon its reserves until after it has suffered a reduction that is well below the normal. This illustrates the unusual factor of safety a fish has for swimming through waters of low oxygen content. This is an interesting contrast to our experience with white rats who will practically exhaust their reserves in an effort to maintain their initial level of hemoglobin and red cells.

In Table 5 we have assembled data for the specimen upon whose blood the most studies have been carried out. Dr. Youngberg[1] studied the phosphorous distribution upon three different samples of this blood. As a concluding experiment we determined the blood volume by injecting a solution of Evans Vital Red directly into the circulation in the ventricle of the heart. After allowing the fish to swim for six minutes another blood sample was withdrawn and the blood volume determined by the method of H. Bakuin and H. Rivkin, employed upon babies.[2] This yielded a value which showed the blood volume to be eight per cent of the body weight. While we consider this value too high, other data indicate that it should lie somewhere between three and five per cent of the total body weight.

[1] Dr. Guy Youngberg of the University of Buffalo School of Medicine renderep important assistance by cooperating with Dr. McCay in these studies.

[2] Am. J. Dis. Children (1924) *27* p. 340.

TABLE 4.— EFFECT OF BLOOD REMOVAL UPON ROCK BASS (*Ambloplites rupestris*)
WEIGHT OF SPECIMEN 325 grams

DATE	Volume removed	Hemoglobin per cent	Erythrocytes per cm.	Erythrocytes vol. per cent
8/29	2	Clotted before sampling		....
8/30	1.6	75	1,450,000	21
8/31	2.2	59	1,170,000	24
9/5	2.2	44	1,500,000	20
9/5	1.1	47	1,130,000	14

This last sample was taken one hour after the previous one. A series of samples were taken after this one but they clotted so rapidly that no determinations could be run. In contrast to its control, this rock bass turned light in color over its entire body during the last period of the experiment.

TABLE 5.— EFFECT OF BLOOD REMOVAL UPON LAKE CATFISH (*Villarius lacustris*)
WEIGHT OF SPECIMEN AT END OF EXPERIMENT. 4,000 GRAMS (ABOUT 8 LBS.)

DATE	Volume removed cc.	Hemoglobin per cent	Erythrocytes per cm.	Erythrocytes vol. per cent
7/10	2	Lost	2,100,000	....
7/11	2	80	1,900,000	....
7/12	Fed raw liver		....	....
7/16	30	85	2,300,000	41
7/30	15	51	1,200,000	21
7/31	Fed raw liver		....	....
8/6	15	57	1,300,000	22
8/17	Ran a blood volume by the dye method			

TABLE 6.— EFFECT OF BLOOD REMOVAL UPON CARP (*Cyprinus carpio*)
WEIGHT OF SPECIMEN, 600 GRAMS

DATE	Volume removed cc.	Hemoglobin per cent	Erythrocytes per cm.	Erythrocytes vol. per cent
8/13	2	67	1,465,000	25
8/19	1.9	50	770,000	18
8/23	2	58	1,000,000	....
8/28	1.7	40	Lost	....
8/28	5.1	47	Lost	20 (4 hrs. later than first sample.)
8/28	5.6	32	Lost	12 (5 hrs. later than first sample.)
8/28	2.3	....	....	(8 hrs. later than first sample.)
8/28	2.0	....	....	(9 hrs. later thna first sample.)
8/28	1.3	7	....	3 (9 hrs. later than first sample.)

TABLE 7.— EFFECT OF BLOOD REMOVAL UPON COMMON BULLHEAD (*Ameiurus nebulosus*)
Weight of specimen, 180 grams

DATE	Volume removed cc.	Hemoglobin per cent	Erythrocytes per cm.	Erythrocytes vol. per cent
8/2	1	80	1,280,000	....
8/6	1	55	1,000,000	....
8/13	1	34	880,000	....
8/23	0.8	36	750,000	19
Fed considerable amounts of raw liver during this period.				
9/14	1.5	67	1,330,000	24

TABLE 8.— EFFECT OF BLOOD REMOVAL UPON PICKEREL (*Esox lucius*).
Weight of specimen, 225 grams

DATE	Volume removed cc.	Hemoglobin per cent	Erythrocytes per cm.	Erythrocytes vol. per cent
8/2	1	58	....	....
8/3	1.5	50	....	....
8/8	0.5	Lost	....	....
8/9	1.0	36	880,000	....
8/13	1.5	33	1,000,000	....
8/19	0.6	47	1,260,000	23
8/23	1.0	36	850,000	15
8/28	1.3	33	790,000	15
8/31	0.8	32	760,000	15

In conclusion we wish to state that a mere beginning has been made in a vast field of fundamental physiology. Its extension must ultimately reflect in marked improvements in both the quality and quantity of fish that inhabit our streams through improvements in both the quality of the waters and the fish.

Today we know practically nothing of fish physiology. The poverty of our information is very evident in the field of fish blood. Since the determining factors that decide whether fish can live in a stream reflect immediately in the blood, this very important field must be exploited with the tools of modern biochemistry. After the fundamental information has been acquired, it has an immense field of application in determining which streams are fit for fish life and how depleted streams should be changed for their improvement.

VI. FISHES OF THE ERIE-NIAGARA WATERSHED

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As in the two preceding watershed surveys, the program included a study of the fish life of the region. The problem was, primarily, to gather data regarding the distribution and habits of the various species of fishes, the conditions of environment under which they are found, their relative abundance, and their relative economic importance. As a part of the work, collections were supplied for stomach examinations, for physiological experiments, for parasite examination and for the colored illustrations.

The collecting party was made up of seven members and was equipped to divide into three sub-units* or to work as one unit. Collections, totalling over 2,000 lots of specimens, were made in Lake Erie, the Niagara river and in all tributary stream systems, as well as in ponds and small lakes of the region. Representative series of specimens have been placed on record at the New York State Museum at Albany. The chief reliance in collecting was upon a number of fine mesh seines, ranging from 6 to 200 feet in length. Gill nets formed an important supplement to these. Fyke nets, trammel nets, spears and bobinette dip nets were used as circumstances required. Collecting was done by day, usually, but much seining was done at night in Lake Erie, since better catches could be secured then during the warmer weather.

Considerable work had been done on the fishes of the region previous to the survey, although this area had never been so extensively collected. A review of the information in regard to the species known from Lake Erie may be found in "A Provisional List of the Fishes of Lake Erie" by J. R. Dymond.[1] Additional records are given in "A Check-List of the Fishes of the Great Lakes and Tributary Waters," by C. L. Hubbs.[2] An account of fish life in streams near Buffalo is presented in "A Preliminary Report on a Fish Survey in Western New York," by T. L. Hankinson.[3] Several interesting records were added from specimens at the United States National Museum which were collected by A. J. Woolman in 1893. From June 1 to June 15, 1928, T. L. Hankinson made collections in streams of the eastern part of the drainage, and provided many of the specimens used in making the

* Mr. T. T. Odell, assisted by Mr. F. J. Trembley, gave particular attention to collecting along the shore of Lake Erie. Dr. D. J. Leffingwell, with Mr. W. C. Ritter, seined in streams primarily. The writer, assisted by Mr. C. E. Van Deman, acted as a separate sub-unit or, more often, worked with either of the other groups. Mrs. J. R. Greeley served as curator of the collections, labelling and cataloguing the specimens.

[1] Publications of the Ontario Fisheries Research Laboratory No. 4, 1922.

[2] Univ. of Mich. Museum of Zool. Miscell. Publications No. 15, 1926.

[3] Bulletin of the Buffalo Society of Natural Sciences, Vol. XIII, 1924.

illustrations, as well as valuable data regarding distribution of many species.

General Nature of the Region.— The New York state part of the Lake Erie watershed, together with the Niagara river drainage, comprises an area of 2,440 square miles, lying entirely within the glaciated territory of the State. The highest points of the watershed are toward the south and east where all of the longer tributary streams have their sources. The greatest elevations are at the headwaters of Cattaraugus creek, tributaries of which have their sources at points over 1,900 feet above sea level. The lowest point is at the mouth of the Niagara river, at an elevation of 246 feet. Near the lake shore, the slope is uniformly gentle, the hills being remote from the shore. However, at the western border of the state the hills are closer to the shore, and at the vicinity of Westfield the streams are precipitous and very short.

Fish Distribution.— In the region studied 94 species (including sub-species) of fishes were found by the survey party. Previous records, mainly from other parts of Lake Erie, bring the total list up to 116 species. These will be found listed, and briefly discussed, in the annotated list.[1]

Considering the subdivisions of the drainage area, fish are distributed as follows: Lake Erie 95 species, Lake Erie tributaries 73 species, the Niagara river 49 species and Niagara river tributaries 51 species.[2]

It may be of interest to discuss, briefly, the relationships of the fish fauna of the area under consideration with that of other watersheds. Lake Erie resembles the Great Lakes west of it in having many Mississippi drainage species, examples of which are the white bass, Storer's chub and the white carp. Still others of its fishes are species of northern distribution, such as the ling, whitefish and fine-scaled sucker. Lake Erie tributaries show relationships with streams west of them, especially in such Mississippi drainage forms as the rainbow darter, and the big-eyed chub. The upper Niagara river has practically the same species as Lake Erie, while the lower Niagara river is much like Lake Ontario having, in common with it, a few distinctive Atlantic coast fishes, as the sawbelly and two-spined stickleback. Niagara river tributaries are closely related in respect of fish fauna to Lake Ontario tributaries, but have one or two western species. At present there is opportunity for species to extend their ranges eastward or westward by means of the Barge canal.

A glance at the geological history of the Great Lakes throws light on the problem of the present distribution of the fish of these waters. Before glaciation the area was drained by the great Laurentian river flowing to the Atlantic and following much the same course as the present drainage, except that there were no

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[1] See page 166.
[2] See page 164.

Great Lakes through which to flow. Upon glaciation the fish life of the area must either have been destroyed or forced southward. With recession of the ice sheet, fish could have gained access to the great glacial lakes, since these overflowed southward into the Mississippi drainage. Coleman[1] states "The Mississippi and its tributaries supplied a harbour of refuge when the northern part of the continent was ice-covered and lifeless, and colonized the lakes and rivers which arose after the melting of the ice sheets." He substantiates this view upon evidence of fossil mollusks and other forms of life. Late stages in the melting of the ice uncovered outlets lower than the Mississippi one, and the Great Lakes overflowed to the Atlantic. There was an invasion of the waters of this ocean into Lake Ontario which may account for certain of the differences between it and Lake Erie in relation to fish fauna.

Ecological Data in Regard to Problems of Stocking.— The fact that each species has its own requirements as to conditions of environment is of fundamental importance in the matter of natural distribution and in the practical problems of stocking waters with fish. The conditions as to food, shelter, spawning grounds, chemical content of the water and temperature are decisive factors. The size of stream or other body of water, the type of current and bottom must be considered. The problem is further complicated by the effects of competition between the various species and by the activities of parasites, natural enemies and of man.

When the particular requirements for a species can be analyzed, the problem of increasing its numbers becomes more simple. A limited number of fishes has been studied thoroughly enough so that waters may be successfully stocked with them. This is true of the brook trout and a few others, but there are very many species that are greatly in need of study as a guide to practical problems of conserving them in a wild state and of increasing the supply by fish cultural methods.

In so far as possible, ecological data was gathered for all species of fish collected. The type of bottom, current and the temperatures were observed at each collecting station. Space forbids complete tabulation of this data, but brief notes on the type of environment are given, for many species, in the annotated list.

Food and Game Fishes.—Of the 116 species considered in the annotated list, at least 36 are important in greater or less degree economically, being used either in the commercial fisheries, or being caught by anglers, or serving both purposes. General notes as to such importance are given under the accounts of the various species. The food and game fishes are: sturgeon, lake herring, whitefish, brown trout, rainbow trout, steelhead trout, lake trout, brook trout, buffalo mullet, common sucker, red-fin suckers (4

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[1] Coleman, A. P. Glacial and Post-Glacial Lakes in Ontario. Publications of the Ontario Fisheries Research Laboratories X, 1922.

species), carp, catfish (2 species), bullheads (2 species), chain pickerel, northern pike, muskalonge, eel, white bass, yellow perch, sauger, yellow pike, blue pike, black bass (2 species), sunfish (2 species), rock bass, crappie (2 species), sheepshead and ling.

Commercial Fisheries.—Commercial fishing within the region covered by the survey[1], is centered mainly at Dunkirk, Irving, and Barcelona which are ports from which gill-net boats carry on a fishery of considerable importance. New York State prohibits the use of pound nets, although these devices are extensively used in

The type of gill-net boat used on Lake Erie

the western parts of Lake Erie and along the Canadian side. Seining is carried on only in lower Cattaraugus creek. Set lines are a means of taking certain species and spears are used to take fish in the Niagara river and in many creeks.

Statistics of the Great Lakes fisheries have been gathered by the United States Bureau of Fisheries over a long period of years. An excellent account of the fishing industry is that prepared by Walter Koeltz.[2] A more recent one is a bulletin by O. E. Sette.[3] It is noteworthy that Lake Erie ranks first among the Great Lakes

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[1] Through courtesy of Mr. M. W. Brackett of the Conservation Department the following data pertaining to equipment used in the New York State fisheries of the Erie-Niagara watershed is available: There are ten boats fishing gill nets out of Barcelona; seventeen out of Dunkirk; two out of Irving; one out of Silver creek; one out of Angola; two out of Lackawanna and seven out of Buffalo. There are twelve seine licenses issued for Cattaraugus creek from Lake Erie to the Snow farm. Licensed set lines number sixty-six in Lake Erie and forty-one in the Niagara river. The wholesale fish houses number seventeen in all, one being at Barcelona; three at Dunkirk; one at Irving; eleven at Buffalo and one at Lewiston.

[2] Fishing industry of the Great Lakes. Appendix XI, Report of U. S. Commissioner of Fisheries, 1925.

[3] Fishing Industries of the United States. Appendix V, Report of U. S. Commissioner of Fisheries, 1927.

in production and that, unlike others of the Great Lakes, the bulk of the production is of "rough fish", species other than the white-fish and herring. This may not hold for New York State in normal years.

The important commercial species which are taken in the gill net fishery within New York boundaries are herring, blue pike, perch, yellow pike, suckers, whitefish, saugers and trout. Less important in gill net catches are ling, white bass, red-fin suckers, rock bass and occasional other species. Carp, suckers, red-fin suckers, catfish (2 species), buffalo mullet, white bass, sheepshead, bullheads and others are taken with seines, principally in spring and early summer. Set lines are the most important means of taking catfish and a few sturgeon are so captured. The fish traps of the lower Niagara river are reported to capture a few sturgeon, as well as perch and blue pike. Since the gill net fishery is carried on, with some interruptions all summer, there was some opportunity to gather data on catches made by this apparatus.

As pointed out by Koeltz,* the most valuable production of Lake Erie is that of "rough fish". This author further brings out that a high production has been maintained only by means of utilizing additional species and utilizing more equipment than was formerly used. As the numbers of certain of the more highly prized species, such as whitefish, become reduced, it has been found profitable to turn to the less highly prized but more plentiful ones, as the sucker. Consequently, at the present time there is danger of depletion not only of the supply of the first class fish, but also of these others which have grown more valuable. Production should be carefully watched, and when it is apparent that the supply of any species is becoming less, steps toward conserving that supply should be taken. At present, only 4 of the 22 species of commercial fish receive any protection† within the New York State part of Lake Erie: The whitefish and sturgeon are protected by size limit; the yellow pike by size limit and closed season; and the lake trout by size limit only. Of the commercial group, only 4 species, the whitefish, herring, yellow pike (pike-perch) and yellow perch are propagated within the state.

Angling.— The number of persons engaged in fishing as sport is very large in the Erie-Niagara watershed. This is a thickly populated area, with good roads and it is not surprising that practically every body of water that contains any game fish receives much attention from hook and line fishermen. The numbers of the trout, bass, and other choice game fish are kept rather low in most waters. When the fishing for these fish is poor, anglers turn to the less esteemed, but nevertheless desirable species such as the pickerel (northern pike), the perch and the rock bass, just as in the commercial fishery it has been necessary to turn toward the rough fish to keep production high. There is practically no species

* Loc. cit.

† See N. Y. State Conservation Law for 1928.

of fish that can be taken by hook and line that is not sought after by someone. The following are more or less important as anglers' fish: brook trout, brown trout, small-mouthed bass, perch, pickerel (northern pike), yellow pike (pike-perch), rock bass, large-mouthed bass, rainbow trout, muskalonge, bullhead (2 species), catfish (2 species), common sunfish, common sucker, red-fin sucker (4 species), sheepshead, eel, chain pickerel, white bass, sauger, crappie and bluegill sunfish. The last 2 species are too uncommon to furnish much fishing at present but are being recommended for stocking small ponds.[1] Large numbers of brook, brown, and rainbow trout are planted in streams of the area each year. Stocking[2] has been done with small-mouthed bass, yellow pike (pike-perch), yellow perch, muskalonge, and steelhead trout and probably with a few other species of which we have no record.

There is a considerable amount of spearing of coarse fish that is carried on as sport fishing, that is, non-commercial. This is confined largely to the spring of the year when suckers, red-fin suckers, carp, and catfish enter streams to spawn. Catfish, at least, do not appear to be sufficienly common to make it advisable to permit this to occur without danger of depletion of the supply. Spearing is most effective when fish are on their spawning grounds and should not be allowed unless it is evident that the supply will stand this reduction of breeders.

Non-Food, Non-Game Fishes.— The greater number of the species, 58 [considering only those of which specimens were found within the region], would come under this designation. These may be summarized as follows: Lampreys (3 species), gar, moon-eye, hog sucker, goldfish and 28 other species of the minnow family, stonecats (2 species), mud minnow, little pickerel, killifish, trout-perch, pirate-perch, log-perch and 7 other species of the darter family, silversides, sculpins (5 species), sticklebacks (2 species). Many of this group are of high importance as food for important economic fish. The ones identified from stomachs of fish from this watershed are listed in Dr. Sibley's report.[3]

Bait Fishes.— The majority of the fishes that are used for bait are members of the classification just discussed. In Lake Erie, by far the most important bait species is the lake shiner, *Notropis atherinoides*. These shiners are of economic value,[4] being sold by several persons along Lake Erie and the Niagara river. Most of those used, however, are caught by the anglers, themselves.

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[1] See page 235.

[2] Fish Distribution, Waters in New York State Stocked in 1925, State of New York Conservation Commission 1926.

[3] See page 183.

[4] The following data has been supplied by Mr. M. W. Brackett: There are fifteen minnow net licenses issued for the Niagara river; ten for Lake Erie; four for Cattaraugus creek from Lake Erie to the Snow farm and one for Little Canadaway creek from Lake Erie to source. Licenses to sell minnows for bait number two in Dunkirk; one in Buffalo and two in Lackawanna.

A small seine, usually 20 feet or less in length, is employed. At other times, when none can be taken near shore, they are attracted by the light of a gasoline lantern and are secured with a dip net. The log-perch, *Percina caprodes zebra* is a popular bait for black bass along the lake shore, where it goes by the name of "modoch". Among other fish used as bait are stone-roller minnows, black-nosed dace, the common shiner and the horned dace. Small suckers are not minnows and it is illegal to use them. These are seined from creeks, usually, but apparently not in great enough numbers to seriously interfere with the production of this type of food. Soft-shell crayfish are more sought after in the creeks and the weed beds of the Niagara river than the small fish are, as the soft-shell "crab" is the most preferred bass bait.

The Problem of Conserving Lake Erie Resources.—As Lake Erie waters lie within the jurisdiction of the states of New York, Pennsylvania, Ohio, and Michigan and the Province of Ontario, the problem of conserving the supply of commercial and angling fish is an interstate and international one. Effective solution of this problem requires cooperation between all parties concerned. Cooperation by various interested organizations in a program of fishery research is now being accomplished.* The U. S. Bureau of Fisheries is making a study of apparatus with a view to making recommendations as to the sizes of mesh which are most efficient and at the same time least destructive to under-sized fish. Life history investigations are in progress as a part of the work of the Bureaus of Fisheries of both the United States and Ontario. The more that is learned of the fish themselves, the more intelligently can the proper conservation measures be devised. When the governments of the several states concerned, and of Ontario can come to agreement regarding the wisest restrictions as to type of gear, fishing seasons, minimum size limits, and other conservation measures, much will have been accomplished toward the insuring of continued yields to the fisheries as well as to anglers.

Natural Production in Lake Erie.—At present the replacement of the majority of the commercial fish taken is entirely by natural reproduction. This is supplemented by artificial stocking in the case of the herring and whitefish.

In regard to the New York area of the lake, considerable information bearing on the problem of natural production was collected during the survey. As judged by the distribution of the young fish, certain areas of this territory are important spawning and rearing grounds, while others are not. Along stretches of rocky cliffs, and along extensive stretches of the beach that are exposed to full force of wave action, comparatively few young fish were taken. On the other hand, in sheltered bays, in lagoons at the

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* Higgins, Elmer. Cooperative Fishery Investigations in Lake Erie. Scientific Monthly, Oct. 1928.

mouths of creeks and in the great weed beds of the upper Niagara river, they were much more common, in some places being, literally, in myriads. To be sure, several of the lake species have pelagic

A cliff along the shore of Lake Erie—an unproductive stretch of water for young fish

young, swimming in the open waters of the lake, and not requiring shelter. Several members of this category are very important species, notably the whitefish and herring. However, most forms require shelter when young and spawn only in sheltered places. This is true of a majority of the fishes of commercial importance.

A summary of the information as to spawning places of Lake Erie fish in the area surveyed may prove useful for subsequent investigations and as an aid in fixing restrictions aiming at a conservation of the numbers of reproducing fish. In regard to where they spawn, these may be classed into:

(1) Species which ascend streams well into the riffles: Common sucker, red-fin suckers (probably true of all 4 species), trout-perch, log-perch, Copeland's darter, lampreys (the 2 lake species), spot-tailed minnow.

(2) Species which go down to the ocean to spawn (catadromous): The eel.

(3) Species which spawn under sheltered conditions along the shore zone, in creek mouths, sheltered bays or in the Niagara river: gar, buffalo mullet, carp, goldfish, *Notropis heterodon*, *N. deliciosus*, golden shiner, blunt-nosed minnow, catfish (2 species), bullheads (2 species), northern pike, muskalonge, killifish, white bass, yellow perch, sauger, yellow pike, johnny darter, Iowa darter, black bass (2 species), common sunfish, rock bass, crappie, sheepshead, stonecat.

(4) Species which spawn in open waters of the lake: Sturgeon (reported to spawn on bars), herring, whitefish, lake trout, sculpin (probably 3 species), ling.

This classification is, of course, merely approximate. In many cases there is considerable variation in the spawning place. For example, not all individuals of the trout-perch go to the riffles of streams to spawn, judging by the numerous specimens in spawning condition that were found at gravel areas along the lake shore.

Extensive collections were made of young fish, that is, those that are in their first season, being less than one year old. These may be classed according to the same outline used for spawning areas:

(1) Those found in the riffles of streams: None. Most of the young hatching from eggs laid in such places probably find their way downstream to a more sheltered environment. In the case of several species, notably the common sucker, at least some of the young remain well up the creeks. The young of the trout-perch apparently go out into the open lake.

(2) Those which are in the ocean, later ascending to fresh water: The eel.

(3) Those which are found in sheltered areas as mentioned under group 3 of spawning fish: Common sucker, red-fin suckers (at least 3 of the 4 species), spot-tailed minnow, gar, buffalo mullet, carp, goldfish, *Notropis deliciosus,* golden shiner, blunt-nosed minnow, catfish (2 species), bullheads (2 species), northern pike, muskalonge, killifish, white bass, yellow perch, yellow pike, johnny darter, Iowa darter, black bass (2 species), common sunfish, rock bass, crappie, sheepshead, stonecat, *Notropis atherinoides* (in part, at least), trout-perch (rarely), sculpin (*Cottus b. kumlieni*). There are probably others that should be grouped here but are omitted for lack of definite records.

(4) Those which are pelagic, living in open waters of the lake: Herring, whitefish, lake trout,[1] and others.[2]

This classification is, again, quite approximate. It is based upon scant evidence in the case of a few species whose young were collected in very limited numbers, but in the case of most species specimens were common enough to support this grouping. Unfortunately, the various sizes of young fish cannot be here recorded in full. However, notes on sizes of young found are included in the annotated list for a good proportion of the species.

Collecting demonstrated that the most important centers for the production and rearing of young of the large group of fish that are found in sheltered areas (group 3) were: The upper Niagara river, areas at the mouth of Cattaraugus, Eighteenmile, Sister and other creeks, Dunkirk harbor and sheltered bays along the lake shore (limited in number). Weed beds[3] were particularly productive of young fish. Several species have young which seem quite dependent upon the dense shelter of weeds as is the case with the

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[1] A fragment of evidence in regard to the habitat of young lake trout is here recorded: The writer took a specimen 2 $\frac{5}{16}$ inches long (total length) from Hemlock lake, Sept. 19, 1926, at a point where the depth was 60 feet.

[2] See page 166.

[3] See pages 190 and 193.

common bullhead and the muskalonge. Young of the yellow pike and black bass, among others, do not limit themselves to a weedy environment but are seldom found far from shelter.

A sheltered lagoon at the mouth of Cattaraugus creek—a productive place for young fish

Obviously, these centers are important as it is here that young of many food fish are reared. Here also, are producing centers for the minnows and other smaller species that are important food resources for predacious fish. In many cases, when the young become of sufficient size to leave sheltered conditions, they apparently migrate to more open situations in the lake.

Migrations of Lake Erie Fish.— It would be difficult to make detailed studies of the migrations of fish, and only a few facts in regard to this problem were gathered. It was quite apparent from experience in collecting along the lake shore and in the creeks that there is a definite, inshore migration of many lake species for the purpose of spawning, occurring in spring and early summer. Along with this there are feeding migrations as in late June, when the inshore, spawning run of trout-perch, spot-tailed minnows, *Notropis deliciosus* and such small species brought yellow pike, saugers, perch and other predacious fish close inshore where they were found to be feeding on these smaller fish. Large quantities of food washed into the lake by heavy rains seemed to be responsible for an inshore movement of perch and others at several times during the summer. Such migrations are of a temporary nature and it was noticed that with a return to low, clear water in entering creeks, relatively few fish could be found close to shore, although a few carp, catfish, stonecats, as well as smaller species could often be found feeding inshore at night where they could not be found by day. An important type of migration is that of the young which, as mentioned above, leave sheltered conditions as they become larger. It is evident that this is the case in the upper Niagara river from analysis of the results of seining there during July. This area was then extremely rich in young fish but there were very few large ones. In the case of the yellow perch, abundant here, young were thickly distributed in weed beds and yearling specimens were common, but large size perch were very scarce. Apparently they seek deeper water as they get larger, in this case doubtless migrating to Lake Erie. The movements of fish within Lake Erie are of considerable concern to the commercial fishery on account of their influence on the availability of certain ones, such as the herring, which may sometimes be taken in large numbers, and sometimes in scarcely any numbers.

Because of the migratory character of fish, among other reasons, it would be difficult to classify each species according to habitat in the lake. It is worthy of note, however, that comparatively few species are taken in the very deep water, where summer temperatures are cold. Herring, blue pike, whitefish, ling, lake trout, perch, sculpins and trout-perch are practically all of the fishes found there. The vast majority of species are limited to more shallow water. Some, as the perch and blue pike, range over both types of habitat.

Factors Contributing Toward a Decline of Fish Numbers.— The finny tribe seems to be on the decline wherever civilization has brought its influence. Some of the factors that are concerned in the present case are:

(1) Clearing of the forests: This has resulted in a great many streams becoming too warm for trout, and others becoming entirely dry[1] in the hot season. Stream conditions must influence lake conditions, particularly in regard to those fish which spawn in streams.

(2) Pollution: The pollution of streams must act to reduce the number of fish resident in them and also to reduce the number of lake fish that use streams as spawning areas. Many areas, otherwise suitable for spawning and rearing young, are ruined for these purposes by pollution. Lower Buffalo creek is obviously unfit for eggs or young of fish, and seemed to contain no form of fish life. (The oxygen test at its mouth was zero.[2]) Buffalo harbor had few young fish when collections were made there. Although almost all water that was seined yielded at least a few fish of one sort or another, conditions in parts of Smoke, Cattaraugus, Canadaway, Silver and other creeks, and in the Niagara river did not appear to be optimum conditions for adult fish to find their natural food and to spawn, or for the young to thrive. As mentioned in a previous report,[3] the mere fact that a polluted area of water will not kill fish placed there as a "minnow test"

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[1] Rafter, G. W. The Hydrology of the State of New York. N. Y. State Museum Bull. 85, 1905.

[2] See page 129.

[3] Oswego survey, 1927, p. 92.

does not indicate that such water is fit for fish life, in the sense of being a place where fish can maintain themselves naturally.

(3) Dredging operations: Old fishermen agree that sturgeon formerly spawned on bars which lay just off Buffalo harbor. These bars have been removed by dredging. During the past summer dredging was in progress in the upper Niagara river, at Strawberry island, which was an important spawning area for muskalonge according to competent authority.

(4) Lack of protection against fishing during the spawning season: At this season, most species are concentrated on the spawning grounds, whether these places be areas in the lake, as occurs in the case of the herring, or areas in creeks, as occurs in the case of the common sucker. At this time, they are easiest to take in large numbers and there is danger of destroying so many breeders that future production thereby suffers. Most species are not protected against this danger, and commercial fishermen, anglers and spear fishermen take many spawning fish. Sturgeon were very heavily fished on their spawning beds in the past.[1] Herring, suckers, red-fin suckers and catfish are some of the species that are so fished today. Can the supply keep up?

All types of fishing act, of course, toward a decrease in the number of fish, but fishing outside of the spawning season is a less destructive process.

(5) Diseases and parasites: During the summer there were considerable numbers of dead fish cast up on the shore of Lake Erie. Although some of these appeared to be fish that had been discarded by commercial fishermen because too small or in too soft a condition to market, or because they were worthless species (as stonecats), many were fish killed by other than net injuries. A great many perch die, in the warm months, from a disease which appears as a large sore on the side. A fungus, *Saprolegnia,* was evident on a dozen or more of such fish, which were examined. The blue pike suffers from the same disease; apparently fewer of this species were affected during this season, however. Whether an initial injury is necessary before the disease will take effect is not known. All fish seen that were from deep, cold water showed no signs of the disease, while many that were taken from only about 30 feet of water did have the disease.

There are two species of parasitic lampreys in Lake Erie, which live by sucking the blood of fish.[2] One of the two (*Petromyzon*) is very rare in the lake, and the other (*Ichthyomyzon*) does little apparent damage. Lamprey injuries might offer opportunity for disease to take effect, but at least the sores referred to above are not like the deep, round hole of a lamprey scar. Other parasites of fish are discussed by Dr. Hunter.

(6) Natural enemies, native or introduced: These may influence

[1] Smith, H. M. and Snell, Merwin-Marië. Fisheries of the Great Lakes in 1885 Appendix 1, Report of U. S. Commissioner of Fish and Fisheries for 1887.

[2] Gage, S. H., in Oswego Report 1927, pp. 158–191 gives an excellent account of the natural history of lampreys.

the abundance of fish directly, by actually destroying them, or indirectly, by competing with them for food.

Fish are fed upon by a great many animals, including other fish, amphibians, reptiles, birds, mammals, crayfish and even insects (in the case of young fish). In general, the most serious of these predacious enemies seem to be other fish. The examination of stomachs* showed that a rather large number of species are fed upon by members of their own class. A great many fishes will eat spawn. Many species of minnows, certain darters and the yellow perch are only a few of those that are known to do so. In Lake Erie, the very common salamander known as the mud puppy (*Necturus maculatus*) is accused probably justly, of eating small fish and spawn. Frogs, especially the bull-frog, will eat small fish. Watersnakes and snapping turtles are moderately common fish eating reptiles of the region. One snapping turtle found at Silver creek had taken a minnow (*Notropis atherinoides*) as well as a crayfish. Among the fish-eating birds, kingfishers, great blue herons, green herons, herring gulls and common terns were seen in limited numbers, during the summer. A flock of about 200 of the latter species was seen in the upper Niagara river, August 2, and many of the birds were diving after fish. Four were shot and found to contain minnows (*Notropis atherinoides, N. hudsonius*). Fish-eating mammals are practically negligible as enemies of fish life in the region concerned, although a few mink are probably present. In limited numbers natural enemies do little or no harm, and as they ordinarily take those fish which are most easily caught they may serve as useful checks upon the too rapid increase of small, abundant species. There is some danger, however, that interference by man, as in fishing out certain species and not others may favor the latter to such a point that they may become seriously destructive to the former. For instance, by concentrating on whitefish and herring, and taking ling only accidentally, it is possible that the increase of this latter species might be favored at the expense of the other two, whose spawn and young might thereby suffer heavier losses to this natural enemy. [We do not know that this is the case in this instance.]

The problem of food competition is an intricate one, and quite apparently, an important problem. The study of aquiculture has not reached as advanced a stage of knowledge as has that of agriculture. To illustrate, if a farmer had as many cows in a pasture as the grass would support, he would not be likely to try and support an equal number of horses there, in addition. Yet, although the food resources of an area of water might be just enough to take care of the number of fish there at the time, we might be unaware of the fact and put in a great number of additional ones. Under natural conditions it is reasonable to suppose that there would be a natural balance between the amount of available food and the number of fish in an expanse of water, for although food is not the only factor in limiting a species, it is a major one. Under

* See page 184.

present conditions, certain selected species are fished, thus removing large numbers of them from competition and making a larger per cent of the food available to the species that are not fished. This places these in a position favoring their increase to such a point that they will consume, in all probability, so large a per cent of the available food as to constitute a check to further increase of species requiring the same type of food. Although the last statement is of a theoretical nature, there is much evidence to support it. Take for example, trout streams that are so heavily fished as to greatly reduce the numbers of trout. Minnows, and perhaps others, will become very numerous, so numerous as to make it difficult for trout to increase fast in the face of this food competition. It is quite true that Lake Erie is rich in food, especially in plankton, and the fish there appear to grow fast. Many are indeed fat. But, young of certain of these same species are concentrated in relatively small areas where there is shelter, and must stand heavy competition from other young fish and also from adult fish of those species which inhabit similar situations and feed upon similar food.

Suggestions and Recommendations.—As a result of a brief study, covering only three months, extensive recommendation cannot be proposed. The following suggestions are made:

(1) If it is proved by analysis of full statistics of catches that a desirable species is decreasing, with or without artificial propagation, give this species protection during the spawning season.

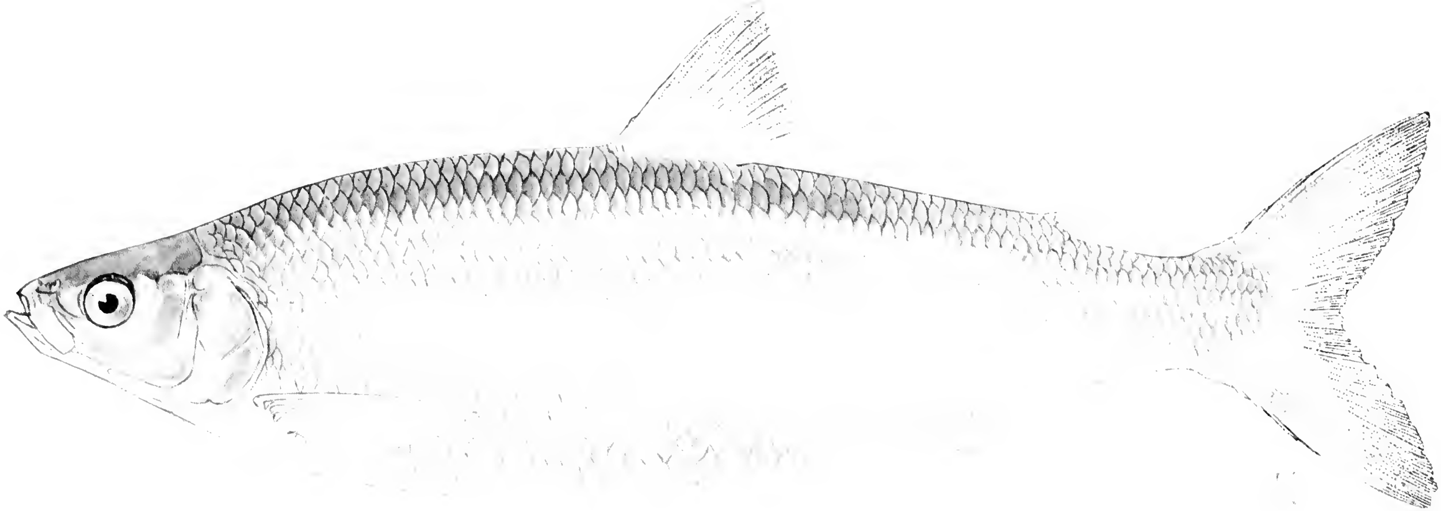
(2) Such areas as are proved to be spawning grounds of fish or rearing areas for young fish should be kept free from pollution.

(3) All conservation measures as to fishing seasons, size limits, method of capture and the like should be based on careful study and should be adopted for the entire area by joint action.

CHART OF FISH DISTRIBUTION OF THE ERIE-NIAGARA WATERSHED

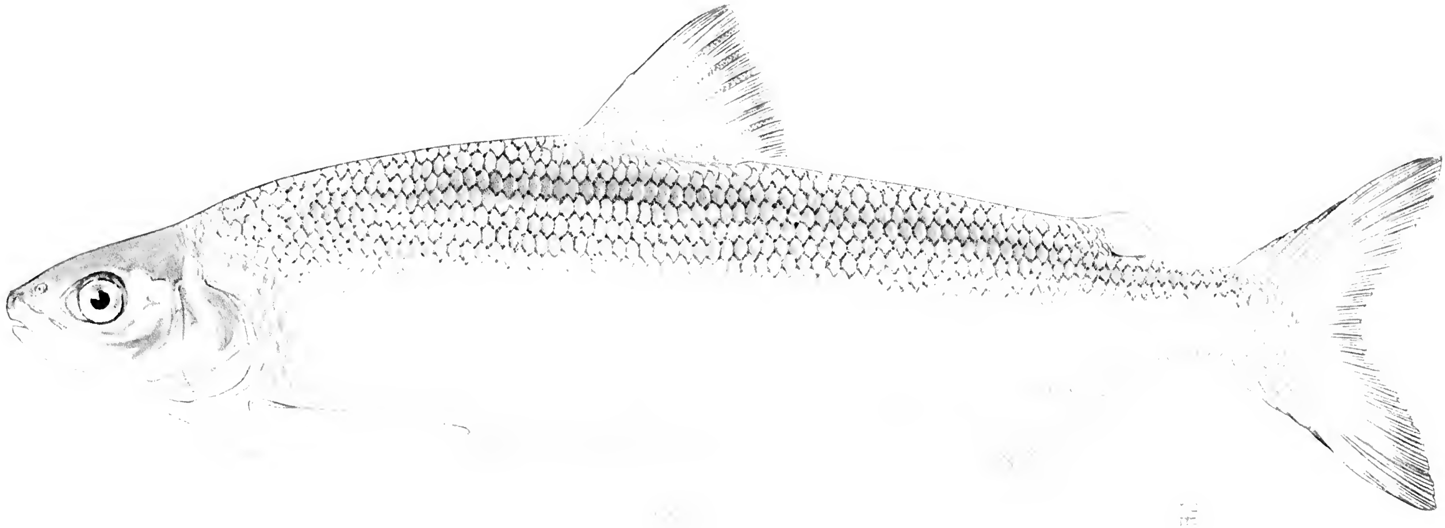
X = recorded from actual specimen; R = recorded on reliable authority; St = stocked but apparently not established

	List number	Subdivisions of the Drainage																								
		Lake Erie	Niagara R.	Chautauqua Cr.	Slippery Rock Cr.	Canadaway Cr.	Crooked Cr.	Scott Cr.	Beaver Cr.	Silver Cr.	Cattaraugus Cr.	Muddy Cr.	Delaware Cr.	Sister Cr.	Little Sister Cr.	Pike Cr.	Eighteenmile Cr.	Rush Cr.	Smoke Cr.	Buffalo Cr.	Seajaguada Cr.	Ellicott Cr.	Cayuga Cr.	Gill Cr.	Tonawanda Cr.	Barge Canal
Silver lamprey	1	X																								
Reighard lamprey	2																			X						
Lake lamprey	3	R																								
Brook lamprey	4										X															
Paddlefish	5	R																								
Sturgeon	6	X	X																							
Short-nosed gar	7	R																								
Long-nosed gar	8	X	X																							
Dogfish	9	R																								
Mooneye	10	X																								
Golden shad	11	R																								
Sawbelly	12		X																							
Gizzard shad	13	R																								
Herring (Leucichthys a. artedi)	14a	X																								
Herring (Leucichthys a. albus)	14b	X																								
Whitefish	15	X																								
Brown trout	16			X		St					X			R			St			X		X				
Steelhead trout	17a	R		St																						
Rainbow trout	17b	X				R				R	X									R						
Lake trout	18	X																								
Brook trout	19			X							X									X					X	
Big-mouth buffalo	20	R																								
White carp	21	X				X				X	X	X	X	X			X									
Common sucker	22	X	X	X		X		X		X	X	X	X	X	X	X	X		X	X	X	X		X	X	X
Fine-scaled sucker	23	R																								
Hog sucker	24	X	X	X		X		X		X	X		X	X			X		X	X					X	
Chub sucker	25											X														
Striped sucker	26	R																								
Common red-fin sucker	27	X	X								X									X		X			X	
White-nosed red-fin sucker	28	X	X							X	X			X			X									
Short-headed red-fin sucker	29	X	X										X	X			X									
Fine-scaled red-fin sucker	30	X															X									
Big-mouth red-fin sucker	31	R																								
Carp	32	X	X			X				X	X			X	X		X	X			X	X	X		X	X
Goldfish	33	X																								R
Horny-head	34		X																						X	
Crested chub	35		X	X		X				X	X			X	X		X			X						
Spotted chub	36	R																								
Storer's chub	37	X																								
Big-eyed chub	38													X			X			X					R	
Black-nosed dace	39			X	X	X	X	X	X	X	X		X	X		X	X			X		X			X	
Long-nosed dace	40	X	X	X		X		X		X	X				X		X			X		X			X	
Horned dace	41	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X	X		X			X	
Pearl minnow	42										X															
Red-sided dace	43								X		X		X	X	X		X									
Pug-nosed minnow	44	R																								
Notropis heterodon	45	R	X																							
Black-nosed minnow	46	X	X								X	X		X	X	X	X					X			X	
Notropis v. volucellus	47	X									X			X			X					X				
Notropis d. stramineus	48	X	X	X		X				X	X		X	X	X	X	X			X						
Gilbert's minnow	49																					X			X	
Spot-tailed minnow	50	X	X	X						X	X		X	X	X		X									X
Satin-fin minnow	51	X	X			X				X	X		X	X	X	X	X									
Lake shiner	52	X	X	X		X				X	X		X	X	X		X			X		X				X
Rosy-faced minnow	53	R									X						X			X		X			X	
Common shiner (Notropis c. chrysocephalus)	54a	X	X	X		X				X	X	X	X	X	X	X	X		X			X			X	X
Common shiner (Notropis c. frontalis)	54b	X		X		X		X	X	X	X		X	X	X		X			X		X			X	



CISCO, *Leucichthys artedi albus* (Le Sueur)
From immature specimen $10^{3}/_{16}$ inches long.

PLATE No. 1.

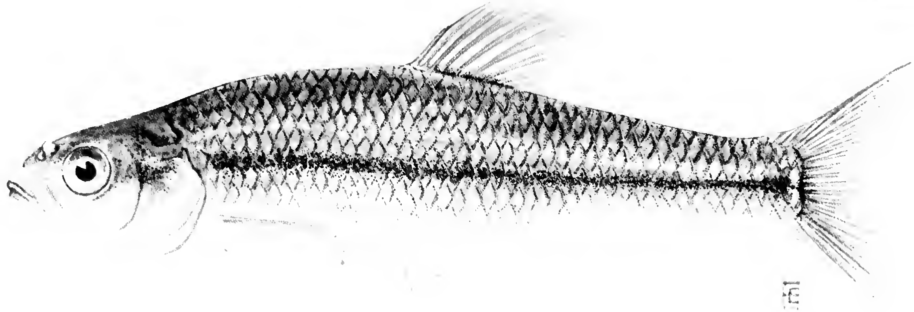


WHITEFISH. *Coregonus clupeaformis* (Mitchill)
From immature specimen $12^{11}/_{16}$ inches long.

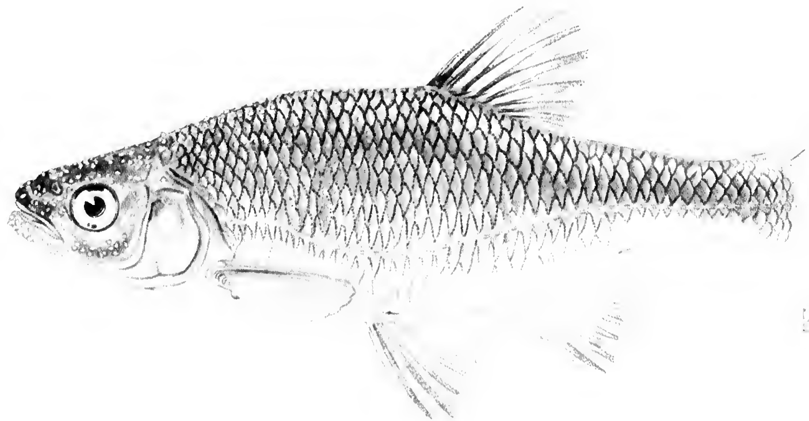
PLATE No. 2.

GOLDFISH, *Carassius auratus* (Linnaeus)
From female 9⅝ inches long.

PLATE No. 3.

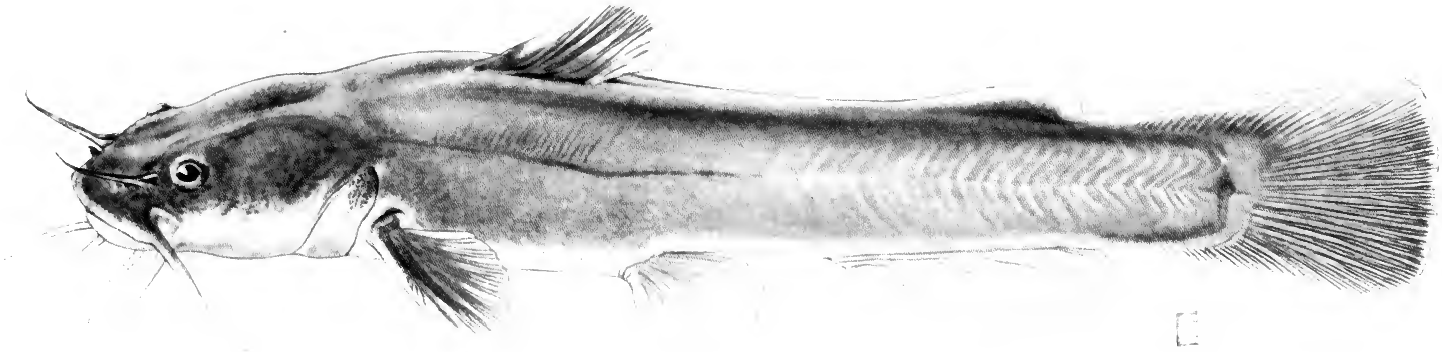


FAT-HEAD MINNOW, *Pimephales promelas promelas* Rafinesque
From female 2 1/16 inches long.



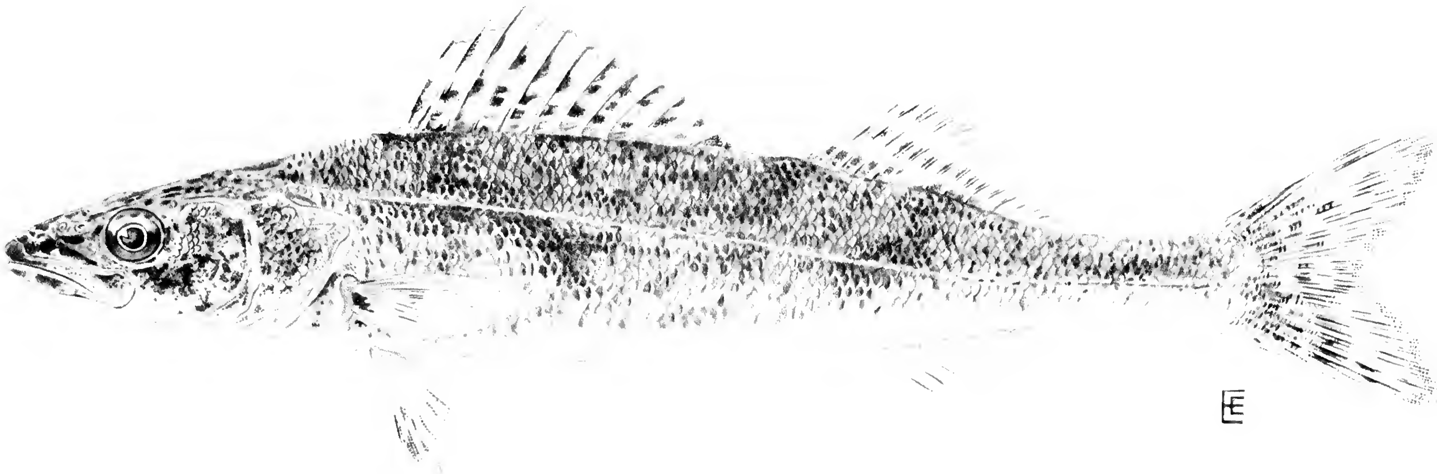
RED-FIN MINNOW, *Notropis umbratilis cyanocephalus* (Copeland)
Breeding colors from male 2¾ inches long.

PLATE No. 4.



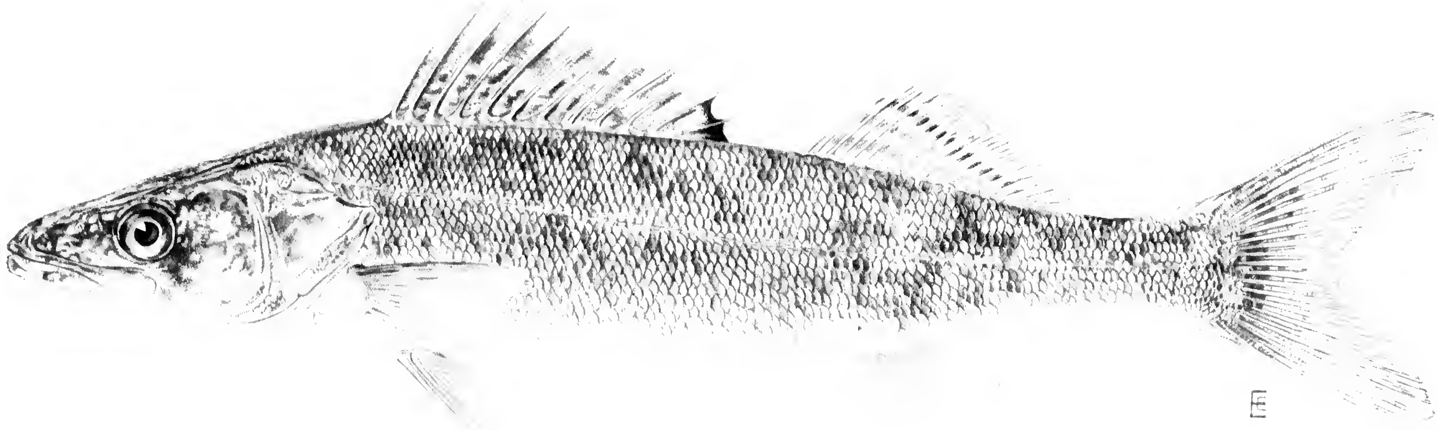
STONECAT, *Noturus flavus* Rafinesque
From male 7¾ inches long.

PLATE No. 5.



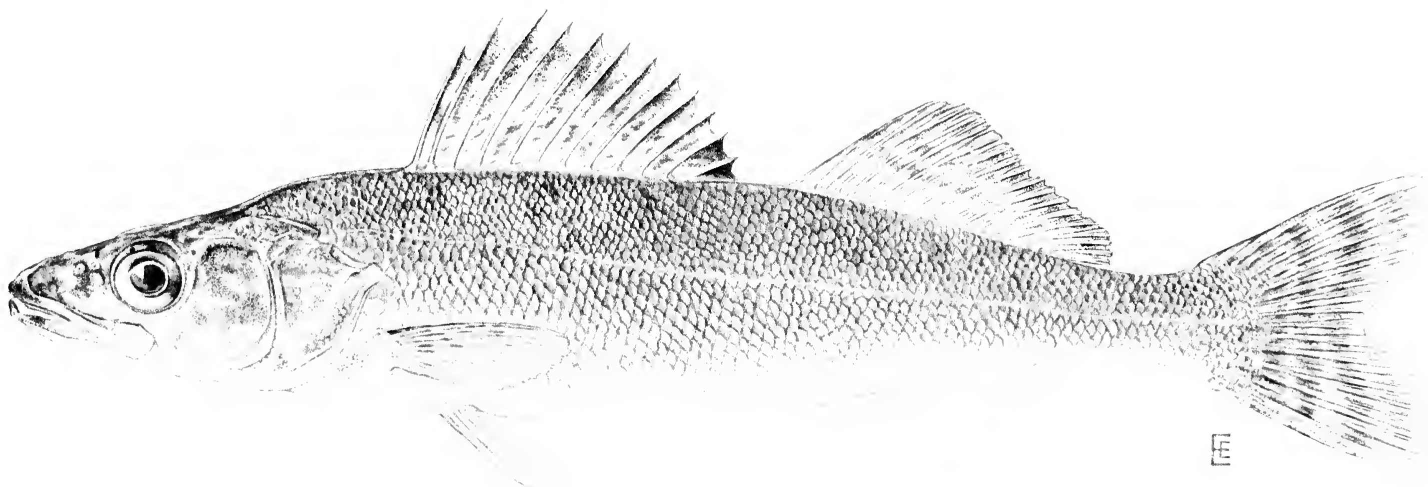
SAUGER, *Stizostedion canadense griseum* (De Kay)
From male 10¼ inches long.

PLATE No. 6.



YELLOW PIKE, *Stizostedion vitreum* (Mitchill)
From female 16¾ inches long.

PLATE No. 7.



BLUE PIKE, *Stizostedion glaucum* Hubbs
From male 10¾ inches long.

PLATE No. 8.

CHART OF FISH DISTRIBUTION OF THE ERIE-NIAGARA WATERSHED — (*Continued*)

X = recorded from actual specimen; R = recorded on reliable authority; St = stocked but apparently not established

		Subdivisions of the Drainage																								
	List number	Lake Erie	Niagara R.	Chautauqua Cr.	Slippery Rock Cr.	Canadaway Cr.	Crooked Cr.	Scott Cr.	Beaver Cr.	Silver Cr.	Cattaraugus Cr.	Muddy Cr.	Delaware Cr.	Sister Cr.	Little Sister Cr.	Pike Cr.	Eighteenmile Cr.	Rush Cr.	Smoke Cr.	Buffalo Cr.	Scajaquada Cr.	Ellicott Cr.	Cayuga Cr.	Gill Cr.	Tonawanda Cr.	Barge Canal
Red-fin shiner	55											X			X											
Golden shiner	56	X	X							X	X	X		X	X		X			X		X	X	X	X	X
Hybagnathus hankinsoni	57																			X						
Red-bellied dace	58													R							X	X				
Blunt-nosed minnow	59	X	X			X		X		X	X	X	X	X	X		X	X	X	X	X	X		X	X	X
Fat-head minnow	60	R	X							X	X	X	X	X	X	X	R			X	X	X			X	X
Stone-roller minnow	61	X	X			X		X	X	X	X		X	X	X	X	X		X	X						
Spotted catfish	62	X	R								X			X			X									
Lake catfish	63	X												X			X									
Black bullhead	64	R																								
Common bullhead	65	X	X			X				X	X	X		X	X		X	X			X	X		X	X	X
Yellow bullhead	66	X										X			X											
Mud-cat	67	R																								
Stonecat	68	X	X								X			X			X			R					X	
Tadpole stonecat	69	R																				R			X	X
Brindled stonecat	70	R																								
Mud minnow	71	X	X								X	X		X							X		X		X	
Little pickerel	72	X	X								X	X			X							X	X	X		X
Chain pickerel	73	R									X															
Northern pike	74	X	X								X	X		X	X			X				X			X	X
Muskalonge	75	X	X																							
Eel	76	X	X																							
Barred killifish	77	X	X																							
Trout-perch	78	X	X							X	X		X													
Pirate-perch	79	R																					X			
White bass	80	X	X			X				X	X			X			X									
Perch	81	X	X							X	X			X			X				X	X				X
Sauger	82	X								X	X			X												
Yellow pike	83	X	X							X	X			X			X									
Blue pike	84	X	X																							
Black-sided darter	85										X			R						X		X			X	
Log perch	86	X	X	X		X				X	X		X	X			X									X
Copeland's darter	87	X		X							X						X									
River darter	88	R																								
Sand darter	89	R									X															
Johnny darter	90	X	X							X	X	X	X	X	X		X		X	X		X			X	
Rainbow darter	91		X	X	X	X		X		X	X			X	X		X			X		R			X	
Iowa darter	92	X	X								X									X						
Fan-tailed darter	93	R		X		X	X		X	X	X		X	X	X	X	X			X		X			X	
Green-sided darter	94	R									X									R		R			X	
Small-mouthed bass	95	X	X			X				X	X		X	X			X			R		R			X	
Large-mouthed bass	96	X									X							X							X	
Warmouth bass	97	R																								
Bluegill sunfish	98	R											X													
Long-eared sunfish	99	R																								
Common sunfish	100	X	X			X					X	X	X	X	X		X	X	X		X	X	X	X	X	X
Rock bass	101	X	X							X	X		X	X	X		X			X		X			X	X
White crappie	102	X									X			X	X		X	X								
Black crappie	103	X																								
Brook silversides	104	X								X							X									
Sheepshead	105	X	X							X				X			X									
Triglopsis thompsoni	106	X																								
Sculpin (Cottus b. bairdii)	107a			X						X	X			X						X					X	
Sculpin (Cottus b. kumlieni)	107b	X	X																							
Sculpin (Cottus cognatus)	108	X																								
Rice's sculpin	109	X																								
Brook stickleback	110	X	X								X	X		X	X						X	X			X	
Two-spined stickleback	111		X																							
Ling	112	X								X																

Annotated List of Fishes Occurring in the Erie-Niagara Drainage

PETROMYZONIDAE *Lampreys*

1. *Ichthyomyzon concolor* (Kirtland).—Silver lamprey, lamprey eel. Uncommon. Occurs in Lake Erie as a parasite of fish where it is the more common of the two parasitic species. Reported to ascend streams in early spring to spawn.

2. *Ichthyomyzon unicolor* (DeKay).—Reighard lamprey. Rare. Found by Prof. T. L. Hankinson in Little Buffalo creek, June 12. We collected larvae in the mud there June 17, but no adults were seen. These evidently die after spawning, as is the case in other lampreys. This small species is not parasitic and is limited to streams.

3. *Petromyzon marinus Linnaeus.**—Lake lamprey, lamprey eel. Rare. Recorded from Lake Erie by Dymond. This species is parasitic on lake fish. Its life history and economics are fully discussed by Gage.[1]

4. *Entosphenus appendix* (DeKay).—Brook lamprey. Rare. One larva, 7½ inches long was taken by Dr. G. C. Embody in Lime lake outlet, July 25. Dr. E. H. Eaton, of Hobart College, has found this lamprey in streams near Springville. It is not parasitic.

POLYODONTIDAE *Paddle-fishes*

5. *Polyodon spatula* (Walbaum).*—Paddle-fish, spoon-bill cat. Rare. Only two specimens have been recorded from Lake Erie.[2] Thought to have entered the lake by the Wabash and Erie canal.[3]

ACIPENSERIDAE *Sturgeons*

6. *Acipenser fulvescens* Rafinesque.*—Lake sturgeon, rock sturgeon. Rare. Although once an important commercial fish in Lake Erie and the Niagara river, few are now taken. At present, they are fished only to a limited extent. It seems advisable to give them complete protection. New York protected the species for a short period but complete protection by all states and Canada would be necessary to restore this resource. It is reported that sturgeon do not spawn until their 22nd year.[4]

LEPISOSTEIDAE *Gar-pikes*

7. *Lepisosteus platostomus* Rafinesque.*—Short-nosed gar. Rare. Recorded from Lake Erie by Dymond.

8. *Lepisosteus osseus* (Linnaeus).—Long-nosed gar, gar-pike, bill-fish. Moderately common in Lake Erie and the Niagara river. Usually found in

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[1] Oswego Survey Report, 1927 (also contains colored plates).

[2] Hubbs, C. L. A Check-List of the Fishes of the Great Lakes and Tributary Waters, 1927.

[3] American Food and Game Fishes. 1908.

The nomenclature followed is that given by Hubbs, C. L. and Greene, C. W. in Further Notes on the Fishes of the Great Lakes and Tributary Waters, Mich. Acad. of Science, Arts and Letters, Vol. VIII, 1927. There is one exception to this, in that for the family *Esocidae*, the authority followed is Weed, A. C., Pike, Pickerel and Muskalonge, Field Museum of Natural History Zoological Leaflet 9, 1927. Records cited as from Dymond refer to Dymond, J. R. A Provisional List of the Fishes of Lake Erie, University of Toronto Studies: Publications of the Ontario Fisheries Research Laboratory No. 4. Those cited as from Hubbs refer to Hubbs, C. L. A Check-List of the Fishes of the Great Lakes and Tributary Waters, with Nomenclatorial Notes and Analytical Keys, University of Michigan Museum of Zoology Miscellaneous Publications No. 15, 1926. Species marked by an asterisk (*) are ones of which no specimens were taken by the present survey. All measurements refer to total length.

[4] Harkness, W. J. K. The Rate of Growth and the Food of the Lake Sturgeon. Publications of the Ontario Fisheries Research Laboratory No. 18. 1923.

sheltered bays, mouths of creeks, or weed beds. Generally considered harmful as it feeds on fish, but is not common enough to do serious, if any, damage in the region surveyed. Young ranging in size from $1\frac{7}{16}$ to $3\frac{1}{8}$ inches were seined in weed beds at the east side of the Niagara river, near Tonawanda, on July 27.

AMIIDAE *Bowfins*

9. *Amia calva* Linnaeus.*—Bowfin, dogfish. Rare. Recorded from Lake Erie by Dymond.

HIODONTIDAE *Mooneyes*

10. *Hiodon tergisus* Le Sueur.—Mooneye, toothed herring. Common in Lake Erie. Small schools were found, close inshore, at many points along the lake shore and in creek mouths. No commercial value, at present, in the eastern part of the lake, but of minor commercial importance at the western end of the lake where greater number are taken.

CLUPEIDAE *Herrings*

11. *Pomolobus chrysochlorus* Rafinesque.*—Golden shad, skipjack. Rare. This species has entered Lake Erie through canals, according to Jordan and Evermann.[1]

12. *Pomolobus pseudo-harengus* (Wilson).—Sawbelly,[2] alewife, Seth Green shad. Common in Lake Ontario and enters the mouth of the Niagara river every year in large numbers according to fishermen at Youngstown.

13. *Dorosoma cepedianum* (Le Sueur).*—Gizzard shad, sawbelly. Rare. Koeltz[3] lists this species as one of commercial insignificance in Lake Erie. It is believed to have entered the lake by canal connections.

COREGONIDAE *Whitefishes*

14-a. *Leucichthys artedi artedi* (Le Sueur).—Lake herring, cisco. Common. This and the next subspecies[4] are very important commercial fish in Lake Erie. In New York boundaries they are usually taken by bull nets, which are twice the depth of ordinary nets and are rigged so that they may be set off the bottom, at any level that proves best. Herring are usually found in the deep, cold water during the summer. The catch has been decreasing due in a large measure, it seems likely, to heavy fishing in the fall when the species spawns.

14-b. *Leucichthys artedi albus* (Le Sueur).—Lake herring, cisco. (Plate 1.) Common. From observations of Mr. C. W. Greene at Dunkirk, during the summer of 1928, this subspecies was more common in catches than the preceding one which it resembles.

15. *Coregonus clupeaformis* (Mitchill).—Whitefish. (Plate 2.) Common in Lake Erie. In summer, it is found in the deep, cold water. This is the choice commercial fish of the lake, but is less important than the herring due to its fewer numbers. Very few were taken in New York waters during the period of the survey. The total catch in Lake Erie is less valuable now than the catch of the common sucker in this lake.

SALMONIDAE *Trouts*

16. *Salmo fario* Linnaeus.—Brown trout, German brown trout. Common in a few streams. A very popular anglers' fish. More streams are suitable for it than for the brook trout on account of its tolerance of a higher temperature.[5]

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[1] Bulletin 47, United States National Museum (1896).

[2] Illustrated in Oswego Survey Report, 1927.

[3] Appendix XI to the Report of the U. S. Commissioner of Fisheries, 1925.

[4] In regard to nomenclature we follow Koeltz, who has made a thorough study of the whitefishes and lake herrings, including their migrations and local races. His Monograph of the Great Lakes Coregonidae is now in press.

[5] Oswego Survey Report, 1927, p. 27.

17-a. *Salmo irideus*[1] Gibbons.*—Steelhead trout. Rare. Recorded from Lake Erie by Dymond.[2] Dunkirk fishermen on one boat, the Albert E. Baker, told of catching in gill nets, one or two trout that fitted the description of this species. Steelheads have been planted in several streams[3] tributary to Lake Erie and apparently are established in limited numbers in this lake.

17-b. *Salmo irideus shasta* Jordan.— Rainbow trout. Common in several streams of the watershed, where it is important for sport fishing. Will stand warmer water than the brook trout. Large ones tend to migrate downstream. In hatcheries, the *shasta* rainbow has been crossed with the steelhead. subspecies *irideus*, so that many of the specimens in streams of the State are not typical of the former subspecies. However, all that we have seen from the region are nearer *shasta* in characters than they are to the steelhead.

18. *Cristivomer namaycush namaycush* (Walbaum).*—Lake trout. Uncommon. Restricted to the deep parts of Lake Erie where it is sometimes taken in gill nets. Trout are scarcer in Erie than in deeper ones of the Great Lakes, and the species is of minor commercial importance for that reason. Good catches are sometimes made late in fall.

19. *Salvelinus fontinalis fontinalis* (Mitchill).—Brook trout, speckled trout. Restricted to cold streams and cold ponds and is common in several headwater streams. This is a favorite fish of the majority of anglers and its numbers are kept rather low by heavy fishing in spite of replacement by stocking.

CATOSTOMIDAE *Suckers*

20. *Megastomatobus cyprinella* (Cuvier & Valenciennes).*— Big-mouth buffalo. Rare. One specimen is reported from Lake Erie by Hubbs. The species was planted in the lake.

21. *Carpiodes cyprinus* (Le Sueur).—White carp, buffalo mullet, quillback, swordfin. Common in Lake Erie, going well up into creeks to spawn. Taken in considerable numbers by seines in Cattaraugus creek in the spring and at this time it is of considerable economic value. As a food fish it is comparable to the red-fin suckers, of good quality although bony. Young were found in mouths of creeks, and in Cattaraugus creek they were numerous several miles from the mouth along shallow, mud flats. A specimen taken at the mouth of Sister creek, July 12, was $1\frac{5}{16}$ of an inch long, about the youngest one that was found.

22. *Catostomus commersonnii* (Lacépède).—Common sucker, white sucker, mullet. Abundant. Widely distributed, occurring in nearly all waters of the area. Inhabits cold or warm streams as well as Lake Erie. Many live in streams all the year round, but the greater part of the suckers in Lake Erie enter streams only to spawn. It seems probable that many of them spawn in the lake, judging from the number of sucker fry collected along the lake shore far away from stream mouths. Lake Erie suckers are large and are of considerable commercial value. The flesh is good, even in the warm months. The sucker has grown[4] in importance with the increasing scarcity of the more choice species. Commercially, it is taken in seines, fykes and gill nets. Sport fishermen catch many by hook and line, and by spear, mainly in spring. By July 25, young found in the Niagara river averaged about $\frac{7}{8}$ of an inch in length. Within the region, the sucker is divisible into two races, one being made up of those which are permanently resident in streams, and the other being made up of those in Lake Erie, which spawn to a large extent in streams but are not resident there. The Lake

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[1] We are not here distinguishing between the Columbia river steelhead, *Salmo irideus gairdneri*, and the coast range steelhead, *Salmo irideus irideus*.

[2] Recorded as *gairdneri*.

[3] Fish Distribution, Waters in New York State Stocked in 1925. State of New York Conservation Commission 1926.

[4] It now ranks fourth in importance in Lake Erie.

Erie race has larger scales, is deeper in the forward part of the body and averages much larger.

23. *Catostomus catostomus* (Foster).*—Fine-scaled sucker, long-nosed sucker, sturgeon sucker. Rare. There seem to be no recent records, but statements of its occurrence in Lake Erie, cited by Dymond.

24. *Hypentelium nigricans* (Le Sueur).—Hammerhead, hog sucker, stone-roller sucker. Common. Prefers large, shallow, warm creeks. Occurs in Lake Erie, usually near stream mouths. Unimportant as a food fish, but is sometimes used (illegally) as bait, particularly for muskalonge.

25. *Erimyzon sucetta* (Lacépède).—Club sucker, sweet sucker. Rare. One specimen was taken in Muddy creek, near Angola. Records from Lake Erie are given by Dymond. This species is the smallest member of the sucker family in the region.

26. *Minytrema melanops* Rafinesque.*—Striped sucker. Rare. Dymond cites the records of its occurrence in Lake Erie.

27. *Moxostoma aureolum* (Le Sueur).—Red-fin mullet, red-horse sucker. Common in large streams of the eastern part of the drainage, such as Ellicott creek. It is found in the Niagara river and in Lake Erie, but is less common in the lake than the next species. This large red-fin sucker, living as it does in creeks, is probably the most important of its genus as an anglers' fish. All of the group are good food fish, bringing a better price than the common sucker and they are increasing in value. There is danger of their becoming too rare, from pollution of streams in which they live or go into to spawn, and from fishing and spearing during their spawning, in spring. The few young that were found came from streams. One taken August 10 from Tonawanda creek measured $1\frac{1}{16}$ inches.

28. *Moxostoma anisurum* Rafinesque.—White-nosed red-fin mullet, red-horse sucker. Common in Lake Erie, ascending streams to spawn. Economically, this is the most important of the *Moxostomas.* This species is said to run up streams to spawn, the run beginning as soon as ice is out of streams. They are taken in Cattaraugus creek by means of seines and are said to reach a size of 7 or 8 pounds. Young were found at several creek mouths. Six specimens from the mouth of Eighteenmile creek, taken July 21, averaged $1\frac{3}{16}$ inches.

29. *Moxostoma lesueurii* (Richardson).—Short-headed red-fin mullet, red-horse sucker. Common in Lake Erie, running up streams to spawn. The run of "short-heads" in Cattaraugus creek is said to occur in May, later than the run of the preceding species. The present species is smaller and slimmer than *anisurum* but is said to be of the same quality. Limited numbers of both species are taken in gill nets. The principal means of capture is the seine.

30. *Moxostoma duqesnii* (Le Sueur).—Fine-scaled red-fin mullet, red-horse sucker. Uncommon. Occurs in Lake Erie. Small specimens were numerous at the mouth of Eighteenmile creek, and there is no doubt that this species runs up streams to spawn. It is probably not distinguished from other red-fin suckers by fishermen, and has been confused with others by ichthyologists. However, characters of scale count and body proportions distinguish it from allied species.[1]

31. *Placopharynx carinatus* Cope.*—Big-mouth red-horse sucker. Rare. Listed from Lake Erie by Hubbs.

CYPRINIDAE *Minnows*

32. *Cyprinus carpio* Linnaeus.—Carp,[2] German carp. Common. Widely distributed, occurring in nearly all waters except the small, rapid streams. Although unpopular with anglers, it is important as a commercial fish, many being shipped to New York City for sale. A few are smoked, mostly for home consumption. In Lake Erie there are many carp, throughout the

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[1] We are indebted to Dr. Carl L. Hubbs for a manuscript copy of The Species of Red-horse Suckers of the Great Lakes and Mississippi Drainage Systems.

[2] Oswego Survey Report, 1927, contains illustration of young.

shallow parts. They come inshore in bays and creek mouths to spawn, and most of those caught are taken at this time. Seines are used in Cattaraugus creek and the Niagara river. Adults full of eggs were taken as late as June 27 at Dunkirk bay, although many others had spawned by this date. A series of 95 young taken August 1 from Black creek, near Buffalo, showed a variation in size from 1⅞ to 3 inches, additional evidence of a long spawning period. The age of these specimens was checked by scale examination.

33. *Carassius auratus* (Linnaeus).—Goldfish, gold carp. (Plate 3.) Common in Lake Erie in shallow parts, especially bays and creek mouths. Like carp it is an introduced fish. It reaches a weight of about 2 pounds but is of questionable economic value in the lake. Gold colored individuals are less common than brown ones. It hybridizes with the carp, and several of the intermediates were collected. The numbers of goldfish in Lake Erie have increased to a point where the fish has become a nuisance, as it competes with many other bottom-feeding species for food. Young were very common in Dunkirk harbor during late summer. They much resembled young carp in appearance, size, and habits. The habitat of the young (shallow, weedy places) and the fact that they grow very fast makes it unlikely that they would be important items in the food of predacious fish.

34. *Nocomis biguttatus* (Kirtland).—Horny-head, river chub. Uncommon. Restricted to the eastern part of the drainage, where it is locally common in many warm streams of the Tonawanda creek system.

35. *Nocomis micropogon* (Cope).—Crested chub, river chub. Common in warm streams throughout the region, not ranging into headwaters. This is a large minnow, and is sometimes caught on hook and line by boys. It is a nest building fish, each breeding male building a large heap of pebbles by picking them up, one by one. Such a nest was observed, July 9, in Silver creek, and the male guarding it was seen to spawn with each one of several females. Pebbles were piled on the nest after each spawning act, so that the eggs were covered. An egg measured 2 millemeters after preservation in formalin. The water temperature at this date was 83 degrees.

36. *Erimystax dissimilis* (Kirtland).*—Spotted chub. Rare. A record from a Lake Erie tributary in southern Ontario is cited by Hubbs.

37. *Erinemus storerianus* (Kirtland).—Storer's chub. Common in Lake Erie and at mouths of tributary creeks. This is one of the largest, native species of the minnow family in the region, reaching a size of over 10 inches. In the lake, it ranges out into rather deep water, sometimes being taken in gill nets. Apparently, it spawns quite late, as females taken June 21 were nearly ready to spawn.

38. *Erinemus hyalinus* (Cope).— Big-eyed chub. Rare. This rather insignificant appearing fish is found in the lower courses of streams of the southern and eastern part of the area. It was most common in the Buffalo creek system, frequenting shallow, mud flats, where the current was moderate. Apparently, this is about the eastern limit of its range.

39. *Rhinichthys atronasus lunatus* (Cope).—Black-nosed dace.[1] Abundant. Widely distributed, occurring in practically every small stream, warm or cold. It is rare in the lower courses of streams and occurs in Lake Erie only as a stray. One of the common fish of trout streams. Spawning was observed June 17, in Little Buffalo creek at the head of a riffle, where there was clean gravel. In at least one instance, a male was seen to crowd a female against a small stone during a spawning. A few eggs found in the gravel were probably, but not certainly, eggs of this species.

40. *Rhinichthys cataractae* (Cuvier & Valenciennes).—Long-nosed dace[1]. Abundant. Occurs in nearly all streams, but does not inhabit the headwater streams as often as does *atronasus*. It is common along the shore of Lake Erie in rocky places, and in streams it is most common in the riffles where there are stones. It inhabits a few trout streams.

41. *Semotilus atromaculatus atromaculatus* (Mitchill).—Horned dace,[2] chub. Abundant. Inhabits practically every stream. It is less common in

[1] Illustrated in Genesee Survey Report, 1926.
[2] Illustrated in Oswego Survey Report, 1927.

large streams than in small ones, and is rare in Lake Erie. A common fish of upland streams, thriving in warm or cold waters. In food habits it resembles the trout, and is evidently one of the most serious competitors of these.

42. *Margariscus margarita* (Cope).—Pearl minnow.[1] Uncommon. Is limited to a few, small streams of the uplands. Usually found in cold waters, often associated with the brook trout.

43. *Clinostomus elongatus* (Kirtland).—Red-sided dace[2]. Common in many streams. Reaches its highest abundance in small streams of muddy or rubble bottom. Does not avoid waters cold enough for trout.

44. *Opsopoeodus emiliae* (Hay).—Pug-nosed shiner. Jordan and Evermann[3] give it as occurring in Lake Erie. There appear to be no definite records.

45. *Notropis heterodon* (Cope).—Rare. A few specimens were obtained from the Niagara River among weed beds, on July 26. Several individuals were nearly ready to spawn.

46. *Notropis heterolepis* Eigenmann & Eigenmann.—Black-nosed minnow. Common. Found in sluggish streams and ponds and in sheltered bays of Lake Erie. A common fish of swamp situations. Females nearly ready to spawn were found as late as July 26, in the Niagara river.

47. *Notropis volucellus volucellus* (Cope).—Common. Occurs in Lake Erie, especially in creek mouths. Inhabits many of the larger streams, such as Ellicott creek, and other sluggish ones of the eastern part of the drainage where it seems to be an important source of food for pickerel, bass, and other game fish.

48. *Notropis deliciosus stramineus* (Cope).—Straw-colored minnow. Abundant in Lake Erie and many of the larger tributaries, in their lower courses. Thousands were seined in late June and early July, when they were close inshore for the purpose of spawning. This species is fed upon by many lake fish[4].

49. *Notropis dorsalis* (Agassiz).—Gilbert's minnow. Common in many streams of the Tonawanda and Ellicott creek drainages. Not taken in Lake Erie, seeming to prefer streams.

50. *Notropis hudsonius* (Clinton). Spot-tailed minnow[5]. Abundant in Lake Erie, and ascends certain of the larger creeks. Numerous specimens were taken in late June and early July along the lake shore and in the lower parts of creeks where spawning takes place, judging from the ripe condition of the eggs of many of these.

51. *Notropis whipplii spilopterus* (Cope).—Satin-finned minnows[6], silverfin. Common in the lower courses of several tributaries of Lake Erie; rare in the lake, itself.

52. *Notropis atherinoides* Rafinesque.—Lake shiner, emerald minnow. Abundant. We consider this the most plentiful fish of Lake Erie. It occurs there in great schools, in deep as well as shallow water, and is also abundant in the Niagara river and in the lower courses of large creeks. This species forms an important food supply for the blue pike, yellow pike, white bass and other predacious lake fish. It is the most widely used bait minnow of the region. A few specimens that were full of nearly ripe eggs were taken close inshore in late June (the 21st) but nothing definite was learned of their spawning. Young were found in the Niagara river and in lake Erie during the latter part of the summer.

53. *Notropis rubrifrons* (Cope).— Rosy-faced minnow. Uncommon. Is found in several of the larger creeks, usually where there is strong current.

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[1] Illustrated in Genesee Survey Report, 1926.
[2] Illustrated in Genesee Survey Report, 1926.
[3] Bulletin 47 United States National Museum (1896).
[4] See Dr. C. K. Sibley's report, p. 184.
[5] Illustrated in Oswego Survey Report, 1927.
[6] Illustrated in Genesee Survey Report, 1926.

We took no specimens in Lake Erie, although the species has been found there (Dymond).

54-a. *Notropis cornutus chrysocephalus* Rafinesque.—Common shiner, red-fin shiner. Abundant. This large-scaled subspecies of the common shiner is restricted to the lower courses of streams, Lake Erie, and the Niagara river. In the upland streams its place is taken by the next subspecies. Many individual male shiners die after the spawning season. Several spent males of *chrysocephalus* were found in Cattaraugus creek, July 10, in a dying condition. The many scars of these and of similar ones are evidence of the fighting that takes place among males at the spawning season.

54-b. *Notropis cornutus frontalis* (Agassiz).—Common shiner,[1] red-fin shiner. Abundant. This, the fine-scaled subspecies, is widely distributed, occuring in nearly every creek. In the lower courses of streams it is less common than *chrysocephalus* and in Lake Erie it is of only stray occurrence. Where both subspecies occur at the same locality, intermediates are usually found. The present subspecies is a common fish of the upland trout streams, but does not range quite as far into headwaters as the black-nosed dace, or the horned dace. On June 17, spawning was observed in Little Buffalo creek, and on July 9 in Silver creek. In both instances, an area of clean gravel, lying in rather strong current, was chosen. At Silver creek, the spawning took place on the nest of another species, the crested chub (*Nocomis micropogon*). There were three males of *cornutus* present, competing for possession of the spawning area, the selected spot being at the upstream side of the pile of stones constituting the nest. The individual in possession of this spot mated with several females in rapid succession, and defended the spawning position against other males. He was soon supplanted by one of these, however, after several attacks from this adversary. The eggs were very numerous in the gravel. They were 1.5 millimeters in diameter, after preservation in formalin, and were pink, before preservation. They were lightly adhesive, sticking to gravel or to each other. After each spawning operation, eggs were eagerly sought out by a number of fish which had been attracted by this food supply. Those seen to seek out eggs included rainbow darter, log perch, horned dace, and small individuals of the two spawning species (the shiner, and the crested chub). The water temperature was 83 degrees.

55. *Notropis umbratilis syanocephalus* (Copeland).—Red-fin minnow. (Plate 4.) Uncommon. Is restricted to several weedy creeks near Angola, where it was first discovered by Prof. T. L. Hankinson in June. Males in full breeding color were found as late as July 16. This species is, characteristically, a Mississippi drainage fish.

56. *Notemigonus crysoleucas crysoleucas* (Mitchill).—Golden shiner. Common. Prefers a habitat where there is aquatic vegetation. Specimens were found in Lake Erie, in sheltered bays and in many weedy streams and ponds. An occasional specimen was taken in several of the more rocky creeks.

57. *Hybognathus hankinsoni* (Hubbs).—Hankinson's minnow.[2] Rare. A single specimen at the U. S. National Museum (No. 70002), taken in Cazenovia creek near Buffalo, by A. J. Woolman on August 8, 1893, is the only record for the area covered by the survey.

58. *Chrosomus erythrogaster* Rafinesque.—Red-bellied dace. Uncommon. In our drainage, this minnow is restricted to several sluggish streams and small ponds, near Buffalo and eastward.

59. *Hyborhynchus notatus* Rafinesque.—Blunt-nosed minnow.[3] Abundant. One of the predominant species, in point of numbers, of the larger creeks and the ponds of the watershed. In Lake Erie, it is common only in sheltered areas. It is a prolific little fish, and has a long spawning season, lasting until late summer. Eggs were found July 13 in Sister creek near the mouth. They averaged 1.5 millimeters in diameter, after preservation in formalin, and were transparent, with a polished appearance, when fresh. They

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[1] Illustrated in Oswego Survey Report, 1927.
[2] Specimen determined by Dr. C. L. Hubbs.
[3] Illustrated in Genesee Survey Report, 1926.

adhered, individually, to the under side of a large, flat stone, and covered an area 7 by $4\frac{1}{2}$ inches. The total number, accurately estimated, was 11,812. These were laid by more than one female, judging by the fact that some were hatching when found, and others were far less advanced. The eggs were guarded, when found, by a male fish approximately $3\frac{1}{4}$ inches long, whose position was directly under the stone. The water temperature was 82 degrees. It is interesting, in its bearing on the subject of the efficiency of natural fertilization of fish eggs, to note that every one of these was fertile with live embryo.

60. *Pimephales promelas promelas* Rafinesque.—Fat-head minnow, black-head minnow. (Plate 4.) Common. Much resembles the last species in habits, but is less numerous. It reaches a high concentration of numbers in several small ponds and reservoirs, but seems to be rare where there are many other species in competition with it. A few were found at mouths of several Lake Erie tributaries. It is known[1] to continue spawning throughout much of the summer, and young of several sizes were collected on the same date, on a few occasions. A school of fry, each about $\frac{15}{32}$ of an inch was taken July 5 at the reservoir on Silver creek.

61. *Campostoma anomalum* Rafinesque.—Stone-roller minnow.[2] Common. This is a characteristic fish of shallow, warm creeks. It is not found at head waters. In Lake Erie it is of stray occurrence.

AMEIURIDAE *Catfishes*

62. *Ictalurus punctatus* Rafinesque.—Spotted catfish, silver cat, channel cat. Common in Lake Erie, and is found in the Niagara river and large streams. It is an important commercial species in Lake Erie and is also sought by anglers. This is the best of the catfishes as a food and game fish. The greater number of those taken are caught in late spring when they are in mouths of creeks to spawn. They are captured, commercially, by set line and seine, and sport fishermen take them with hook and line and spear. Specimens taken June 27 at Dunkirk contained ripe eggs. Young of this (possibly of the next) species were found in sheltered bays and lagoons at creek mouths; a specimen from Lake Erie near the mouth of Silver creek on August 23, was $1\frac{13}{16}$ inches long. The next size obtained, $5\frac{15}{16}$ inches (same date), we think is a yearling. This and similar ones are spotted like the adults; the smallest size is not.

63. *Villarius lacustris* (Walbaum). Lake catfish, blue cat, lake lugger. Uncommon. Occurs in Lake Erie, where it is less common than the spotted cat but averages larger. The means of capture are the same for both species. The blue cat spawns in early summer; females shedding the last of their eggs were seen July 8, having been speared near the mouth of Sister creek, at a point where there are clay banks. Fishermen say that they spawn in such places, guarding the eggs as does the common bullhead. Intensive fishing of the catfishes, when they are in the creeks to spawn, cannot fail to result in low production of young.

64. *Ameiurus melas* Rafinesque.*—Black bullhead. Rare. Several records for Lake Erie are cited by Dymond. Fowler[3] reported it abundant and frequently marketed at Erie, Pa.

65. *Ameiurus nebulosus* (Le Sueur).—Common bullhead, horned pout. Common. A resident of the larger, more sluggish streams and the ponds and lakes. In Lake Erie, the species is common only in sheltered areas. It is an important anglers' fish in small lakes, as Java lake, and in large streams, as lower Ellicott creek, but in Lake Erie it is not extensively fished in New York waters. Some are marketed from Cattaraugus creek, being taken by seine. Specimens in spawning condition were found at Dunkirk harbor, on June 27. Young are usually in weed beds.

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[1] Lord, R. F. Notes on the Use of the Blackhead Minnow as a Forage Fish. Trans. Amer. Fish. Soc. 1927.

[2] Illustrated in Genesee Survey Report, 1926.

[3] Fowler, H. W. A List of the Fishes of Pennsylvania. Proc. Biol. Soc. Washington, Vol. 32, 1919.

66. *Ameiurus natalis* (Le Sueur).—Rare. Taken only in Muddy and Little Sister creeks, and in Lake Erie at Dunkirk bay. The species has little economic value in the region, due to scarcity. It averages smaller than the common bullhead. Young from Little Sister creek, July 18, averaged $1\frac{1}{16}$ inches in length, being appreciably smaller than young of *nebulosus* found with them.

67. *Leptops olivaris* Rafinesque.*—Mud cat. The only record for Lake Erie is that quoted by Osburn.[1] Hubbs remarks that probably only stragglers of the species have entered the lake through canals. No specimens are on record.

68. *Noturus flavus* Rafinesque.—Stonecat, mongrel bullhead, deep-water bullhead. (Plate 5). Common in Lake Erie; occurs, also, in many of the larger tributaries. In streams, it is found among stones, usually in the riffles. In the lake it is most common along rocky shores, and ranges out into water of 30 feet or more in depth. Many are taken in gill nets set for perch and pike, and they are considered a great nuisance by fishermen. Stonecats from the lakes are large, often a foot long, and the flesh is excellent. They are not marketed, however, as there is no demand for them, and they are troublesome to dress on account of their poisonous[2] spines. This species feeds upon minnows and crayfish and competes with black bass for food; it is suspected, also, of feeding on spawn of other species. Two egg masses of the stonecat were found in lower Sister creek, on July 13, under flat stones. One of these was guarded by two of the fish, probably the parents. In the other case, the male only was located under the stone. The eggs were yellow, opaque and were cemented together by a jellylike substance to form a rounded mass, about 2 inches in diameter and one inch thick. The eggs measured from $3\frac{1}{2}$ to 4 millimeters in diameter, and numbered approximately 500. The water temperature was 82 degrees.

69. *Schilbeodes gyrinus* (Mitchill).—Tadpole stonecat. Rare. This diminutive catfish inhabits weed beds. Our specimens came from the Barge canal and tributaries. Records from Lake Erie are given by Dymond.

70. *Schilbeodes miurus* (Jordan).*—Brindled stonecat. Rare. Recorded from Sandusky bay by Osburn.[1]

UMBRIDAE *Mud Minnows*

71. *Umbra limi* (Kirtland).—Mud minnow. Common. A fish of sluggish, weedy streams and ponds. Inhabits many streams of the northeastern area of the watershed. In Lake Erie it is rare, being confined to weed beds.

ESOCIDAE *Pickerels*

72. *Esox americanus* Gmelin.—Grass pickerel, little pickerel. Common in several sluggish creeks, and in the Niagara river. In Lake Erie it seems limited to stream mouths. It has a preference for weedy places. This species is like others of the family in habits, but is smaller than others, adults seldom exceeding a foot in length. For this reason it is unimportant as a game fish.

73. *Esox niger* Le Sueur.—Chain pickerel, eastern pickerel. Rare. This fish is found in Lime lake, where it is an important anglers' fish. It was probably artificially introduced there. This reaches a larger size than the preceding pickerel. This species is listed by Fowler as introduced in Lake Erie.

74. *Esox lucius* Linnaeus.—Pickerel, northern pike. Common in large, weedy streams. It is an important angler's fish in the waters of the eastern

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[1] Osburn, R. C. The Fishes of Ohio. Ohio State Acad. of Science, Special Papers No. 4, 1901.

[2] Reed, H. D. The Morphology of the Dermal Glands in Nematognathus Fishes. Zeitschrift fur Morphologie und Anthropologie. Bd. XXIV 1924.

part of the drainage, notably Ellicott creek. In Lake Erie it is uncommon, but there is said to be good fishing for it at the mouth of Little Sister and a few other creeks, in spring.

75. *Esox masquinongy* Mitchill.—Muskalonge. Uncommon. Specimens were taken in the upper Niagara river and in Lake Erie, at Eagle bay, both times in close proximity to aquatic vegetation. The upper Niagara river has been a notable fishing ground for it, but only a very few seem to be taken there now. Young were found in weed beds of the Niagara river, July 27; one of them measured 1⅞ inches. The muskalonge of the St. Lawrence drainage is now regarded as a species different from the Chautauqua[1] one. There are constant differences in head proportions and color pattern.[2] The Chautauqua muskalonge has been planted in Ellicott creek, Tonawanda creek and the upper Niagara river, but there seem to be no definite records of its capture in these waters.

ANGUILLIDAE *Eels*

76. *Anguilla rostrata* (Le Sueur).—American eel. Uncommon. Most of the eels taken within the area under study are caught at the mouth of the Niagara river, with hook and line. The species is less common in Lake Erie.

CYPRINODONTIDAE *Killifishes*

77. *Fundulus diaphanus menona* Jordan & Copeland.—Barred killifish, grayback minnow. Uncommon. In Lake Erie it is restricted to sheltered situations such as Dunkirk harbor. The largest schools were found in the upper Niagara river along sheltered beaches, in water only a few inches deep.

PERCOPSIDAE *Trout-perches*

78. *Percopsis omiscomaycus* (Walbaum).—Trout-perch. This little, spotted fish is one of the most common ones of Lake Erie. A small number were collected in the Niagara river. It usually inhabits quite deep water, but comes close inshore to spawn, often ascending creeks. Hundreds were seined along shore from June 20 to July 12, after which they became rare in such situations. Specimens in spawning condition were abundant in riffles in Cattaraugus creek (near Irving), on July 2. One egg, almost certainly that of this species, was dipped from the gravel at this spot. The smallest young specimen that was found close inshore, one ⅞ of an inch long, came from the Niagara river, July 25. During, and just after, their spawning run dead adults are common along the beach of the lake. Whether all die after spawning is not known, but at least some of them die.

APHREDODERIDAE *Pirate-perches*

79. *Aphredoderus sayanus* (Gilliams).—Pirate-perch. Rare. A few specimens were taken in Cayuga creek at a muddy and weed-choked place. Records from Lake Erie are given by Dymond.

SERRANIDAE *Sea basses*

80. *Lepibema chrysops* Rafinesque.—White bass, silver bass. Common in Lake Erie and the Niagara river, also entering the mouths of streams. Has a minor importance as a game and commercial fish in New York borders. It is often seen in schools pursuing other fish, notably *Notropis atherinoides*, and is often captured by anglers who cast a minnow bait or a small spinner into where the fish are feeding. Silver bass so taken are usually small,

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[1] For an account of the biology of the Chautauqua Muskalonge see Moore, Emmeline. Problems in Fresh Water Fisheries. State of New York Conservation Commission 1926.

[2] Weed, A. C. Field Museum of Natural History Zool. Leaflet 9, 1927.

about a half pound in weight. In spring, they are caught by seines in Cattaraugus creek and a few are caught, during the summer, in gill nets. Young were fairly common in several places along the lake shore and in creek mouths. One was taken in the Niagara river, on July 27, that measured $\frac{13}{8}$ of an inch.

PERCIDAE *Perches*

81. *Perca flavescens* (Mitchill).—Yellow perch. Very common. A fish of high economic importance in Lake Erie, and the Niagara river. It occurs also in small lakes, as Lime lake, where it has been introduced. Several of the larger, deeper creeks also have perch, but they are fewer in number in these places. In the New York area of Lake Erie, perch are fished by gill nets, principally. The species ranges widely, being found in deep as well as shallow water. Young were found, commonly, in sheltered places along the lake shore, and especially in the weed beds of the Niagara river. Specimens taken at the latter locality, on July 26, ranged in size from 1¼ to 1½ inches. A larger size taken with them, from 3¼ to 4⅛ inches, proved by scale examinations to be yearlings.

82. *Stizostedion canadense griseum* (De Kay).—Sauger, sand pike. (Plate 6.) Common in Lake Erie, where it it is often taken by net fishermen and anglers. The sauger, like the next species and unlike the blue pike, is most common in relatively shallow water, avoiding the deepest parts of the lake. It is inferior to the yellow pike in size and quality of flesh. However, it is a good fish and has a ready sale. All those taken at the beginning of the summer's collecting had spawned, with one exception. This was in the case of one taken in Silver creek bay, on July 4, which contained eggs ready to deposit.

83. *Stizostedion vitreum* (Mitchill).—Yellow pike, pike-perch, wall-eyed pike. (Plate 7.) Common in Lake Erie and the Niagara river. Has been established in a few of the small lakes, notably Java lake. This is the largest member of the genus, and is the most important one for angling. Its numbers are fewer than the blue pike, however, and it is less important commercially, than the latter. Young were seined at numerous localities along the lake shore and in the Niagara river, and were more common in sheltered areas than in exposed places. They grow rapidly. Four specimens from the Niagara river, taken July 26, were from 1⅞ to 2⅛ inches long.

84. *Stizostedion glaucum* (Hubbs).—Blue pike. (Plate 8.) Very common in Lake Erie, inhabiting also the upper and lower Niagara river. A very important commercial fish in Lake Erie; in New York waters the principal means of capture is by gill nets. Although by no means confined to deep water, it is most common there. A limited number of small specimens was taken along shore, but no young were found there that could be positively determined as belonging to this species rather than to *vitreum*.

85. *Hadropterus maculatus* (Girard).—Black-sided darter. Uncommon. Occurs in many warm streams of the eastern and southern parts of the watershed, but is not present in headwater brooks.

86. *Percina caprodes zebra* (Agassiz).—Log perch, modoch. Very common in Lake Erie and the lower courses of streams, as well as in the Niagara river. This is a choice bait fish (used illegally since it is not a minnow) for black bass in Lake Erie, going by the name of modoch. It ascends streams to the riffles for spawning, the run lasting until the last part of June. Late in summer it was less common inshore.

87. *Rheocrypta copelandi* Jordan.—Copeland's darter. Common in Lake Erie and in the lower courses of several tributaries. Like the last species, many individuals ascend streams to spawn. Ripe males were found in Eighteen-mile creek on July 11, in the riffles about ¼ mile from the mouth.

88. *Imostoma shumardi* (Girard).—River darter. Forbes and Richardson[1] state that it has been reported from Lake Erie. There seem to be no definite records.

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

89. *Ammocrypta pellucida* (Baird).*—Sand darter. Rare. The U. S. National Museum has specimens that were collected in Cazenovia creek, near Buffalo, and in Cattaraugus creek, at Gowanda and at Irving, by A. J. Woolman in 1893. This species may, quite possibly, have been exterminated in these creeks by pollution.

90. *Boleosoma nigrum nigrum* (Rafinesque).—Johnny darter.[1] Common and widely distributed, inhabiting nearly all stream systems as well as Lake Erie and the Niagara river. In the lake it is most common in weedy places.

91. *Poecilichthys coeruleus coeruleus* (Storer).—Rainbow darter, soldier darter. Common. This is distinctly a stream fish, living in shallow creeks, especially in the riffles, and avoiding lakes. It is found in the majority of streams of the southern and western part of the drainage, becoming less common to the east and north. A few were found in trout streams.

92. *Poecilichthys exilis* (Girard).—Iowa darter. Uncommon. It is locally common in sheltered spots along Lake Erie, especially Dunkirk harbor. Specimens were collected in one of the small lakes, Java lake.

93. *Catonotus flabellaris* (Rafinesque).—Fan-tailed darter.[2] Common. Like the rainbow darter, it is a stream species. It inhabits practically every stream system, ranging farther into headwaters than any other darter, and being commonly found in trout streams. Eggs[3] were found in Ellicott creek near Bowmansville, on June 18. They were attached to the under side of a stone.

94. *Etheostoma blennioides* Rafinesque.—Green-sided darter. Uncommon. It was taken in shallow, warm streams of the eastern and southern divisions of the drainage. Like the other darters, with the exception of the fan-tail, it does not inhabit headwater streams of the region.

CENTRARCHIDAE *Sunfishes*

95. *Micropterus dolomieu* Lacepédè.—Small-mouthed bass, black bass. Common. This is one of the most popular angler's fish of the region, especially in the shore zone of Lake Erie. Bass are found in the Niagara river and in several of the larger creeks, as Cattaraugus. Many of the lake bass enter creek mouths to spawn, and the young inhabit such situations during their first season. The protection given by law does not fully cover the spawning season, as several bass taken after July 1 had not laid their eggs. The latest of these, of which we have record, was a female which was caught at the mouth of Sister creek, on July 8. It seems to be the general opinion that bass are decreasing; probable causes are intensive angling and the tapeworm disease.[4] Young were common in the Niagara river, and in sheltered areas along the lake shore. The smallest were from ½ to ¾ of an inch, taken at the mouth of Eighteenmile creek, July 18.

96. *Aplites salmoides* (Lacépède).—Large-mouthed bass. Uncommon. Less important as an angler's fish than the preceding species. In Lake Erie it is limited to weedy areas, as Dunkirk bay. It is well established in Lime lake and Crystal lake, and is found in Tonawanda creek and several other large, sluggish streams. This species spawns earlier than does the small-mouthed bass. Young from Lake Erie, seined July 19, measured from 1¼ to 1⅝ inches.

97. *Chaenobryttus gulosus* (Cuvier & Valenciennes).*—War-mouth bass. Rare. Mentioned as occurring in Lake Erie by Forbes and Richardson. There are apparently no definite records.

98. *Helioperca incisor* (Cuvier & Valenciennes).*—Bluegill sunfish. Rare. Mr. T. L. Hankinson took specimens at the mouth of Delaware creek in June. There are several records for Lake Erie. It is too rare, at present, in this region to be an important angler's fish but is being recommended for stocking small ponds.[5] This species is larger, and more desirable than the common sunfish.

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[1] Illustrated (subspecies *olmstedi*) in Oswego Survey Report, 1927.
[2] Illustrated in Oswego Survey Report, 1927.
[3] For description see Genesee Survey Report, 1926.
[4] See page 198
[5] See page 235

99. *Xenotis megalotis* (Rafinesque).*—Long-eared sunfish. Rare. Dymond cites the records of its occurence in Lake Erie.

100. *Eupomotis gibbosus* (Linnaeus).—Common sunfish. pumpkinseed. Common. Widespread in distribution. being found in sluggish creeks, ponds and small lakes. In Lake Erie it is restricted to weedy spots. This is a good pan fish and receives attention from many anglers, in spite of its small size. One young specimen from Tonawanda creek, taken September 8, was ½ inch long.

101. *Ambloplites rupestris* (Rafinesque.—Rock bass, goggle-eye bass. Abundant, the most plentiful member of the sunfish family. It is found in almost all waters of the drainage, except very small or very cold streams. In Lake Erie this species is often taken by anglers seeking bass or perch, and it is also of some commercial importance. In creeks and ponds the rock bass provides considerable fishing, especially for young sportsmen. The average size of those taken is less than ½ pound. Numerous young were taken in aquatic vegetation. Those from the Niagara river, collected July 27, were from ⅝ to ¾ of an inch.

102. *Pomoxis annularis* Rafinesque.—White crappie. Uncommon. Specimens were collected in sheltered bays and creek mouths along Lake Erie. Few are caught by anglers. This species is a desirable one for small lakes as it grows to a larger size than others of the pan-fish type.

103. *Pomoxis sparoides* (Lacépède).*—Black crappie, calico bass. Rare. There are specimens from Lake Erie in the U. S. National Museum collection, that were collected at Silver creek in 1894. Other records from Lake Erie are given by Dymond. At the present date it is much less common than the preceding species, which it resembles in most respects.

ATHERINIDAE *Silversides*

104. *Labidesthes sicculus* (Cope).—Brook silversides, skipjack. Rare. Our only specimens came from Lake Erie at the mouths of Silver and Eighteenmile creeks.

SCIAENIDAE *Drumfishes*

105. *Aplodinotus grunniens* Rafinesque.—Sheepshead, fresh-water drum. gray bass. Common in Lake Erie, where it is gaining in popularity as a commercial fish. It is taken by anglers, although it is not particularly sought by them. The species is in the Niagara river, and enters the mouths of creeks. Sheepshead are taken with seines at the mouth of Cattaraugus creek. The smallest young specimen was one 1⅝ inches, from the mouth of Eighteenmile creek, taken August 14.

COTTIDAE *Sculpins*

106. *Triglopsis thompsonii* Girard.—Deep-water sculpin. Rare. The lake survey party collected small specimens[1] in young fish trawls, from deep water of Lake Erie. This is the only record of its occurrence in this one of the Great Lakes.

107-a. *Cottus bairdii bairdii* Girard.—Sculpin,[2] millers thumb. Common in many creeks, especially toward the headwaters; often found in trout streams. In Lake Erie it is replaced by the next subspecies.

107-b. *Cottus bairdii kumlieni* (Hoy).—Lake sculpin, miller's thumb. Uncommon. Limited to Lake Erie and the Niagara river, within the region. Our specimens were seined near shore but it occurs in rather deep water, also.

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[1] Identified by Marie P. Fish.
[2] Illustrated in Genesee Survey Report, 1926.

108. *Cottus cognatus* Richardson.—Sculpin,[1] millers thumb. The only definite records for Lake Erie are those[2] collected from deep water by the lake survey party. A specimen examined, taken from the stomach of a ling collected in deep water off Dunkirk, seemed to be this species but was not in condition to be identified with certainty.

109. *Cottus ricei* Nelson.—Rice sculpin. Small specimens[3] were collected by the lake survey party; as in the preceding species they are the only records for Lake Erie.

GASTEROSTEIDAE *Sticklebacks*

110. *Eucalia inconstans* (Kirtland).—Brook stickleback. Common in weed beds of the Niagara river, and occurs in many creeks of the watershed, particularly those of the Tonawanda system. Often occurs in trout streams if there are weeds.

111. *Gasterosteus aculeatus* Linnaeus.—Two-spined stickleback. Rare. Small specimens were seined from the mouth of the Niagara river in weed beds. It has not been found above Niagara Falls.

GADIDAE *Codfishes*

112. *Lota maculosa* (Le Sueur).—Ling,[4] ell-pout, burbot, lawyer, gudgeon. Common in Lake Erie. It is often taken in nets set for herring, and is gaining importance as a commercial fish. Those caught were formerly discarded by the fishermen, but many of them are now marketed. Demand for them is on the increase. The ling is usually found in deep water, but is not limited to this habitat. A small specimen, 7 inches, was seined at night from the mouth of Silver creek, on September 4.

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[1] Illustrated in Oswego Survey Report, 1927.
[2] Identified by Marie P. Fish.
[3] Identified by Marie P. Fish.
[4] Illustrated in Oswego Survey Report, 1927.

VII. THE FOOD OF CERTAIN FISHES OF THE LAKE ERIE DRAINAGE BASIN

By C. K. SIBLEY

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During the summer of 1928 food records were obtained for 64 species of fish. The alimentary tracts of 2,010 individuals were examined and 1,128 of these contained food.

In all cases, the length to the base of tail is used, that is, the distance from the end of the snout to the end of the vertebral column. The percentages given are estimates of the volume of the various food organisms present in stomachs. The species examined are grouped according to food preferences in order to facilitate comparison.

Species Feeding Mainly upon Animal Plankton.—While plankton organisms are the sole food of many very young fish, few species continue to take them in large quantities. A diet of over 50 per cent animal plankton for fish more than two centimeters long was found in only four species, summarized as follows:

Leucichthys artedi.— Herring, cisco. Number of records, 53. Length, 21.3–30.3 cm. or 8–12 inches. *Daphnia pulex,* 78 per cent; *Leptodora kindtii,* 20 per cent; *Limnocalanus macrurus,* 2 per cent.

Notropis atherinoides.—Emerald minnow, slender minnow. Nummer of records, 33. Length, 2.9–7.5 cm. or 1⅛–3 inches. *Daphnia pulex,* 46 per cent; *Leptodora,* 4 per cent; *Bosmina longirostris,* 1 per cent; *Diaptomus sicilis* and *D. ashlandi,* 4 per cent; *Epischura lacustris,* 2 per cent; misc. adult insects, 36 per cent; misc., 5 per cent (silt, Oscillatoria, diatoms, Heptagenia, 1 earthworm).

Labidesthes sicculus.— Brook silversides. Number of records, 15. Length, 1.9–3.5 cm. or ¾–1¼ inches. About 50 per cent of the food was Cladocera; *Acroperus harpae; Alona rectangula; Chydorus sphaericus; Scapholebris mucronata.* Second in importance was the copepod *Leptocyclops agilis* and third was insects found either near the surface or floating on the surface, midge pupae and adults; Corixidae; Collembola; 1 thrips and 1 aphid.

Perca flavescens.—Yellow perch; a plankton diet was found in limited groups of this species.*

Assistance in the identification of material was given by Messrs J. R. Greeley, P. R. Burkholder, W. L. Tressler and Dr. C. B. Wilson.

* See table 2, p. 185.

TABLE 1.—SPECIES FEEDING ON ALGAE AND FRAGMENTS OF HIGHER PLANTS

NAME	Number of records	Lengths		Silt	Food materials
		Cm.	Inches		
Margariscus m. margarita... (Pearl minnow)	10	3.7–4.8..	1$\frac{3}{4}$.....	10%	Misc. algae, 90%: Spirogyra, Ulothrix, Oedogonium, Characium, Gomphonema, Scenedesmus, Cosmarium, Navicula, Cymbella, Synedra, Oscillatoria
Notropis cornutus.......... (Red-fin shiner)	33	4–9.8....	1$\frac{1}{2}$–3$\frac{3}{4}$..	10%	Plants, 50%: plant fragments, Spirogyra, Oedogonium, Ulothrix, Cladophora, Cosmarium, Closterium, diatoms; fish eggs, adult insects and earthworms, 30%
N. c. frontalis............. (Common shiner)	5	4.4–6.4..	1$\frac{1}{2}$–2$\frac{1}{2}$..	40%	Oscillatoria, 30%; diatoms, 5%; plant fragments, 25%
N. c. chrysocephalus........ (Common shiner)	2	4.5......	1$\frac{1}{2}$.....	30%	Diatoms, mainly Synedra and Navicula, 70%
Hyborhynchus notatus....... (Blunt-nosed minnow)	21	4.3–7.7..	1$\frac{1}{2}$–3...	40%	Fish eggs, 15%; algae, 45%; Pediastrum, Cosmarium, Closterium, Scenedesmus, Spirogyra, Oedogonium, Cladophora, Oscillatoria, Navicula, Synedra, Encyonema, Gomphonema, Cymatopleura, Pleurosigma
Pimephales promelas....... (Fat-head minnow)	16	3.2–5.8..	1$\frac{1}{4}$–2$\frac{1}{4}$..	40%	Misc. algae, 60%
Notemigonus crysoleucas.... (Golden shiner)	8	5–12.....	2–4$\frac{5}{8}$...	8%	Snails, 8%; Cyclops, Ostracoda, Leydigia qaudrangularis, 7%; adult midges, 12%; Triaenodes larvae, 8%; algae, 53%: Oscillatoria, Ulothrix, Navicula, Merismopaedium
Campostoma anomalum..... (Stone-roller minnow)	3	1.6–2....	$\frac{5}{8}$–$\frac{3}{4}$....	....	Chironomus larvae, 90%; diatoms, 10%
	6	2.6–6....	1–2$\frac{1}{4}$...	35%	Difflugia, Anurea cochlearis, 25%; misc. algae, 40%: Scenedesmus abundans, S. bijuga, S. arcuatus, S. dimorphus, Spirogyra' Ulothrix, Oedogonium, cosmarium cyclicum, Phormidium, Synedra, Encyonema, Pediastrum, Merismopaedium tenuissimum, Staurastrum alternans, Navicula, Meridion

Species Feeding Mainly upon Immature Aquatic Insects and Crustacea.—Thirty-four of the 64 species studied come under the above heading. In this area the forms which are found most commonly in stomachs are the larvae and pupae of the midges (Chironomidae). These are taken by all of the species in this group. The percentages are usually high. Among the suckers, for example, the averages range from 50 to 80 per cent.[1]

[1] For a summary of the food of members of this group, see Table 3 on p. 186.

Egg-eating Species.—An interesting seasonal variation in diet was noted for several species. During the first three weeks of the period covered by the survey many fish were spawning. As noted in Table 3, the eggs formed a considerable portion of the diet of several fish, especially in a sucker (*Moxostoma anisurum*), the long-nosed dace (*Rhinichthys cataractae*); three minnows (*Notropis volucellus, N. deliciosus, N. hudsonius*); the log perch (*Percina caprodes*); and two darters (*Poecilichthys coeruleus* and *Cottogaster copelandi*). Later in the season the diet of these fish changed radically. This is shown most clearly in the case of *N. deliciosus*. It was not possible to determine by what species the eggs were laid. However it seems probable that most of the eggs were deposited by other small minnows and darters.

Species Feeding Mainly on the Surface.—Four species of fish are included in this group. A summary of their stomach contents is as follows:

Hiodon tergisus (Mooneye): Twenty-four specimens contained food. The length varied from 10.6 cm. or 4 inches to 14.6 cm. or 5⅝ inches. Cladocera, 6 per cent; mayfly subimagoes and adults, 35 per cent; midge pupae and adults, 8 per cent; misc. terrestrial insects, 51 per cent.

Clinostomus elongatus (Red-sided dace): Eleven fish contained food. The length varied from 3.8 cm. or 1½ inches to 6.4 cm. or 2½ inches. The stomach contents were made up entirely of miscellaneous adult insects which could be found only at the surface of the water.

Semotilus atromaculatus (Horned dace). Records were obtained for 19 fish. Lengths varied from 3.7 cm. or 1¼ inches to 19 cm. or 7½ inches. Summary of food: Green algae, 5 per cent; plant fragments, 20 per cent; misc. adult insects, 40 per cent; Millipedes, 5 per cent; earthworms, 30 per cent.

Notropis umbratilis (Blood-tailed minnow). Twelve records were obtained. Lengths, 3.3 cm. or 1¼ inches to 3.9 cm. or 1½ inches. One Pleuroxus denticulatus was eaten. Otherwise the food was surface drift and was almost entirely adult insects.

The Fishing-eating Species.—Small fish are an important article of diet for many of the food and game fishes of this drainage. An effort was made to determine which species are most commonly eaten. All fish remains found in stomachs were saved and were identified by Mr. J. R. Greeley whenever their condition permitted this. Table 2 shows the results of this work and gives a summary of the stomach contents of the fish eaters.

A List of the Small Fish Found in Stomachs of Fish:

Total Number	*Name of species*
—	Sucker fry
6	Common sucker (*Catostomus commersonii*)
3	" " (*Catostomus commersonii?*)
14	Straw-colored minnow (*Notropis deliciosus*)
20	Spot-tailed minnow (*N. hudsonius*)
84	Emerald minnow (*N. atherinoides*)
17	" " (*N. atherinoides?*)
3	Red-fin shiner (*N. cornutus*)
2	(*Notropis sp.*)
1	Long-nosed dace (*Rhinichthys cataractae*)
1	Crested chub (*Nocomis micropogon*)
6	(*Cyprinidae*)
38	Trout perch (*Percopsis omisco-maycus*)
3	Yellow perch (*Perca flavescens*)
1	Log perch (*Percina caprodes*)
5	Johnny darter (*Boleosoma nigrum*)
7	Common sunfish (*Eupomotis gibbosus*)
2	Rock bass (*Ambloplites rupestris*)
1	Sculpins (*Cottidae ?*)
119	Unidentified because digestion had proceeded too far

TABLE 2.— TABULATION OF FISH-EATING SPECIES SHOWING FOOD IN PER CENT

NAME	Number of records	Length: Centimeters	Length: Inches	Fish	Crayfish	Daphnia pulex	Chironomidae	Mayfly nymphs	Misc.	Species of fish eaten, and notes
Lepisosteus osseus............ (Gar-pike)	2	29 –53	$11\frac{1}{2}$–21	100	....	.....	.....	......	....	7 Notropis atherinoides; 1 N. hudsonius; 1 Percopsis omisco-maycus
Noturus flavus............ (Stonecat)	13	11.5–24	$4\frac{1}{2}$– $9\frac{1}{2}$	71	20	.....	3	2	....	2 Notropis hudsonius; fish eggs, 3%; 12 N. deliciosus; Tipulid; 22 Percopsis; Hydropsyche; 2 unidentifiable
Ameiurus nebulosus............ (Bullhead)	18	2.2– 6	$\frac{7}{8}$– $2\frac{1}{4}$	....	....	.....	27	5	68	Misc.: Tubificidae, Gammarus, Hyalella, Asellus, Hydracarina, Enallagma, Agraylea multipunctata, Ostracoda sp., Difflugia pyriformis, Closterium, Ulothrix, Leydigia quadrangularis, Chydorus sphaericus, Alona rectangula, Simocephalus serrulatus, Acroperus harpae, Cyclops vulgaris, Pachycyclops annulicornis
Micropterus dolomieu............ (Small-mouthed bass)	3	6 – 9.5	$2\frac{3}{8}$– $3\frac{3}{4}$	100	....	.....	.....	......	....	4 Catostomus commersonii; 3 Catostomus commersonii (probably); 1 Notropis hudsonius; 2 backbones
Aplites salmoides............ (Large-mouthed bass)	2	25 –32.8	10 –13	75	25	.....	.....	......	....	2 Notropis hudsonius
	4	2.7–10	1 – 4	45	....	55	.....	......	....	5 Eupomotis gibbosus
	1	20.6	8	....	100	.....	.....	......	....	....
Pomoxis annularis............ (White crappie)	2	12.5–18.1	5 – 7	90	5	.....	5	x*	....	6 small Cyprinidae
Aplodinotus grunniens............ (Sheepshead)	11	3 –10.5	$1\frac{1}{4}$– 4	....	....	.....	87	9	....	Misc.: Leptocerus larvae, 1%; silt, 3%.
	8	15 –37	6 –$14\frac{1}{2}$	30	12	.....	1	35	....	Misc.: Earthworms, 16%; Trichoptera, 2%; misc. fragments, 2%; Tipulid larvae, 2%; mayfly nymphs—Ephemera; Potamanthus; Heptagenia; Ephemerella; 2 Notropis deliciosus; 2 unidentified.
Stizostedion griseum............ (Sauger)	4	20	8	100	....	.....	.....	......	....	2 Percopsis omisco-maycus; 1 Perca flavescens
S. glaucum............ (Blue pike) in seine catch along shore	4	18.5–26.5	$7\frac{1}{2}$–$10\frac{1}{2}$	100	....	.....	.....	......	....	2 Perca flavescens; 2 Notropis atherinoides.
(Gill net 9 fathoms).......	1	22.5	9	....	....	.....	.....	......	....	Mysis relicta, 100% (representative of 40 others)
	1	25.4	10	....	....	.....	.....	......	....	Mysis relicta, 100% (representative of 80 others)

S. vitreum (Yellow pike)	9	3.1– 5.4	$1\frac{1}{4}$– 2	100	....	.....	.....	......	....	Castostomidae fry
	22	18.3–34.6	$7\frac{1}{4}$–$13\frac{1}{2}$	100	....	.....	.....	......	....	12 Notropis hudsonius; 12 N. atherinoides; 9 N. atherinoides (probably); 2 N. cornutus; 1 Nocomis micropogon; 1 Boleosoma nigrum; 3 Percopsis omisco-mayeus
Ambloplites rupestris (Rock bass)	4	8–17	$3\frac{1}{4}$–$6\frac{3}{4}$	50	25	.....	.....	......	25	1 Notropis sp.; 1 Percopsis; misc. insect fragments
	43	8–19	$3\frac{1}{4}$–$7\frac{1}{2}$	80	1	16	1	x	2	52 N. atherinoides; 3 Percopsis; 1 Rhinichthys cataractae; 27 unidentified; fish eggs; Corixa; Cyclops vulgaris
Perca flavescens (Yellow perch)	5	2.6	1	10	....	.....	5	......	85	Misc.: Cladocera, 45% (Leptodora, Sida crystallina, Daphnia longispina, Alona rectangula, Bosmina longirostris); Copepoda, 40% (Cyclops vulgaris, Diaptomus sicilis, Epischura lacustris)
	15	5.5	2	....	....	.....	5	3	....	Gammarus, 77%; Tubificidae; Oscillatoria
	8	12.5–15	5 –6	....	....	100	.....	......	....	....
	54	16.5–20.2	$6\frac{1}{2}$–8	40	35	20	.....	......	5	3 Percopsis omisco-mayeus; 1 Percina caprodes; 10 N. atherinoides; 8 N. atherinoides (probably); 1 sculpin (?); 74 unidentified
	2	25.4	10	100	....	.....	.....	......	....	1 Percopsis; 2 Notropis hudsonius
	3	12.2–22.5	$4\frac{3}{4}$–9	30	13	.....	8	......	49	1 N. atherinoides; 1 unidentified; insect remains, 5%; Spirogyra; Cladophora; silt; Tipulid; earthworms
Ictalurus punctatus (Spotted cat)	3	3.8–12	$1\frac{1}{2}$–$4\frac{3}{4}$	....	....	.....	45	......	55	Misc.: Gammarus, 25%; misc. insect larvae, 30%
	3	37	$14\frac{1}{2}$	30	45	.....	.....	......	25	2 Percopsis; misc. insect larvae and surface insects; plant fragments
Esox lucius (Northern pike)	5	8.5–51.3	$3\frac{1}{2}$–$20\frac{1}{2}$	85	15	.....	.....	......	....	2 Catostomus commersonii; 1 Notropis cornutus; 1 Notropis sp.; 1 Eupomotis gibbosus
E. americanus (Little pickerel)	4	6.4–18	$2\frac{1}{2}$–7	90	....	.....	5	......	5	3 Boleosoma nigrum; 1 Eupomotis gibbosus; Corixa; Enallagma
E. masquinongy (St. Lawrence muskalonge)	2	3.4– 5	$1\frac{3}{8}$–2	100	....	.....	.....	......	....	2 Ambloplites rupestris; 1 Boleosoma nigrum; 4 unidentified
Lepibema chrysops (White bass)	14	1.7– 4.5	$\frac{1}{2}$–$1\frac{1}{4}$	21	....	.....	50	4	25	7 advanced fry; Cyclops vulgaris; Aedes; Gammarus; Hydracarina; Hydropsche; Alona; Chydorus

* Less than 1%.

TABLE 3.— SPECIES FEEDING MAINLY ON IMMATURE AQUATIC INSECTS AND CRUSTACEA

Percentages of food materials by volume

NAME OF FISH	Number of length to base of tail			Food organisms							
	Records	Centimeters	Inches	Fish eggs	Midge larvae	Misc. insects	Misc. crustacea	Plants	Misc.	Silt	Notes on food taken
Catostomus commersonii	3	1.5	.6	......	......	......	100	......	......	......	Diaptomus sicilis
	8	1.8– 9	.75– 3.5	......	75	......	6	5	2	12	
	7	18 –51	7 –20	10	55	......	4	10	1	20	
Hypentelium nigricans	14	6 –26	2.4 –10.2	6	62	2	2	3	15	10	Misc.— Baetis (mayfly)
Moxostoma duquesnii	8	4 –12	1.6 – 4.7	......	50	......	35	2	3	10	
M. lesueurii	5	7 –21	2.7 – 8.2	......	80	9	1	......	......	10	
M. aureolum	1	6	2.4	......	80	......	......	10	......	10	Green alga — Closterium
M. anisurum	8	6 –24	2.4 – 9.4	25	50	......	6	2	2	15	
Carpiodes cyprinus	4	4.5– 7.7	1.7 – 3	......	10	......	41	9	15	25	
	9	10.3–25	4 –10	2	65	......	16	3	4	10	
Cyprinus carpio	24	1.8– 5.5	.75– 2.2	......	52	1	9	14	1	14	
	4	13 –20	5 – 8	......	25	10	15	14	16	20	
Nocomis biguttatus	3	5.7– 6.6	2.5	......	13	14	......	20	43	10	Misc.— Elmidae adults
N. micropogon	25	2.6–10	1 – 3.8	1	28	34	4	22	4	7	
Rhinichthys cataractae	28	3.7– 6	1.4 – 2.4	20	33	12	......	13	2	20	Misc.— 1 Corixa; 1 earthworm
Rhinichthys atronasus	22	4 – 5	1.5 – 2	2	30	6	......	40	2	20	
R. atronasus lunatus	4	5.5	2.1	......	31	9	......	40	......	20	
Erinemus storerianus	4	9 –11	3.5 – 4.2	......	77	10	......	......	13	......	Misc.— Corixa; snail fragments
Notropis heterolepis	17	4 – 4.7	1.75	......	30	......	36	12	12	10	

N. volucellus	9	3.5– 5	1.4 – 2	70	25	......	......	......	......	5	
N. deliciosus: June 25 Aug. 21	 20 6	 3 – 5 4.4	 1.1 – 2 1.75	 95	 4 100					 1	Note seasonal variation in diet
N. deliciosus stramineus	2	3.3	1.25	......	35	......	......	45	......	20	
N. dorsalis	26	3 – 5.5	1.1 – 2	......	45	4	......	31	......	20	1 Leptocyclops agilis
N. hudsonius	5 30	1.5 3.5–10	.55 1.4 – 3.8	 41	 10	 1	100 2	 17	 24	 5	Mainly Diaptomus sicilis. Misc. — earthworms; adult midges
N. whipplii	15	2.3– 7.2	.9 – 2.7	......	40	4	......	......	56	......	Earthworms; misc. adult insects
N. rubrifrons	3	4.2– 6	1.5 – 2.4	......	70	......	......	......	25	5	Adult Muscidae.
Umbra limi	7	2.7– 7.2	1 – 2.7	......	2	33	41	18	5	......	2 Cyclops leuckarti; Hydroporus
Fundulus diaphanus menona	8	5.2	2	......	15	20	27	......	25	13	Misc.—larval fish 12%
Percopsis omisco-maycus	19	4.8– 8.5	1.7 – 3.2	......	26	52	6	......	16	......	Larval fish 1%
Percina caprodes	32	5.1– 8.8	2 – 3.4	43	30	7	7	2	4	7	Larval fish 1%
Boleosoma nigrum nigrum	19	2.7– 5.2	1 – 2	1	90	......	......	2	3	4	
Poecilichthys coeruleus	20	3.1– 4.5	1.1 – 1.7	16	65	13	......	......	4	2	Ancylus; 1 Leptocyclops agilis; 1 Thrips
Catonotus flabellaris	4	3 – 5	1.1 – 2	......	60	9	15	10	6	......	
Cottogaster copelandi	4	3.7– 4.7	1.4 – 1.7	25	70	......	......	......	5	......	
Etheostoma blennioides	5	4.3	1.6	......	60	40	......	......	......	......	
Eupomotis gibbosus	21	2.5– 8	1 – 3.1	......	40	15	23	5	16	......	Physa and Ancylus 12%
Eucalia inconstans	18	2 – 4.6	.75– 1.7	......	40	2	56	......	......	2	
Lota maculosa	2 1	.9– 1 17	.... 6.8	....	 5	....	100 90	....	....	....	Cyclops bicuspidatus; Limnocalanus macrurus Records from other localities show that mature individuals of Lota feed mainly upon other fish

SUMMARY

1. Small fish are very important in the area studied as food for the larger species. Probably the abundance of minnows is a contributing factor to their being found so frequently in stomachs. The percentage of fish in the diet of species like the yellow perch and the white bass, *Lepibema chrysops*, seems unusually high.

2. Data indicate that Notropis atherinoides is eaten far more frequently than any other species.* Since this fish feeds largely on plankton crustacea, it enters competition with very few other fish and should be very desirable for that reason.

3. As in other waters the larvae and pupae of midges or Chironomidae form the most important food for a large number of species. Mayfly numphs and caddis worms are also valuable.

4. In this area mollusks seem to be relatively unimportant as food. Scuds (Gammarus and Hyalella) are also less important than in other sections of New York State.

5. The food of very young fish here as elsewhere consists entirely of plankton crustacea. Copepods seem to be taken in preference to Cladocera.

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* See table of distribution of species, p. 164.

VIII. VEGETATION OF THE NIAGARA RIVER AND THE EASTERN END OF LAKE ERIE

By W. C. Muenscher,

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A brief survey of the distribution and composition of the vegetation in the Niagara river and the eastern end of Lake Erie was made between August 14 and August 30, 1928. More specifically, this report covers observations made on the American side of the Niagara river, including the shores of Grand island and several small islands near it, as well as the shallow channels between the islands, and from Buffalo harbor along the south shore of Lake Erie to the Pennsylvania State boundary.

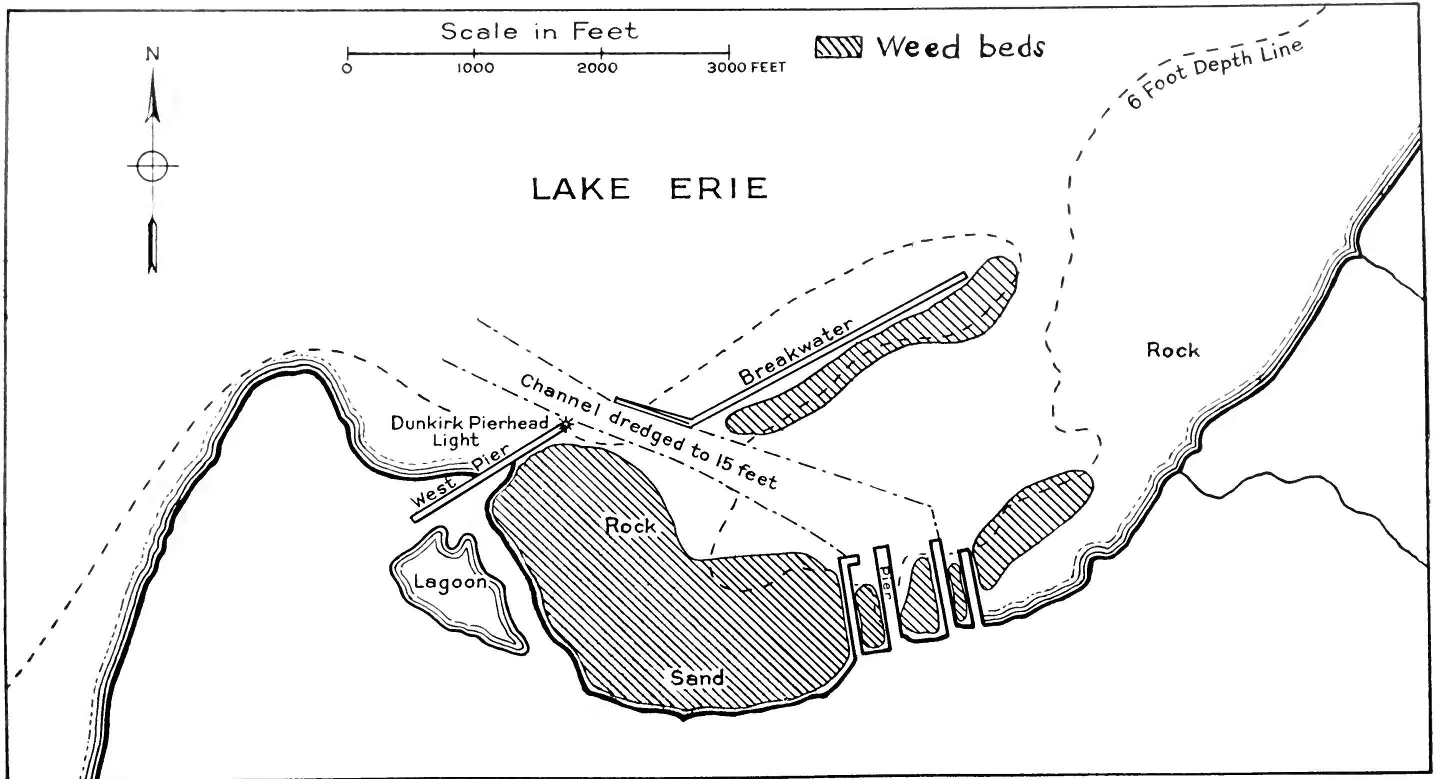
The discussion of the vegetation of the region under consideration may for convenience be taken up under the following areas: 1, the south shore of Lake Erie; 2, Buffalo harbor; 3, the upper Niagara river; 4, the lower Niagara river.

South Shore of Lake Erie.— In general the part of the south shore of Lake Erie which is included within New York State is very barren as far as aquatic vegetation is concerned. Rather extensive weed beds were observed in Dunkirk harbor which is protected by breakwaters. A few small patches of weeds were observed behind the landing at Sturgeon point and near the mouth of Cattaraugus creek. The rest of the lake shore was barren except for the branched green alga, *Cladophora*, (locally referred to as "moss" by the fishermen) which was frequently rather common on the rocks. The shore line is quite even and in most places the shore or the shallow bottom is rocky. In some places small sandy beaches occur. There are no large shallow bays or low marshy places with backwaters along the lake shore. The rocky nature of the shore and the severe wave action present unfavorable conditions for the existence of rooted aquatic plants. This accounts for the almost total absence of weed beds, except in Dunkirk harbor, along the sixty miles of lake shore in New York.

The small bay in which Dunkirk harbor is located also affords protection enough against the waves to make it possible for vegetation to become established. Artificial breakwaters add additional protection to this, the only area of aquatic vegetation along the lake shore that can be considered of importance as a spawning place for fish. A proper realization of the importance of this area as a spawning ground for fish should lead to a discontinuance of the present practice of running untreated sewage into Dunkirk harbor.*

Vegetation in Dunkirk Harbor.— The most common species in the harbor was the eel-grass, *Vallisneria spiralis.* It appeared in

* See page 121 and page 134.



Map of Dunkirk harbor showing location of weed beds (shaded areas). The predominating forms consist of eel-grass, *Vallisneria spiralis*, and pondweeds, *Potamogeton Richardsonii* and *P. pectinatus*. (Base map from War Department, Lake Erie Coast Chart No. 1) shallow water ranging in depth from one to four meters where it formed the dominant plant over extensive areas. Among the pondweeds, *Potamogeton Richardsonii* and *P. pectinatus* were very common, especially at a depth of 2–3 meters. *Potamogeton angustifolius, P. gramineus, P. pusillus, P. bupleuroides*, and *P. compressus* were less frequent, in the order named. *Najas flexilis* was found growing profusely in shallow water even near the outlets of sewers where there was much pollution from the sewage. *Elodea canadensis, Zannichellia palustris, Heteranthera dubia, Ceratophyllum demersum* and *Nitella* sp. were observed among the pondweeds in several places. A number of dredgings were made in deeper water but no vegetation was found below the five meter depth. *Chara* was found in quite extensive areas in water from 2–5 meters deep toward the northeast side of the harbor. *Potamogeton gramineus* var. *graminifolius* was often associated with *Chara*. Along the marshy shore of the east side of the harbor, a narrow zone was occupied by emersed plants consisting chiefly of *Sagittaria heterophylla, S. latifolia, Scirpus acutus, S. americanus*, and a few cattails, *Typha latifolia*.

Buffalo Harbor.—Along the eastern end of Lake Erie considerable areas of weed beds were found between the shore and the outer breakwaters of Buffalo harbor. These breakwaters protect most of the shore line between the head of the Niagara river on the north and the city of Lackawanna on the south. However, the extensive alterations of the shore line and bottom required for maintaining channels for ships entering the harbor, the numerous docks, the canal, the inner harbor, and the filling in by refuse of various kinds, rather limit the important areas of aquatic plants to the lake shore from the mouth of Buffalo creek to the south for about two miles and to smaller areas in the shallow water just inside of the breakwaters. The deeper channels and the area around Lackawanna contained no rooted aquatics.

Vegetation in Buffalo Harbor.—While the weed beds in the harbor were rather extensive and prolific, the number of species was very small. *Vallisneria spiralis*, which sometimes covered areas of several acres to the exclusion of everything else, was the most abundant species. Among the pondweeds, *Potamogeton Richardsonii, P. gramineus* var. *graminifolius* and *P. pectinatus* were the dominant species. The first two species frequently formed the bulk of the vegetation in the two to four meter depth. In the shallow water, especially to the south of the mouth of Buffalo creek, extensive beds of *Chara* sp. covered the bottom. *Potamogeton filiformis* and the dwarf compact form of *Najas flexilis* flourished in shallow water near the shore where the bottom was sandy. *Elodea canadensis, Heteranthera dubia* and *Najas flexilis* frequently formed a dense growth over the bottom among the larger pondweeds.

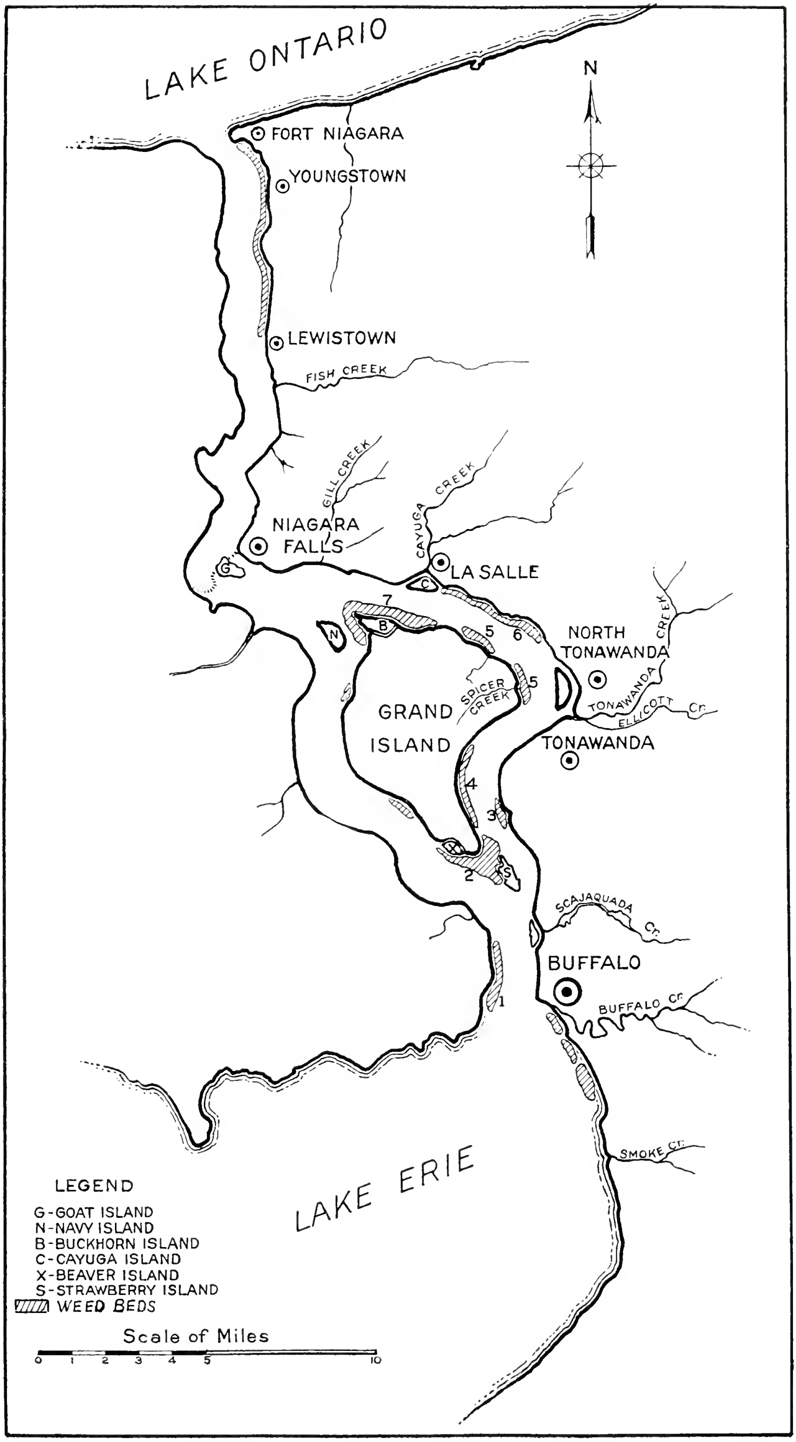
The Upper Niagara River.—Water flowing out of Lake Erie at the head of the Niagara river produces a very swift current for several miles. About five miles below Lake Erie the upper part of the Niagara river is divided by Grand island into two channels, the Tonawanda channel on the east and the Chippewa channel on the west. A few miles above the falls of the Niagara, these channels unite again into one main stream. The most extensive and luxuriant weed beds were found in the shallow bays and shoals around Grand island, especially on the Tonawanda channel side. The weed beds along the east side of the Tonawanda channel not only were less extensive but were composed of a very limited number of species. The effect of the pollutions of various kinds from Buffalo and Tonawanda as well as from several manufacturing plants between these cities undoubtedly accounts for the absence of many species in the existing weed beds and the total absence of vegetation in several places along the east shore of the Tonawanda channel.

Vegetation of the Upper Niagara River.— The locations of the larger areas of weed beds in the upper Niagara river are indicated by numbers on Map 2. The predominating species of which they are composed are indicated below:

1. Between the Peace bridge and the International railroad bridge. A few small areas of weeds occured on the American side and extensive areas of vegetation occured on the Canadian side of the river. The predominating species consisted of *Potamogeton Richardsonii, P. pectinatus, P. pusillus, P. gramineus* var. *graminifolius* and *Vallisneria spiralis.* The emersed zone on the Canadian side was occupied largely by *Typha angustifolia, T. latifolia, Scirpus acutus, S. americanus, and Sagittaria latifolia.*

2. Strawberry island and the shoal water between it and Frog island and Grand island as far as Beaver island. This area included one of the most extensive and prolific areas of aquatic vegetation in the Niagara river. The series of submerged sandbars were covered with a dense growth consisting mostly of pondweeds, *Potamogeton Richardsonii, P. angustifolia, P. gramineus, P. pectinatus, Vallisneria spiralis* and *Najas flexilis.* The greater part of Strawberry island is only a large sandbar raised a few feet above the level of the river and covered with a growth of *Spartina micheauxiana, Scirpus acutus* and *S. americanus.* These species also extend into the shallow water around the island. In the shallow channels which dissect the island such species as *Sagittaria latifolia, S. heterophylla* and *Eleocharis palustris* were common. It was learned from local sources that the area of Strawberry island had been reduced considerably by the removal of sand. Sand was being loaded on scows and hauled away at the time the island was visited. If this continues, in time the whole island will probably be replaced by shoal water. This will undoubtedly modify the composition of the existing vegetation considerably.

3. The small bays above and below Rattlesnake island. These contained extensive areas of submerged and emerged vegetation.



Map of the eastern end of Lake Erie and the Niagara river showing the location of the principal areas of aquatic plants. The areas are numbered to correspond to the numbers used in the discussion of the vegetation on pages 192–4 of the text. The width of the Niagara river has been exaggerated to make it possible to indicate the location of the weed beds.

The predominating species in general were the same as those occurring about Strawberry island.

4. The small bay near Grand island landing and about two miles northward. In addition to the forms mentioned under Strawberry island, the following common species were observed: *Potamogeton amplifolius, P. natans, P. bupleuroides, P. compressus, Heteranthera dubia, Ceratophyllum demersum, Myriophyllum exalbescens, Nymphozanthus advena, Pontederia cordata* and *Equisetum limosum*.

5. The shallow water about the mouth of Spicer creek to the mouth of Gun creek. This area, which seems to be used as a dumping ground for old ships, was occupied by a greater number of species than any other locality observed during the survey. The species observed include nearly every species listed on page 195. In addition to the dominant species observed in other localities in the river *Elodea canadensis* formed a very dense covering over considerable areas.

6. From Edgewater landing some distance below the slag fill below North Tonawanda to Cayuga island. The margin of the channel and the small bays were occupied by a very dense bed of *Vallisneria spiralis*. This species, apparently being more tolerant of the pollution than the other species, occupied this area to the almost total exclusion of other forms.

7. The shallow water north and west of Buckhorn island. Large areas of submerged vegetation and also an irregular emersed zone which, in some places, extended out into the shallow water for considerable distances, occupied this area. The narrow shallow channel between Buckhorn island and Grand island was covered with a very dense growth of *Scirpus acutus, S. americanus, Sagittaria latifolia, S. heterophylla* and *Eleocharis palustris*, and near the shore *Typha angustifolia* was common.

The Lower Niagara River.— The American shore of the Niagara river, from its mouth on Lake Ontario to the Suspension bridge at Lewiston, was lined with a rather uniform zone of aquatic vegetation, which began about three to ten meters from the shore and extended over a strip about ten to twenty meters wide, occupying a depth of about one to four meters. The uniformity of the vegetation is probably due to the lack of variation in habitat. The water of the Niagara river is well aerated and mixed when it passes over the falls and as it passes through the whirlpool it is again churned up. The lower Niagara river flows through a deep gorge. It is too deep for rooted aquatics except for a narrow zone along each side of the stream. The washing of the shore by the swift currents and waves and the fluctuations in the river level make it unfavorable for the development of the larger aquatics at the shore line.

Vegetation of the Lower Niagara River.—*Vallisneria spiralis* and *Potamogeton pusillus* were the dominant species in the shallow water. Near the outer margin of weed beds, or in three to five meters of water, *Potamogeton Richardsonii* and *P. pectinatus* were the most abundant forms. *Potamogeton gramineus, P. americanus* and *P. angustifolius* frequently occurred in local areas, principally in the lower part of the river. *Najas flexilis* was common in shallow water, especially in the upper part of the river. *Elodea canadensis* appeared locally in protected beds in the river and about boat landings at Youngstown. In a number of places where the weed beds were very luxuriant, the water surface was covered with a dense blanket-like mat of algae, mostly *Cladophora* sp. which made it almost impossible to row a boat through it. On the shallow bottom between the shoreline and the inner margin of the weed beds. *Chara* sp. formed a low scattered growth, especially in small bays made by bends of the river. *Cladophora glomerata* was frequently very common on rocks along the shore.

A List of Aquatic Plants Observed in Niagara River and the Eastern End of Lake Erie

EQUISETACEAE

Equisetum limosum L. Horsetail.
In shallow water near the mouth of Spicer creek, Grand island.

TYPHACEAE

Typha angustifolia L. Narrow-leaved Cat-tail.
Frequent in marshy ground and shallow water along shores and islands of Niagara river; Dunkirk harbor.
Typha latifolia L. Common Cat-tail.
Very local. Near the mouth of Spicer creek, Grand island; on Canadian shore of Niagara river between Peace bridge and International bridge; Dunkirk.

SPARGANIACEAE

Sparganium eurocarpum Engelm. Giant Bur-reed.
Shallow water about Strawberry island and Grand island.

NAJADACEAE

Potamogeton amplifolius Tuckerm. Broad-leaved Pondweed.
Local. In a bay near Grand island landing; north of Buckhorn island.
Potamogeton americanus C. & S. var. novaeboracensis (Morong) Benn.
Frequent. Niagara river; Buffalo harbor; Dunkirk harbor.
Potamogeton angustifolius Birch, and Presl.
Frequent in deep swift water in the Niagara river.
Potamogeton bupleuroides Fernald.
In shallow water. Buffalo harbor; Dunkirk harbor; Grand island.
Potamogeton compressus L.
Frequent. Niagara river; Dunkirk harbor.

Potamogeton filiformis Pers.
Near shore, Buffalo harbor.
Potamogeton foliosus Raf.
Among *Scirpus acutus* about Strawberry island.
Potamogeton gramineus L. var. graminifolius Fries.
Common in the outer zone of vegetation. Niagara river; Buffalo harbor; Dunkirk harbor.
Potamogeton lucens L.
In deep swift running water. North of Buckhorn island, Niagara river.
Potamogeton natans L. Floating Pondweed.
In several small bays along Grand island.
Potamogeton pectinatus L. Sago Pondweed.
One of the most common species of Potamogeton.
Potamogeton pusillus L.
Frequent in the Niagara river; Dunkirk; Sturgeon point.
Potamogeton vaginatus Turcq.
In deep water north of Buckhorn island, Niagara river.
Potamogeton Richardsonii (Benn.) Rydb.
The most prominent Potamogeton in the Niagara river and Lake Erie.
Najas flexilis (Willd.) Rostk. and Schmidt. Naiad.
Frequent. Dunkirk harbor; Buffalo harbor; Niagara river.
Zannichellia palustris L. var. major (Boen.) Koch. Horned Pondweed.
Infrequent. Dunkirk harbor; Niagara river below Lewiston.

ALISMACEAE

Sagittaria heterophylla Pursh. Arrow-head.
Common in the outer zone of emersed plants. Tonawanda channel of Niagara river; Dunkirk harbor.
Sagittaria latifolia Willd. Arrow-head.
Common in the upper Niagara river.
Sagittaria latifolia Willd. var. obtusa (Muhl.) Wiegand. Arrow-head.
Along shore, Dunkirk harbor.

HYDROCHARITACEAE

Elodea canadensis Michx. Water-weed.
Common in several protected bays along the Grand island side of Tonawanda channel; infrequent elsewhere.
Vallisneria americana Michx. Eel-grass.
The most common aquatic plant of the region.

GRAMINEAE

Spartina michauxiana Hitchc. Slough Grass.
On sandbars about Strawberry island.

CYPERACEAE

Scirpus americanus Pers. Shore Rush.
Frequent in shallow water along sandy or gravelly shores.

Scirpus validus Vahl. Bulrush.
In shallow water near mouth of Spicer creek and Gun creek, on Grand island.

Scirpus acutus Muhl. Bulrush.
Common in shallow water. About Strawberry island and Buckhorn island; along the upper Niagara river; Dunkirk.

Eleocharis palustris (L.) R. & S. Spike Rush.
Frequent in the emersed zone about Strawberry island and Rattlesnake island.

Eleocharis palustris (L.) R. & S. var. vigens Bailey. Spike Rush.
Forming extensive beds off the north end of Grand island.

LEMNACEAE

Lemna minor L. Duckweed.
Rare in protected pools about Grand island.

Spirodela polyrhiza (L.) Schleid. Duckweed.
Rare in protected pools about Grand island.

PONTEDERIACEAE

Pontederia cordata L. Pickerel weed.
Infrequent where streams enter the Niagara river from Grand island.

Heteranthera dubia Jacq. MacM. Mud Plantain.
Frequent. Niagara river; Buffalo harbor; Dunkirk harbor.

JUNCACEAE

Juncus brachycephalus (Engelm.) Buch. Bog Rush.
In shallow water about Strawberry island.

CERATOPHYLLACEAE

Ceratophyllum demersum L. Hornwort.
Rare. Dunkirk harbor; mouth of Spicer creek, Grand island; Beaver island.

NYMPHAEACEAE

Nymphozanthus advena (Ait.) Fernald. Yellow Water-lily.
In shallow water, near Grand island landing; mouth of Spicer creek.

RANUNCULACEAE

Ranunculus longirostris Godr. White water-buttercup.
Rare. Mouth of Spicer creek; Grand island landing.

HALORAGIDACEAE

Myriophyllum exalbescens Fernald. Water Milfoil.
In a shallow bay near Grand island landing.

IX. FURTHER EXPERIMENTAL STUDIES ON THE BASS TAPEWORM, *PROTEOCEPHALUS AMBLOPLITIS* (Leidy)

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Introduction.— The study of the life history of the bass tapeworm, *Proteocephalus ambloplitis* (Leidy), is of interest not only to scientists but also to fish culturists and sportsmen. In the first place, the parasite affects the "king of fish," the small-mouthed black bass (*Micropterus dolomieu*) as well as the large-mouthed black bass (*Aplites salmoides*) and a number of other less important forms. Secondly, it does irreparable damage for the larval stage (plerocercoid) is frequently passed in the reproductive organs which may inhibit the spawning of the fish. In the third place, the parasite's ability to establish itself in small ponds causes it to be of particular importance in privately stocked lakes or hatcheries. Finally it may destroy the food value of the fish because of the inherent distaste of eating parasitized fish even though harmless.

One might expect that a parasite capable of doing so much damage would have a long criminal record. That it has not indicates that its harmful effects have only been recognized in comparatively recent years. It was first described by Joseph Leidy[1] in 1887 but apparently the first record of its pathogenic effects is found in the reports of the Division of Scientific Inquiry of the Bureau of Fisheries for 1923[2] where its ravages are recorded. Moore[3] notes the effect of this tapeworm upon the reproductive organs in a report before the American Fisheries Society and the next year again calls attention to this tapeworm.[4] Bangham (1927) in a mimeographed report tells of the harm done by this parasite in the Ohio hatcheries and again mentions this briefly in two papers appearing the subsequent year.[5,6] The senior author[7] ran a series of experiments for the U. S. Bureau of Fisheries during the summer of 1927 in which it was shown how the life cycle might be com-

[1] Leidy, J. Notice of some parasitic worms. Proc. Acad. Nat. Sci. Phila., 39:20–24:8 figs. 1887.
[2] Rich, W. H. Progress in biological inquiries, 1923. Rep. Div. Sci. Inq. Fiscl. Yr. 1923, Bur. Fish. Doc. No. 956. 1924.
[3] Moore, Emmeline. Further Observations on the Bass Flat-worm (*Proteocephalus ambloplitis*). Trans. Amer. Fish. Soc., 1925:91–94. 1926.
[4] Moore, Emmeline. Problems in fresh water fisheries. N. Y. Conserv. Comm., 15th Ann. Rep., 1925, 22 pp. 1926.
[5] Bangham, R. V. Diseases of fish in Ohio hatcheries. Trans. Amer. Fish. Soc., 1927, 4 pp. 1928.
[6] Bangham, R. V. Life history of bass cestode *Proteocephalus ambloplitis*. Trans. Amer. Fish. Soc., 1927, 3 pp. 1928a.
[7] Hunter, G. W., III. Contributions to the life history of *Proteocephalus ambloplitis* (Leidy). Jour. Parasit., 14:229–243, 1 pl. 1928.

pleted in the large-mouthed black bass (*Aplites salmoides*). A more detailed discussion of the problem will be found in that paper. During the summer of 1928 the authors carried on further experimental studies on the life cycle of this tapeworm. The results will be found in the following pages.

The Adult Tapeworm.— The developmental cycle of the tapeworm was first worked out in part by Cooper[1] in which he gave an excellent account of the early growth in the final host, the small-mouthed black bass (*M. dolomieu*). At this time he proposed the theoretical life cycle which was subsequently proved correct. This was followed by the suggestion of Bangham[2] based upon an examination of fish stomachs that a copepod functions as an intermediate host. The life cycle was first worked out experimentally by the senior author in 1927. Plate I of this paper is the pictorial representation of the life cycle. The adult tapeworm occurs in the digestive tract with the head or scolex as it is called lodged in one of the pyloric ceca (diverticula of the upper intestine). This worm often reaches a length in excess of that of its host, the largest specimen recorded is one found by the senior author which measured slightly over 750 mm., or 2½ feet. The mature proglottids (or segments) are found at the posterior end of the chain and are filled with eggs. From time to time the chain breaks thus permitting the proglottids to be passed from the host (Fig. 2). Upon contact with the water eggs are spewed out and gradually settle to the bottom.

The adult stage of this parasite was first reported by Leidy[3] from the rock bass (*Ambloplitis rupestris*). Later it was found in both the large and small-mouthed black bass as well as the fresh water dogfish (*Amia calva*). Many parasites are found in a single species or at the most are confined to a single genus. In this case there are four different genera which may carry the tapeworm and disseminate the eggs of the parasites. This condition clearly complicates the problem of control.

The Eggs.— The mature proglottids which are passed by the bass sink to the bottom. Usually before they settle most of the eggs will have been voided thus spraying them over a wide area (Fig. 2). Typically the eggs appear dumb-bell shaped (Fig 6) although other shapes are recorded (cf Cooper and Hunter). This can only be seen under a microscope which magnifies about 350 diameters. Then the six hooked oncosphere (or embryo) may be seen surrounded by its investing envelopes. During the course of the summer the viability of the eggs was studied and it was found that the enclosed embryo started to disintegrate after 36

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[1] Cooper, A. R. Contributions to the life history of *Proteocephalus ambloplitis* (Leidy). Contr. Canad. Biol. Fac. II, fresh water fish and lake biology, 177–194; pl. 19–21. 1915.

[2] Bangham, R. V. A study of the cestode parasites of the black bass in Ohio with special reference to their life history and distribution. Ohio Jour. Sci., 25:255–270; 2 pl. 1925.

[3] Loc. cit.

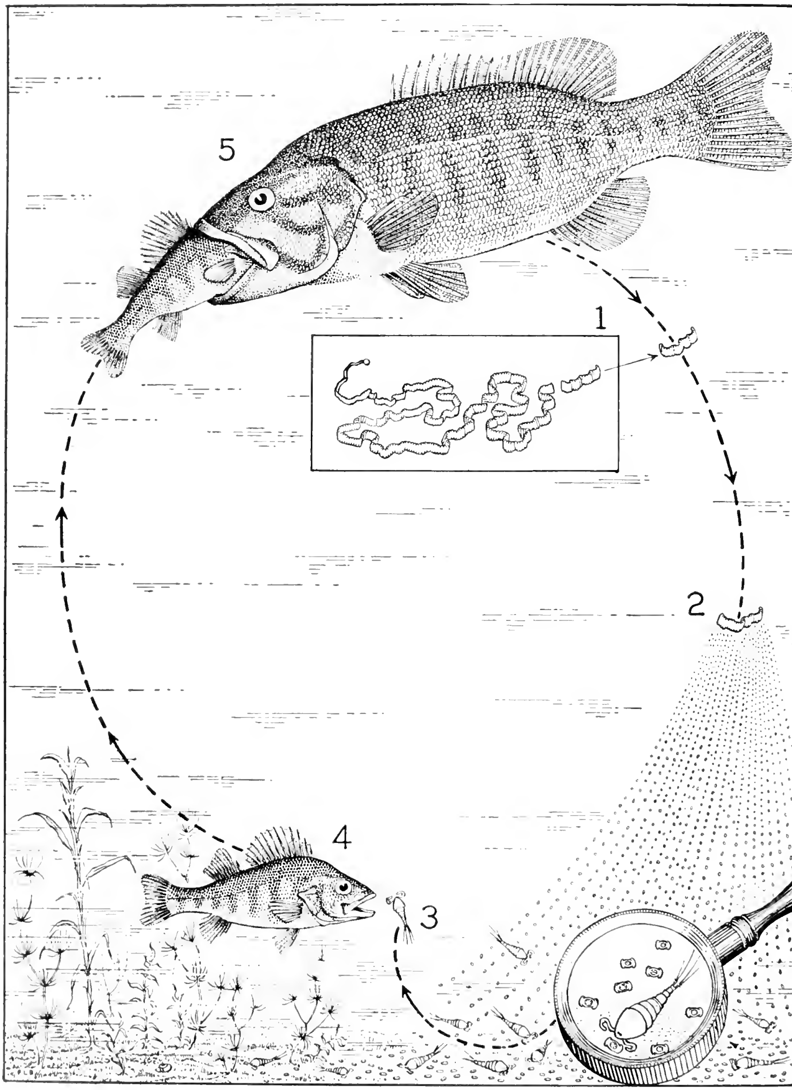

Plate I

Plate 1.—Pictorial representation of the life cycle of the bass tapeworm, *Proteocephalus ambloplitis* (Leidy), magnified to show the early stages.

(1) Adult bass tapeworm (P. ambloplitis) from intestine. The mature proglottids (segments) occur at the posterior end. These break off and are passsed with the feces. (Drawing natural size.)

(2) Mature segments falling to the bottom, liberating thousands of eggs upon contact with the water.

(3) FIRST INTERMEDIATE HOSTS. Five (?) species of Cyclops and *Hyalella knickerbockeri* eat the eggs from the bottom. The eggs disintegrate after being in the water 36 to 48 hours. The jaws and digestive juices of the copepods liberate the larva of the tapeworm which bores through into the body cavity. (Drawing of copepods magnified disproportionately to bring out details.)

(4) SECOND INTERMEDIATE HOSTS. Young large-mouthed and small-mouthed black bass, rock bass, pumpkinseed sunfish, yellow perch, pickerel and the top minnow (*Fundulus diaphanus*) feed on the first intermediate hosts. The larval tapeworm bores through the digestive tract and into the body cavity; it encysts.

(5) DEFINITIVE HOSTS. Large-mouthed and small-mouthed black bass and rock bass harbor the adult tapeworm which is secured by eating the second intermediate host thus bringing the larval tapeworm back to the digestive tract where proglottid formation takes place and the cycle is repeated.

to 48 hours. The first stage of this breakdown appears to be the rupture of the granular secondary membrane liberating the larval oncosphere and permitting it to wander about within the confines of the outer hyaline membrane. Soon thereafter the oncosphere itself undergoes disintegration.

The First Intermediate Hosts.—As noted above the eggs of the bass tapeworm must be eaten in a relatively short period of time. It was likewise suggested previously that the outer hyaline membrane (which gives the egg its dumb-bell shape) must prove a delicacy since it was observed that the Cyclops apparently trimmed it off and usually rejected the inner membranes containing the oncosphere. Infection occurs when the embryo is accidentally eaten with the membrane. During this summer eggs were recovered from the stomach of the Cyclops which had just been eaten. In this instance the rounded ends of the eggs had been snipped off by the mandibles of the animal thus releasing the parasite which was almost out of the shell as the secondary granular membrane had broken (Fig. 7). Whether this is the usual method of release of the parasite is a matter for conjecture. Normally the oncospheres may be seen in the body cavity of the copepod four to five hours after ingestion. They undoubtedly reach their goal through the use of the three pairs of oncospheral hooks (Figs. 8,9).

During the course of the experiments it was possible to infect only two species of copepods, *Cyclops vulgaris* (=*C. viridis*) and *Eucyclops agilis* (=*C. serrulatus*) (See Fig. 10). Negative results were secured with a cladoceran, *Daphnia pulex*, and *Macrocyclops annulicornis* (=*C. albidus*). The successful infection yielded 50 and 25 per cent respectively. Bangham[1] reported finding the larval form of this parasite in the body cavity of the well known Malacostracan, *Hyalella knickerbockeri*. In 1928[2] he reported finding a copepod infected by the procercoid of *P. ambloplitis*. This he informed the senior author had been identified as *Cyclops leuckarti*; the senior author gave Bangham credit for this in a recent publication knowing that he had a paper in press. The paper however does not mention the species of copepod. Infection of two other species experimentally was accomplished at the U. S. Fisheries Station in Neosho, Missouri.[3] These were *C. prasinus* and *C. albidus*; the latter species of which is the same one (*M. annulicornis*) with which we secured negative results this past summer. For the experimental work the following copepods were examined as controls; *C. vulgaris*, 107 examined and 4.6 per cent infected; *E. agilis*, 121 examined and 3.3 per cent infected, and *M. annulicornis*, 75 examined and none infected.

The following species have been experimentally infected, *C. prasinus*, *M. annulicornis*, *C. vulgaris* and *E. agilis*. An unidentified species of copepod (previously denoted by Hunter as *C. leuckarti*) and *H. knickerbockeri* are reported to act as the first intermediate host; these were determined by an examination of stomach contents.

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[1], [2], [3] Loc. cit.

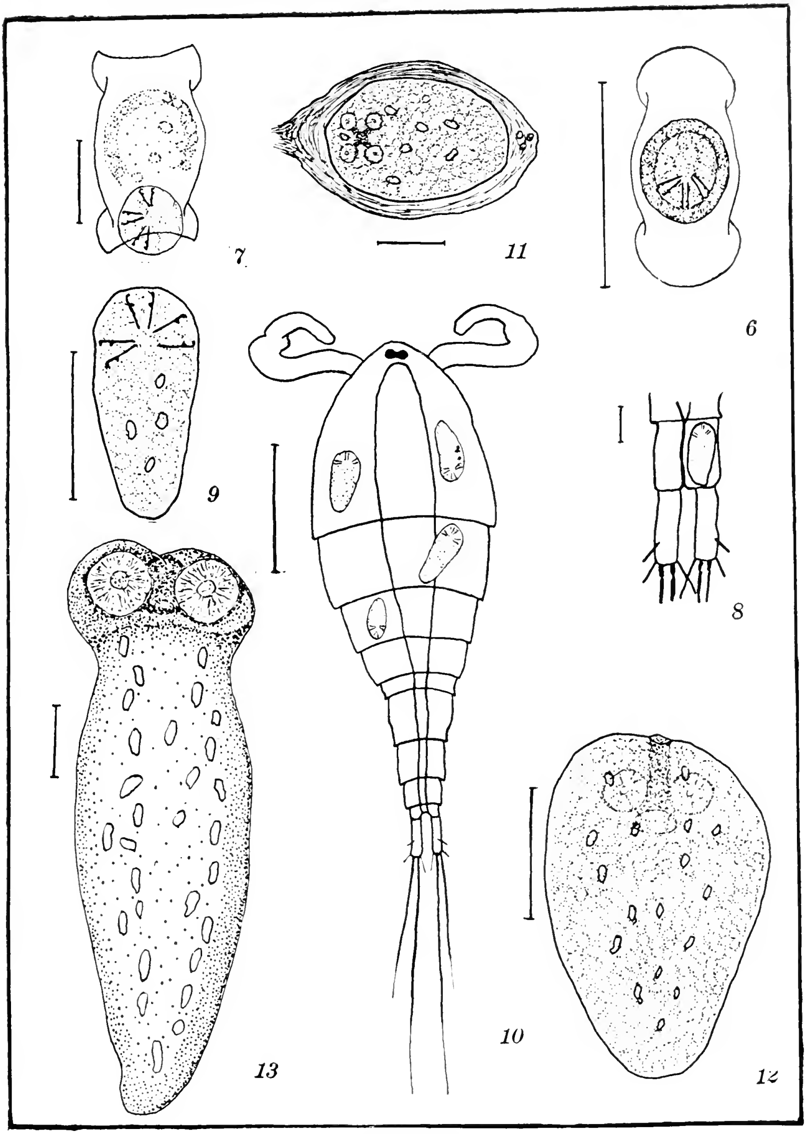


Plate II

Fig. 6.—Typical egg of bass tapeworm, *Proteocephalus ambloplitis* (Leidy)
Fig. 7.—Egg recovered from *Eucyclops agilis* showing clipped ends of outer hyaline membrane and escaping oncosphere
Fig. 8.—Procercoid larva in anal segment of *Cyclops vulgaris*
Fig. 9.—Procercoid larva shown in figure 8 enlarged
Fig. 10.—Outline drawing of *Cyclops vulgaris* showing procercoid larvae of *P. ambloplitis* in body cavity; 2nd day of experiment
Fig. 11.—*P. ambloplitis* larva recovered from rock bass, *A. rupestris* after feeding on infected copepods
Fig. 12.—*P. ambloplitis* larvae recovered from upper intestine of small-mouthed bass, *M. dolomieu* after eating sunfish, *E. gibbosus*
Fig. 13.—Plerocercoid larva of *P. ambloplitis* from upper intestine of *M. dolomieu*, 16 days after eating second intermediate hosts
The lines in the figures have the following values: 0.02 mm. in Fig. 7; 0.2 mm. in figures 10 and 12; in all others 0.05 mm.

The Second Intermediate Hosts.— Most of the experimental work of the past season fell upon the fish which eat the animal harboring the procercoid larvae of the tapeworm. Up to the summer of 1928 the only fish incriminated experimentally was the large-mouthed black bass (*A. salmoides*). The experimental fish were added to cultures of infected copepods and were left for 24 to 48 hours before examinations were started; these were continued at intervals. In this manner the rock bass (*A. rupestris*) was infected in 80 per cent, the yellow perch (*Perca flavescens*) in 66.6 per cent, and the top minnow (*Fundulus diaphanus*) in 50 per cent of the cases. Controls were of course examined in every case. Fifteen young rock bass from the same lot used for the experiments yielded no cestode parasites at all, while the 44 young yellow perch gave only 4.5 per cent infection with *P. ambloplitis*, and 14 top minnows (*Fundulus diaphanus*) did not contain any tapeworms at all. It is evident therefore that the figures secured experimentally were significant. In most cases the parasites which were recovered occurred encysted in the mesenteries of the host (Fig. 11). In such locations a fibrous cyst is thrown about the developing plerocercoid; the cyst walls are less distinct in the cases of the parasites recovered from the liver of the rock bass and perch. Negative results were secured with the spottailed minnow (*Notropis hudsonius*), the emerald minnow (*N. atherinoides*) and the blunt-nosed minnow (*Hyborhynchus notatus*).

In some cases infection was transferred from one host to the other without any apparent change in the development of the parasite. Thus infected liver containing young plerocercoids of *P. ambloplitis* were fed to 3 yearling small-mouthed black bass. The same number of parasites which were fed were recovered a few days later. Ten of these fish were examined as controls and all were uninfected. In another experiment infected liver and cysts attached to the mesentery were fed to the rock bass (*A. rupestris*). The parasites were also recovered from these, some from the digestive tract and some from the body cavity where they had apparently re-encysted. No doubt re-encystment depends upon the developmental stage attained by the parasite before ingestion takes place. Again upon two different occasions young pumpkinseed sunfish (*Eupomotis gibbosus*), 8 in all, which were carrying 100 per cent infection with the plerocercoids of *P. ambloplitis* were fed to as many yearling small-mouthed black bass (*M. dolomieu*). Some we kept for over two weeks and when examined 50 per cent were infested. In this case all the parasites which were found were recovered from the digestive tract. The plerocercoid larvae were young and small (Fig. 12), and although the suckers were usually invaginated they were thrust out from time to time. The ones recovered at the end of the second week retained the everted scolex (cf Fig. 13).

It was found advisable to spend a portion of the time on the shores of a pond which contained fish showing nearly 100 per cent infection by the bass tapeworm. The following data briefly summarizes the infection with the plerocercoids of this parasite and indicates something of its economic importance in small bodies of water.

No. examined	Species	Per cent infection with larval *P. amblopl itis*
7	Small-mouthed black blass (*M. dolomieu*)	100%
8	Large-mouthed black bass (*A. salmoides*)	100%
9	Yellow perch (*P. flavescens*)	100%
14	Pumpkinseed sunfish (*E. gibbosus*)	100%
8	Chain pickerel (*E. reticulatus*)	25%

In order to avoid confusion with other parasites the material was sectioned and carefully studied. The authors feel confident that this constitutes a new and accurate record for these hosts. Infected yellow perch were also found in the Niagara river in small quantities.

Definitive Hosts.— Once more turning to the experimental work we find the only record of the final or definite host lies in the paper of Hunter[7] in which the large-mouthed black bass (*A. salmoides*) was artifically infected. This was accomplished by feeding them small bass carrying the plerocercoid larvae in the body cavity (cf. Fig. 4). During the summer of 1928 two experiments were run to show that the infection could be transferred from the second intermediate hosts to the small-mouthed black bass which were used as the definitive hosts. Unfortunately yearling bass were scarce. Four experimentally infected yellow perch were fed to 2 *M. dolomieu* and 4 top minnows were fed to 3 of the small-mouthed black bass. In the first experiment both fish yielded unsegmented plerocercoids of *P. amblopltis* from the upper part of the digestive tract (Fig. 13), while in the second two of the fish gave parasites in a similar stage of development; the third bass is still unexamined.

Distribution and Economic Importance of the Bass Tapeworm.—As has been previously stated the bass tapeworm (*P. amblopltis*) is of considerable economic importance. It has been noted that there are 4 fish which may harbor the adult worm, the rock bass (*A. rupestris*), small and large-mouthed black bass (*M. dolomieu* and *A. salmoides*) and the fresh water dogfish (*Amia calva*). All four hosts are reported from the Great Lakes drainage[1] and likewise from the Mississippi river basin.[2] The senior

[1] Hubbs, C. L. A check-list of the fishes of the Great Lakes and tributary waters, with nomenclatorial notes and analytical keys. U. of Mich., Mus. Zool., Misc. Publ. No. 15; 77 pp. 1926.

[2] Forbes, S. A. and R. E. Richardson. The fishes of Illinois. Vol. III. Ichthyology, Ill. St. Lab. Nat. Hist.; 342 pp. 1908.

author has collected this parasite from the lakes of Minnesota and Wisconsin and this summer Mr. John W. Titcomb sent some viscera of parasitized black bass from Ontario, Canada. Moore[1] lists in addition Michigan, Connecticut, New Jersey, Ohio and New York. The senior author also found the parasite in fish from the ponds of the U. S. Fisheries Station at Neosho, Missouri. Pearse[2] in addition records the presence of visceral cysts in a number of other species.

There is great danger of spreading this parasite through the planting of bass from infected hatchery ponds. In such cases the infection may be high and may well serve as a means of establishing this harmful helminth in a new locality. Once introduced it stands an excellent chance of surviving due to the number of possible first and second intermediate hosts as well as the relatively large number of definitive hosts.

Some locality should be sought where the bass are free from this helminth and this should be preserved carefully as a source for breeders. In the case of breeders the fish would be too large to eat each other and so could not bring any plerocercoid larvae back to the intestine where they could reach maturity. Likewise there is danger in following the old policy of securing breeders from the west end of Lake Erie. It was noted that bass taken from the east end of Lake Erie were less heavily parasitized than those from the west end. Thus only 27 per cent of 22 small-mouthed bass sheltered the adult tapeworm compared with 43 per cent of 14 bass taken from the vicinity of Put-in-Bay, Ohio. Even this lower percentage is not low enough, for none of the breeders should be parasitized if we desire to keep the bass in sufficient numbers to retain its place in the heart of the sportsman and tourist.

Unsolved Problems.— Before any real cures can be effected certain of the remaining problems must be solved. In the first place the maximum period of life in each of the intermediate hosts and the definitive hosts should be determined. This in itself constitutes a very real problem. Secondly, it is important to determine the most successful way of breaking the life cycle and so rendering it possible to control the parasite at least in the hatchery ponds. At present all indications point to the advisability of wiping out the copepods and replacing them with some type of food which cannot carry the larval stages of the tapeworm. That this may be the practical solution of the problem is indicated by the successful production of fish food in various parts of the country. The U. S. Biological Fisheries Station at Fairport, Iowa and Dr. G. C. Embody of Cornell University are working on this problem while the state hatcheries at Pratt, Kansas[3] and Hacketts-

[1] Loc. cit.

[2] Pearse, A. S. The parasites of lake fishes. Trans. Wis. Acad. Sci., Arts, and Letters, 21:161–194. 1924.

[3] Schnegerger, E. and Minna E. Jewell. Factors affecting pond fish production. Kansas For., Fish and Game Comm., Bull. No. 9, 14 pp. 1928.

town, New Jersey have large daphnia producing plants in operation. In the next place it is essential to investigate the permeability of the parasite eggs to selective dyes, and lastly, to determine the resistance of copepods to freezing and dessication. As a result of the experimental work outlined it is hoped that the bass tapeworm may be eliminated from the hatcheries which are planting these fish.

Infection of Lake Erie Fish by the Broad Tapeworm of Man.—Although a routine examination was made of 46 different species of fish from Lake Erie and tributary streams only a few of the results can be noted here. Nearly every species of fish examined was infected with some species of helminth. However particular attention was paid to the intermediate hosts of the broad tapeworm of man (*Diphyllobothrium latum*). The following table summarizes the results of the examinations of the usual intermediate hosts. In no cases were plerocercoids of this worm recovered.

TABLE 1.— SHOWING RESULTS OF EXAMINATIONS FOR THE BROAD TAPEWORM OF MAN

HOST	Number examined	Locality	Infection with *D. latum*
Wall-eyed pike (*Stizostedion vitreum*)..	5	Lake Erie, near Silver creek, N. Y........	None
	1	Lake Erie, near 18-Mile creek, N. Y........	None
	2	Niagara River, N. Y...	None
Sauger, sand pike (*S. canadense griseum*)	10	Lake Erie, near Silver creek, N. Y........	None
Pickerel (*Esox lucius*)...............	3	Lake Erie, N. Y.......	None
Ling, burbot (*Lota maculosa*)........	3	Lake Erie, near Silver creek, N. Y........	None

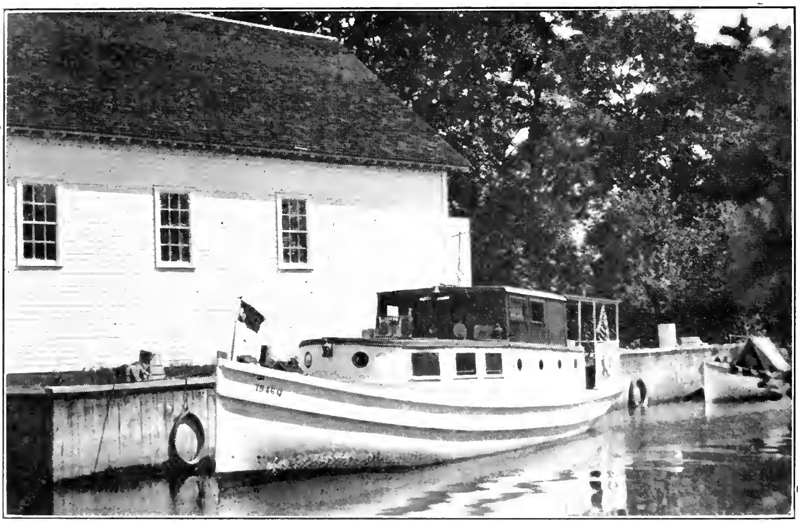
These records are published in this account because of the importance of all data on this particular helminth.

X. CARP CONTROL STUDIES IN THE ERIE CANAL

By P. H. Struthers

Assistant Professor of Zoology, Syracuse University

The carp control studies made during the past summer were conducted on the Erie canal between Utica (Lock 20) and May's Point (Lock 25), the Oswego canal, inlets and outlets of these canals and the four closely associated lakes—Oneida, Onondaga, Cross and Neatahwanta. This territory represents three hundred miles of actual shore line, all of which was surveyed at least twice during the three months of work. In order to collect accurate data on so extensive a region, the members of the field unit lived on a cabin cruiser, which also served as laboratory and transport for the scientific and collecting equipment.



The "Mildred," laboratory boat of Dr. P. H. Struthers, in the service of carp control studies undertaken in the Barge Canal and Lake Oneida

Following the investigations of 1927, made on Oneida lake, it was thought advisable to devote the major portion of our time to carp control studies in the adjacent Erie and Oswego canals with a small time allotment to the continuation, in Oneida lake, of such specific problems as, migration of carp, breeding habits, lake seining and the sale of carp. The underlying object of all these studies being to furnish information which will aid in the formulation of a policy for the control of carp in the waterways of the State.

Carp Habitats.— Lake carp are communal fish, congregating in numbers wherever the natural conditions are most favorable. It has long been known that carp frequent different habitats throughout the year. Investigations made in Oneida lake show that carp, early in April, migrated to the submerged lowlands and swamps where they wandered about in detached groups for several weeks. With the appearance of warm weather (middle of May) the fish assembled in schools along the shores of the lake where the water was shallow and dense-leaved pondweeds were growing. Here they spawned. During the summer and fall, although carp were found more or less common in the shallow waters throughout Oneida lake, there were only a few places where this fish congregated regularly and in large numbers. Listed in the order of their importance these carp grounds are: Fisher's bay, Upper South bay, including Verona beach, North bay, Lakeport and Shaw's bay. Each is a shallow bay, having abundant growths of weeds (Potamogetons, Vallisneria and Scirpus), a mud or sand bottom and is easily accessible to deep water.

In Onondaga lake carp are found chiefly near the western end where feeding grounds are available. Cross lake has several excellent carp habitats—the shoals about Strawberry island and wide submerged flats at both ends of the lake. About lake Neatahwanta are extensive cat-tail marshes which carp inhabit as well as a continuous region of shallow water on the east side covered with weed beds. The conditions in this lake are unusually favorable for carp and they are abundant, but not so numerous as reports would indicate.

Carp were found inhabiting all the waters of the canal system investigated during the past summer.* This waterway consists of canalized rivers and creeks with numerous excavations. The channel averages from ninety to three hundred feet wide with a minimum depth of twelve feet. The channel banks, normally steep with a narrow fringe of shallow water, occasionally slope shoreward in a gradual incline terminating in a deep bay or marsh. From Utica to New London much of the canal has been excavated and the shores are for the most part uniformly steep and narrow, while west of Lock 23 (Brewerton) the canalizing of the Oneida, Seneca and Oswego rivers has produced a very irregular shore line, marked by many inlets and outlets, marsh lands and bordering regions of shallow water which support luxuriant growths of aquatic plants. Canal carp live primarily in the channel proper. Their abundance is commensurate with the availability of natural feeding grounds, irrespective of other prevailing conditions as, pollution, current, width of canal, presence of inlets and outlets.

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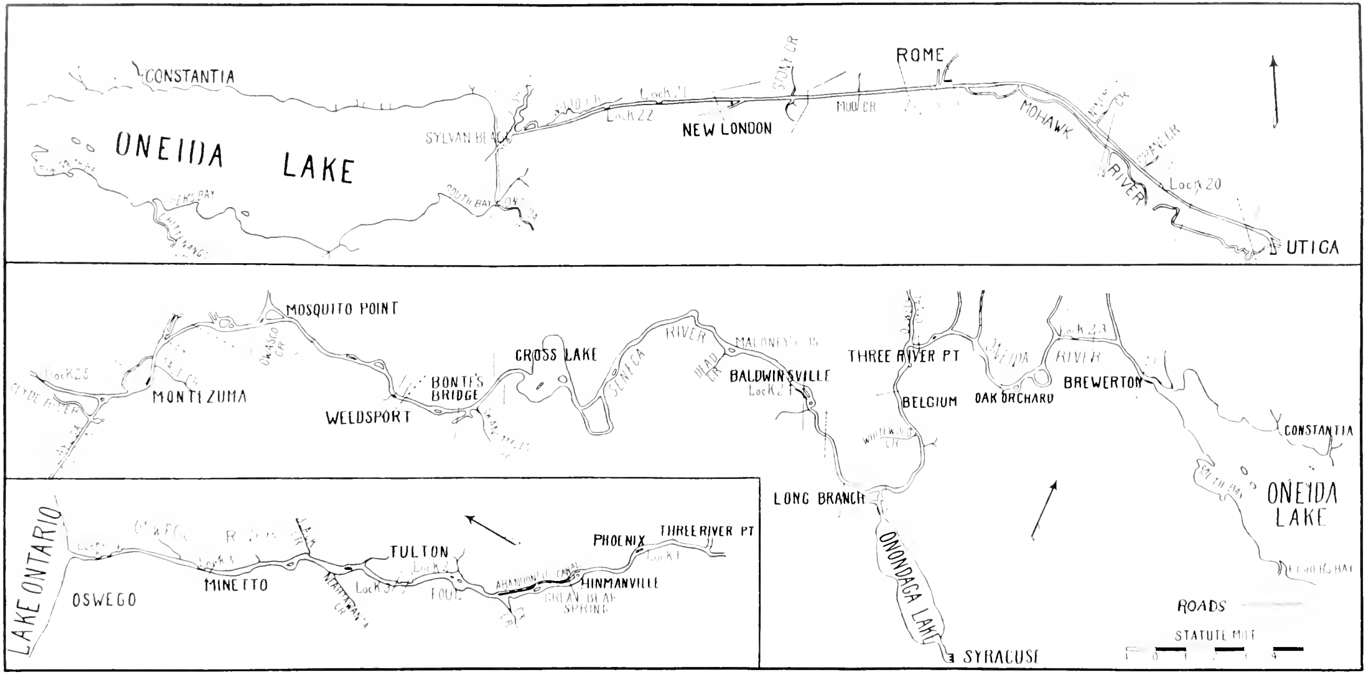
* A forty-pound carp caught on a line by George Flint was taken near the Montezuma bridge. This is one of the largest specimens taken during the two seasons of carp control work.



Portion of Barge canal—lock 20 to lock 25 and the Oswego canal—the territory surveyed by the carp control study unit during the summer of 1928

Following are listed the regions where carp are very abundant (see map):

Vicinity of highway bridge, New London.
Mouth of Fish creek, near Sylvan Beach.
Entrance to canal, Brewerton.
Inlet of Oneida river, west of Lock 23.
Shallows west of stone cut, Oak Orchard.
Wide water one-half mile east of Belgium.
South side of canal at Great Bear spring.
Foul one mile east of Fulton.
Vicinity of Mud Lock and Long Branch.
Shallows west of Baldwinsville.
Wide water one mile west of Maloney island.
Vicinity of Bonte's bridge.
Wide waters and old channel west of Mosquito point.
Wide waters and flood channels in the Montezuma marsh.
Old Erie canal in vicinity of Canastota.

In contradiction of the popular belief that carp inhabit by preference polluted water, is the fact that very few carp live near the inlets of Wood and Owasco creeks, the two streams most badly polluted by city sewage encountered in the present survey (Wagner).[1] Industrial wastes entering the canal at such places as Rome, Fulton and Onondaga lake do not seem to effect the distribution of this fish.

Canal carp live in small schools, thirty individuals forming the largest school observed as compared with a school of nine hundred fish taken at Fisher's bay in Oneida lake. This is due to the absence of extensive feeding grounds in the canal and the frequent disturbing of fish by passing boats. That it is not an inherent characteristic is shown by the fact that carp assemble in large numbers, during the spring, in creeks and flood waters covering the marsh lands which border the canal.

The portion of the old Erie canal between New London and Canastota harbors many carp. The fish have free access to the barge canal through a flood channel at New London, but it is doubtful if carp use this passage since the old canal possesses natural conditions favorable to carp. A similar region is found in the old Oswego canal extending for five miles from Walter's island to Morseman's lock. The old canal connects with the new channel at frequent intervals, thus making the former easily accessible for spawning and feeding grounds.

Breeding Habits.— The first spawning of carp was observed by Mr. R. Landgraff[2] at Billington's bay on May 14. From this date until the 7th of July breeding carp were seen in this bay, at Upper South bay and at many different locations in the Erie and Oswego canals. They were also found spawning as late as

[1] Wagner, F. E. Chemical Investigations of the Oswego Watershed. [In Oswego Survey Rept. N. Y. Conservation Department. 1928.]

[2] Carp seiner in field unit.

July 15 in one small stream, Tannery creek, which flows out of Lake Neatahwanta. This cold sluggish creek had beds of the pondweed, *Potamogeton pectinatus* growing along its border upon

Seine laid out at New London

which plant the carp eggs were attached. In the canal all eggs were found adhering to *P. pectinatus* or *Vallisneria* growing along the edge of the channel in water six inches to three feet deep. In Oneida lake the eggs were found on the same kinds of plants with one exception. At Damon's point a school of carp were observed spawning on filamentous algae which grew on rocks in six inches to two feet of water.

During the breeding season carp show practically no fear and their characteristic splashing make them very conspicuous. On June 28 there were about 1,000 carp spawning in the shallows between Damon's point and Fisher's bay, a distance of perhaps two miles. In the canal we saw only scattered groups of spawning carp, no schools numbering over 50 individuals. A spawning female flounders about here and there in shallow water closely followed by three or four males. The actual depositing of eggs seems to occur at times when the female breaks the surface of the water over a bed of pondweed. This is followed immediately by a great splashing of the males over the place, which scatters the eggs and covers them with milt. The eggs deposited during one such operation covers an area six feet in diameter and they are attached to the fronds, stem and even the bottom. The number of eggs laid at one time are from 500 to 700 and during the spawning period each female will deposit several such lots of eggs. These are grayish-white in color and about the size of a radish seed (2 mm. in diameter).

The breeding period is interrupted by short periods of activity followed by a long interval of quiescense. The operations continue day and night, during which time the carp move from one spawning ground to another or to deep water. A catch of 58 carp taken at Damon's point June 26th had 38 males and 20 females, while another catch at New London had 28 males and 6 females. The average weight for both catches was 3.3 pounds, indicating roughly that the average age was between three and five years. The females run consistently heavier than the males.

Carp spawn at approximately the same time both in Oneida lake and the canal. There is a gradual increase in the number of breeding fish up to the first week in July when spawning suddenly ends. The period varies somewhat with the type of season which affects the rise in water temperatures. No spawning carp were observed where the water temperature was less than 60 degrees Fahrenheit. The latest spawning was witnessed at Tannery creek, in which the water is several degrees cooler than in the canal. By November first female carp are very heavy with spawn, a natural prevision doubtless associated with the physiological inactivity of this fish during the winter.

Carp eggs hatch four days after spawning occurs. Authenticity for this statement is based on actual observations made in the field, as well as from eggs artificially fertilized and developed in aquaria. Judging from the exposed position of the spawning grounds, carp eggs are resistant to the agitation of water caused by wind or boats, yet the percentage of eggs destroyed by natural enemies must be tremendous.

Young Carp.—At the time of hatching carp fry are one-eighth inch long. The rate of growth during the first three weeks as recorded by Doctor W. M. Smallwood is as follows:—

July 2	Eggs hatched	
July 3	Fry total length.........	5.5 mm
July 5	Fry total length.........	7 mm
July 7	Fry total length.........	8 mm
July 17	Fry total length.........	8.5 mm
July 25	Fry total length........	9 mm (3/8 inch)

At nine millimeters total length the carp fry begins to take the form of adult fish, there is a distinct sucker mouth, the skin has a yellowish hue and a dark spot begins to appear at the base of the tail. More advanced stages of young carp were taken at different points along the canal:

July 10, two carp (1 in. long) in Elodea, shallows near Walter's island.
July 13, ten carp (1 in. long) in Elodea, Foul east of Fulton.
July 15, forty carp (½ in. long) in Elodea, Tannery creek.
Aug. 14, three carp (3 in. long) in *P. pectinatus*, shallows east Cayuga Division.
Aug. 15, two carp (1½ in. long) Elodea, shallows back of Aqueduct at Montezuma.
Sept. 5, one carp (1½ in. long) Elodea, Foul at Fulton.
Nov. 24, two carp (6 in. long) in trap net set in Foul at Fulton.*

Little carp living in the canal inhabit the same type of region as those found in Oneida lake. It is surprising however that so

* These young carp were about six months old. They were living in water from three to six feet deep in common with adult carp.

few were taken considering the emphasis placed on the catching of little carp. This may be due to the destruction of large numbers of eggs by natural causes, to little carp living in deeper water than the young of game fishes or to some protective habit as taking shelter in the mud bottom and thus escaping our nets.

Both in the canal and in Oneida lake yearling carp were taken in the seine together with adults. The weight of these young carp from the lake averaged one-half pound; the total length nine inches. Those caught in the canal were somewhat smaller.

Migration.—With an object of determining to what extent carp migrate, we placed an aluminium tag on the caudal fin of two hundred adult carp. Each tag bears the initials N.Y.C.D. together with a number which identifies each fish with a record of its length, weight, sex, the date and exact place of liberation. The distribution of tagged fish was as follows:—

Oneida lake	70
Erie canal at New London	50
Seneca division of canal	50
Oswego canal	30

It is anticipated that through more extensive seining operations and the cooperation of local fishermen, who catch tagged fish, many of the tags will be returned together with the place of capture, so that our records may be completed. The degree of carp migration, its direction and rate outside of a purely natural history interest has an important bearing on the subject of carp control.

Food Habits.— The digestive tracts of forty-two adult carp taken at ten different places in the barge and Oswego canals were examined by Mr. Sidney Britten.* His condensed report follows:—

		Per cent
Plant material 31.4 per cent.		
	Vegetable debris	25.0
	Filamentous algae	5.0
	Seed	1.4
Animal matter 68.6 per cent.		
	Insect larvae	24.8
	Snails	16.4
	Midge larvae	5.0
	Bivalves	6.5
	Ostracods	4.8
	Malacostraca	3.0
	Animal debris	2.8
	Copepods	1.9
	Cladocera	1.6
	Decapoda	1.1
	Insects	.5
	Crustacea (unidentified)	.2

* Scientific assistant in field unit.

This report compares closely with that of last year based on carp living in Oneida lake and it adds confirmation to the statement that carp feed primarily on the lower forms of animal life. At the same time it must not be overlooked that carp show selective preference for some plant materials such as corn or potatoes, both of which were used successfully as bait.

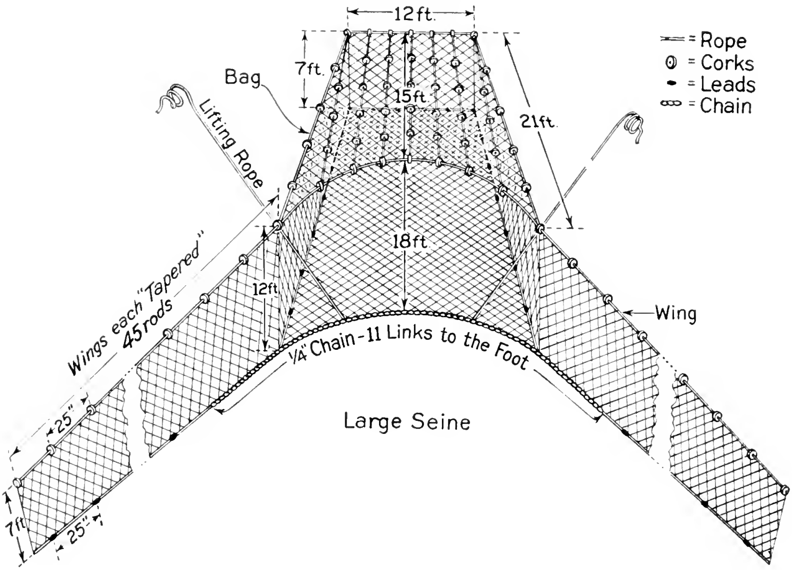
The intestinal contents of eight young carp taken in the Oswego canal consisted principally of insect larvae, midge larvae, with smaller amounts of Ostracods, Copepods, Cladocera and vegetable debris.

In spite of the vast body of water comprising the canal system, there are very few feeding grounds comparable with those to be found in Oneida lake. Such a situation accounts for the important movement of canal carp during the night as they patrol the shore in search of food. Under the glare of the boat's spot light, carp singly and in small groups were seen to work along the narrow fringe of shallow water bordering the channel, methodically routing the mud bottom or sucking about the foliage of scattered aquatic plants. That this is a nocturnal movement is shown by our trap net records which show that not a single carp was caught during the day between 7 A.M. and 5 P.M.

Associated Fish Fauna.— The number of fish, exclusive of carp, taken in five hauls made between Oneida lake and Lock 20 consisted of 2 small-mouthed bass and 1 bullhead. From twenty hauls made at fourteen different carp habitats along the Seneca and Oswego divisions of the canal the following were caught: 23 pike-perch, 44 calico bass, 28 large-mouthed bass, 9 small-mouthed bass, 3 rock bass, 43 common suckers, 96 red-fin suckers, 14 pickerel, 242 bullheads, 6 catfish, 27 sunfish, 1 eel, 3 garpike and 18 lawyers (Amia calva). Lamprey scars were detected on carp taken at New London, at the mouth of Fish creek, in Oneida lake and in the canal near the Cayuga division.

The relatively large number of game fish taken on grounds frequented by carp, their fat condition and the fact that these game fish ignore the bait of fishermen, indicate that there is an abundance of food. As long as the available natural food exceeds the demand fishermen will have difficulty in attracting game fish to the baited hook, irrespective of carp or other supposedly detrimental fish.

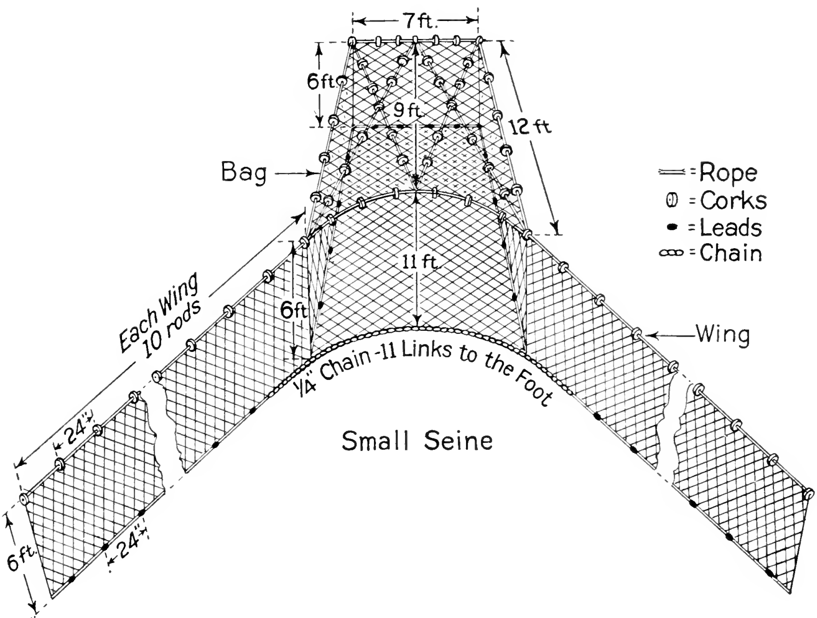
The degree and manner in which carp are detrimental to game fish are poorly understood. It is popularly believed that carp eat the young of game fish, but such an idea is not supported by our studies. Its sucker mouth is not adapted to predacious habits and the food material found in the digestive tract includes no fish remains. A second accusation against the carp is that it destroys the spawn of game fish. No evidence was obtained to support this belief. The most important charge against the carp is the usurping of shallow waters frequented by game fish. Omitting the question of food, this large fish with aggressive movements keeps the smaller more timid game fish and minnows from enjoying the unmolested tenure of its natural habitat. Carp have been found most numerous in places where such natural fish grounds exist. It is essential that this domination of these regions by carp be removed.



Large seine for lake seining

Netting of Carp.— The seining method has proved most successful in Oneida lake. A sixteen hundred foot seine fishing seven feet at the ends and at least twelve near the bag, will in the hands of an experienced seiner assisted by three men, work very satisfactorily on grounds free of submerged obstacles or dense vegetation. In the canal this type of netting is not satisfactory because carp do not school in large numbers, muddy conditions of the water make it difficult to detect a carp roil, possible seining grounds are very rare, much labor is required to prepare these grounds for seining, they are covered with great masses of flora and the suction produced by passing tankers exposes the net to frequent danger of being drawn into the propeller. A five hundred foot seine fishing six feet is valuable for shutting off setbacks, flood channels and small creeks. A type of channel seining has been suggested, but with the interruptions caused by passing boats and the scattered condition of the carp it would not prove profitable.

The use of a net that will fish twenty-four hours a day, so placed as to catch the fish working along the shore, is the most practical method of taking large numbers of carp in the canal. Pound nets will catch carp but they are expensive and require the attention of several men. The trap net is more satisfactory, being inexpensive, easily set and tended by two men, and if properly laid out catches carp. A seven-foot trap net with a tunnel opening twelve inches high was fished frequently during the past summer and fall.* The trap was placed in about six feet of water bordering the channel and the leader laid toward the shore. The wings and leader fished top and bottom. Carp patrolling the shore hit the leader and



Small seine for canal seining

taking fright headed for the channel, encountered the wings and were led into the trap. By this method from thirty to one hundred pounds of carp were taken after each of the ten nights the trap net was set. A good many game fish are caught by this method, but if the net is tended daily they are not harmed. Non-game fish such as suckers and lawyers are better out of the canal and the suckers have a market value equal to carp. A commercial taking of carp by this method would necessitate the transferring of fish to a live car where they could live until a sizable shipment had accumulated.

The baiting of carp in the canal to a place suitable to seine was tried, but the results proved rather uncertain. It requires constant watching to catch the carp at the time they are on the grounds and the few fish congregating at one time, do not when sold, pay for the cost of operations. In the lake seining the use of corn proved successful, for at Verona beach the catches were materially increased by its use.

* Observations made during the present fall show that trap netting operations can be continued as late as December 1st.

The taking of carp in the spring after they have migrated up the creeks and over the flooded lowlands has great possibilities well known to many a farmer and it should not be overlooked in any program for carp control.

Lake Neatahwanta was the object of special study because of the many carp reported living there. A survey around the entire shore revealed no place where a large seine could be operated with-

Foul east of Fulton, showing an excellent region for trap net

out the removal of dense beds of flora and submerged obstacles, or the lowering of the water level in the lake.

Marketing of Carp.— This problem received unavoidably a minor portion of our time. The seven days of actual commercial seining on Oneida lake netted 8,219 pounds of carp. Through the cooperation of Mr. Bert Winn, the local dealer, we were able to get detailed information concerning the cost of packing, transporting the fish from our net to the shipping point and the sale of these fish in New York City.

Based on the present demand, carp properly packed bring from nine to eleven cents per pound net at the shipping point as a flat season's rate in amounts not exceeding 150 tons per week. By selling net the only cost to the dealer is his labor and cost of transportation, an average expenditure of $2.50 per one hundred pounds of fish. Local markets will take up to five tons of live carp per week at a price considerably above that of the New York market.

The carp at present is much in favor as a food fish by the Hebrew and Italian trade. By proper treatment it should have a more general use. When smoked it rivals the mackerel; used with bacon it makes an excellent stock for fish chowder and by a treatment with alum and vinegar its red flesh resembles that of salmon.

General Considerations of Carp Control.—Future control methods should be directed toward the reduction in the numbers of carp wherever they are very abundant so that they will not dominate the natural habitats of game fish. In the lakes this can best be accomplished with large seines. In the canal where the carp are more dispersed the trap net and small seine will work to advantage. The method of netting during the spring migration must be selected to suit any one of a variety of situations. The importance of this phase of carp seining should not be under estimated especially in the canal.

A previously unattacked stage in the life cycle of the carp has been its egg. With the millions of spawn deposited yearly, during May and June, along the borders of the lakes and canals and attached to easily identified pondweeds, it would be a simple matter for untrained labor to patrol the shores in a small boat and destroy large numbers of eggs. This method of attack should occupy at least a minor place in the general plan of carp control.

XI. QUANTITATIVE STUDIES OF THE FISH FOOD SUPPLY IN SELECTED AREAS

By P. R. Needham

Instructor in Limnology and Ecology, Cornell University

During the summer of 1927 work was started upon a few of the main problems relating to trout foods as they are found in the streams in New York State. This work was continued during the past summer (1928) as the problems seemed to warrant further investigation, the data obtained in 1927 being insufficient upon which to base definite conclusions. Also this summer several additional projects were started, the results of which are presented here.

The problems under consideration in this report are as follows:

(1) Relation of width of stream to quantity of food organisms (continued from last year).

(2) Relation of bottom types to quantities of food (continued from last year).

(3) Amounts of terrestrial insects which fall into the water (defined as "stream drift", 1927) and the consumption of this class of food by trout.

(4) Productivity of various types of aquatic plants in relation to trout foods (continued from last year).

Last season's work was entirely on available foods, those actually eaten by trout not having been considered. This summer, in connection with problems 3, stated above, trout were taken for stomach examinations in order to correlate available foods with foods consumed. The principal streams in which these studies were carried on were Sixmile creek, Newfield creek, Haybrook, and Owasco inlet near Ithaca, N. Y., and Heron brook, Point Rock creek, and Fish creek near Constableville, N. Y.

Relation of Width of Stream to Quantity of Food Organisms. — The apparatus and methods used in getting data upon this problem have already been described[1] and need no further comment here. In Table 1 will be found the combined results of two seasons' work upon this problem.

Leger[2] has stated that, in a stream over 5 meters in width (16.4 ft.), the food decreases one-half or 50 per cent from the

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Mr. E. H. Wheeler of Hobart College, Geneva, N. Y. and Mr. William Phillips of Ithaca assisted the writer in this work.

[1] See Biological Survey of the Oswego River System, supplemental to Seventeenth Annual Report. N. Y. State Conservation Department. 1927.

[2] Leger, L. Principes de la Methods Rationelle du Peuplement des Cours d'eau a Salmonides. Travaux du Laboratoire de Pisciculture de L'Université de Grenoble. Fascicle 1, p. 531, 1910.

shore line to the middle of the channel. The findings shown in Table 1 are based upon streams above and below 18 feet in width. The dividing point at eighteen feet was selected because this seemed to be the width of stream found in this vicinity where bottom foods are quite evenly distributed over the entire floor of the stream.

TABLE 1.— DISTRIBUTION OF AVAILABLE FISH FOOD IN STREAMS ABOVE AND BELOW 18 FEET IN WIDTH

	Average weight in grams of nutritive elements per sq. ft. at sides of streams	Average weight in grams of nutritive elements per sq. ft. at centers of streams	Rate of increase or decrease from sides to centers of streams
Below 18 ft....	1.44	1.64	Increases 12.19% or approximately one-eighth.
Above 18 ft...	0.92	0.81	Decreases 11.95% or approximately one-eighth.

The average weight of nutritive elements per sq. ft. found at the sides of streams was 0.92 grams (Table 1) in streams above 18 feet in width. The average for centers of streams of the same width was 0.81 grams, a decrease of 11.95 per cent or approximately, one-eighth. On the other hand, in streams below 18 feet the average weight of the nutritive elements at the sides was 1.44 grams; centers, 1.64 grams, giving an increase of 12.19 per cent or approximately one-eighth, from shore line to mid-channel. Thus it is seen that in streams below 18 feet in width more food is found in their centers, and they are proportionately much richer at both sides and centers than streams above eighteen feet in width. Also these figures show that there is a slight decrease in the amount of food present in the middle of streams over 18 feet in width, as contrasted with the amount contained at the sides of streams of this width but this decrease is so slight that we may consider it to be negligible.

This is not in agreement with the findings of Leger. However, the figures given here are the averages derived from 91 unit area bottom studies taken in many types of trout streams under varying conditions as they are found in the vicinity of Ithaca, N. Y., and while these results may be true for streams in this vicinity, very dissimilar conditions might be found in the streams of France in which Leger worked.

Multiplicity of Factors.— Table 1,* p. 195 of last year's report on this problem shows that the individual unit area bottom studies varied tremendously in the weights of available fish food present.

* Loc. cit.

In an effort to explain such large variations, complete notes were kept on depth, current velocity, shade and type of bottom. A later examination of this data in the laboratory showed that the most important of these influences were type of bottom, velocity of current and depth. The relative influence of each factor is very difficult to determine but of those mentioned above, type of bottom seems to be the most important.* Table 2 gives a few of the general results derived from two seasons' work on the distribution of bottom foods. A comparison of the averages shows that slightly less bottom foods were available per unit area during the past summer than was available during the summer of 1927. If yearly variations are no larger than those indicated in this table, they may be considered as inconsequential in relation to fish life.

TABLE 2.— COMPARISON OF THE PRODUCTIVITY OF STREAMS STUDIED IN 1927 AND 1928. Given by Gram Weight of Food per One Sq. Ft. as Found Under Varying Conditions

	1927	1928
Average for streams below 7 feet in width	2.36	2.06
Average for streams above 7 feet in width	1.04	0.94
Average for all streams regardless of width	1.21	1.05
Average for streams flowing through non-cultivated lands	....	1.36
Average for streams flowing through cultivated lands	....	1.06
Average for pools in all types of streams	0.26	0.21

Streams flowing through wild, uncultivated lands such as are found in the Adirondack region in this state, are generally considered to contain more natural foods such as mayfly nymphs, caddisfly larvae and other aquatic insects than streams which flow through cultivated lands. A week was spent during the past summer working the headwaters of Point Rock and Fish creeks near Constableville, N. Y. in an effort to ascertain whether or not streams flowing through wild conditions are actually more productive in bottom foods. Twelve unit area studies were made in this region and gave an average production of 1.36 grams per sq. ft. The bottom studies taken near Ithaca, N. Y. in streams draining cultivated lands gave an average of 1.06 grams per sq. ft. From these figures, streams flowing through wild lands are somewhat richer in food per unit area. However, more data must be available before this fact can be definitely determined.

It will be noted in Table 2 that the average weight in grams of the nutritive elements per sq. ft. in pool bottoms was 0.26 grams in 1927 and 0.21 grams in 1928 which shows a negligible decrease. The average for all streams regardless of width was 1.21 grams in 1927 and 1.05 grams in 1928. It would be well to state here that these averages "over all streams", as expressed in Table 2, mean the average production per unit area in the *riffles* in streams as contrasted with the *pools*. The riffles are the larders of the streams and it is here that the bulk of the fish food is produced. Pools, as has already been shown, are lacking in quantities of food, but

* Lack of space did not permit insertion of full proof of all statements made. This will be found in the files of the Limnological Laboratory of Cornell University.

they are valuable in many other ways to trout than in merely food production.

Relation of Type of Bottom to Quantity of Food.— Table 3 gives a summary of the stream bottom types studied during the past two summers with the relative amounts of food found in each. While this year's results differ slightly from those obtained in 1927, the same proportionate amounts of food were found in each type of bottom. As is shown in Table 2,* silt produced an average of 4.29 grams per one sq. ft. in 1927 while this year an average of 3.46 grams was obtained. Likewise there was a slight decrease in the amounts found in rubble, coarse gravel and fine gravel, this year. The figures presented here in Tables 2 and 3 show clearly that there is a yearly fluctuation in the productivity of streams in bottom foods.

TABLE 3.— STREAM BOTTOM TYPES SHOWING AVERAGE AMOUNT OF AVAILABLE FISH FOOD PER ONE SQ. FT. IN EACH

Number of Determinations	Type of bottom	Average weight in grams per sq. ft.	
		1927 results	1928 results
6	Silt	4.29	3.46
33	Rubble	1.88	1.23
44	Coarse gravel	1.28	1.21
12	Fine gravel	.98	.82

Foods Consumed by Trout by Comparison with Available Foods.— Last season the relative abundance of each class of available drift and bottom food was determined without correlating these findings with foods actually consumed by trout. This year trout were taken in connection with the drift and bottom studies to determine, if possible, what foods of those available are most largely consumed by trout.

In order to determine the foods which trout selected from those floating in or on the water, trout were seined or caught with hook and line during the same time that drift food was being collected from the water by the drift net. The net was run for an hour for each catch and an attempt was made to obtain six trout stomachs within the time that the net was in the water. The later stomach examinations of the trout showed what foods of those available the trout had selected.

At the end of the summer a total of 29 drift catches and 147 trout stomachs were studied and tabulated in the laboratory and the general results are presented in Table 4. Of the 147 stomachs, 32 were from rainbow trout, 6 from brown trout and 109 from brook trout. The average length of all the fish was 6½ inches and

* See Oswego Survey, p. 196, Table 2.

they ran from 4 to 10 inches. They are to be considered as small adult trout. No distinction is made here as to the individual foods selected by the different kinds of trout. In Table 4 consumed foods are placed on a 100 per cent basis; vegetation, trash, debris and indigestible materials being omitted entirely though some usually occurs in most stomachs. The columns headed "Terrestrial" give the numbers of terrestrial or land insects of each class found in the drift and in the stomachs and include all insects or other animals which normally do not live in or on the water. "Aquatic" is used to designate those animals, mostly insects which live in or on the water such as stonefly nymphs, caddis larvae, etc. At the bottom of Table 4 the term "Miscellaneous" includes a few millipedes, centipedes and dragonfly nymphs which were taken in both drift and stomachs but which were of little importance in these studies. It is to be remembered that this data is given in per cent by number and not per cent by volume as has been done in most other works on stomach contents of fishes. In a comparison

TABLE 4.— COMPARISON OF FOODS CONSUMED AND AVAILABLE FOODS

Data derived from examination of 147 trout stomachs taken during 29 drift net catches in June, July and August, near Ithaca, N. Y., 1928

ORDER	Consumed foods from stomach examinations			Available foods from drift net catches		
	Terr.*	Aquatic	Per cent	Terr.*	Aquatic	Per cent
Mayflies	226	356	29.70	675	102	31.46
Caddisflies	22	528	26.37	43	59	4.13
Two-winged flies	134	187	15.39	627	38	28.14
Beetles	137	33	8.15	111	30	5.71
Ants, bees, wasps	153	0	7.33	130	0	5.26
Plant lice, aphids, etc	107	0	5.13	451	0	18.26
Stoneflies	10	41	2.44	29	9	1.54
Grasshoppers, etc	31	0	1.49	6	0	0.24
True bugs	25	2	1.29	50	12	2.51
Moths	21	0	1.01	4	0	0.18
Spiders	17	3	0.96	23	0	0.93
Shrimps, crabs, etc	0	15	0.72	0	5	0.2
Worms	8	0	0.38	0	0	0.0
Fish	0	4	0.19	0	0	0.0
Miscellaneous	4	18	1.25	36	0	1.45

of foods consumed by trout and available foods this seemed the most practical manner of presentation since thousands of organisms were being handled in a limited period of time and it would have been very difficult to calculate volume of each class of drift and bottom food as collected.

It is shown in Table 4 that mayflies formed 29.70 per cent of all foods consumed and 31.46 per cent of all available foods. In other

* Terr.— Terrestrial.

words, mayflies were the most available food and they were consumed by trout more than any other food. Caddisflies were second in importance and formed 26.37 per cent of foods consumed and only 4.13 per cent of available drift foods. Thus from these figures it is evident that the trout feed on larval caddisflies on stream bottoms since so few were available in the drift. Two-winged flies formed 15.39 per cent of the trout diet and 28.14 per cent of available foods which indicates that many more were available in the drift than were being consumed by the fish. Similarly, plant lice formed only 5.13 per cent of consumed foods and 18.26 per cent of those available. Plant lice and flies were much more abundant in the drift than in the trout. The reason for this would seem to lie in the fact that most of the flies and lice taken in the drift were quite small and would be hard for trout to see. It has been found by other workers that the smaller insects are most largely consumed by the smaller fishes, 1–3 inches in length. Many of the flies which were taken from the stomachs were of good size which the trout could have readily seen before eating. Beetles and ants, bees and wasps formed 8.15 per cent and 7.33 per cent respectively of consumed foods and 5.71 per cent and 5.26 per cent of available foods which shows a close correlation between the availability and consumption of these two foods. Likewise the stoneflies, true bugs and spiders show a close correlation between availability and consumption. Grasshoppers, moths, shrimps, crabs and worms were more abundant in the stomachs than in the drift. This probably is due to the fact that the trout were consuming these foods, and perhaps other foods as well, before they had time to reach the drift net. Only four fish were taken from the 147 stomachs examined. If larger trout had been taken, doubtless many more fishes would have been found, as it is well known that large trout oftentimes feed voraciously upon minnows, trout fry and other small fish. Metzelaar,* in work upon trout in Michigan, found that fish formed 3.7 per cent of the stomach contents by volume of fishes 7 to 16 inches long. In larger trout, 17 to 28 inches long, fish formed 23.8 per cent of the stomach contents by volume. Dr. Metzelaar's results are not truly comparable to the results given here, since his are expressed in per cent by volume and ours in per cent by number. However, he does show that fish are consumed in greater quantities by larger trout and that fish form but a minor part of the diet of small trout. Shrimps and crabs were low in number, forming only 0.72 per cent of consumed foods, and likewise they were unavailable to the trout, forming only 0.2 per cent of the drift food. However, in some streams, particularly those in which the waters are high in calcium, shrimps oftentimes will be very abundant and will be a principal part of the diet of trout in such streams.

Chart 1 (derived from Table 4) shows graphically the consumption and availability of each food. By reference to Table 5, it is to

* Metzelaar, Dr. Jan. "The food of rainbow trout in Michigan." Preliminary report to the Department of Conservation; Lansing, Michigan. Jan. 1928.

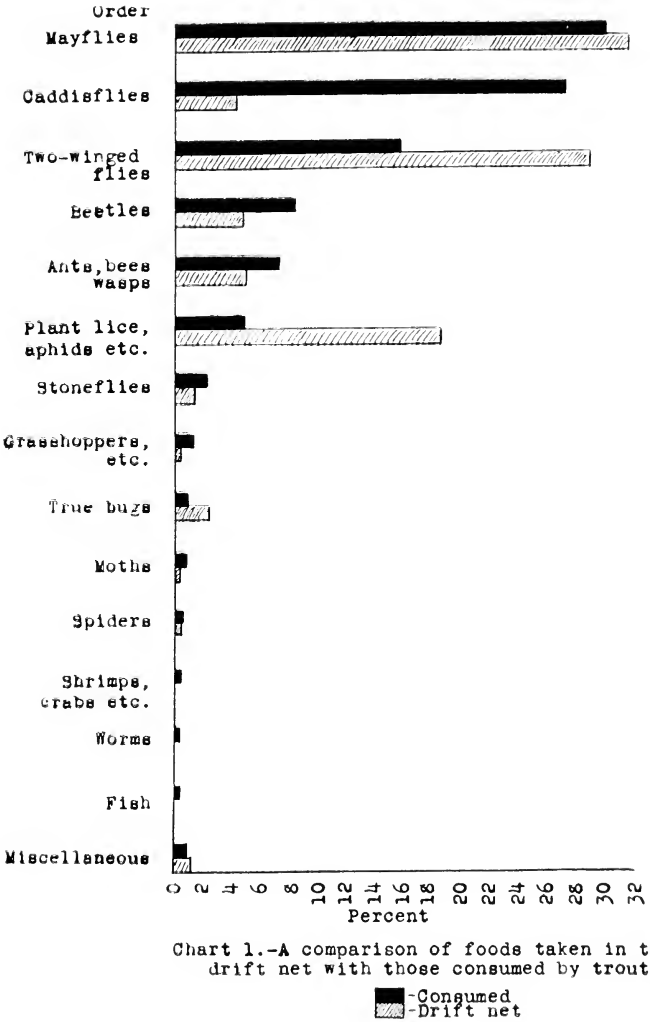


Chart 1.-A comparison of foods taken in the drift net with those consumed by trout.

be noted that of all the foods consumed, 43.34 per cent were terrestrial and 56.66 per cent were aquatic in origin. Since these trout were taken during June, July and August, when land insects are most numerous, it is surprising to note that more than half of their diet (56.66 per cent by number) is composed of aquatics. The reverse is true of the available drift foods, wherein 89.87 per cent was terrestrial in origin, while only 10.13 per cent was aquatic.

As has been noted above with certain classes of foods, a greater per cent has been consumed than was available in the drift. This is significant because it indicates that trout must feed off the bottom. It also may indicate, as seems to be the case with the larger sized food organisms such as grasshoppers, moths, worms, etc., that the trout were eating them before they had a chance to reach the drift net. Furthermore, the larger terrestrial foods would probably not drift far in a stream on account of their size and structures.

Aquatic Foods, Consumed and Available.— By referring to Table 5 the principal preferred foods are shown.

TABLE 5.— COMPARISON OF FOODS TAKEN IN THE DRIFT NET WITH FOODS CONSUMED BY TROUT

	Consumed foods		Available foods	
	Number	Per cent	Number	Per cent
Terrestrial	904	43.34	2,220	89.87
Aquatic	1,182	56.66	250	10.13
Totals	2,086	100.	2,470	100.

TABLE 6.*— COMPARISON OF AVAILABLE AQUATIC FISH FOODS IN STREAM BOTTOMS AND AQUATIC FOODS CONSUMED BY TROUT

ORDER	Available aquatic foods		Consumed aquatic foods	
	Number	Per cent	Number	Per cent
Mayfly nymphs	2,316	36.90	356	30.12
Caddisfly larvae and pupae	1,335	21.27	528	44.67
Stonefly nymphs	921	14.67	41	3.47
Fly larvae and pupae	869	13.84	187	15.82
Beetle larvae	476	7.58	33	2.79
Crayfish and shrimps	235	3.74	14	1.18
Miscellaneous	125	1.99	23	1.94
Totals	6,277	99.98	1,182	99.99

* Derived from Table 3, p. 197 of 1927 Oswego Survey and Table 4 of this report.

Mayfly nymphs, it will be noted, were the most abundant of the available aquatic foods and formed 36.90 per cent of the total number collected. Caddis larvae and pupae, while forming only 21.27 per cent of available foods of this type, were eaten in the greatest numbers forming 44.67 per cent of the total. In other words, mayfly nymphs while being the most available aquatic food, were consumed second to caddis larvae and pupae. The reasons for larger consumption by trout of a less available food seem to lie in the following factors; viz.: the average size of mayflies is much smaller than the average for caddis larvae and pupae making them harder for trout to see; mayfly nymphs live closely attached to the rubble and gravel in swift water to avoid being swept away by the current while the larvae of most caddisflies live in conspicuous portable cases which they drag about with them or in cases and shelters fixed to stones in prominent positions. Also caddis pupae in order to emerge from the water and become adults must leave their shelters and swim to the surface. During this period, short as it may be, they are entirely unprotected and at the mercy of any fish which may happen to see them. Examination of the 147 stomachs showed that a very large percentage were eaten during this emergence period when the pupae were rising to the surface to take flight from the water as adults. Thus while mayfly nymphs are numerically more available, actually they are less available as shown by the numbers eaten by the trout.

Muttkowski* states that fish life in rapid streams is dependent upon stoneflies for food. In the data presented here the stoneflies form only 2.44 per cent of all consumed foods and 3.47 per cent of aquatic consumed foods in the streams thus far studied in New York State. Furthermore this food formed only 1.54 per cent of the available drift foods and 14.67 per cent of the available aquatic foods.

Fly larvae and pupae may be counted a major trout food as this group formed 13.84 per cent of available aquatic foods and 15.82 per cent of consumed aquatic foods. Beetle larvae, crayfish and shrimps may be considered as minor foods as applied to the streams and fish stomach examinations reported here.

No aquatic vegetation was found in either the brown or brook trout stomachs. However the rainbows were found to feed rather consistently upon small amounts of the fresh water alga. Cladophora. Metzelaar† found vegetation in rainbow trout, 7–16 inches long to the extent of about 9 per cent by volume while in larger rainbows, 17–28 inches long vegetation formed 17.8 per cent of the stomach contents by volume.

In last season's report a similar comparison of available and consumed foods is made from twelve trout stomachs. Since that study was based upon a few stomachs taken at one time it is hardly comparable with the data given here which is based upon 147 stomachs

* Muttkowski, Dr. Richard A. "The food of trout in Yellowstone National Park." Roosevelt Wild Life Bulletin, Vol. 2, No. 4, pp. 470–497, Feb. 1925.

† Loc. cit

taken over a three months period in many types of streams. However the general tendencies are somewhat similar though the actual figures vary considerably. For instance, 83 per cent of the food found in the above mentioned twelve trout was aquatic and 17 per cent terrestrial in origin. This year of the 147 stomachs 56.66 per cent of the food was aquatic and the remaining 43.34 per cent terrestrial in origin. Crayfish and shrimps were abundant in the stream (Newfield creek) studied last year and formed 32 per cent of the food consumed by the trout taken there. This class of food formed only 0.72 per cent of consumed foods found in trout this year and were generally quite unavailable forming only 0.2 per cent of all available foods.

From both seasons' work it is evident that trout consume to the greatest extent those foods which are the most numerous. They are opportunists like most organisms and eat what they find on hand at the moment. The practical applications of this work will lie in feeding trout upon these natural foods and determining the relative amounts of each necessary to produce so many pounds of fish. Then by determining quantitatively and qualitatively the amount and kinds of food available in any selected stream, a stocking policy can be developed to suit the food conditions in that stream.

Available Fish Food of Submerged Plant Beds.— In Table 7 will be found the combined results of two season's work upon the productivity of plant beds. Three additional types were studied this year; namely, Curly Pondweed (*Potamogeton Crispus*), water moss (*Fontinalis*) and a mixed bed of water moss and an alga, Cladophora. It is to be remembered that only one unit area study has been made in each type and these figures must not be considered as average. Much more work is necessary upon this problem before any true evaluation of plant beds in trout streams may be attained.

Of the new types of plant beds studied this year, the Curly Pondweed was the most productive and gave a weight of 5.85 grams (Table 7) of available fish food. The mixed bed of Cladophora and Fontinalis produced 4.15 grams and the Fontinalis alone, 3.4 grams per unit area.

TABLE 7.—TYPES OF SUBMERGED PLANT BEDS AND THE WEIGHT IN GRAMS OF AVAILABLE FISH FOOD PER SQUARE FOOT FOUND IN EACH

COMMON NAME	Scientific name	Date and place collected	Weight in grams of fish food from 1 sq. ft.
Stonewort	Chara	North brook, Price spring, Auburn, N. Y., August 17, 1927	37.0
Watercress	Nasturtium nasturtium aquaticum.	As above	12.8
Long-leaved Pondweed.	Potamogeton americanus.	East Branch of Owego creek, Harford Mills, N. Y., August 25, 1927	5.85
Curly Pondweed	Potamogeton crispus	Union Springs, N. Y., August 29, 1928	[1] 5.85
Willow root bed	Salix (sp.)	Sixmile creek, Slaterville, N. Y., August 13, 1927	4.88
Alga and moss; a mixed bed.	Cladophora and Fontinalis.	Caledonia creek, Caledonia, N. Y., August 25, 1928	4.15
Water buttercup	Ranunculus aquatilis.	West Branch of Owego creek, Caroline, N. Y., August 23, 1927	3.51
Sago Pondweed	Potamogeton pectinatus.	East Branch of Owego creek, Harford Mills, N. Y., August 26, 1927	3.19
Water moss	Hygrohypnum dilatatum.	Sixmile creek, Slaterville, N. Y., August 15, 1927	[2] 3.12
Moss	Fontinalis (sp.)	Canoga Spring brook, Canoga, N. Y., August 24, 1928	3.4
Horned Pondweed	Zannichellia palustris.	Canoga Spring brook, August 16, 1927	2.93
		Average weight in grams over all types studied	7.88

[1] Includes shell weight of the mollusks collected.
[2] Based upon actual weight of nutritive elements from one square foot.

It has been estimated that if Chara produces 37.0 grams of animal food per one square foot, an acre of such bed would produce approximately 3,553 pounds. Richardson,* in quantitative studies of the Illinois river bottom fauna, states that the highest yield per acre which he found was 5,196 pounds. He also states that these enormous yields were evidently due, at least in a measure, to the sluggish current and consequent heavy sedimentation and to the great preponderence (99 per cent) of large, thick-shelled snails. Snails formed but 0.74 per cent of the total number of animals taken in the Chara study listed here. It is indicated that Chara, with an estimated yield of 3,553 pounds per acre, with very few heavy, thick-shelled snails to add to the weight, produces an enormous amount of available fish food. Furthermore this estimate greatly exceeds most of Richardson's

* Richardson, R. E. The Small Bottom and Shore Fauna of the Middle and Lower Illinois River and its Connecting Lakes, Chillicothe to Grafton: its valuation; its sources of food supply, and its relation to the fishery. State of Ill. Nat. Hist. Survey, Vol. XIII, Art. XV, pp. 363 522, Urbana, Ill., 1921.

estimates in pounds per acre of food as he found it in various conditions and sections of the Illinois river.

Of the 1,767 animals taken in Chara, 61.46 per cent (1,086) were crustaceans, mostly the large Caledonia shrimp, *Gammarus limnaeus*, one of the best trout foods known. "Bloodworms" or midge larvae, another excellent trout food, formed 31.92 per cent of the catch and were living in great abundance in the mud beneath the Chara. These two classes of foods constituted 93.38 per cent of the total taken and are both highly desirable as food for trout. Other animals taken here were beetle larvae, caddis larvae, mollusks (snails), leeches but these were relatively scarce.

In the watercress study, Caledonia shrimps formed 81.47 per cent (1,675) of the 2,056 animals taken and were dominant in this type of bed as they were in the Chara bed.

By comparing the relative productiveness of these two types of beds, Chara is shown to be much the better. A larger number of animals (2,056) was taken in the watercress but their total weight was 24.2 grams less than the total weight of the (1,767) animals taken in Chara. The reason for such a wide variation in the total weight of each catch seems to be due, partly, to the shrimps. Those taken from Chara were exceedingly large and heavy, 10–15 mm. in length while those taken from the cress were mostly small, 3–7 mm. long and weighed considerably less. Caddis worms also helped to increase the weight of the Chara bed catch as 42 were taken, most of which were large in size, 8–14 mm. long while only one small one was taken in the watercress. The factors contributing to this difference in productivity of the plant beds form an important and broad field for further study.

Table 8.— Available Fish Foods of Submerged Plant Beds

ORDER	Number	Per cent
Crayfish and shrimps (Crustacea)	3,830	42.16
Fly larvae and pupae (Diptera)	2,014	22.17
Caddis larvae and pupae (Trichoptera)	807	8.88
Aquatic bugs (Hemiptera)	710	7.82
Beetles (Coleoptera)	578	6.36
Mayfly nymphs (Ephemerida)	514	5.66
Snails and clams (Mollusca)	247	2.72
Stonefly nymphs (Plecoptera)	83	0.91
Sialis larvae et. al. (Neuroptera)	11	0.12
Dragonfly nymphs (Odonata)	4	0.04
Miscellaneous	286	3.15
Totals	9,084	99.99

The other types of plant beds in which crustaceans were abundant are given as follows with the per cent formed in each by this group: Curly Pondweed, 57.96 per cent; Fontinalis alone, 98.4 per cent, and Horned Pondweed, 60.61 per cent. The last mentioned type of bed gave the lowest weight of potential food per unit area of any studied.

Considering next the potential fish foods available over all types of plant beds, Table 8 shows the relative abundance of each class of food. In a total of 9,084 organisms collected, crayfish and shrimps constituted 42.16 per cent. Most of these were Caledonia shrimps, a few water sowbugs, Asellus, being included. Fly larvae and pupae formed 22.17 per cent and were the second most abundant food in plant beds. Other foods largely eaten by trout occurred in the following ratios: Caddis larvae and pupae, 8.88 per cent; mayfly nymphs, 5.66 per cent and stonefly nymphs, 0.91 per cent. Bugs and beetles formed 7.82 per cent and 6.36 per cent, respectively. Miscellaneous organisms, 3.15 per cent, consisted of a few leeches, oligochaetes and nematodes and are unimportant.

One fact which this study has definitely shown is that stream or pool bottoms bare of plant beds are much less productive of available fish food than such places in which aquatic vegetation has developed. The average for plant beds (Table 7) is 7.88 grams per one square foot. The average for bare stream and pool bottoms is 1.05 grams and 0.21 grams (Table 2) respectively, using this year's figures. These findings substantiate last year's results in showing that: (1) plant beds are 37.5+ times as rich in food as bare pool bottoms; (2) 7.5+ times as rich as bare stream bottoms and (3) stream riffles are 5.0 times as rich as pools in available nutritive elements.

Effects of Spring Floods upon Aquatic Fish Foods.— On March 7, 1927, the writer ran the drift net in Sixmile creek just above the village of Slaterville for approximately fifteen minutes. The waters of the creek were a raging torrent due to the sudden melting of a heavy snowfall. This was done in an effort to ascertain the effects of high waters on the bottom organisms which furnish the major part of trout diet.

The results were most illuminating. Practically every kind of aquatic organism which had been collected from this stream during the previous summer was taken in the net. The great majority were dead or injured by the grinding action of the rocks and gravel which were being swept downstream by the force of the current. Many parts of insect larvae such as heads, legs, tails and abdomens offered simple evidence of the destructive action of high waters. Many aquatics such as the blackfly larvae (Simulium) which are never taken in the drift under normal circumstances and which normally live in fixed positions on rocks in swift water, were collected, bruised and battered as they were carried downstream. In brief this carries back to the problem of reforestation which means flood control and in the end, natural and undisturbed propagation of aquatic insect larvae upon which, as has been shown above, trout are dependent for the major part of their diet.

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. B. = 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 of the Erie-Niagara Watershed

Stream and Tributary Number	Map	Mileage available for stocking	Stocking policy per mile
Niagara river	1A, 2A	Above falls, polluted or natural spawning adequate	None at present (see p. 28).
		Below falls, 14 miles	Pp.
Niag. 1 (Ont. East) — Gill Niag. 1 and tribs	1A, 2A	Polluted, dry or warm	None.
Cayuga cr	1A	Lower, 3 miles	(Sm. B., Y. P.) natural spawning adequate
		Remainder, small and warm	None.
C. N. 1–C. N. 3 and trib	1A	Dry	None.
Tonawanda cr	1A, 1B, 2A, 2B, 3B	Lower 12 miles (Barge canal)	Sm. B., Pp., Bg. S.
		From trib. 7 to Attica, 60 miles	Sm. B., Bg. S.
		Upper 6 miles	450 B. T.+, 200 R. T.+
		Remainder, small or warm	None.
1 (Ellicott cr.)	1A, 2A, 2B	Mouth up, 5 miles	Lm. B., Bg. S., Bh. C.
		Trib. 8 to Williamsville, 2.5 miles	500 B. T.+
		Remainder, small and warm	None.
1–7 and tribs	1A, 2A	Dry, small or warm	None.
8	2A	2 miles	140 B. T.+
Pond	2A	2 acres, deficient in C^2	None.
9	2A	1 mile	100 B. T.+
10	2A	0.5 mile	100 B. T.+
11–29 and tribs	2A, 2B	Dry, small or warm	None.
2	1A	Small	None.
3 (Bull cr.)	1A	Lower, 2 miles	(Lm. B., Bg. S., Bh. C.), natural spawning adequate
		Remainder, small	None.
1–4	1A	Small	None.
4–5 and tribs	1A	Dry	None.
6 (Ransom cr.)	1A, 2A	Upper, 6 miles	300 B. T.+
		Remainder, warm	None.
1–3 and tribs	1A	Dry or small	None.
4 (Got cr.)	1A, 2A	Upper, 4 miles	250 B. T.+
1–2	1A, 2A	Small	None.
5–7	1A, 2A	Dry or small	None.
Barge canal	1A	Pendleton to Lockport, drained	None.

Appendix III—Continued

STOCKING LIST OF THE ERIE-NIAGARA WATERSHED

Stream and Tributary Number	Map	Mileage available for stocking	Stocking policy per mile
Niagara river — (*Cont'd*)			
Tonawanda creek — (*Cont'd*)			
7–10 and tribs	1A, 2A	Dry or small	None.
11 (Ledge cr.)	1A, 1B	4 miles	700 B. T.+
1 (Murder cr.) and tribs	1A, 1B, 2B	Dry, small or warm	None.
Pond at Griswold	2B	Posted	None.
Reservoir on No. 13	2B	35 acres	Lm. B., Pp., Bg. S., Co. B.
2 (Quarry spring run)	1B	0.5 mile	None (see p. 30)
3	1B	Dry	None.
12–20 and tribs	1A, 1B	Dry or small	None.
Dead lake	1B	2 acres	Lm. B., Bg. S.
21–31 and tribs	1B, 2B	Dry, warm or small	None.
32 (Little Tonawanda cr.)	2B	Linden up, 4 miles	600 B. T.+, 100 R. T.+
		Remainder, warm	None.
1–7 and tribs	2B	Dry or small	None.
8	2B	Lower, 1.5 miles	600 B. T.+
		Remainder, dry	None.
1–3	2B	Dry	None.
9–14 and tribs	2B	Dry or small	None.
33–38	2B	Dry or small	None.
39	2B	Lower, 0.5 mile	350 S. T.+
		Remainder, warm	None.
1–5 and tribs	2B	Dry or small	None.
Stevens reservoir	2B	1.5 acres	Sm. B., Co. B., Bg. S., Y. P.
40–45 and tribs	2B	Dry or small	None.
46 (Crow cr.)	2B	Upper, 3 miles	450 B. T.+ or 200 S. T.+
		Remainder, warm	None.
Old Attica reservoir	2B	4 acres	Sm. B., Co. B.
New Attica reservoir	2B	8 acres	1,500 R. T.+
1–4 and tribs	2B	Dry, small or warm	None.
5	2B	1 mile	180 B. T.+
6–7	2B	Dry	None.
47–76 and tribs	2B, 3B	Dry, warm or small	None.
77 (East Fork)	3B	Upper, 2 miles	700 B. T.+
		Remainder, warm	None.
1	3B	Upper, 1 mile	300 B. T.+
		Remainder, warm	None.
1–2	3B	Warm or small	None.
3	3B	1 mile	300 B. T.+
2 (Engine cr.)	3B	1 mile	190 B. T.+
1	3B	Small	None.
3	3B	0.5 mile	190 B. T.+
1	3B	Small	None.
4	3B	Small	None.
78 (Perry br.)	3B	2 miles	300 B. T.+
1	3B	1 mile	125 B. T.+
79	3B	1.5 miles	350 B. T.+
1	3B	0.5 mile	50 B. T.+
80	3B	Small	None.

Appendix III—Continued

STOCKING LIST OF THE ERIE-NIAGARA WATERSHED

Stream and Tributary Number	Map	Mileage available for stocking	Stocking policy per mile
Niagara river—(*Concl'd*)			
Tonawanda Niagara 1—Scajaquada cr. and tribs	1A, 2A, 3B	Polluted or small	None.
Erie 1 (Buffalo cr.)	2A, 3B	Trib. 6 to 30, 25 miles.	Sm. B.
		68 to source, 5 miles	216 B. T.+, 100 R. T.+
		Remainder, polluted, warm or small	None.
1–3 and pond	2A	Polluted	None.
4 (Cazenovia cr.)	2A, 3B	Trib. 1 to 14, 13 miles.	Sm. B.
		Remainder, polluted	None.
1–6 and tribs	2A	Dry or small	None.
7 (Spring br.)	2A	0.7 mile	360 S. T.+
1	2A	Small	None.
8–13 and tribs	2A	Dry or small	None.
14 (East Branch)	2A, 3B	From E. Aurora dam, 3 miles	Sm. B., Co. B.
		Holland to source (Protection cr.), 6 miles	300 B. T.+, 200 R. T.+
		Remainder, small or warm	None.
1–23 and tribs	2A, 3B	Dry or small	None.
24	3B	1.5 miles	75 B. T.+
1	3B	Small	None.
25	3B	Small	None.
26	3B	Mouth to trib. 3, 1.5 miles	125 B. T.+
		Remainder, warm	None.
1–2	3B	Dry	None.
3	3B	0.8 mile	180 B. T.+
4–5 and trib	3B	Dry or small	None.
27–29	3B	Dry	None.
Ponds	3B	Posted	None.
30	3B	1.5 miles	275 B. T.+
31	3B	Small	None.
15 (West Branch) and tribs	2A, 3B	Dry, small or warm	None.
5	2A	Small	None.
6 (Cayuga cr.)	2A, 2B, 3B	Between No. 40 to 50, 3.5 miles	200 B. T.+, 100 R. T.+
		Remainder, small, warm or polluted	None.
1–6 and tribs	2A	Dry or small	None.
Como lake	2A	8 acres	Co. B., Bg. S.
7–52 and tribs	2A, 2B, 3B	Dry, small or warm	None.
7–15 and tribs	2A	Dry or small	None.
Railroad pond	2A	2 acres	Lm. B., Bg. S., Co. B.
Sinking pond	2A	Small	None.

Appendix III—Continued

STOCKING LIST OF THE ERIE-NIAGARA WATERSHED

Stream and Tributary Number	Map	Mileage available for stocking	Stocking policy per mile
Erie 1 (Buffalo cr.)—*(Cont'd)*			
16–20 and trib	2A	Dry, small or warm	None.
21	2A	1.5 miles	270 S. T.+
1	2A	Small	None.
22 (Belowe br.)	2A	1.5 miles	200 B. T.+
1	2A	0.5 mile	100 B. T.+
2	2A	Dry	None.
23 (Ells br.)	2A	0.8 mile	270 S. T.+
24–29 and tribs	2A	Dry or small	None.
30 (Hunter cr.)	2A, 3B	Trib. 6 to source, 3 miles	200 B. T.+
		Remainder, warm	None.
1–12 and tribs	2A, 3B	Dry or small	None.
31–44 and tribs	2A, 2B, 3B	Dry or small	None.
45 (Glade cr.)	3B	Lower, 3 miles	100 R. T.+
		Remainder, small	None.
1–3 and trib	3B	Small	None.
46–54 and tribs	3B	Dry or small	None.
55 (Beaver Meadow cr.)	3B	Below falls, 1 mile	1,200 B. T.+
		Above falls, 5 miles	700 S. T.+
1	3B	Warm	None.
2	3B	1.5 miles	450 S. T.+
56–57	3B	Dry or small	None.
58	3B	4 miles	500 B. T.+
1	3B	1.5 miles	75 B. T.+
2	3B	2 miles	250 S. T.+
1	3B	0.5 mile	180 S. T.+
2 (Fitzgerald br.)	3B	0.8 mile	190 S. T.+
3	3B	Small	None.
3–5	3B	Warm or small	None.
59 (Plato cr.)	3B	Warm	None.
1 and tribs	3B	Small	None.
2	3B	1.5 miles	126 S. T.+
3–4	3B	Small	None.
60–68 and tribs	3B	Small	None.
69	3B	1 mile	300 S. T.+
1	3B	Warm	None.
2	3B	2 miles	125 S. T.+
3	3B	Small	None.
70	3B	Small	None.
Erie 2 (Smoke cr.)	2A, 3B	Polluted or warm	None.
1 (South Branch)	2A, 3B	From trib. 2 to 4, 3 miles	300 B. T.+, 100 R. T.+
		Remainder, warm	None.
1–5 and tribs	2A	Dry, small or warm	None.
2 and tribs	2A, 3B	Small	None.
East Freeman pond	2A	Small	None.
West Freeman pond	2A	1 acre	Bg. S., Bh. C.
3–8 and tribs	2A, 3B	Small	None.
Erie 3 (Rush cr.) — Erie 12 and tribs	2A, 3A	Polluted, dry or small	None.

Appendix III—Continued

Stocking List of the Erie-Niagara Watershed

Stream and Tributary Number	Map	Mileage available for stocking	Stocking policy per mile
Erie 13 (Eighteenmile cr.)	3A, 3B	Mouth to trib. 4, 5 miles	(Sm. B.) natural spawning adequate.
		Hamburg dam up, 1 mile	Sm. B.
		Boston to source, 7 miles	400 B. T.+, 100 R. T.+
		Remainder, small and warm	None.
1–3 and tribs	3A	Dry or small	None.
4 (South Branch)	3A	Trib. 5 to New Oregon, 8 miles	100 R. T.+
		New Oregon to source, 4 miles	720 B. T.+
		Remainder, warm	None.
1–26 and tribs	3A, 3B	Dry, small or warm	None.
27	3A	1 mile	100 B. T.+
1–2	3A	Small	None.
28	3A	Dry	None.
29	3A, 3B	1.5 miles	100 S. T.+
1	3A, 3B	Dry	None.
30–35 and tribs	3A	Small	None.
5–60 and tribs	3A, 3B	Dry, warm or small	None.
61	3B	1 mile	180 B. T.+
62	3B	Dry	None.
63	3B	0.5 mile	180 B. T.+
64–65 and trib	3B	Dry or posted	None.
Erie 14–Erie 19 and tribs	3A	Dry, small or warm	None.
Erie 20 (Sister cr.)	3A	Upper, 3 miles	450 B. T.+, 200 R. T.+
		Remainder, warm	None.
1–11	3A	Dry or small	None.
12	3A	0.5 mile	150 B. T.+
13–21 and tribs	3A	Dry, small or warm	None.
Erie 21 (Delaware cr.)	3A	Lower, 6 miles	300 R. T.+
		Remainder, small	None.
1–4	3A	Dry or small	None.
Erie 22 (Muddy cr.)	3A	Lower, 1 mile	(Bh. C.) natural spawning adequate.
		Remainder, small	None.
1–3 and tribs	3A	Dry or small	None.
Erie 23 (Cattaraugus cr.)	3A, 3B, 4B, 4C	Lower 17 miles, polluted	None.
		Gowanda to trib. 48, 34 miles	Sm. B.
		Trib. 48 to 58, warm	None.
		Trib. 58 to 70, 8.5 miles	1,500 B. T.+
		Trib. 70 to source, 2.5 miles	360 R. T.+

Appendix III—Continued

STOCKING LIST OF THE ERIE-NIAGARA WATERSHED

Stream and Tributary Number	Map	Mileage available for stocking	Stocking policy per mile
Erie 23 (Cattaraugus cr.)—(*Continued*)			
1–5 and tribs	3A, 4B	Small or warm	None.
6 (Clear cr.)	3A, 4B	Trib. 8 down, 3 miles	200 R. T.+
		Remainder, warm	None.
1–3 and tribs	3A, 4B	Dry or small	None.
4 (North Branch)	3A, 4B	Lower, 2 miles	200 R. T.+
		Remainder, warm	None.
1–13 and tribs	3A, 4B	Dry, warm or small	None.
State Hospital Reservoir	3A	56 acres	Sm. B.
7–9, 11–18 and tribs	3A, 4B	Dry, small or warm	None.
10	3A	1 mile (on Federal land)	None (S. T.+)
19 (Point Peter br.)	4B	3 miles	315 S. T.+
1	4B	Small	None.
20 (South Branch)	4B, 4C	Lower, 14 miles	Sm. B.
		Trib. 11 to 15, small and warm	None.
		Trib. 15 to source, 3.5 miles	540 B. T.+
1–6	4B	Small	None.
7	4B	Lower 1 mile, polluted	None.
		Upper 3 miles	500 B. T.+
1–3	4B	Dry or small	None.
8–10	4B	Small	None.
Otto pond	4B	2 acres	Sm. B.
11 (Mansfield cr.)	4B, 4C	Lower 2 miles	1,600 B. T.+
		Upper 5.5 miles	540 S. T.+
1	4B	2 miles	350 B. T.+
1	4B	0.5 mile	100 B. T.+
2 (Jersey Hollow br.)	4B	Middle, 1 mile	252 B. T.+
		Remainder, warm or dry	None.
1–2	4B	Small	None.
3 (Eddyville cr.)	4B	Upper 2 miles	172 S. T.+
		Remainder, warm	None.
1 (Five Points br.)	4B	1 mile	200 S. T.+
2	4B	1 mile	150 S. T.+
4	4B, 4C	1 mile	700 S. T.+
5	4B	Small	None.
6	4B	0.5 mile	100 S. T.+
7	4C	0.5 mile	300 S. T.+
1	4C	0.3 mile	300 S. T.+
8 and tribs	4B, 4C	Dry, warm or small	None.
9 (Goodell cr.)	4C	3 miles	400 B. T.+
1 (Stony Pitcher br.)	4C	1 mile	400 B. T.+
1	4C	0.3 mile	300 B. T.+
2	4C	0.5 mile	350 B. T.+
10	4C	1 mile	350 S. T.+
11	4C	Small	None.
12–15 and tribs	4B, 4C	Dry, warm or small	None.
16	4C	1.3 miles	180 B. T.+
1	4C	Small	None.

Appendix III—Continued

Stocking List of the Erie-Niagara Watershed

Stream and Tributary Number	Map	Mileage available for stocking	Stocking policy per mile
Erie 23 (Cattaraugus cr.)—*(Continued)*			
21 (Waterman br.) to 26 and tribs	3A, 4B	Dry, warm or small	None (see text).
27 (Connoisarauley cr.)	4B, 4C	Upper, 3 miles	315 B. T.+
		Remainder, warm	None.
1	4C	Small	None.
2	4C	2 miles	360 B. T.+
1	4C	0.5 mile	270 B. T.+
3–6	4C	Small	None.
28 (Derby br.)	3A, 3B, 4B	4 miles	810 S. T.+
1	4B, 4C	Small	None.
2	3A, 4B	0.8 mile	36 S. T.+
3 (Morton Corners br.)	3A, 4B	1.5 miles	72 S. T.+
1	3A, 4B	0.8 mile	72 S. T.+
1	3A	Small	None.
2–3	3A	Small	None.
4	3A	0.8 mile	450 S. T.+
29	3B, 4C	Small	None.
30 (Spooner cr.)	3A, 3B, 4C	Warm	None at present (see text).
1–7	3B, 4C	Dry or small	None.
31 and trib	4C	Small	None.
32 (Spring br.)	3B, 4C	Upper, 3 miles	441 S. T.+
		Remainder, polluted	None.
1	3B	Polluted	None.
Wyatts pond	3B	Posted	None.
Springville water supply pond	3B	Posted	None.
2 and trib	3B	Posted	None.
3	3B	Small	None.
East Concord pond	3B	5 acres	Lm. B., Bg. S., Co. B., Bh. C.
33 (Buttermilk cr.)	4C	Upper, 3 miles	315 B. T.+
		Remainder, warm	None.
1–6 and tribs	4C	Dry, small or warm	None.
7	4C	2 miles	126 B. T.+
1	4C	Small	None.
34 (Stony br.)	4C	Small	None.
Spring run	3B, 4C	Precipitous	None
Ponds on stream	3B	Posted	None
Spring run	3B, 4C	Small	None.
35–47 and tribs	3B, 4C	Small	None.
48 (Elton cr.)	3B, 4C	From trib. 3 to 6, 5 miles	500 R. T.+
		From trib. 15 up, 2 miles	300 B. T.+
		Remainder, warm	None.
1 (Stony cr.)	3B, 4C	3 miles	360 S. T.+
1–3	4C	Small	None.
2 and tribs	3B, 4C	Small or warm	None.

Appendix III—Continued

STOCKING LIST OF THE ERIE-NIAGARA WATERSHED

Stream and Tributary Number	Map	Mileage available for stocking	Stocking policy per mile
Erie 23 (Cattaraugus cr.)—(*Continued*)			
48 (Elton cr.)—(*Concluded*)			
3 (Lime lake outlet or Delevan cr.)	4C	4 miles	1,800 B. T.+
1	4C	1 mile	270 B. T.+
1	4C	Small	None.
2 (McKinstry cr.)	4C	4 miles	378 S. T.+
Spring run	4C	Small	None.
1	4C	1.5 miles	180 S. T.+
1	4C	0.3 mile	450 S. T.+
2-4	4C	Warm	None.
3	4C	1 mile	180 B. T.+
Spring run	4C	0.3 mile	234 B. T.+
Sucker pond and Frog pond	4C	Posted	None.
Lime lake	4C	256 acres	Lm. B., Bh. C., Co. B., Bg. S.
4-9 and tribs	4C	Dry, small or warm	None.
Beaver lake	4C	15 acres	Lm. B., Bh. C., Co. B., Bg. S.
10-12 and tribs	4C	Dry, small or warm	None.
Mud lake	4C	Posted	None.
13-18 and tribs	4C	Dry or small	None.
49 and tribs	4C	Dry	None.
50 (Sardinia cr. or Hosmer br.)	3B	4.5 miles	1,000 B. T.+, 100 R. T.+
1	3B	0.5 mile	300 S. T.+
2-3 and trib	3B	Dry or warm	None.
51-55 and tribs	3B	Dry, small or warm	None.
56 (Clear cr.)	3B, 4C	11 miles	450 B. T.+, 50 R. T.+
1-8 and tribs	3B, 4C	Dry or small	None.
9	3B, 4C	3 miles	440 S. T.+
Spring run	3B	Small	None.
1	3B	1.8 miles	190 S. T.+
2-3	3B	Dry or small	None.
10 and Hurlberts pond	4C	Small	None.
11 (Skim lake outlet or Hayden br.)	4C	1.3 miles	504 S. T.+
1	4C	0.3 mile	200 S. T.+
Skim lake	4C	15 acres	2,500 S. T. (exp. plant).
12-13 and Burleson pond	4C	Dry	None.
14 (Crystal lake outlet)	4C	0.5 mile	450 S. T.+
Moores pond	4C	2 acres	400 S. T.+
Crystal lake	4C	40 acres	Lm. B., Bh. C., Co. B., Bg. S.
15-16 and tribs	3B, 4C	Dry	None.
South Wilson pond	3B	1 acre	Bh. C., Co. B., Bg. S.
North Wilson pond	3B	4 acres	Lm. B., Bh. C., Co. B., Bg. S.

Appendix III—Continued

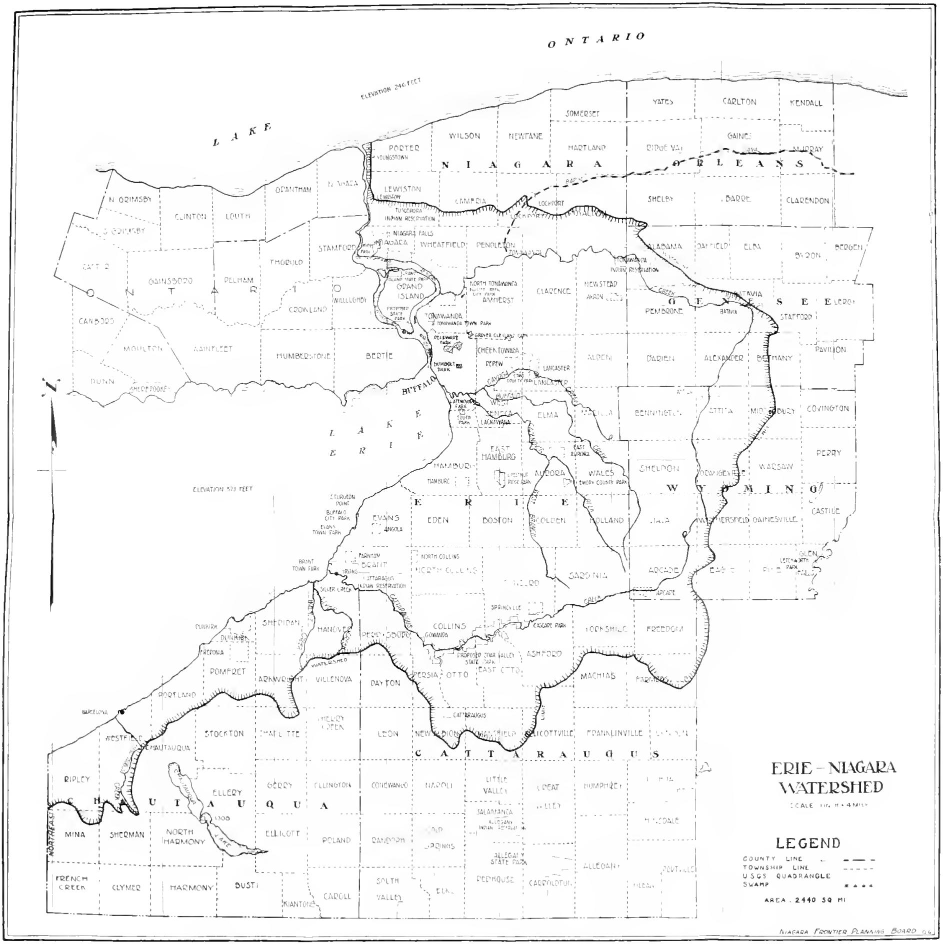
Stocking List of the Erie-Niagara Watershed

Stream and Tributary Number	Map	Mileage available for stocking	Stocking policy per mile
Erie 23 (Cattaraugus cr.) — (*Concluded*)			
57–59	3B	Dry	None.
60 (Monkey run)	3B	Upper, 2 miles	360 B. T.+
		Remainder, warm	None.
1–5 and tribs	3B	Dry, small or warm	None.
61	3B	1 mile	90 B. T.+
62–64	3B	Dry or warm	None.
65	3B	2 miles	200 B. T.+
Fishermans pond	3B	2 acres, stocking not desired	None (B. T.+)
66	3B	Dry	None.
67 (Spring or Flynn br.)	3B	5 miles	440 B. T.+
1	3B	0.5 mile	90 B. T.+
2	3B	1.5 miles	126 B. T.+
1	3B	0.5 mile	180 B. T.
3–5	3B	Small or warm	None.
6	3B	0.3 mile	65 B. T.+
Spring run	3B	Small	None.
68 (Tyler br.)	3B	2 miles	72 B. T.+
1	3B	Small	None.
69 (Witherill br.)	3B	2 miles	360 B. T.+
1	3B	0.5 mile	63 B. T.+
2	3B	0.5 mile	90 B. T.+
Spring run	3B	0.5 mile	90 B. T.+
70	3B	Warm	None.
Java lake	3B	123 acres	Pp., Lm. B., Co. B., Bh. C.
1 and trib	3B	Dry	None.
71–72	3B	Dry or small	None.
Erie 24 and trib	3A	Small	None.
Erie 25 (Silver cr.)	3A, 4B	Warm	None.
1 (Walnut cr.), 2–6 and tribs	3A, 4B	Dry, warm or small	None.
Smith Mills pond	3A	10 acres	Lm. B., Bh. C., Bg. S.
7–9 and tribs	3A, 4B	Dry, warm or small	None.
Silver cr. reservoir	4B	70 acres	5,000 R. T.+
Erie 26 — Erie 36 and tribs	3A, 4A, 4B	Dry, warm or small	None.
Pond on Crooked br	4A	1 acre	Bh. C., Bg. S.
Erie 37 (Canadaway cr.)	4A, 4B	1 mile between No. 14 and No. 17	400 B. T.+
		Remainder, warm or polluted	None.
1–6 and tribs	4A	Small	None.
7 (South Branch)	4A	1.5 miles above reservoir	300 R. T.+
		Remainder, warm	None.
Fredonia reservoir	4A	30 acres	3,000 R. T.+
8–22	4A, 4B	Dry, warm or small	None.
Erie 38 — Erie 67 and tribs	4A, 4B	Dry, warm or small	None.
Erie 68 (Chautauqua cr.)	4A, 5	Lower 4 miles, warm	None.
		Upper 12 miles	200 B. T.+, 200 R. T.+

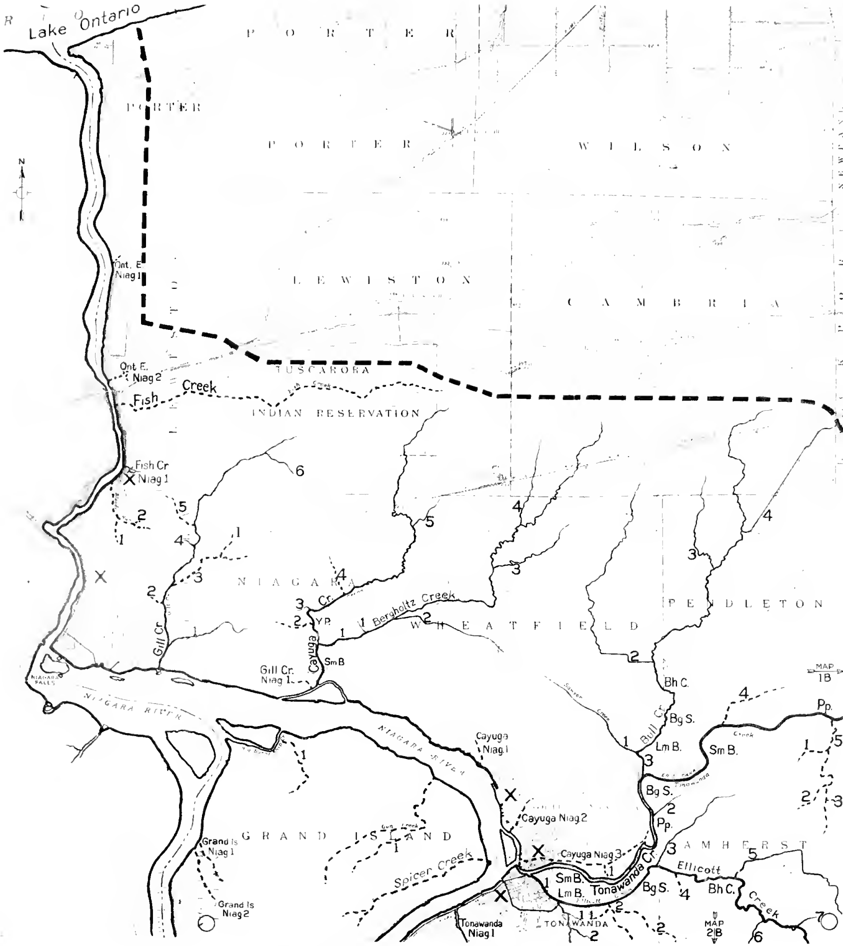
Appendix III—Concluded

STOCKING LIST OF THE ERIE-NIAGARA WATERSHED

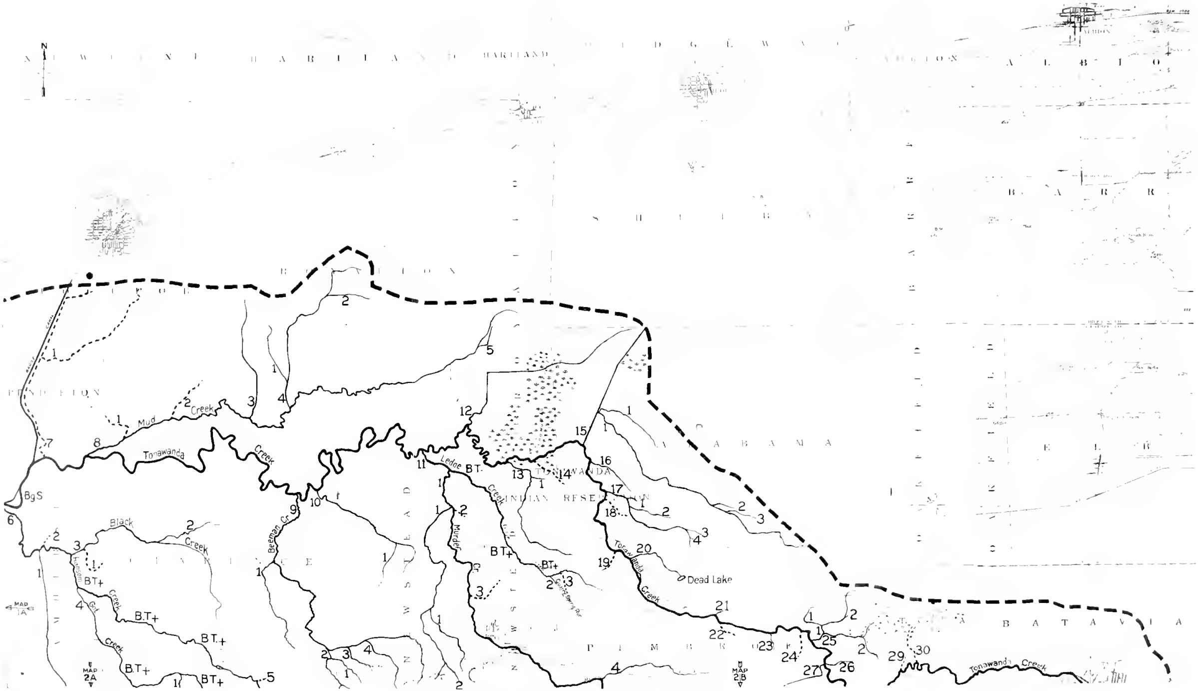
Stream and Tributary Number	Map	Mileage available for stocking	Stocking policy per mile
Erie 68 (Chautauqua cr) — *Concluded)*			
1 (Little Chautauqua) and tribs	4A	Small or warm	None.
2	4A	1.5 miles	300 B. T.+
1–2	4A	Small	None.
3–4	4A	Small	None.
Pond	4A	0.3 acre	Private, none (Bg. S.).
5	4A	Small	None.
6 (The Bly)	4A	0.5 mile	100 B. T.+
7	4A	1 mile	100 B. T.+
1 and trib	4A	Small	None.
2	4A	Warm	None.
8 and trib	4A	Small	None.
9	5	0.75 mile	125 B. T.+
Spring run between 9 and 10	5	0.8 mile	75 B. T.+
10	5	0.5 mile	360 B. T.+
1	5	Small	None.
11–15 and tribs	5	Dry or small	None.
16	5	2.5 miles	500 B. T.+
1	5	Small	None.
17	5	Small	None.
18	5	2.5 miles	500 B. T.+
1–4 and tribs	5	Dry or small	None.
19 (Clark's br.)	5	0.5 mile	400 S. T.+
20	5	1.5 miles	315 B. T.+
1	5	Small	None.
2	5	0.4 mile	180 B. T.+
3	5	Small	None.
21	5	1.5 miles	500 B. T.+
1 and trib	5	Dry	None.
Erie 69 — Erie 74 and tribs	5	Dry or small	None.
Erie 75 (Bell cr.) and trib	5	Small	None.
2	5	0.25 mile	450 B. T.+
3–7	5	Small	None.
Erie 76 — Erie 95	5	Dry or small	None.
Erie 96 (Twentymile cr.)	5	Lower 3.5 miles in Pa.	None.
		Pa. line to No. 21, small	None.
		No. 21 to source, 3 miles	200 B. T.+, 200 R. T.+
1–20 and tribs	5	Dry or small	None.
21	5	1.5 miles	400 B. T.+
1	5	1 mile	190 B. T.+
1–3	5	Small	None.
2	5	1 mile	125 B. T.+
1	5	0.5 mile	315 B. T.+
3–5	5	Small	None.
22–26	5	Small	None.
27	5	0.5 mile	250 B. T.+
Erie 97 and trib	5	Dry	None.



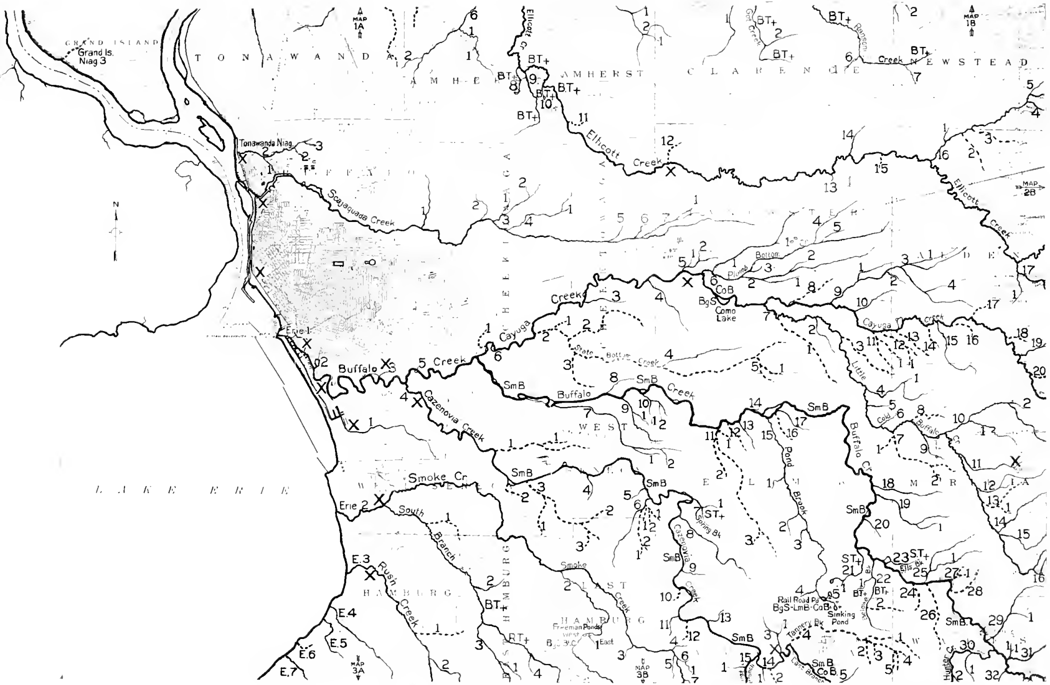
Key map of Erie-Niagara watershed showing the principal tributary streams, cities, towns, townships and park areas. Outlines in red indicate the boundaries of the U. S. G. S. quadrangle.



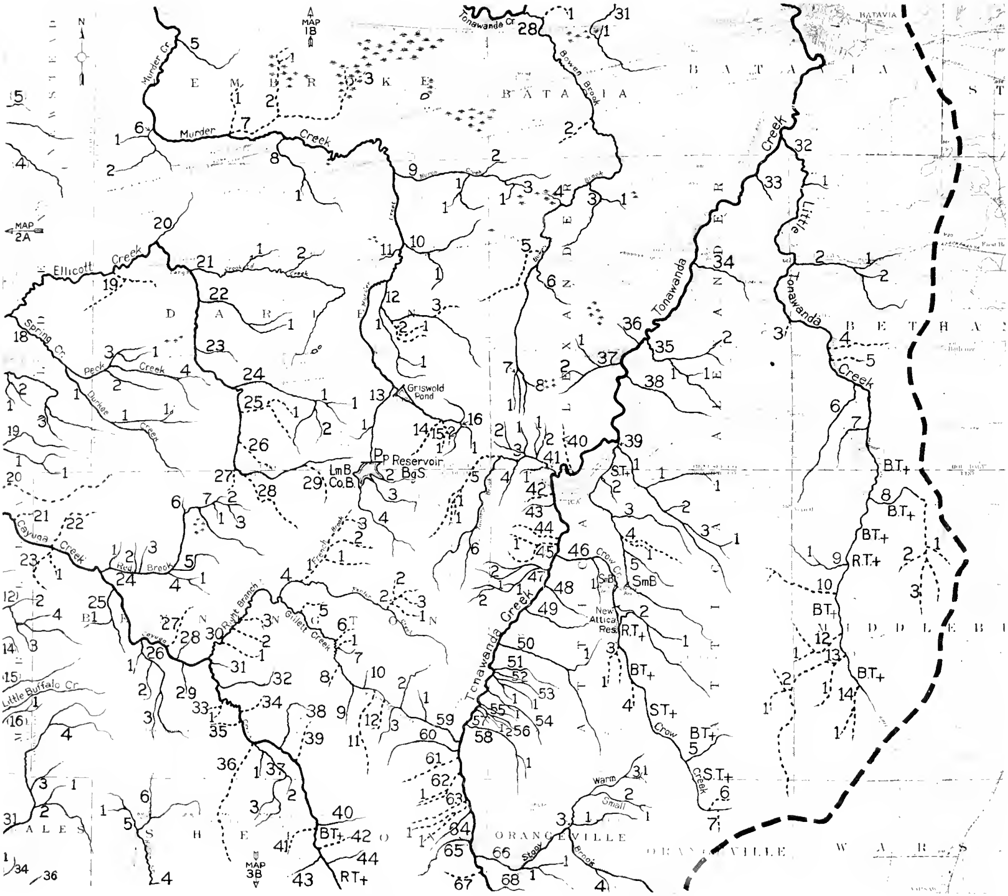
Map 1A.—Niagara Falls and Tonawanda quadrangles



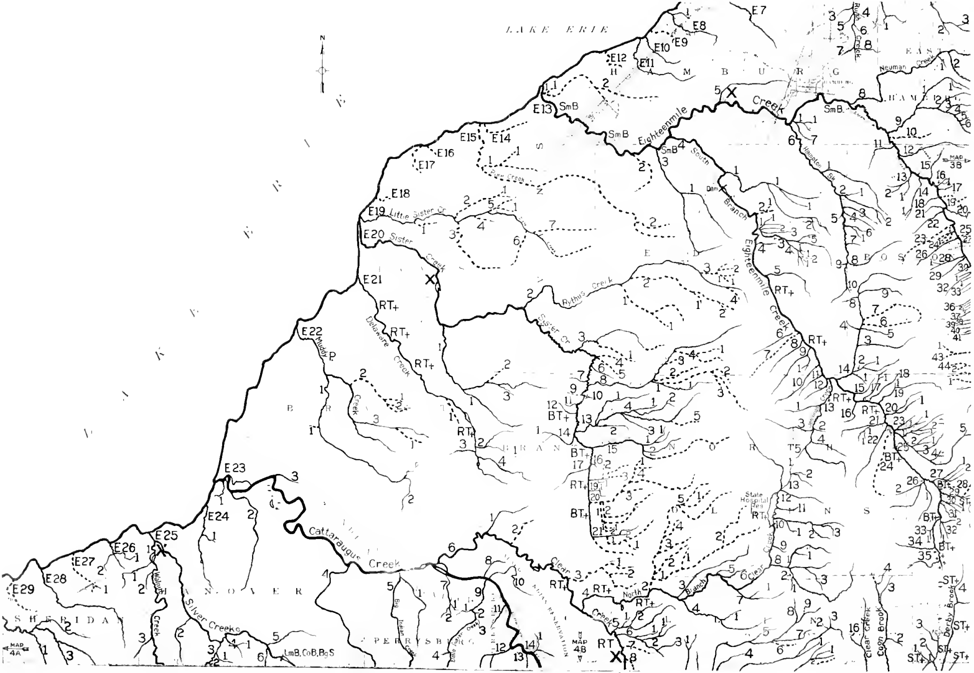
Map 1B. Lockport, Medina and Albion quadrangles



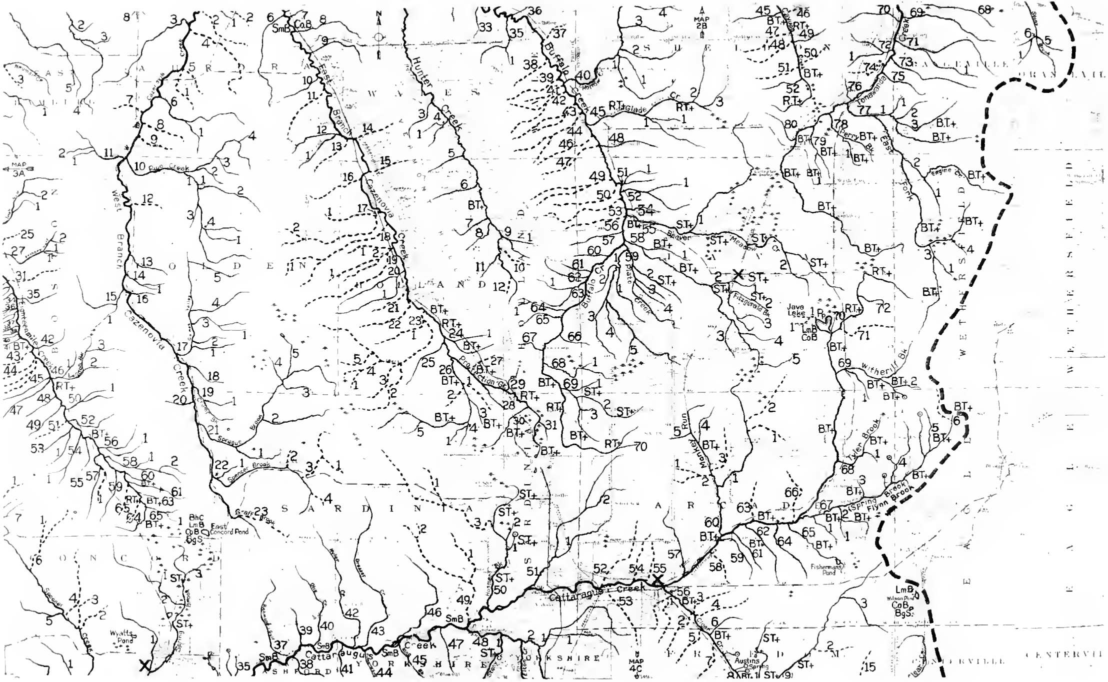
Map 2A.—Buffalo and Depew quadrangles



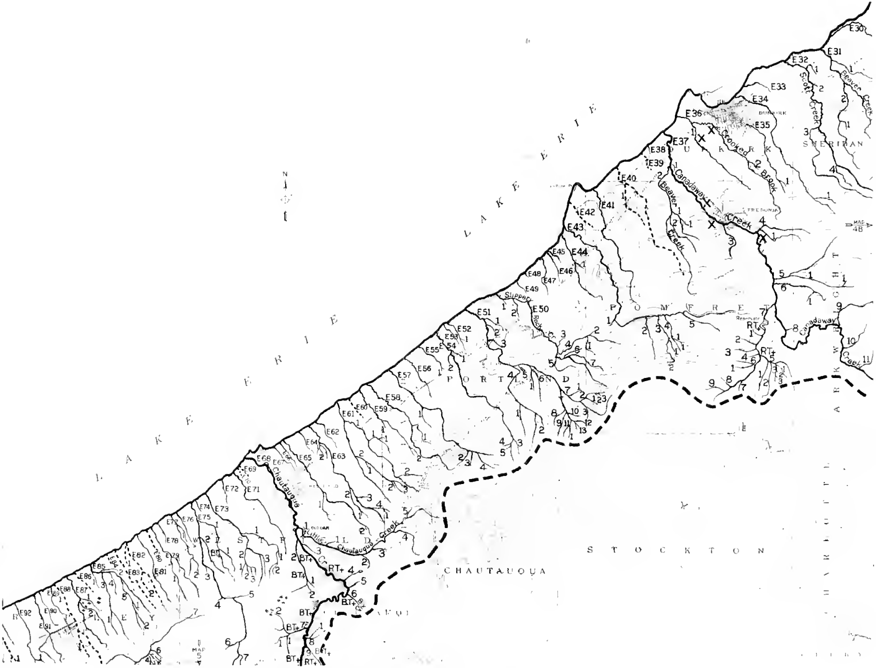
Map 2B.—Attica and Batavia quadrangles



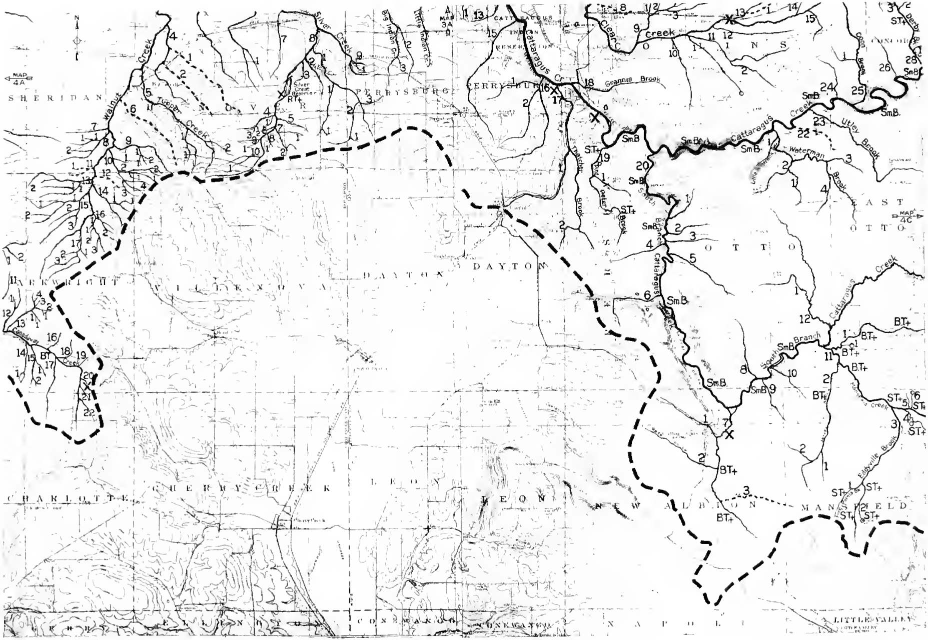
Map 3A.—Silver Creek and Eden quadrangles



Map 3B.–Springville, Arcade and Portage quadrangles

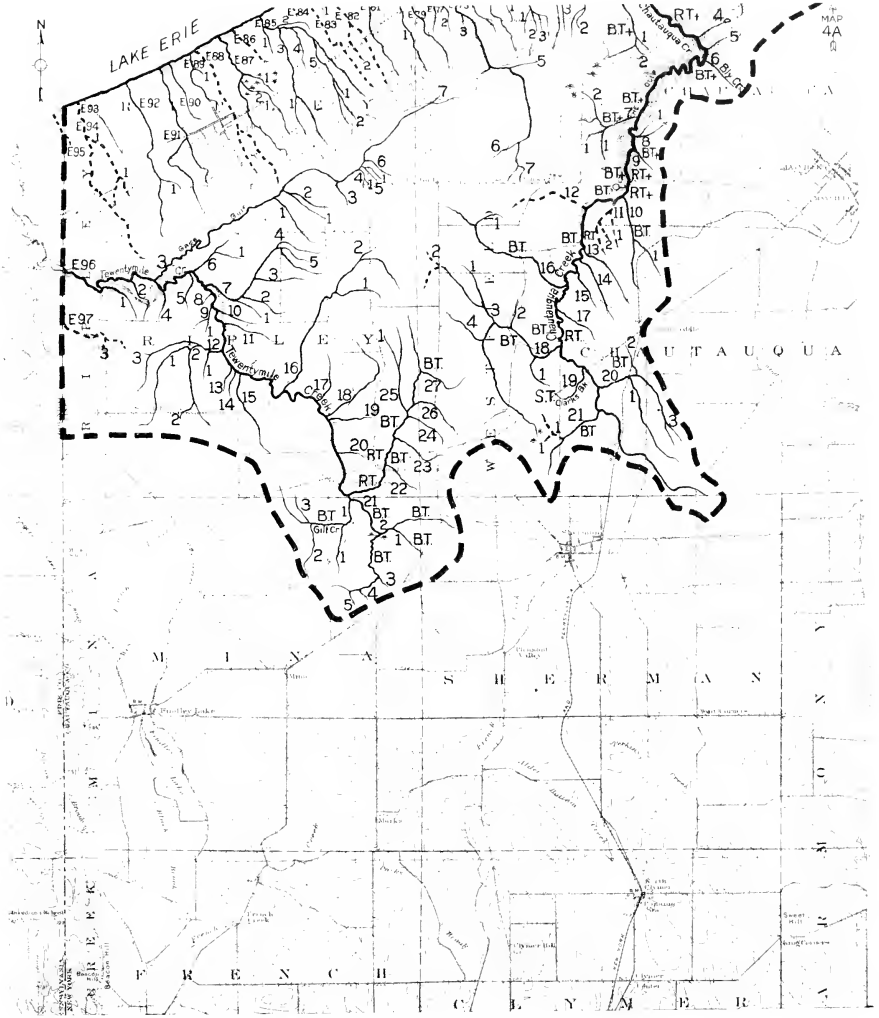


Map 4A.—Westfield and Dunkirk quadrangles



Map 1B Cherry Creek and Cattaraugus quadrangles

Map 4C. Ellicottville and Franklinville quadrangles



Map 5.—North East and Clymer quadrangles

CONSERVATION DEPARTMENT SURVEYS AND STUDIES (BIOLOGICAL)

Reprints and Supplementary Reports

1916: Fish Planting in Public Waters, by Tarleton H. Bean.
1917: Working Plans for Increasing Fish Production in the Streams of Oneida County, by Wilbert A. Clemens. (Out of print.)
1919: Stream Pollution in New York State, by Henry B. Ward.
1921: Limitations of Black Bass Culture, by J. W. Titcomb.
1922: Report Upon a Study of the Fish Producing Waters of Tompkins County, N. Y., by G. C. Embody.
1922: A Biological Survey of Lake George, N. Y., by Jas. G. Needham, Chancey Juday, Emmeline Moore, Chas. K. Sibley and John W. Titcomb. (Out of print.)
1922: Stream Pollution Studies, by Russell Suter and Emmeline Moore, and Studies in Oyster Culture, by Wm. Firth Wells.
1922: Problems in Oyster Culture, by Wm. Firth Wells, Diseases of Fish in State Hatcheries, by Emmeline Moore. In: Report of Bureau of Prevention of Stream Pollution.
1923: Report on Investigation of the Pollution of Streams, by Russell Suter.
1923: Results of Shellfish Investigations, by Wm. Firth Wells; Diseases of Fish in State Waters, by Emmeline Moore. In: Report of Bureau of Prevention of Stream Pollution.
1924: Fish Diseases, by Emmeline Moore.
1924: Oyster Investigations, by Wm. Firth Wells.
1925: Problems in Fresh Water Fisheries, by Emmeline Moore.
1925: A New Chapter in Shellfish Culture, by Wm. Firth Wells.
1925: Proper Methods of Fish Planting, by Sumner N. Cowden.
1926: Biological Survey of the Genesee River System.
1927: Biological Survey of the Oswego River System.
1928: Biological Survey of the Erie-Niagara System.