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A FISHERY SURVEY OF IMPORTANT CONNECTICUT LAKES

By

State Board of Fisheries and Game
Lake and Pond Survey Unit

Bulletin No. 63

HARTFORD
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STATE GEOLOGICAL AND NATURAL HISTORY SURVEY

EDWARD L. TROXELL, Ph.D., Superintendent

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STATE BOARD OF FISHERIES AND GAME
LAKE AND POND SURVEY UNIT

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STATE OF CONNECTICUT

December 31, 1939

State Board of Fisheries and Game
State Office Building
Hartford, Connecticut

Gentlemen:

We have the honor to transmit herewith a report on "A Fishery Survey of Important Connecticut Lakes" which is the first of a series of studies inaugurated for the purpose of determining how to improve fishing in the impounded waters of the state.

The report was designed primarily to acquaint sportsmen with the problems involved in the proper management of lakes because it becomes increasingly evident that the most effective measures can be successful only through the understanding, co-operation, and participation of fishermen.

One section has been devoted to a description of the life histories and habits of the species encountered. This can be used as a reference by anglers and students because it embodies a review of the pertinent and available literature to date, as well as information gathered during the course of the Survey. Photographs and keys have been included to aid readers in recognizing fishes.

A mass of technical information has been gathered and analyzed but is not included, since it has no interest to the sportsman. We have attempted to present the basic facts, together with their interpretation.

Respectfully submitted,

Lyle M. Thorpe

Aquatic Biologist in Charge
of Survey.

LMT/ES

TABLE OF CONTENTS

TABLE OF CONTENTS

Section III. The Life Histories of Some Connecticut Fishes

TABLE OF CONTENTS

TABLE OF CONTENTS

FIG. 1. Map of Connecticut showing location of waters covered by the Survey, 1937 - 1939.

A FISHERY SURVEY OF IMPORTANT CONNECTICUT LAKES

INTRODUCTION

LYLE M. THORPE, *Biologist in Charge of Survey*

Scope of Survey

This report presents the results of a fishery investigation of 47 Connecticut lakes and ponds, and includes data gathered over a period of three years (1937, 1938, and 1939). The greater part of the field work was carried on during the summer months of each year (June 15 - September 15), but determinations of some basic fertilizers and measurements of ice fishing were, of necessity, carried on during the winter months.

In 1937, purely preliminary work was done. The help of one temporary assistant biologist was secured for the purpose of gathering data which would reveal the character of the problems involved and indicate the equipment, organization, and procedures best adapted to Connecticut conditions. This initial study served its purpose and led to an organization which was designed to fit circumstances peculiar to Connecticut.

It was felt that a crew of six men was the minimum for efficiency of operation. However, financial limitations restricted the size of the 1938 crew to three men, two of whom were temporary employees. No funds were available for the purchase of essential equipment and practically all scientific equipment and materials used by the Survey in 1937 and 1938 were supplied by the University of Connecticut and Yale University without cost to the Department. Inadequate equipment and man power permitted work on relatively few lakes and necessitated rechecking several of these bodies of water in 1939. In 1939, necessary field equipment was purchased and a crew of seven men was placed in the field. This crew was composed of three specialists, one student assistant who worked without salary and three regular Department employees, two of whom were deputy wardens. These wardens were technically trained men and fully capable of assuming their share of the scientific work. It reflects credit on the Connecticut warden service to be able to supply men for such specialized work.

It will be noted from Fig. 1 that the waters surveyed during 1937, 1938, and 1939 are widely scattered throughout the

State. This was done deliberately to permit a satisfactory analysis of the state-wide pondfish problems. With this information at hand, it is planned to continue the survey by systematically covering all of the important lakes and ponds of the State by districts.

Organization and Personnel

The survey crew was divided into three units, each of which was responsible for a specific part of the work. Base camps were established in various sections of the State and selected lakes were covered within a radius of twenty-five miles of each base camp. Whenever possible, the entire crew gathered field data on a lake at the same time. Certain phases of chemistry, limnology, and parasitology require apparatus which cannot be carried conveniently in the field and, for this reason, the specialists in charge of these studies made frequent trips to laboratories at Yale University and Wesleyan University. The remainder of the work was done at the base camp.

The Survey crew was organized as follows:

Lyle M. Thorpe, Biologist in charge of Survey‡†*

Chemistry and limnology

Dr. Edward S. Deevey, Yale University, Unit Chief†*
James S. Bishop, Deputy Warden, Assistant*

Fish parasites and diseases

Dr. George W. Hunter, III, Wesleyan University, Unit Chief*
William Dimick, University of Maine, Assistant*

Fishery studies

Dwight A. Webster, Cornell University, Unit Chief‡†*
Douglas D. Moss, Deputy Warden, Assistant*

Purpose of Survey

It should not be necessary to remark on the purpose of a Fishery survey conducted by a state conservation agency, but one has to talk with only a few sportsmen to realize that a clear statement of purpose is entirely justified. Anglers are taking a greater interest in scientific investigations because of a realization that such work may hold the key to better fishing. Many fishermen are interested in learning how their sport may be improved, and they have been turning to scientific reports for this

‡—on 1937 survey
†—on 1938 survey
*—on 1939 survey

information. However, these reports are scattered and it is almost impossible for the lay reader to secure a continuity of presentations which give a clear understanding of the biology, chemistry, and physics of fishery conservation. The result is that many misconceptions have arisen as to the purpose served by a fishery survey.

The responsibility for these misconceptions rests almost entirely with those technicians who have failed to reduce their work to simplest terms, apparently for fear of criticism from others in their field. Biologists frequently bemoan the fact that their science, which is the fundamental knowledge on which sound con-

FIG. 2. Typical base camp of the Lake and Pond Survey.

servation must rest, is often disregarded in the administration of fish and game work. No science is appreciated and used until it is either generally understood or has conclusively demonstrated its practical value. Biology has been able to demonstrate its ability to provide better sport and in some instances to save money, but its practical application to almost every phase of conservation is not yet widely understood and appreciated.

Throughout its existence the purpose of the Connecticut Lake and Pond Survey has been to gather fundamental information on the physical, chemical, and biological conditions in each body of water and to secure knowledge of the life history and habits of each important species of fish. It has attempted to investigate the kind, extent, and probable effect of fish parasites, to measure the fishing load imposed by the present concentration of anglers, and to interpret this data in terms of recommendations for the improvement of fishing. There was unmistakable evidence that a survey would pay for itself many times over through the elimination of superfluous and unwise stocking and in the general improvement of fishing. For example, funds saved by eliminating rainbow trout plants in unsuitable waters would alone be sufficient to finance the survey to date.

FIG. 3. Survey equipment packed and ready to be moved to a new location.

Prior to the present survey, the only information by which the pondfish restoration program could be guided was the work directed by Dr. David L. Belding, now of Boston University. This work, begun in 1925 and carried on for a period of several years, was in the nature of a superficial reconnaisance since survey technique as well as personnel and equipment was limited. The work of Dr. Belding represents some of the earliest attempts to provide a biological, chemical, and physical background for fish restoration.

Reasons for Publication

This survey of some of the lakes and ponds of Connecticut has revealed that there are numerous ways by which fishing in each body of water may be improved. Stocking, posting, and patrol come within the province of the State Board of Fisheries and Game. If these activities were all that could be done to improve fishing, there would be little need for making a survey report public. However, there are other measures, equally important, which can best be carried out by local groups. It would be impracticable to publish all of the detailed information on each lake covered, but enough information can be summarized and presented to give a general idea of the program most likely to show results on each lake. It is hoped that this report will stimulate sportsmen's clubs and riparian property owners to take an active part in improving fishing conditions in their localities. An effort has been made in this report to present informative items of particular interest to sportsmen. The language used has purposely been kept as simple and as non-technical as possible in dealing with a rather complex subject. If this results in a more general understanding of the basic problems involved in the restoration of Connecticut's pond fishes, then the publication of this report is justified.

Acknowledgments

The Connecticut Lake and Pond Survey wishes to thank Yale University, Wesleyan University and the University of Connecticut for supplying equipment and laboratory space, and Cornell University for laboratory space and library facilities.

The Osborne Zoological Laboratory and the Bingham Oceanographic Laboratory of Yale University have been extremely generous in permitting use of specialized equipment and reagents. Several technicians of the Osborne Zoological Laboratory have assisted by making chemical analyses and the staff members in general have contributed many helpful suggestions. In this latter respect, we are particularly indebted to Dr. G. E. Hutchinson and to Dr. Gordon A. Riley.

Cornell University faculty members C. McC. Mottley, Associate Professor of Limnology and Fisheries; H. John Rayner of the Laboratory of Limnology and Fisheries; and Dr. Edward C. Raney, Instructor in Zoology, are thanked for critically reading parts of the manuscript. Miss Priscilla Copley, graduate student in limnology, has been extremely helpful in making stomach analyses and tabulating data.

Nearly all of the staff of the State Board of Fisheries and Game have given assistance during the progress of the field work and preparation of the manuscript. We are particularly indebted to Captain Frank N. Banning, to the staff of the Noank Lobster Hatchery for designing and repairing equipment, to the Connecticut Warden Service for supplying two technical assistants in 1939 and for considerable help in the field work, to Leslie A. Williamson for preparation of field maps from the Fairchild Aerial photographs, and to Miss Rose Sharfman for typing and clerical work.

It is regretted that space does not permit mentioning by name the many sportsmen who have contributed to our knowledge by submitting for examination scale samples and fish specimens which have been taken by angling. The help given by these sportsmen is gratefully acknowledged.

All illustrations are by members of the Survey staff unless otherwise indicated.

Section I.

Fishery Management

Lyle M. Thorpe, *Biologist in Charge of Survey*

PART I. MANAGEMENT METHODS AS APPLIED TO PONDFISH RESTORATION

Introduction

The word "management" has recently come into popular usage in connection with wildlife problems. Unfortunately, it has been used with conspicuous abandon so that at present there is considerable uncertainty as to just what is meant by the term. It has been used to describe methods of improving habitat, studies of fish populations, regulating fishing, stocking, and many other phases of restoration work. Because the word has lost considerable significance as a result of loose application, it seems advisable to offer the following arbitrary definition for the purpose of this report: Management is an attempt to manipulate all of those chemical, biological, and physical factors which are responsible for game fish production and which lend themselves to human control so as to secure the maximum sustained yield of desirable species from each body of water.

In the following pages an attempt will be made to (1) present a picture of the complex interrelating factors which combine to produce a crop of game fishes, (2) indicate which of these factors are largely beyond human control and which are subject to modification, (3) review past restoration efforts in the light of present knowledge, (4) explain some controversial subjects among anglers, (5) indicate what procedures are most likely to give results in unusual situations, and (6) describe the application of the modified CONNECTICUT PLAN to pondfish management.

Balance of Natural Factors

Theoretically, a state of balance or stability existed under primitive lake conditions. Each lake contained basic fertilizers which were gradually supplied through a leaching from the surrounding watershed and from decomposing plant and animal matter. These fertilizers promoted the growth of green plants which, in turn, supported a host of animals including fishes (Fig. 4).

The fishes that survived were those best adapted to the prevailing conditions. Fish were removed only by old age, predators, parasitism, and disease, and the rate of survival and growth

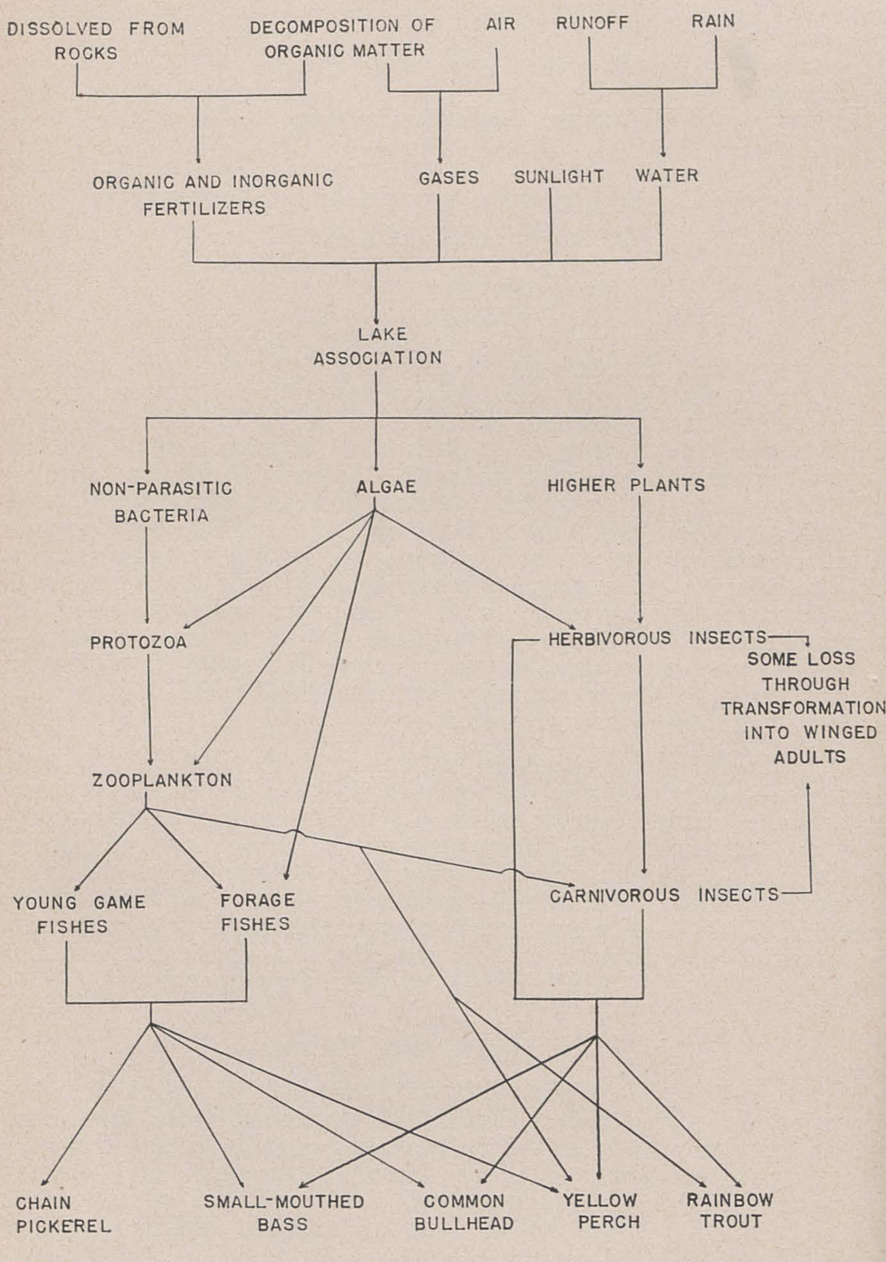

FIG. 4. An attempt to illustrate the complex interrelationship extending from inorganic matter and energy to the production of fishes. The indicated chain of events becomes transformed into a cycle with the death of the organisms and subsequent reduction to organic fertilizers.

of young fishes was geared to the rate of removal of older specimens so as to maintain a balanced population level. Man disturbed nature's balance by removing fish of selected sizes and species, by adding fertilizers to the surrounding watershed for agricultural purposes, by raising and lowering water levels, by restocking native and exotic species, and by introducing chemicals which were either harmful to fishes or to some of the intermediate organisms of the food chain.

A rule of lake biology is that a given area will support *a certain poundage of fish.* This is an optimum maintenance level for all sizes and species of fish in each lake, and it can be raised only by increasing the basic fertility of the water. Pond management is an attempt to guide this potential productivity so as to yield the greatest number of desirable fishes. It is entirely possible to balance the factors of food, relative numbers of various species and age groups, reproduction, and angling, when adequate information on which to base a management program is available. This balance might well be entirely different from one established naturally, for it would be planned to serve human needs.

Stocking

No activity of the State Board of Fisheries and Game receives so much popular support as stocking, and no pondfish restoration activity is so costly when measured by fish brought to creel. A large portion of the pondfish stocking in Connecticut, as well as in other states, has little basis in biology and is much more valuable in promoting good public relations than in improving fishing. Favorable natural conditions in Connecticut lakes and ponds have not been greatly changed by industrialization or other activities of civilization, and, therefore, the pondfish problem is entirely different from the trout program, which is admittedly a costly process of "put and take" (Table 1).

Exotic Species

In the past an effort was made to establish a number of exotic species in Connecticut lakes and ponds. The cost of these plants cannot now be determined, but there can be no doubt that many thousands of dollars were spent. In a few instances, these introductions did result in improved fishing, but the majority of the fish either never became established or did become established and are now regarded as undesirable.

A brief review of some of these non-native fish and their present status is of interest.

Largemouth and **smallmouth black bass** were introduced into many Connecticut lakes. They now provide excellent fishing in those lakes which provide a suitable habitat.

TABLE 1. PLANTS OF WARM-WATER FISHES IN CONNECTICUT LAKES AND PONDS FROM 1930 to 1939, INCLUSIVE.

Fingerlings and Adults

Species	1930	1931	1932	1933	1934	1935	1936	1937	1938	1939	Total
Pickerel	4,512	8,537	4,121	3,576	1,552	1,851	702	1,014	864	534	27,263
Yellow Perch	16,339	115,187	28,520	51,964	6,890	77,484	46,570	130,807	31,714	35,781	541,256
White Perch	1,988		8		272	503	888	273	2,228	144	6,304
Largemouth Bass	206		24	325	33	135	143	32	180	103	1,181
Smallmouth Bass	140	7,352	103	647	86	376	959		23	94	9,780
Calico Bass	41,074	73,625	84,642	89,827	67,176	22,593	145,229	150,605	39,117	1,945	715,833
Bullheads	268,114	210,560	179,701	168,526	104,888	134,036	527,463	359,814	157,204	133,808	2,244,114
Roach	6,899	57,116	49,026	8,677	12,212	11,375	30,787	10,388	5,891	970	193,341
Shiners	97,070	244,705	82,180	139,911	400	11,375	359,902	167,270	115,776	48,265	1,266,854
Rock Bass	605			1	14	1,856	12	4			2,492
Northern Pike		14									14
Smelt		1,000		228	1,175	1,140		1,345	750		5,638
TOTALS	436,947	718,096	428,325	463,682	194,698	262,724	1,112,655	821,552	353,747	221,644	5,014,070

Fry

Species	1930	1931	1932	1933	1934	1935	1936	1937	1938	1939	Total
Yellow Perch	60,500,000	62,150,000	90,300,000	53,900,000	13,000,000	26,800,000	10,500,000	20,150,000		200,000	337,500,000
Pike Perch		2,500,000			12,000,000	12,787,500					27,287,500
Smelt		2,500,000									2,000,000
Smallmouth Bass	10,000	30,500	40,000	270,000	292,000	401,000	382,000	179,000	416,000	386,000	2,406,500
TOTALS	60,510,000	66,680,500	90,340,000	54,170,000	25,292,000	39,988,500	10,882,000	20,329,000	416,000	586,000	369,194,000

Calico bass were introduced widely because they were easily propagated and are now well established in numerous waters. They are regarded highly as a pan fish but are disappointing in their game qualities. They compete for food with chain pickerel, yellow perch, and the black basses, and are of questionable value as an addition to Connecticut game species.

Bluegill sunfish were placed in several lakes apparently to serve as forage fish. There is no evidence that they fill this role in Connecticut and they support little fishing for adults. This was another unwise introduction.

Pike perch fry were planted in recent years in four Connecticut lakes: Candlewood, Zoar, Alexander and Waumgumbaug. They became established in Candlewood Lake only, where they support limited fishing.

Pacific salmon of at least two different species were planted widely in Connecticut lakes. Only the sockeye became established and that in one lake, East Twin. The remaining introductions gave no results. The Twin Lake sockeyes are numerous and provide some fishing. The money spent on Pacific Coast salmon plantings must be regarded as wasted.

Land-locked salmon and **lake trout** were stocked in prodigious numbers in nearly every sizable lake in Connecticut. The land-locked salmon was never successful, although there are reports of scattered specimens being taken from one or two lakes. The lake trout became established in Wononscopomuc Lake and there are reports of a few being taken from Twin Lakes, Shenipsit Lake, and Highland Lake.

Carp were distributed by the U. S. Bureau of Fisheries and are now established in several lakes. It is commonly regarded as a "weed species" and efforts are made to remove it from fishing waters. Carp support some commercial fishing in the Connecticut River and in Lake Zoar.

Tench were introduced probably by private efforts because there are no official records of its distribution. It was discovered by the survey in Wattles Pond (Winnemaug Lake), Watertown. The tench is an Old World minnow, carp-like in appearance. It serves no useful purpose in Connecticut and may be undesirable for the same reasons as carp.

White perch are native to Connecticut brackish and coastal fresh water and have been widely distributed in lakes and ponds. In a few lakes they have been tremendously successful and provide considerable fishing. In other waters they show a tendency to become stunted and provide little sport. Not much is known of their life history in fresh water and their widespread distribution may be attended with danger to other species.

Salt-water smelt were introduced quite widely over a period of years to serve as a forage fish for lake trout and salmon and to provide ice fishing. They are now established in two lakes and provide limited ice fishing.

Overstocking

Overstocking has been a factor contributing to poor fishing in several Connecticut lakes. This has been particularly true of yellow perch fry plants. It is easy to secure yellow perch spawn from the Connecticut River and to stock the fry in other waters. Literally millions of fry have been placed in the principal lakes, although there was no evidence that natural reproduction in these waters was inadequate. Waters with stunted perch populations such as Highland Lake, Tyler Pond, and Alexander Lake have been heavily stocked so that these "restoration" measures were actually harmful.

Carefully controlled experiments carried on in Alabama[6] have demonstrated that fish production in pounds per acre may actually become less as a result of stocking too many fish. The size of fish stocked apparently made little difference in the final result. Small fish with adequate food quickly became large fish and brought the characteristic total production of the pond up to par. However, even when larger specimens were stocked in excess of the normal production of the lake, they soon lost weight or died so that the total poundage was not increased. Overstocking resulted in the fish being more numerous but smaller and hence much less desirable from an angling point of view. Such findings are frequently questioned or disregarded by sportsmen who believe they must depend on artificial methods for their sport. When it is clearly understood that producing a crop of fish in water is, in principle, the same as good agricultural practices, it becomes evident that much of the pond fishing which remains to Connecticut anglers is not the result of artificial methods, but in spite of them.

Unwise Stocking

Connecticut has few lakes which are suitable for trout. These lakes are valuable assets because they give the confirmed lake fisherman an opportunity to catch trout, and because they help to relieve the fishing pressure on overburdened trout streams. It has been the policy in the past to stock yellow perch, calico bass, sunfish, and other warm-water species in trout lakes. There is competition for food between warm-water fishes and trout and, therefore, it seems unwise to continue stocking and managing trout waters for species other than trout.

Perhaps the most conspicuous example of unwise stocking is the *variety of species* which have been planted in many lakes. It is not uncommon to find lakes which have been stocked with practically every native and introduced game species known to

Connecticut lakes (See Appendix I). Several smallmouth bass lakes are now being taken over by largemouth bass; in others, calico bass are increasing rapidly, apparently at the expense of yellow perch or largemouth bass. It is the old story of trying to make a pasture which could carry six sheep annually also support six horses and six cows. This is one of the most important reasons why future pondfish restoration methods must consist of a balanced management program.

Sources of Stock

At the present time several methods are used to secure fish for plantings. Some adults are secured from rescue work and by netting reservoirs, but the largest part come from commercial fishermen who fish the coves of the Connecticut River for carp and suckers. These commercial men are paid a small sum for holding the game species for the Department. This method of securing game fish is relatively inexpensive, but there is debatable economy in moving fish from one body of fishing water so that they may be caught in another.

Yellow perch egg strings were secured in the past from the coves of the Connecticut River. Part of these eggs were hatched in rearing ponds. However, the majority were distributed to the various lakes in "perch baskets". These small wire cages were suspended under the water and the fry were expected to disperse upon hatching. This method of securing stock has been quite largely abandoned in recent years.

Fingerling calico bass, chain pickerel, golden shiners, bullheads, and yellow perch are distributed from several rearing ponds.

Salt-water smelt are taken during the spawning run in the Saugatuck River at Westport. The ripe spawners are stripped and the eggs hatched in hatching jars at the Westport hatchery. Some of the fry and the spent adults have been stocked in inland lakes.

Smallmouth black bass fry are secured from Wangum Reservoir near Norfolk. The fry are taken when they "rise" or "swarm" over the nest, which is before the male bass would normally cease to give parental protection (see p. 180). They are then stocked in strange surroundings. An annual plant of ten thousand bass fry in a lake seems impressive. Actually four or five bass nests properly protected until July 1st would probably place more fry in the lake, and these fry would be guarded by the male parent until they were better able to take care of themselves.

Sound Reasons for Stocking

There are four general purposes which may be served by stocking: (1) to introduce a new species into a body of water, (2) to compensate for lack of natural reproduction, (3) to restore a species which has been badly decimated by parasites, suffocation, loss of a dam, or overfishing, and (4) to provide immediate fishing by planting legal-sized fish.

It is evident from a review of the history of stocking in Connecticut that there is little need to introduce new species. One of the current problems is to remove some species which have been unwisely stocked in the past.

Inadequate reproduction is the most commonly used justification for stocking. This is true of rainbow trout in Connecticut lakes which lack suitable spawning streams and perhaps is also

FIG. 5. Connecticut River commercial fishermen showing live cars in which game fishes are held for stocking other waters.

true of the pike-perch in Candlewood Lake. The smallmouth bass in Taunton Pond, Newtown, apparently are facing extermination because of lack of reproduction, caused by unusually heavy infestation of bass tapeworm (see p. 261). Unfortunately there is no known practicable control measure for this parasite in fishing waters. The advisability of trying to maintain bass in this lake by stocking is questionable. The smallmouth bass in Alexander Lake have a low survival of young because of poor cover conditions along the shore. Stocking would help to only a limited extent because introduced fry would be subjected to the same adverse conditions as are those produced naturally in the lake. The survey has found few situations where natural reproduction of species adapted to the waters does not appear adequate at the present time, or could easily be made so by the application of proper catch regulations or by relatively simple habitat improvement.

There have been two recent examples where fish populations were suddenly lost and the need for restocking indicated. In 1935, all the larger specimens in North Farms Reservoir, Wallingford, were destroyed by a peculiar combination of "working" and weather conditions (see p. 79). In 1938, an external parasite apparently killed almost all of the yellow perch in Shaw Lake

FIG. 6. Sorting and counting game fish from the Connecticut River to be stocked in other waters.

(Hayward Lake), Colchester. It was possible to hurry the return of fishing in these lakes by extensive adult stocking.

Much of the adult pondfish stocking at the present time serve no other useful purpose than "put and take". The numbers of adult fish which can be planted are small when compared to total populations and it is difficult to see how they could possibly improve fishing. This method of providing pond fishing must be regarded as a luxury in view of the fact that the Department is under-financed for the many functions expected of it.

The specific stocking needs as shown by the survey were discussed briefly because they indicate how funds have been spent unnecessarily in the past and point to future savings. They also show that, while the Department must always be in a position to do some pondfish stocking, *there is no present or anticipated need for costly expansion of stocking facilities.*

Rainbow Trout in Ponds

This subject was not discussed in the previous section because it is a separate and distinct problem. There are numerous requests from sportsmen each year to plant rainbow trout in various ponds. It is quite commonly believed that rainbows would do well in many Connecticut lakes and ponds, and such stocking is urged as a measure which would relieve fishing pressure on streams.

Fingerling rainbow trout have been widely distributed in the impounded waters of Connecticut. So far as is known, these fingerling plants gave poor results, and it was not until recent years that rainbows were established in several ponds by the stocking of legal-sized fish. It is quite possible that the primary reason why fingerling rainbows failed to provide fishing even in waters suitable for trout was because of competition for food and predation by other species. No effort was made to reduce the numbers of predatory species before the fingerlings were introduced and, in many cases, pondfish stocking and trout fingerling stocking were made simultaneously.

Legal-sized rainbows were being stocked in fourteen lakes prior to the Survey, but that number has since been reduced to seven. The Survey showed that many plants were being made in unsuitable waters. The common method of testing the suitability of water for trout in the past was to stock trout and see what happened. This test was costly and was not as conclusive as it would seem. It works fairly well under some conditions with fingerling plants but not with legal-sized fish. When fingerlings are planted in unsuitable waters, they perish before reaching catchable size and are never recovered by anglers. Practically all ponds are suitable for trout during the cool months of the year, and usually trout plants are made early in the spring with the result that legal-sized trout so planted do show up in anglers' catches during that spring. Since it is ordinarily impossible to determine what percentage of the trout planted are recovered, it is entirely possible to continue stocking legal-sized trout in unsuitable waters without realizing that there is a tremendous annual loss.

The Green Falls Reservoir situation is a case in point and is reviewed here as a typical example. Over $5,000 worth of two-year old rainbow trout disappeared from Green Falls Reservoir in the five years it was stocked before being surveyed. It is obvious that a leak of this magnitude is of primary importance and the circumstances responsible should hold considerable interest for sportsmen and conservation administrators.

It was realized that returns from plants made in Green Falls Reservoir were small, but there was a comforting belief in some quarters that those trout which escaped the hook were living and growing and would furnish fine sport at some future time. This confidence was justified on the basis that the outlet was screened and that no dead rainbows had ever been observed. The facts uncovered by the 1938 Survey showed that it would be practically impossible for trout to live in Green Falls Reservoir for a period of one year and that those trout which were not caught represented a total loss. A resumé of the facts which substantiate these statements is enlightening.

Green Falls Reservoir, located in the Pachaug State Forest, Voluntown, is entirely artificial in origin. It has an area of 47 acres, a maximum depth of 29¼ feet, and an average depth of 13½ feet. It is fed by several small streams, two of which are more or less permanent, and is reported to receive some inflow from bottom springs. The total watershed is 1.18 square miles, which makes a ratio of 16:1 between watershed and surface area.

The survey was made just following the June rainy spell so that although the data proved Green Falls Reservoir was definitely not trout water, more adverse conditions undoubtedly prevailed later in the summer. On June 28, 1938, the water was stratified (see Section II) in three layers, each approximately 9¾ feet thick at the deepest point in the Reservoir. The top layer was well oxygenated, but closely followed air temperatures which are too warm for trout during summer months. The middle layer had temperatures ranging from 58.3° F. to 49.6° F. and had a dissolved oxygen content ranging from 7.07 to 6.10 parts per million. Temperature and dissolved oxygen content were suitable for trout in this layer. The deeper portions were cold but had only 1.41 parts per million of dissolved oxygen, which is below the tolerance for trout.

During warm weather, trout were restricted to the middle layer of water. The upper layer was too warm; the bottom layer had insufficient dissolved oxygen. On the date of this examination trout would theoretically have been restricted to between one-fifth and one-quarter of the reservoir (volumetric basis); but, actually, in late summer the percentage of water inhabitable for trout would shrink alarmingly because the greater part of the reservoir is too shallow to become stratified and would, therefore, become too warm for trout. It was estimated that, in late summer, the middle layer over the deeper portion of the reservoir would become thinner by at least three feet. With trout so restricted, it is obvious that at such times only a very small part of the food-producing area could be utilized.

The food production in the reservoir was also disappointing.

The water was low in basic fertilizers and the plankton and bottom fauna were far below the average for other Connecticut lakes. Gill nets were used extensively, but no trout were taken. A few rainbows were taken by angling, but only at the mouths of tributaries. Study of the scales of these specimens showed that each was of the *age group last stocked.* These trout had been in Green Falls approximately seven months and had made little or no growth. In fact, most of them were so emaciated as to indicate they had actually lost weight since being planted.

It was believed that trout could not leave the reservoir due to the screen at the dam. This belief was erroneous because rainbows collected below the dam were of the same age as those collected in the reservoir. This was shown by a study of their scales. The stocking policy of the waters below the dam was such that these trout could have come only from the reservoir. There was evidence that the screen had become clogged by leaves and that the water level had been raised sufficiently to permit trout to go over the dam.

It is impossible to determine how many trout escaped, but it is unlikely that this factor explains all of the missing trout because the screen would rarely become clogged and then for only a short period of time. It is quite probable that many trout perished in the reservoir during the hot weather.

Fishing in Green Falls Reservoir was controlled by a free permit system so that an accurate record of the number of trout taken each year was available. These records indicated that when two-year old trout were liberated just prior to and during the fishing season which opened on April 15th, there was a recovery by angling of approximately 40 per cent. When trout were planted in late fall or early spring and the opening day set at June 1st (reasonable management for rainbow trout ponds), there was a recovery by angling of less than 15 per cent. Probably any warm-water fishing lake in the State would have given results as satisfactory.

When the Survey data were available, rainbow stocking was discontinued. The significant fact is that a loss was sustained before adequate information prevented a continued loss. An inexpensive preliminary survey would have established the fact that trout never should have been planted in Green Falls.

The Green Falls Reservoir episode might be interpreted as an indication of administrative stupidity; actually it is not. The responsibility for this and similar situations rests with those who have insisted on blind stocking and have been unwilling to have money spent on investigation.

Stocking Recommendations Based on Survey Data

Some survey reports include recommendations to stock specific numbers of the various warm-water species which are already established in the lakes covered. Apparently the authors have felt an obligation to do this because by tradition such recommendations are considered to be a part of a fishery or biological survey report. The layman quite naturally assumes these recommendations are based on a systematic interpretation of the biological data at hand — actually, they are not. The species best adapted to the waters and those that may need help through stocking can usually be determined quite logically from survey data, but the numbers to be stocked each year cannot.

When the number of fish to be stocked in each body of water is determined from biological data, accurate measurements of the following factors are assumed to be at hand:

1. Annual reproduction necessary to maintain a proper adult population in relation to the food supply, modified by the prevailing fishing load.
2. Actual success of reproduction and rate of survival of young.
3. The food production.
4. The normal or proper ratio between food production and fish production for each species in each lake.
5. The pounds of fish actually being produced or maintained in the lake at the time of the survey.
6. The rate at which fish are harvested.

The survey methods and techniques as applied to angling waters do not accurately measure any of the essential points mentioned above.

The behavior of young fish and protective cover about the shores often make representative collections impossible. Success of reproduction and rate of survival of young fish vary widely. Weather, water levels, type of bottom, amount of protective cover, parasites, and the number of spawning adults are important contributing factors. Ordinary survey methods fail to measure reproduction and survival and their relation to production of catchable fish as well as the intensity of angling.

Improved methods of collecting and treating food production data has largely invalidated the belief that such methods could accurately measure the production of plankton, bottom fauna, and forage fishes. In addition to inherent sampling errors is added the factor of seasonal fluctuation of food organisms. The average survey spends only a limited time on each lake and usually at different seasons of the year. In an attempt to compensate for these inaccuracies, advanced workers are using an increased number of tests, both chemical and biological, all of which have bearing on the food production or potential food production of each body of water. At the present time, measures of food production must be regarded only as relative approximations, and as such, they are extremely valuable and an essential part of survey work.

No method of determining the relationship between food production and fish production is available for application to fishing waters. It is obvious that some definite relationship does exist and that it would vary widely in each body of water according to quantity, quality, and availability to the species of fish present. No method applicable to fishing waters has been devised which will conveniently and accurately measure fish populations.

The success of reproduction, the relation between young and a desirable number of adults, food production and its relation to game fish production, and the fish population present must be measured in order to determine how many fish should be stocked. Survey data can be used to determine what species and sizes should be stocked and it can curb unwise or overstocking. However, any stocking recommendations should be regarded as temporary and subject to change as the food and other conditions in the waters are changed as a result of stocking. Stocking should be under the direct supervision of men trained to recognize symptoms of overstocking, stunting, or other conditions which may warrant changes in the stocking policy.

Fish Populations

The subject of fish populations has always intrigued anglers. There is hardly a fisherman who has not, at some time, wished that just for a moment the waters of some lake would momentarily vanish so that he might see the countless fish with which his imagination has populated the water. The problem of measuring populations of fishes is just as exciting to the fishery biologist, because at present no practical yardstick for measuring them is available and when one is devised, a great advance in fishery management will be made.

The experimental work laying the foundation for future practical usage has consisted mostly of trapping and counting spawning runs and in wholesale counting and weighing of populations following poisoning or drainage.

In Michigan, Eschmeyer[1] found standing populations of fish varying from 21 to 194 lbs. per acre. The Illinois[7] lakes studied were supporting from 232 to 1,143 lbs. per acre, while some Alabama[6] ponds produced from 100 to 580 lbs. per acre depending on the amount of fertilizer added. These figures are of interest mainly because they show that wide variation in productivity results from different combinations of stocking, fertilizing, length of growing season, combination of species present, and bottom contours.

When a practicable method of measuring populations in fishing waters has been devised, it will be possible to formulate sound stocking policies and safe catch regulations. It will be possible, within reasonable limits, to make the annual catch fall into the size groups most favored by anglers and to predict the number which may be taken annually.

Forage Fish

The term "forage fish" is used to designate any small fish which serves as food for the larger game species. Minnows, dace, and shiners are most commonly placed in this category, but practically all species serve as forage to a greater or lesser extent. The forage fish converts food which is unsuitable or unavailable for the larger game fish into a usable form. For this reason, forage fish are an essential link in the food chain and should receive their share of attention.

While many species serve as forage, all are not equally desirable for that purpose. A considerable amount of study has been devoted to the life histories and habits of those species which are regarded as valuable forage species. However, investigation into the extent to which these theoretically ideal forage fishes are actually utilized by game species might indicate a need for revising some of the present management practices. Hubbs and Eschmeyer[4] have defined the ideal forage fish as possessing the following characteristics:

"1. Rapid rate of growth.

2. An adult size suitable for the desired game fish.

3. An extended spawning season, so that a continuous supply of small forage fish will be available for the young game fish as soon as they begin to use such foods.

4. Prolific and ready reproduction in extensive habitats.

5. Adaptability to the habitat in which it is needed.

6. Non-competitive habits, so that it will not seriously deplete the food supply of the younger adult game fish.

7. Non-predatory habits, so that it will not feed to a serious extent on the eggs or young of the species to be serviced.

8. A preference for the habitats occupied by the fishes which are to consume it.

9. Habits permitting it to be caught easily by the larger fish, but not so easily as to be subject to rapid depletion or extermination.

10. Relative immunity to diseases which would greatly limit its own numbers and (as a primary or secondary host) to harmful parasites which later mature in the game fish.

11. Such qualities as relative softness, lack of spines, etc. which make it more acceptable to the game fish than are

the young game fish, thereby preventing serious cannibalism.

12. Practicability of cultivation and control in rearing ponds and in the lakes."

Connecticut has relatively few species of minnows and shiners. The golden shiner is by far the most common forage species in lakes and perhaps the most valuable in Connecticut. The bridled minnow and the barred killifish occur in many ponds but rarely are sufficiently abundant to provide adequate forage for game species. Since the yellow perch is a prolific fish, it may be fortunate that the young are utilized by larger fish or they might become overcrowded and stunted. In Alexander Lake, yellow perch are abundant and badly stunted. Examination of smallmouth black bass stomachs indicated that in this lake yellow perch are the principal food of the larger smallmouth bass.

Connecticut laws are too liberal in permitting the removal of valuable forage fish and crayfish from fishing waters. These foods are important in the production of game fish and should not be removed for bait. Golden shiners and crayfish can be economically propagated in small rearing ponds without damage to fishing waters. This is a practice which should be encouraged through legislation and public opinion. Fishermen should refrain from taking bait from fishing waters. Considerable bait is taken illegally and offered for sale, and the most effective way to curb this practice is for sportsmen to refuse to buy such bait.

Weed Species

The term "weed species" is used within these pages to describe any fish whose abundance is inimical to the maximum production of desirable species. Fish which may in one situation be classed as "weed species" may in another be desirable. The problem implied by the term "weed species" is one of importance if fishing is to be improved in Connecticut lakes, and it is a phase of restoration work which, to date, has been almost entirely neglected. In the era of broadcast stocking, numerous species were introduced and became established in the principal lakes of the State. Apparently little thought was given to the feeding habits and requirements of the species planted. It was considered to be a self-evident fact that all stocking was beneficial and that if a new kind of fish could be "wedged" into the existing population, better fishing would follow. The fallacy of this reasoning has been amply demonstrated and the practice discontinued, but the heritage of complex game fish populations remains. It is not at all uncommon to find six or more game species with essentially similar requirements competing for food and habitat in a single lake. Obviously, all are not equally valuable to anglers and those least favored are being maintained at the expense of more desirable species. The logical solution is reduction of the number of competing game species.

The carp is commonly regarded as a weed species because it is accused of being a spawn eater. It is quite probable that carp do destroy some of the spawn of other fishes which spread their eggs broadcast and do not give parental care. Nature anticipates that losses will occur when no parental care is given and provides such species with the ability to produce prodigious quantities of eggs. Therefore, it hardly seems that the reputation of "spawn eater" alone is sufficient to place the carp on the list of undesirable species. However, other characteristics may do so since the carp competes with other more valuable species for food (see food habits chart, p. 209), and its manner of feeding and spawning often destroys valuable aquatic vegetation.

The common sucker is sometimes regarded as undesirable and its extermination recommended on the basis that it is a spawn eater. Suckers do eat some eggs (p. 150), but it seems probable that in some lakes young suckers furnish forage for game species.

The grass pickerel must be regarded as a weed species. It is predacious and competes for food with game fish. Its maximum length is approximately twelve inches so that it is well protected by the legal length for chain pickerel. The grass pickerel is not protected by law, but many anglers are unable to distinguish it from the chain pickerel. This means that some fishermen carefully return hooked grass pickerel to the water, while to other anglers all small pickerel are grass pickerel and are ruthlessly destroyed. This unintentional protection favors the increase of the weed species at the expense of the valuable chain pickerel. If fishermen were positive in their identification of this species they could greatly aid in its control (Fig. 7).

The three most common sunfishes of Connecticut (common sunfish, red-bellied sunfish, and bluegill sunfish) are practically immune to angling due to their small size. This has undoubtedly been a factor working towards the maintenance of their abundance. In many lakes they are so abundant that they may offer serious competition for food with young game fishes. The sunfishes are a beautiful and interesting group of fishes and no one would desire their extermination from any body of water. They should, however, be brought under control in many lakes where they are now over-abundant.

It has been pointed out that game species may be regarded as a weed species under certain conditions and that other species must be so regarded under any conditions. It is not enough to indicate that the so-called weed species are a definite problem needing solution. Some suggestions for their control should be included.

Sunfish may be removed by seine during their spawning period and this is an activity in which sportsmen's cooperation could be utilized effectively. Grass pickerel can be controlled by sportsmen who have learned to distinguish this species from the

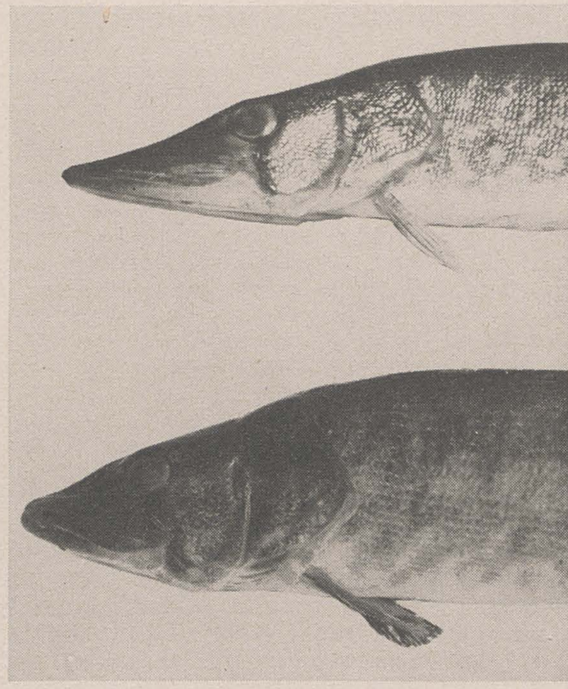

FIG. 7. Fishermen should learn to distinguish between the chain pickerel (above) and the grass pickerel (below) so as to aid in the control of the latter.

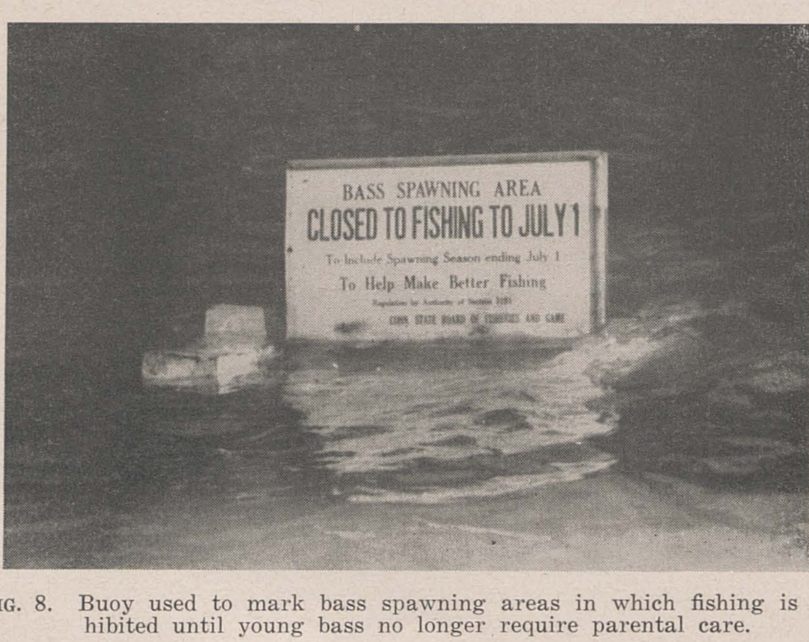

FIG. 8. Buoy used to mark bass spawning areas in which fishing is prohibited until young bass no longer require parental care.

chain pickerel. Carp are at present being controlled in some waters by licensed commercial fishermen. It is possible this procedure could be extended to other waters provided adequate provision against harm to game species can be made. The fallfish or chub, a large minnow occuring in some of our lakes, is easily recognizable and its numbers might be reduced by anglers.

When game species come to be regarded as weed species under conditions peculiar to a given lake, different control methods than those mentioned above should be used. It is possible to trap-net lakes and remove undesirable species. This is an expensive process and not as efficient as might be thought. Several states have despaired of bringing some of their lakes back into productive balance and have poisoned entire fish populations to make a new start. It is possible that this procedure may be advisable in some Connecticut lakes. It seems wasteful to poison game fish, even though their presence is undesirable, if anglers can be permitted the pleasure of their removal.

Connecticut is one of the very few states where the mechanics for such procedures are available. On waters under State regulation, special catch rules may be applied which will permit the angler to improve fishing by removing an over-abundance of undesirable species. To date, regulations aimed at eliminating a species have not been used. It was felt that the majority of anglers did not understand the need for such control measures sufficiently well to give the necessary support, and totally uninformed criticism can often jeopardize a worthwhile program. More detailed knowledge is available as a result of the Survey's activities and this information is becoming more widely disseminated. It is merely a question of time before Connecticut anglers will be doing their own "weeding" with hook and line.

Fishery restoration under crowded Connecticut conditions must necessarily be a business-like procedure which will permit no waste of potential productivity. In order to take full advantage of the peculiar biological, chemical, and physical conditions which exist in each body of water, it is necessary to manage each such area according to its individual potentialities. This means special regulations governing fishing, which in turn means a measure of discretionary power for the State Board of Fisheries and Game. There are those who distrust the motives of a conservation commission that requests discretionary legislation, and oppose the granting of such power as a matter of principle. It is unfortunate that such feelings exist, because the ability to make special adjustments differing from broad general legislation is essential to really efficient fishery administration.

Protection During Spawning

The need for protection of fishes during their spawning season is a widely understood phase of management. Considerable legislation has been drawn to prevent removal of fish at spawning time, but in many cases this legislation is not as effective as it should be. Yellow perch and chain pickerel are usually not through spawning by the opening of the season, April 15th. However, Connecticut ponds rarely have large concentrations of anglers before May 1st because of cold weather. The reluctance of many anglers to fish from a boat during cold spring days is a factor more important than legislation in protecting perch and pickerel during spawning.

Smelt are particularly vulnerable during their spawning runs. Even a limited amount of seining in spawning streams can do tremendous harm through destruction of eggs as well as removal of adults. The Twin Lake sockeye salmon spawn in shallow water in a restricted area. For the past three years the Department has given these breeding grounds special protection.

The black basses have specialized reproductive habits which makes them particularly vulnerable to certain unsportsmanlike practices. These same habits cause bass to respond amazingly well to good management, for man is one of the few creatures that can cause destruction of the eggs in a bass nest. Black bass spawn during early June in most Connecticut lakes. The aggressiveness of the male bass guarding the nest prevents other fishes from disturbing the eggs, but this also leads the male to a strike at lures drawn by the nest (see life history, p. 179). Many thoughtless anglers enjoy catching these nest-guarding bass before the opening of the bass season on July 1st. Since they cannot be possessed legally, they are usually returned to the water — but in most cases the harm has been done. While the parent bass is being played, minnows, perch, sunfish, or other egg eaters have had an opportunity to destroy the eggs. In many cases, the bass is so injured or frightened that he does not return to the nest.

Legislation prescribing a closed season on bass until July 1st is perfectly sound, but additional measures must be taken to prevent thoughtless anglers from destroying thousands of eggs and fry each year. In lakes over which the Department has necessary jurisdiction, bass spawning areas are located and posted as closed to *all fishing* prior to July 1st. This single measure has given gratifying results in many bass lakes. It is one of the first steps in the proper management of black bass and is favorably regarded by sportsmen because it permits them to fish for other species without fear that they may be harming the future bass crop.

Fluctuation in Water Level

Connecticut has a peculiarly localized problem in fish restoration because the majority of lakes and ponds were either created or subsequently modified to provide storage of water for industrial purposes. Although many of the small mill ponds are no longer used, a surprisingly large number of Connecticut lakes are subject to partial drainage each year. Fluctuations in water level are frequently disregarded as a fishery problem as long as no fish are destroyed, but the real effect on fishing is more harmful than is perhaps commonly supposed.

Lowering water levels tends to harm fishing in a number of ways. It may destroy considerable bottom food by exposing the productive shallows; it may kill spawn or prevent some species from finding a suitable spawning habitat; it may kill or retard the growth of desirable weed beds; it may greatly reduce the forage fish population; or it may destroy fish by leaving them stranded in small pools cut off from the main body of water. The ultimate effect of fluctuations in water level depends on the degree of fluctuation, the species of the fish present, the contour of the bottom, and the season of the year at which it occurs.

West Hill Pond and Basham Lake are subject to annual fluctuation in water level. It is doubtful if coincidence alone explains the fact that warm-water game species in both of these lakes grow much slower than in other similar waters. In 1937, some survey work was done in Gardner Lake. At that time, fishing for black bass, yellow perch, and pickerel was reported to be poor. There was a scarcity of the young of these species about the shores and forage minnows seemed to be rare. No real cause for the lack of forage fishes and poor reproduction of game species could be discovered until it was learned that the lake was subject to frequent fluctuations in the water level. Sounding data showed that the customary drop in water level would expose a large percentage of the productive shoal area due to the shape of the lake basin. Lowering of the water level was tentatively held to be the cause of poor fishing. The lake was rechecked late in the summer of 1938. The level had been maintained during this year and a surprising change in the fish fauna had occurred. Young-of-the-year game fish were common about the shores and young golden shiners and barred killifish were abundant. It appeared that a tremendous improvement had occurred in just one year as a result of a stable water level and that good fish production was primarily a matter of maintaining this condition.

Poisons

The use of chemicals to control algae and aquatic vegetation in fishing waters* can be, and frequently is, extremely harmful. Unfortunately, the damage is so indirect that it is not readily apparent to the casual observer. For this reason, opposition to chemical treatments usually comes too late to be effective in preventing the decline of fishing. In order to explain how chemical destruction of the algae and aquatic vegetation is reflected in poor

*The discussion which follows applies only to fishing waters and has no application to municipal reservoirs where the necessity for supplying clean, potable water outweighs every other consideration, or to rearing ponds where it is frequently necessary to eradicate weeds in order to remove the fish.

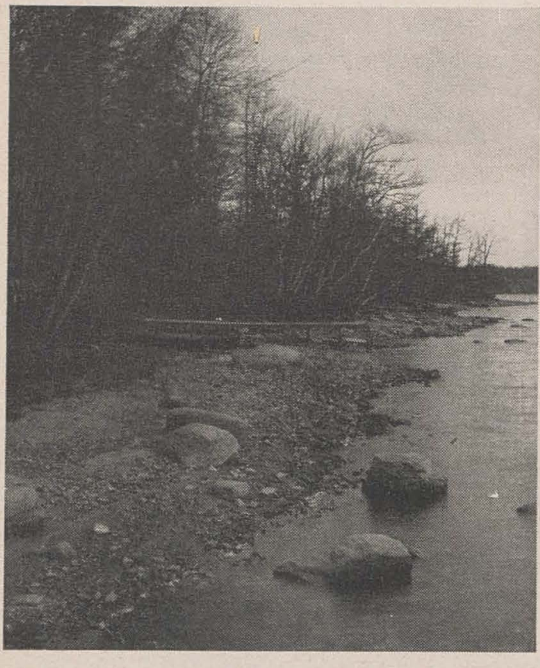

FIG. 9. Shores exposed by lowering water level. Small-mouth bass choose this type of bottom for nest building. Columbia Lake, Columbia.

FIG. 10. Extensive shoals exposed by lowering water levels. This may be particularly harmful to fish production if it occurs in spring or early summer. Waumgumbaug Lake, Coventry.

fishing, it seems desirable to review the steps leading to the production of game fish.

In each lake, basic inorganic fertilizers are dissolved which promote the growth of green plants. These plants are of two general types — free floating algae and rooted plants. The plants support animals which either directly or indirectly support game fish (Fig. 4, p. 22, is a schematic representation of this process). The kinds and amounts of basic fertilizers in solution determine the potential productivity of water, but this ability to produce game fish can not be realized unless all of the links in the food chain are correspondingly strong. Nowhere is the old adage that a chain is only as strong as its weakest link better exemplified. Yet this fundamental truth is quite consistently ignored in considering the effect of poisons on fish life. Limnological data (see pp. 100-110) establishes a definite statistical correlation between fertilizers, plankton, and bottom fauna.

Chemical treatments are harmful because they destroy some of the intermediate organisms composing the food chain, and the fact that such treatments usually do not actually kill fish is irrelevant. The exact chemical reactions which occur when lakes are treated with various types of poison are extremely complex and unpredictable, depending on the chemistry of the water, temperature, currents, and amount of vegetable matter present. It is significant, however, that several of the foremost fishery biologists in the country have publicly warned against the dangers inherent in chemical treatment of fishing waters and no recognized workers have advocated such treatments. It is logical to assume, and survey data indicates that destruction of essential fractions of the plant and animal life in a lake results in a decreased yield of game fish.

Connecticut law (Sec. 3173) recognizes the danger of drugs and poisons "harmful to fish" and prohibits their use in lakes and streams. The statute was amended by the 1939 General Assembly so that municipal water supplies were excluded from the provisions of the Act and, further, so that the Superintendent of the State Board of Fisheries and Game may issue a permit to introduce copper sulphate into any lake or pond for the control of algae and that said Board shall supervise the treatments. This amendment may well increase the number of treated lakes since over a period of years Connecticut has established a bad precedent by permitting copper sulphate introductions in some fishing lakes through a liberal interpretation of the law. The Board now finds it difficult to refuse to issue permits for waters which have been treated in the past, and so it is difficult to discriminate against cottage owners on other waters where algae is also considered to be a nuisance. And so the practice of poisoning fishing waters spreads. In 1939, the number of treated lakes reached a new high of nine with the demand unsatisfied. The Board, an organization established solely to look after the best interests of wildlife, finds itself in the position of permitting and supervising copper sulphate treatments which are harmful to fish in that they destroy part of the basic food supply. The number of copper sulphate permits issued since 1936 are as follows:

1936	1
1937	3
1938	1
1939	9

The waters which have received copper sulphate applications during the past four years are: Lake Garda, Shaker Pond (Pine

FIG. 11. Bed of pickerel weed (*Pontederia*) and spatterdock (*Nuphar*). Such a habitat produces fish food organisms and also provides spawning habitats and protective cover for game and forage fishes. Crystal Lake, Stafford.

Point Lake), Mianus Pond, Beseck Lake, Hidden Lake, Bantam Lake, Dog Pond, Smith Pond, Wononpakook Lake (Long Pond), Branford River (in a swimming pool), Linsley Pond, North Farms Reservoir, and Lake Zoar. Some of these waters are small and semi-private and, therefore, are not of great interest to anglers. However, several are known to many fishermen as fine productive fishing lakes. It is probable that the lakes which were treated in 1939 will be treated in the future because a precedent has now been established. It is impossible to predict the extent of damage resulting from these treatments. The Bantam Lake situation may be cited as an example of what well may happen.

Bantam Lake is the largest natural lake in the State (916 acres) with a past reputation of providing good fishing. It has been treated with copper sulphate to control algae for at least sixteen years and possibly longer. Despite heavy stocking and other management efforts, there has been a general decline in fishing success reported.

FIG. 12. Spatterdock or yellow pond lilies (*Nuphar*) often form the favored haunt of large pickerel and largemouth bass. Vegetation such as this tends to keep the lower waters cool and retard the growth of obnoxious algae through shading. Crystal Lake, Stafford.

Studies made in 1938 and 1939 showed more than average amounts of basic fertilizers for the region. Bottom food in 1938 was greatly impoverished (about 5 per cent of the average production of over 100 lakes carefully studied here and abroad), and the lake had more than twice as much residual copper as any other studied (49.4 p.p.m. of dry weight). Growth rate studies made in 1939 showed extreme stunting of game species.

No copper sulphate treatments were made in 1938 and 1939.

Studies in 1939 showed increased bottom food, but this increase may not accurately measure recovery, since there are inherent errors in bottom sampling, and bottom food organisms are cyclic in abundance as has been pointed out previously.

It is interesting to note that the first studies of the algae in Bantam Lake, made by the State Water Commission, compare favorably quantitatively with their more recent studies. However, they do not compare qualitatively. Continued treatments have reduced the less resistant forms, which apparently has led to increased abundance of more resistant but equally obnoxious forms.

There is no information as to the rate of recovery made by lakes which have been poisoned with copper. However, the survey data does indicate that Bantam Lake may be brought back into production provided that copper sulphate treatments are discontinued. Present conditions are presented because they give a warning of what may result from continued copper sulphate treatments.

Aquatic vegetation is regarded as a nuisance in some lakes by cottage owners. Attempts to eradicate it have usually employed mechanical methods, but some chemicals have been used. Copper sulphate, which is not at all adapted to this purpose, has been tried, although concentrations strong enough to kill rooted aquatic plants will also kill most living organisms present in the water.

Weed beds are important to fish and hence to fishermen for several reasons. Several species of Connecticut game and forage fish find suitable spawning habitat only in weed beds. The survival of the young of several species depends upon the protection afforded by aquatic vegetation. The coarser water plants are not themselves used for food by game fish, but these plants do support quantities of food organisms essential to game fish production. Weed beds provide the only suitable spawning, feeding, and hiding habitat for several important Connecticut game fishes and are important to waterfowl and some fur bearers. It is not mere coincidence that the best fishing for such species as chain pickerel, largemouth black bass, calico bass, and yellow perch is in the vicinities of weed beds. The mechanical removal of weeds from limited areas to promote better swimming conditions is a reasonable compromise between fishing interests and other forms of recreation and should be permitted. The wholesale destruction of weed beds by poisoning is quite a different matter and should be opposed by all persons who are interested in future warm-water fishing.

Many arguments have been advanced attempting to prove that poisons do not harm fishing and may even be beneficial. These arguments fail to consider the fundamental principles of fish production and, in addition, are usually colored by wishful thinking. The most common examples used in these arguments are the municipal reservoirs which have been treated with copper sulphate for years and still contain large fish. It is true that such reservoirs frequently do contain large game fish and large catches of these fish have been made, but this does not invalidate the case against poisoning fishing waters. Most municipal reservoirs in Connecticut are fished surreptitiously or by a limited number of permittees. These few reservoir fishermen enjoy good fishing as might be expected. If these reservoirs were forced to support a heavy burden of fishing, as are the open fishing lakes, it seems likely they would quickly become "fished out."

FIG. 13. Heavy bloom of a blue-green algae (*Anabaena*) on Columbia Lake, Columbia, in late August of 1936. The algae rises to the surface during periods of calm weather and appears as a greenish scum.

It has been observed that fish bite better following an application of copper sulphate, probably because of its effect on algae. However, this is not improved fishing in the true sense of the word, since it fails to make the water produce more fish, but simply makes fish temporarily easier to catch.

There are some biological methods of controlling obnoxious forms of algae and aquatic vegetation without harm to fish production. Such species of fish as the golden shiner and the gizzard shad (the latter is not present in Connecticut) use considerable algae in their diet. Water plants with broad floating leaves shade the water and restrict the growth of algae. Heavy concentrations of crayfish inhibit vegetation by roiling the water and so reducing light penetration. The feeding habits of carp tend to reduce vegetation by roiling as well as actual uprooting. In lakes that produce obnoxious quantities of algae, great care should be exercised to prevent household sewage, drainage from barnyards, or wash from fertilized agricultural land from entering the water because these substances increase algae production.

The preliminary work of two English biologists[2, 5] may have practical application to the problem of controlling obnoxious algae without danger to fishing interests. The blue-green algae are the

FIG. 14. Extensive beds of pickerel weed (*Pontederia*) and spatterdock (*Nuphar*). Crystal Lake, Stafford.

ones most frequently regarded as obnoxious. It has been found that different types of algae need different concentrations of basic fertilizers for maximum abundance. It may be possible to adjust the amounts of basic fertilizers in lakes so as to inhibit the growth of blue-greens and at the same time promote the abundance of less bothersome forms. Control methods would consist of adding fertilizers rather than poisons to the water. Such treatments would serve a two-fold purpose — the control of obnoxious algae for the benefit of swimmers and the increased production of game fish for the angler.

Parasitism

The relation of fish parasites to fishing has received little or no attention in Connecticut prior to the initiation of the Lake and Pond Survey. The fact that parasitized specimens were found dead and that parasitism occasionally reached epidemic proportions was known but such matters were dismissed with the comforting thought that stocking compensated for loss and fishing would never be seriously affected. Survey data indicates that fish parasites are playing an important role in Connecticut pond fishing. The desirability of securing parasite-free stock was disregarded in past stocking activities with the result that some parasites have been distributed widely throughout the ponds and lakes of the State. The full effect of this procedure cannot be predicted at this time, but it will probably be extremely serious with some species in some lakes.

Parasites may affect fishing in four general ways: (1) by reducing natural reproduction, (2) by causing mortality, (3) by making parasitized fish undesirable or unfit for human consumption, and (4) by retarding the normal growth or development of fish.

The bass tapeworm is now widely distributed and is apparently increasing in some bass lakes. This parasite has an adverse effect on natural reproduction and its increase should be viewed with concern. In one pond (Taunton) every black bass examined was infested and natural reproduction was practically nonexistent. It appears that smallmouth bass in this lake are facing a decline in numbers as a result of infection with the bass tapeworm. Extensive stocking might be a partial substitute for lack of reproduction, but the wisdom of trying to make bass fishing under such conditions is debatable.

In 1938, a heavy infestation of leeches apparently killed nearly the entire yellow perch population in Shaw Lake (Hayward). The survey crew was located on the lake at the time; otherwise the apparent cause of mortality might never have been discovered since the leeches leave their dead victims almost at once. This particular leech is quite widely distributed in Connecticut waters, but ordinarily it does not occur in sufficient numbers to cause mortality. Similar destruction may never occur again — or it may occur at any time. The fact that a parasite which is ordinarily little more than an irritation to fish can suddenly become destructive indicates the inherent danger of carelessly introducing parasites into new waters.

So far as is now known the fish parasites in Connecticut which are potentially parasitic to man are destroyed by the usual cooking methods. Many of the larger grubs and worms are visible to the unaided eye and such parasitism detracts from the desirability of infected fish as food. The frequency with which parasitized fish are sent by fishermen to the laboratory for examination seems to be increasing. Either some parasites are increasing or fishermen are becoming more conscious of their presence.

The most disturbing aspect of the situation is that when fish parasites become established in fishing waters it is difficult, if not impossible, to effect control. Most of the common fish parasites have extremely complex life cycles often requiring two hosts in addition to fish. Parasitism is an important although much-neglected part of fishery management. In Section IV of this report information may be found on the life histories, economic importance, distribution, and relative abundance of Connecticut fish parasites.

Stunting

Most anglers know of lakes in which fish are abundant but run consistently small. Occasionally large fish are taken but the average is below "keeper" size. These are symptoms of a stunted population. Apparently most species are susceptible to stunting in varying degrees, but in Connecticut it occurs most frequently in yellow perch and to a lesser extent in white perch, smallmouth bass, largemouth bass, and pickerel. It is possible that stunted populations occurred naturally under primitive conditions, but poor management is largely responsible for present-day stunting. Stunting can be caused by environmental conditions or by heredity, but the latter might be more aptly termed dwarfing.

It is well established that some individuals of a species have the ability to grow more rapidly than others and that this tendency toward faster growth can be passed on to the progeny. This is the reason that selective breeding has been able to produce superior strains of cattle and faster growing strains of trout. Legal lengths favor the selection of slower growing strains because fishes characterized by slow growth are protected for a longer period than faster growing fishes and, therefore, have an opportunity to produce more offsprings. This means that under a heavy fishing load, with a legal length established close to the length at which fast-growing fishes reach maturity, there is a constant decline of fast-growing stock because of selective breeding. It is possible that at some future time catch regulations will prescribe only the total poundage or the total length (laid end to end) of fish which an angler may take without regard to legal lengths. At present this is pure speculation since the biological principles involved have not been sufficiently well worked out to warrant such recommendations. For the present, legal lengths should be long enough to counteract this adverse selective breeding as far as is possible.

Dwarf strains or races of several species of fish have been recognized and described, but so far as is now known the sockeye salmon is the only game species exhibiting this trait in Connecticut fresh waters. Where dwarfing does occur it is further fostered by legal lengths. Fishermen often recognize symptoms of stunting but usually attribute the cause to inbreeding and are insistent that "new blood" be introduced. As a result, the waters which display the highest degree of stunting are usually the waters which have been most heavily stocked. Excessive inbreeding may cause deterioration of stock in domestic animals, but this factor can be disregarded as causing poor fishing in Connecticut lakes and ponds. This may be due to the fact that fish are less susceptible to the ill effects of inbreeding than are warm-blooded animals or to the fact that opportunity for excessive inbreeding is practically non-existent in ponds and lakes. Stunting is not confined to those lakes which are poor in food production for it may occur in lakes which are relatively rich in food. The most common cause seems to be a combination of improper stocking and harvesting.

The presence of stunted fish populations is easily discovered by making growth rate studies of the fish. However, it is not enough to note the presence of such a condition without suggesting curative measures. Corrective measures consist of favoring those species best adapted to existing conditions and in balancing the number of fish in relation to the available food supply. This procedure is simple in principle, but lake associations are so complex that careful study is required to determine the procedures most likely to be successful. With the heavy burden of fishing that prevails in Connecticut, it seems possible that anglers could reduce overcrowded fish populations if legal lengths and creel limits were temporarily suspended. It might also be wise to prescribe a temporary closed season on predacious species such as chain pickerel which would further tend to reduce the numbers of small fish. Such a program holds promise of success in improving fishing in Bantam Lake where white and yellow perch are extremely abundant but badly stunted.

Several methods of correcting stunted fish populations have been advocated and tried in other states. Briefly, these consist of fertilizing to increase food production, stocking large predacious fish, or poisoning all fish in order to make a new start. Some of these measures could be used in Connecticut, but it appears logical to try thinning by angling first.

Lake Improvement

In many lakes it is possible to isolate factors which are limiting fish production and to plan a program of lake improvement that would probably result in an increased fish yield. Some of the more common limiting factors are lack of basic fertilizing materials, inadequate spawning facilities, lack of cover for young fish, interruptions in the food chain, and fluctuating water levels. Complicated and overcrowded fish populations are also frequently responsible for poor fishing. These problems have been discussed in separate sections and will not be repeated here.

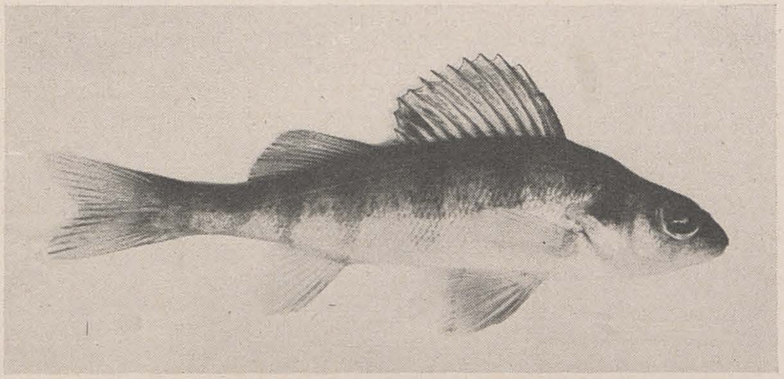

FIG. 15. Yellow perch from Bantam Lake showing stunted condition. Total length, 6 15/16 inches; age four years. Compare with Fig. 16 below.

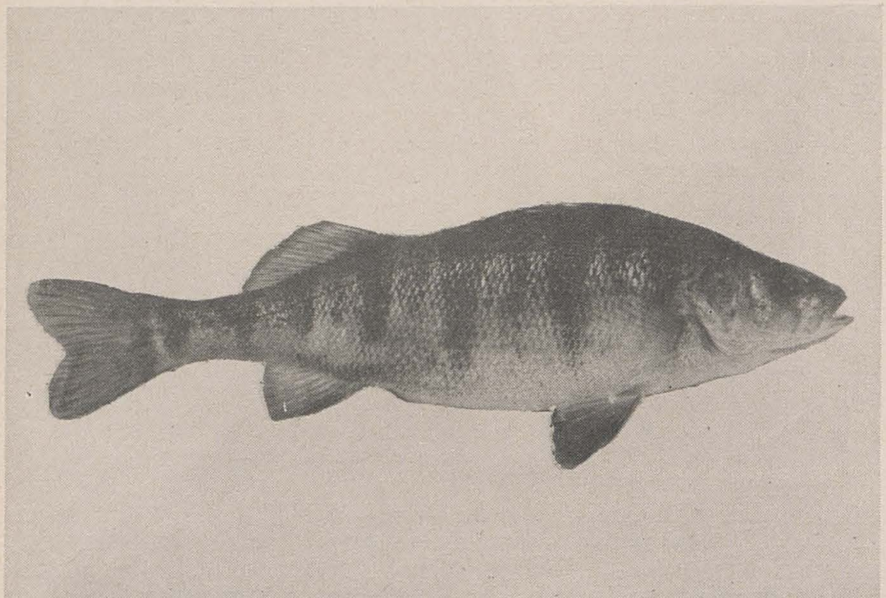

FIG. 16. Yellow perch from Waumgumbaug Lake, an example of typical growth in good perch lakes. Total length, 9 7/8 inches; age, four years. Compare with Fig. 15 above.

Experiments in Alabama have demonstrated that fish production may be increased by systematic fertilization of ponds. In many Connecticut lakes lack of phosphorus is the factor which is limiting fish production (see p. 78). It may be entirely possible to correct this deficiency by fertilizing. The expense involved may seem prohibitive, but actually it would probably cost no more than the expensive stocking carried on in the past without demonstrable results.

The role that fish themselves play in the conservation of lake fertility appears to have been neglected in recent considerations of fish production. Under primitive conditions the majority of the fish eventually died and upon decomposition returned concentrated fertilizers to the water. Connecticut lakes have been heavily fished for many years, during which time literally tons of fish have been removed. It seems entirely possible that this loss of basic fertilizers has reduced the ability of heavily fished lakes to produce fish, and that fertilization is necessary to restore the original potential productivity.

Different species have varying spawning habitat requirements. Yellow perch and pickerel customarily select weed beds or submerged brush and the young of these species need the protection afforded by such a habitat. Cottage owners frequently clean up the shores of lakes by removing submerged brush and snags and destroy aquatic vegetation. This procedure may improve the lake from the esthetic viewpoint, but it destroys valuable breeding grounds and cover for young fish. A reasonable compromise between fish production and other recreational interests is desirable, but the destruction of weed beds and other similar measures should be held to a minimum. Fish will usually gather about piles of brush placed in shallow water. This is a practice which sportsmen's clubs could easily carry on to help improve their fishing.

Smallmouth black bass are restricted in their spawning to rocky and gravel shoals. The production of smallmouth bass in many lakes with limited spawning areas might be increased by building artificial bass nests of assorted gravel in the shallows. The ill effects of changes in water level have been pointed out previously (see p. 40), but is repeated here because of its importance to fishing. Some lakes are drawn more severely than is necessary. If such fluctuations could be reduced, or at least postponed to the least harmful period of the year, fishing might be improved.

Lakes suited to pickerel and largemouth black bass sometimes fail to furnish good fishing apparently because the basic food supply is not available to them through a suitable intermediate form such as the golden shiner. In such cases, attention to the needs of these forage forms is more important than stocking the game species. Lake improvement measures should, under these conditions, attempt to provide additional spawning facilities and protection for the forage fishes.

It is impossible to outline a general program of lake improvement because each lake is a special problem and must be treated as such. In the past, improvement or maintenance of fishing was thought to be dependent only upon stocking. Increased knowledge of the life histories and interrelationships of warm-water fishes has invalidated this belief. It is now quite generally known that good fishing can be provided only by solving all of the problems presented by each body of water.

FIG. 17. Brush piles anchored in shallow water along barren shores provide needed protection for young fish. Several, such as this, have been under observation for the past several years, and are frequented by young of yellow perch, golden shiners, and chain pickerel. Columbia Lake, Columbia.

Ice Fishing

There are few topics related to fishery restoration which can produce a more heated discussion or more diversified opinions than the subject of ice fishing and its effect on summer fishing. Since the subject is important to many Connecticut anglers, it seems proper to summarize the few known facts and to explain the policies and procedures which the State Board has followed in the past.

Accurate catch records are available from one lake on which ice fishing has been permitted. On this lake the ice fishing season ended January 31st rather than on February 9th as is prescribed by State law for other open lakes. There were, on an average, six and one-half times as many summer fishermen as ice fishermen. Angling success measured in terms of fish taken per fishing hour showed that yellow perch were taken more frequently by summer fishing than by ice fishing. The reverse was true for the chain pickerel. Ice fishermen were almost exactly five times as successful as were summer fishermen in taking this species. Ice fishermen took seven per cent of the total number of yellow perch and over forty per cent of the total number of chain pick-

FIG. 18. Shoal waters in Mudge Pond, Sharon, have heavy growths of cat-tail (*Typha*), spatterdock (*Nuphar*), bullrush (*Scripus*) and pickerel weed (*Pontederia*). Shores such as this have an ample supply of cover for young fishes.

erel captured. An interesting survey of ice fishing and summer fishing in Michigan was made by Hazard and Eschmeyer[3]. They found that there were about fourteen times more fishermen in summer than in winter and that fewer lakes were fished in winter. Their average figures for the per cent of total fish caught during the winter and for the entire year are as follows:

SPECIES	PER CENT OF ANNUAL CATCH TAKEN IN WINTER	PER CENT OF SPECIES IN ANNUAL CATCH
Yellow Perch	45%	24%
Pike-Perch	3%	4%
Great Northern Pike	11%	5%
Crappie	4%	6%

The great northern pike was included in these figures because its habits are similar to chain pickerel, and the crappie because it is possible that the closely related calico bass will eventually be

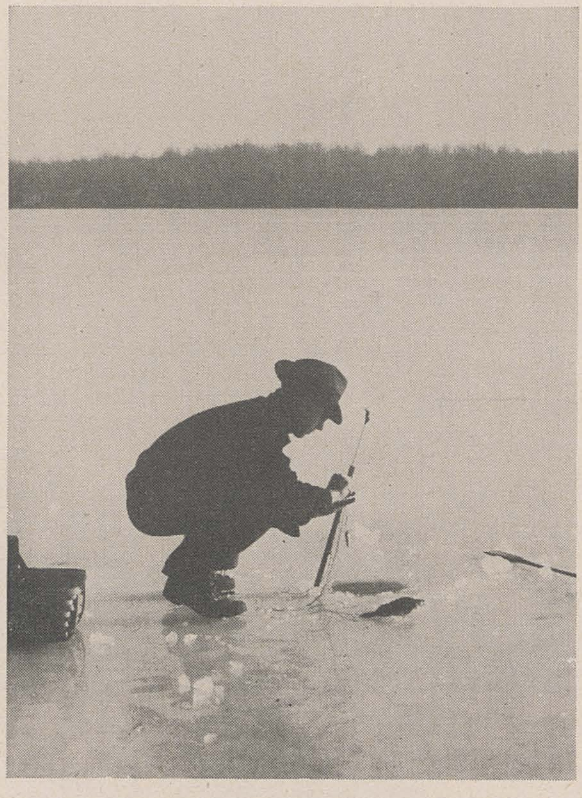

FIG. 19. Ice fishing on Columbia Lake, Columbia.

included on the ice fishing list in Connecticut. From the above figures it appears that even though the ice fishermen were only one-fourteenth as numerous as summer fishermen, they were able to take large numbers of certain species.

None of these data show whether winter fishing is more selective as to size and sex than is summer fishing, although such information is essential to an impartial consideration of the question. There is some evidence that in Connecticut, winter fishing takes the larger yellow perch and chain pickerel, and in late winter the pickerel catch consists largely of females nearly ready to spawn. Census work now in progress should supplement these preliminary findings. The general decline in pickerel fishing in Connecticut is clearly the result of over-fishing and improper catch regulations (p. 62). The pickerel is a valuable game species and, in addition, probably helps keep such prolific species as yellow perch in proper balance. For these reasons immediate steps

FIG. 20. Fishing through the ice is a favored sport with many Connecticut anglers of both sexes. Lake Pocotopaug, East Hampton.

should be taken to restore this species to its former abundance. From our present knowledge it appears that both the winter and the summer kill should be drastically reduced to accomplish this purpose.

The State Board is faced with the problem of making an inadequate fishery resource give the greatest possible recreation to the largest number of anglers. Most ice fishermen also fish during the summer, which means that an ice fisherman can, and usually does, take more than his share of fish. However, there are numerous small ponds which are more or less inaccessible during the summer months but which can be fished through the ice. These considerations have prompted the State Board to prohibit ice fishing, at least temporarily, in some of the lakes which are subjected to the heaviest summer fishing. The General Assembly prohibits ice fishing on a limited number of lakes and several lakes have been closed to ice fishing by the riparian property owners. A total of twenty-nine lakes and ponds were closed to ice fishing by these agencies during the 1939-1940 season. These closed waters represent only a small percentage of the total number of open lakes.

It seems unlikely that a blanket policy governing ice fishing should be adopted. Survey data indicates that ice fishing in some lakes should be discontinued while in other lakes it should be encouraged. Each lake is a problem in itself, and recommendations governing fishing must be based on careful study of the conditions in each body of water.

Pollution

Fortunately, pollution is not an important problem in Connecticut lakes and ponds. The Survey has not encountered any lakes in which industrial wastes or sewage is a factor limiting fish production. A small amount of household sewage finds its way into many lakes, but so far as is now known, not in quantities harmful to fish life. The effect of copper pollution has been mentioned previously and need not be repeated here. Oil pollution from motor boats appears to be more of a nuisance to bathers than a menace to fish life in the quantities in which it normally occurs. Connecticut anglers are fortunate that their lakes and ponds are free of pollution and they should insist that no new source of pollution be established. The State Water Commission has authority to deal with pollution problems and should be consulted whenever it appears that injurious substances are entering the waters of the State.

The Philosophy of Catch Regulations

In the early development of America, wildlife was so plentiful as to seem unlimited, with the result that it was exploited prodigally. The inevitable consequence was a gradual decline in abundance of many species. Scarcity of important food and game animals brought about a new appreciation of their value and the first attempts at conservation, which took the form of legislation designed to restrict the kill. As additional knowledge of the life history and habits of the various forms became available, refinements in legislation were made. Adequate reproduction is the most obvious need of wildlife. Fishery legislation attempted to guarantee perpetuation of important species by giving them protection during the spawning season, by establishing legal lengths designed to protect each age class for at least one spawning season, and by restricting the number which could be taken legally. The present fishing laws of Connecticut, as well as most other states, are based on these principles. Such legislation is essentially sound and, under some conditions, would have prevented a decline in abundance of those species protected. These methods have not been entirely successful under Connecticut conditions even though supplemented by extensive stocking.

Foresters know that the maximum production of timber results from continuous selective cutting. The stand is kept sufficiently thin so that each tree has adequate growing room. A tree is removed when it has completed its period of most efficient growth, thus making room for younger, faster-growing trees. The same basic principle of management should be applied to fishing waters. Regulations should permit fish to complete their period of most efficient growth and then insure their removal, thus making room for the growth of younger fish. Natural factors limit the pounds of fish which can be produced each year in a body of water. Catch regulations determine whether this poundage will be taken as a few large fish or as many small fish. Good fishing results when a favorable compromise is made between size and numbers. As adequate information becomes available, it will be possible to predict within reasonable limits the size and relative numbers that may be taken under a given set of catch regulations. Therefore, the fish harvest from a lake may be made to fall into sizes desired by anglers. Such regulation of fishing is possible when the growth rate of fish and the rate of their removal are known. A discussion of the data on which this statement is based and an explanation of the proposed system of regulation based on growth efficiency will show why the present statutory catch regulations have been unable to prevent a gradual decline in fishing.

For the purpose at hand, four important game fish will be used as examples. These are chain pickerel, largemouth black bass, smallmouth black bass, and yellow perch. The growth rates of these fishes appear in Fig. 21. It is obvious that the rate of growth decreases with advancing age and that this would be reflected by a leveling off of the growth curve. However, these growth curves show little of this tendency. The reason for this is that it has been impossible to secure enough old specimens to plot the level part of the curves, and this gives some hint as to the rate at which anglers remove fish. The figures on growth rate are followed by a chart (Fig. 22) showing "Burden of Fishing", or the rate at which fish are removed by Connecticut anglers. An interpretation of the probable relation of this information to reproduction and to fish populations seems to show one of the most important reasons why Connecticut pond fishing has suffered a gradual decline.

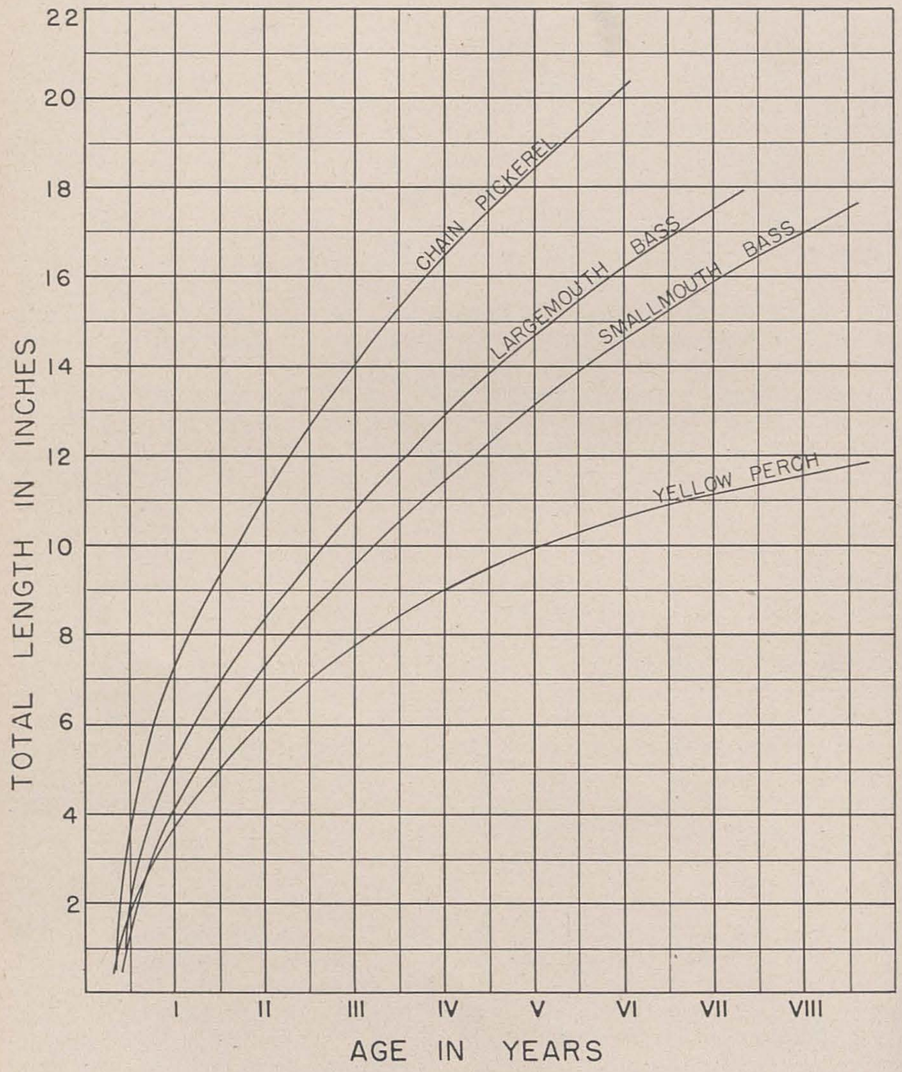

FIG. 21. Average growth curves of four important Connecticut warm-water game fishes. Based on specimens taken throughout the State. See text p. 59.

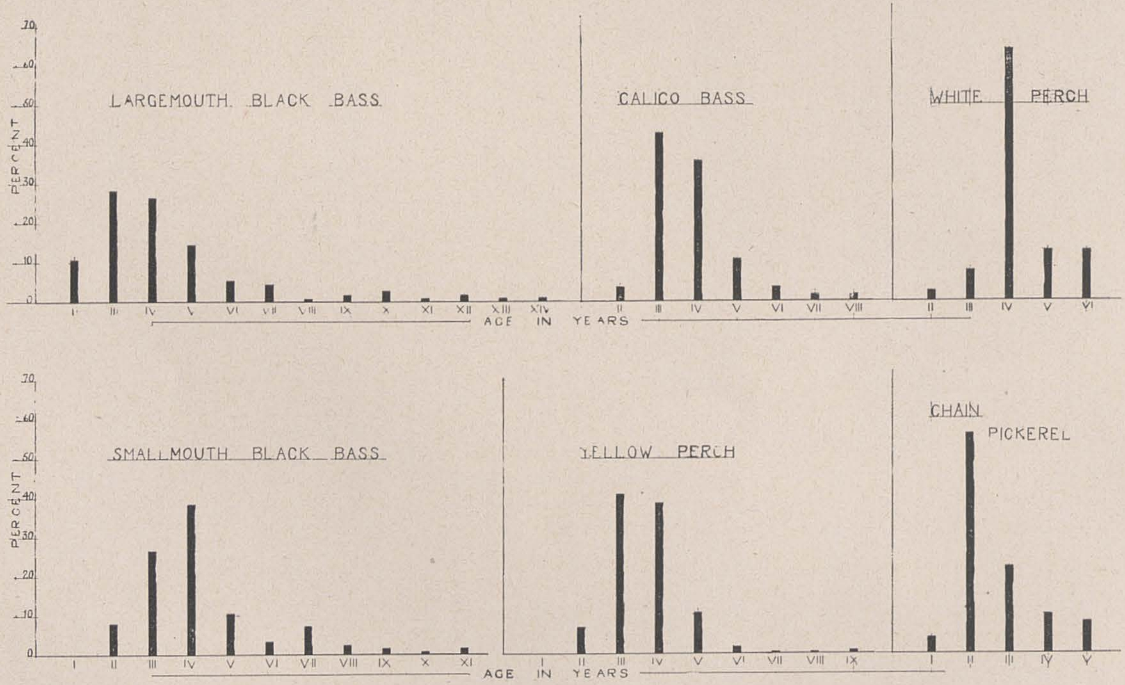

FIG. 22. FREQUENCY OF AGE GROUPS FOUND IN ANGLERS' CATCHES FROM SEVERAL CONNECTICUT LAKES
1935-1939

The growth curves are based on the average size of each year group taken. The curve for chain pickerel and largemouth bass includes all specimens examined by the Survey for the past three years. The curves for yellow perch, which have extremely variable growth in different waters, and for smallmouth bass are based on specimens secured from four lakes that provide good perch or bass fishing. Fig. 22 is based on data gathered by checking anglers' catches. A few records on old black bass have been sent in by anglers. These are not included because there is no way of determining what percentage of the anglers' total catch is represented by these older specimens.

The growth rate curves show the average age at which these species reach legal length in Connecticut. Bass and pickerel show rapid and presumably efficient growth for several years after reaching legal length. However, yellow perch show a marked decrease in growth rate at about their third year.

The Burden of Fishing chart indicates the rate at which fish are removed by angling. The data for largemouth bass, smallmouth bass, and yellow perch are similar. They show that any one year class is decimated within two years after reaching legal length. Since the first two big catch years occur when the fish are relatively young, the survival to seven years of age is small. The numbers of chain pickerel are greatly reduced in only one year after becoming legal length. The big catch of pickerel is of two-year olds and practically all pickerel are taken before they are six years of age. From the standpoint of the angler, these data mean that under the present catch regulations imposed by state law approximately 70 per cent of the largemouth bass taken will be under fourteen inches in length; 80 per cent of the smallmouth bass will be under thirteen inches; 85 per cent of the yellow perch will be under ten inches; and 80 per cent of the chain pickerel taken will measure less than seventeen inches. The bulk of the catch for each of the species is composed of fish which are too small to be regarded as prizes by anglers.

The legal lengths now in effect presumably were designed to permit adequate reproduction. Greater survival of older fish accompanied by increased natural reproduction would result if the burden of fishing were not so heavy. Yellow perch generally appear to reproduce in adequate numbers in most Connecticut lakes. In some lakes, reproduction and survival of yellow perch seem to be so successful as to produce over-crowding and, consequently, poor fishing. In some lakes, bass reproduction is poor but it is often difficult to determine whether this is the result of over-fishing alone or whether there are other contributing factors such as parasitism, changing water level, or too many competing species. Chain pickerel frequently seem to lack adequate reproduction, as might be inferred from the previous data. There seems little doubt that chain pickerel have been seriously depleted within the memory of many anglers, and it

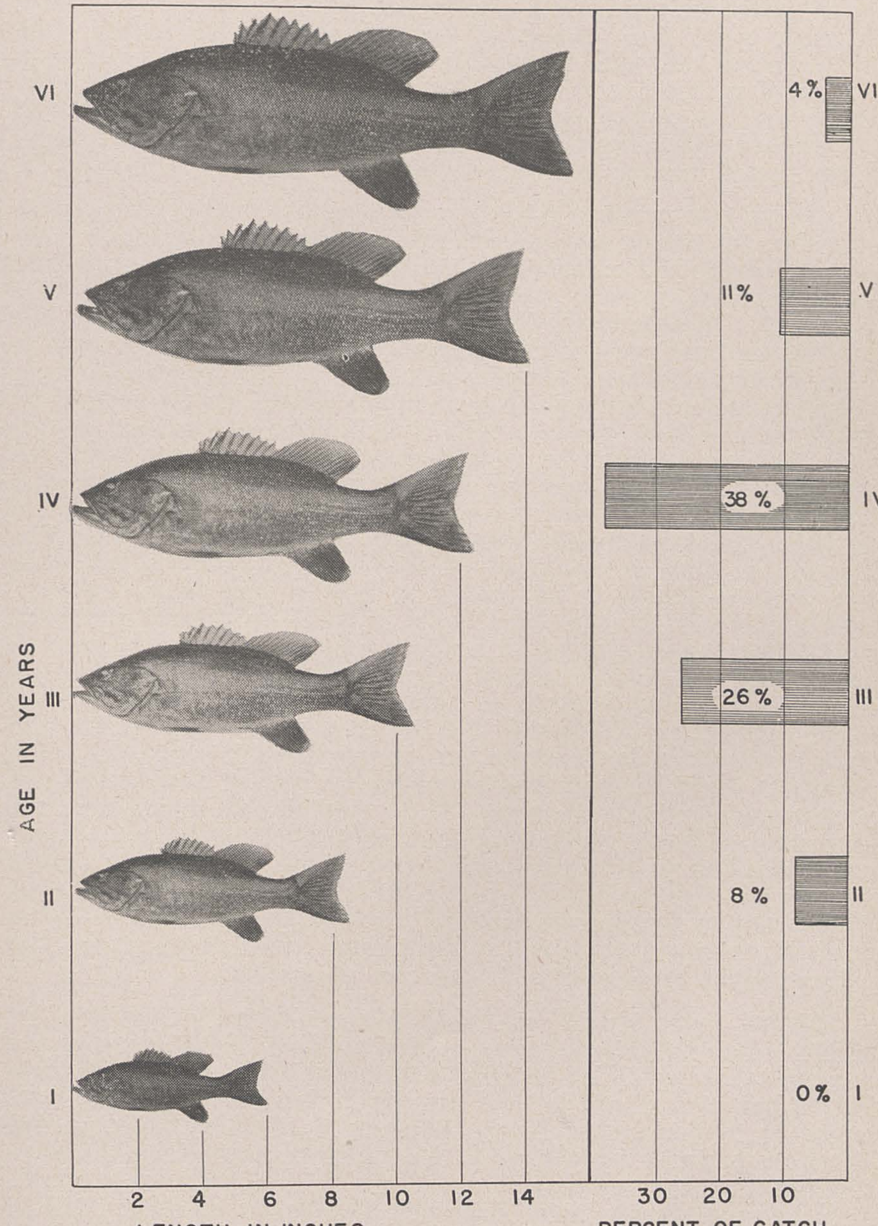

FIG. 23. The diagram shows growth and actual rate of cropping of small-mouth bass in many Connecticut lakes under a legal length of ten inches. It is apparent that the bulk of the catch (72%) is composed of fish which have just reached a legal length (10 to 12 inches). Remaining 13% not shown on the diagram is distributed among older age groups (VII to XI).

seems quite likely that this decline has also had an adverse effect on other pond fish. Many of our lakes are overcrowded with weed species and with the young of yellow perch. A large population of pickerel with adequate protection would help not only to convert this forage into game fish for the anglers, but would also relieve the competition for food which in many lakes may be the factor causing poor growth of black bass and yellow perch.

Under the present catch regulations, fish, with the possible exception of yellow perch, are removed before they have completed their period of efficient growth. This is clearly shown by comparing the growth data and the burden of fishing chart (Fig. 23). In this chart the growth rate and cropping data for smallmouth bass are presented in another form so that it may be more easily visualized. Growth rate is shown by the proportional photographic enlargement of a smallmouth bass on the left. The length of the bars at the right indicate the percentage of the total catch contributed by each year class. From this it can be seen that the major portion of the smallmouth are harvested before reaching five years of age, although growth continues to be rapid and presumably efficient for several more years. The bulk of the crop is composed of the two year classes just past legal length. There is no reason to believe that an increase in legal length within reasonable limits imposed by growth efficiency would alter the *rate* at which anglers remove fish. If the rate of removal, or the "catch pattern", remained the same as is anticipated following an increase in legal length, the result would be a larger proportion of sizeable fish in the harvest. Moreover, the catch composition by sizes or age classes would occur in a manner which could be predicted, provided the rate of removal at any given legal length was known. Thus, smallmouth bass which are harvested, as is shown in Fig. 23, under a ten inch legal length would respond to a twelve inch legal length as follows: eight per cent would be taken as 3-year olds, 26 per cent as 4-years olds, 38 per cent as 5-year olds, and 11 per cent as 6-year olds. Such a catch composition would seem more satisfactory from the angler's point of view than is the case at present.

If the legal length of chain pickerel were changed from twelve inches to sixteen inches, approximately 80 per cent of the pickerel taken would be between sixteen inches and twenty inches and 20 per cent would be over twenty inches in length. A legal length of twelve inches for smallmouth bass and sixteen inches for chain pickerel were used as examples because the data from Connecticut lakes indicate that these legal lengths would apparently be most nearly ideal from the standpoint of sport fishing, perpetuation of the species on a self-maintaining basis, and efficient utilization of available food organisms. However, the same basic principle of manipulating the catch could be used with considerable latitude in improving fishing on areas with peculiar

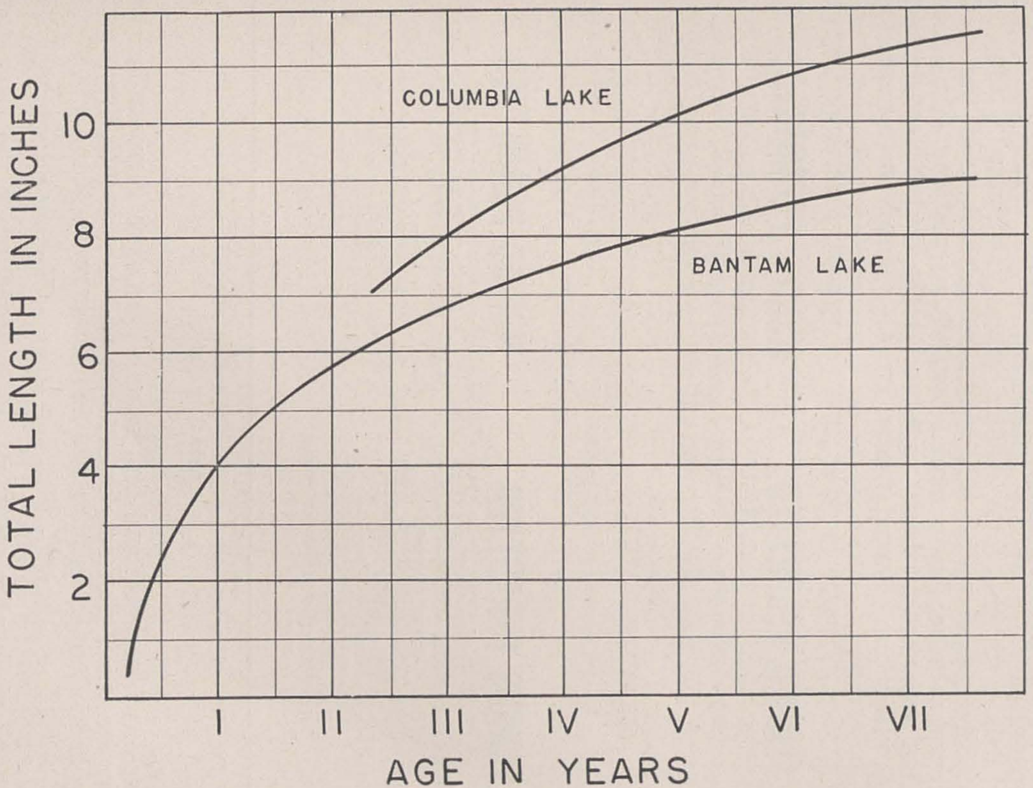

FIG. 24. An excellent example of differential growth rate in yellow perch. Recognition of such conditions is paramount to sound fishery management practices. The perch from Bantam Lake are badly stunted.

individual problems. Reference to the foregoing charts will indicate how an increase in legal length for any of the species shown will be reflected in the composition of the catch. It is entirely possible that even with the increased size limit there would be as many pickerel taken, although this would not hold true for all fish. It is possible that an increase in legal length of black bass and yellow perch would have the effect of providing fewer but larger fish, with the total pounds taken remaining nearly the same. The poundage of fish produced by each lake per year would probably not be increased by such regulations. The total pounds of game fish produced might well be increased through more efficient utilization of weed species by large carnivorous game fish

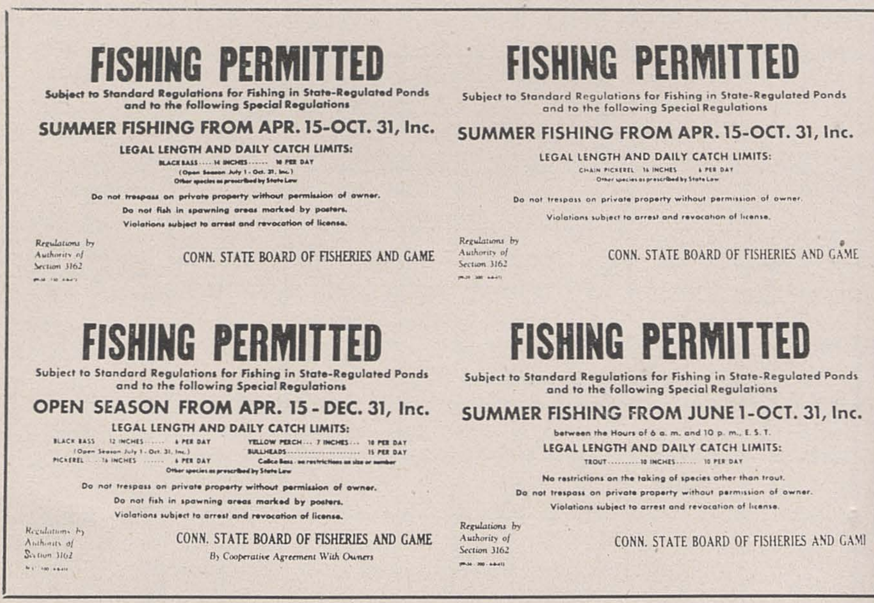

FIG. 25. Examples of posters showing special regulations on individual waters.

such as chain pickerel and largemouth bass. An increase in legal lengths for chain pickerel, largemouth and smallmouth bass seems desirable in Connecticut for the following reasons:

1. It would result in a larger stock of spawning adults.
2. It would make more satisfactory fishing in the sense that more sizable fish would be taken.
3. It should increase the total poundage of game species taken by establishing a more productive balance between species.

From our data it seems that under average Connecticut conditions, the legal length for pickerel should be at least sixteen inches and for the black basses, twelve inches. These legal lengths have been tried experimentally and in several lakes have provided greatly improved fishing. It seems inadvisable to recommend an increased legal length for yellow perch. Lakes which are now providing good yellow perch fishing are doing so under the present seven-inch law. Exceptional growth in a particular lake may warrant a slight increase in legal length, but on lakes having a stunted perch population this would only aggravate the condition.

Fig. 24 shows the growth rate made by yellow perch in two Connecticut lakes. In Columbia Lake perch grow normally and provide good fishing. In Bantam Lake perch are extremely abundant, but badly stunted and provide only poor fishing. Obviously, any procedures such as stocking, increasing the legal length, or reducing the daily creel limit of perch in Bantam Lake would make fishing worse. As long as the present growth rate is maintained in Columbia Lake, measures designed to restrict the kill are desirable. In Bantam Lake just the opposite condition prevails, and the quickest way to improve perch fishing would be to remove a large part of the present population by any practicable method.

These data on yellow perch from two lakes illustrate the point which has been made previously, that it is impossible to prescribe blanket catch regulations which will be suitable for all waters.

The legal lengths proposed are better than the ones now in effect because they are based on a knowledge of the growth made by these fish in Connecticut waters, and on a survey of the rate at which anglers harvest the pond fish crop. Their general adoption appears desirable in the interest of better fishing, but one oft repeated point must not be forgotton: each body of water constitutes an individual problem and must be managed as such for best fishing results.

The Application of the CONNECTICUT PLAN

A program of acquiring hunting and fishing rights for public use was inaugurated in 1925 as a solution to the posting problem. This procedure of securing hunting and fishing rights by gift, purchase, or lease for public use became widely known as the "Connecticut Plan".[8] At first practically all areas were either leased or purchased. The plan was modified and greatly extended in 1933 by substituting a cooperative program between the property owners and the State Board in place of cash compensation. This phase of the "Connecticut Plan" has been extensively applied to lakes and ponds and to the warm-water fish problems, so that at the present time many waters are wholly or partly controlled by this method. Apparently former Superintendent Arthur L. Clark was the first to sense that in this program there were inherent possibilities of improving lake fishing, as well as in providing for open fishing waters. The first special regulations were designed to fill obvious needs and to correct abuses of the rights of property owners. In the absence of adequate biological knowledge, most of the special fishing regulations took the form of a reduction and spreading of the catch. In some cases, these original catch regulations have since been changed as more data became available. However, the important point was not primarily the biological soundness of these far-sighted regulations, but the fact that for the first time a state had inaugurated a program of managing its impounded waters according to their individual needs. The demand for more exact biological knowledge in the management of these state-regulated waters is one of the most important justifications for inaugurating survey work. Under the Connecticut system of state-controlled waters, it is possible to make survey data provide improved fishing through individual management measures adapted to each lake and pond. Survey work aimed at supplying information for a rather complete management program is of necessity more time-consuming and expensive than would be the case if the primary objective was merely to distinguish between trout and non-trout waters. Connecticut's problem is one of securing the maximum production of game fishes from each body of water in an effort to supply recreational fishing to an extremely heavy concentration of anglers. The lake and pond survey program has been designed to serve this purpose.

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Section II.

Limnology

EDWARD S. DEEVEY, JR. and JAMES S. BISHOP

PART I. INTRODUCTION

"A lake is a landscape's most beautiful and expressive feature. It is earth's eye, on looking into which the beholder measures the depths of his own nature."

—THOREAU, "WALDEN", 1854

When Henry Thoreau wrote these words he was thinking primarily of Walden Pond, near Concord, Massachusetts, one of the most transparent of New England lakes. A reading of "Walden" and of Thoreau's "Journal" shows that the Yankee individualist was the first American to concern himself with what is now a very important field of biology—limnology, or the study of lakes. A brief paper by a Swiss physician, Auguste Forel, is usually regarded by limnologists as marking the birth of their science. However, it was not published until 1869, more than twenty years after Thoreau's sojourn on the banks of Walden. Among many important observations, Thoreau noted what is now called "thermal stratification", or the fact that the deep waters of Walden are very cold, and remarked: "How much this varied temperature must have to do with the distribution of fishes in it! The few trout must oftenest go down below in summer." Although this discovery was not published until 1906 and was anticipated by the work of Simony about 1850, it is certain that Thoreau's measurements were independent and thoroughly original.

One of Thoreau's most important generalizations may be used to illustrate the kind of question an investigation of Connecticut lakes may be expected to answer. Having noted the great transparency of Walden Pond, the sparsity of rooted vegetation along its shores, and the apparent lack of an adequate food supply for fish, Thoreau compared Walden with other lakes in Concord and noted that Flint's Pond, a shallower, less transparent body of water, not only supported a larger crop of aquatic plants, but produced a considerably larger quantity of fish per year.

With the advance of biological science and the development of new techniques, many new facts about the productivity of aquatic environments have come to light. The fundamental truth expressed in "Walden" may now be phrased in more precise, if considerably duller language. Lakes, even those situated within a radius of a few miles, can and do differ markedly in the quantity of life that inhabits them, since total production of plant and animal life is primarily dependent on the amount of available nutrient substances. These differences usually extend to all forms of aquatic life (see Fig. 4, p. 22).

The primary purpose of an investigation such as this is to estimate, as accurately as is possible, and using as many different standards of judgment as is possible, the potential ability of Connecticut lakes to produce game fish. In commercial fisheries, studies of the fish yield of an area can usually be estimated directly from catch records and statistical analysis of representative samples. The manner in which angling removes fish usually makes this method of evaluation impracticable or impossible. The most direct method is draining a lake and weighing the fish crop. Naturally, this does not appeal to property holders along the shores and, moreover, it affects the practical value of the conclusions obtained. The indirect method adopted of evaluating the potential productivity of a given lake is based on estimates of other types of life present. From these data it is possible to predict, within reasonably close limits, the capacity of the lake to produce fish.

FIG. 1. Columbia Lake, Columbia, one of the larger bodies of water in the eastern highland region.

If Connecticut were a virgin territory, this, perhaps, would be our only aim. Under natural conditions, populations would be essentially in equilibrium, although subject to the mysterious fluctuations that make agriculture or game management difficult. We would then desire to know the potential productivity, and adjust catch regulations so that maximum yield could be maintained. However, in many cases fish have been removed beyond all justification, while native species have been unwisely replaced by foreign ones, in some instances often unfairly competitive species, or the lakes themselves have been tampered with and new ones formed.

FIG. 2. Twin Lakes, Canaan, are in the Taconic section of Connecticut.

PART II. THE LAKE AS AN ENVIRONMENT FOR FISH

To give a better understanding of the detailed results of this section of the survey, a brief description of the important physical, chemical, and biological features of lakes will be made, and the important differences between neighboring lakes will be noted.

TEMPERATURE

For a few weeks after the ice breaks up in the spring, it is possible for the wind to mix the water in a lake from top to bottom. But as the air temperature rises, the surface waters also warm up, becoming lighter as they do so. The relation between the temperature and the density of water is such that it quickly becomes impossible for complete circulation to take place in lakes deeper than about thirty feet. As a result of the incomplete distribution of heat through the lake by the wind, the deepest waters remain cold and cut off from circulation, and the lake becomes divided into three layers on the basis of the temperature curve (Figs. 3 and 4). This division into three layers is called thermal stratification.

A. The *epilimnion* or "upper layer" is the upper, warm, more or less freely circulating region of approximately uniform temperature. This layer varies in depth with the area of the lake exposed to effective wind action and with the protection offered by the surrounding country, but, in general, is not deeper than 26 feet in Connecticut and usually does not exceed 16 feet.

B. The *thermocline* or "middle layer", or region of rapid change in temperature, is usually defined by a change in temperature of 1.8° F. per 3.28 feet change in depth (1° C. per 1 meter of depth).

C. The *hypolimnion* or "lower layer" is cut off from circulation after development of the temperature curve shown in Fig. 4 and is consequently a cold region of approximately uniform temperature.

Since fishes differ widely in their temperature requirements, part of the biological effect of thermal stratification on fish is direct. Lake trout and whitefish inhabit the lower layer or hypolimnion, perch and bass the upper layer or epilimnion, while the rainbow trout, which can stand somewhat higher temperatures than other trout, are frequently found in the middle layer or thermocline.

Light

The plant life of a lake is of two sorts: the visible, rooted vegetation (pond weeds, water lilies, etc.), and the microscopic freely floating algae. Although invisible, the algae are quantitatively much more abundant in many lakes than the rooted vegetation, since they are not confined to the shallow water at the edges of the lake but inhabit the entire body of open water. Free-floating algae share this characteristic with microscopic animals such as small crustaceans and rotifers which also inhabit the entire lake. Collectively, all of this floating life of the lake is called plankton. The plant and animal proportions called, respectively, phytoplankton and zooplankton, vary greatly in different lakes and at different depths and times.

Neglecting the planktonic animals temporarily, it is important to bear in mind that plants, both rooted and plankton forms, require light for photosynthesis, and the depth to which light penetrates into water of different lakes is exceedingly variable. It is reduced very rapidly in passing through the first few feet of water and more slowly after that. The chief factors causing variations in the depth of light penetration are plankton itself, mineral particles in suspension (silt), and the brown stain or humus derived from decaying vegetation (swamps and bogs) in

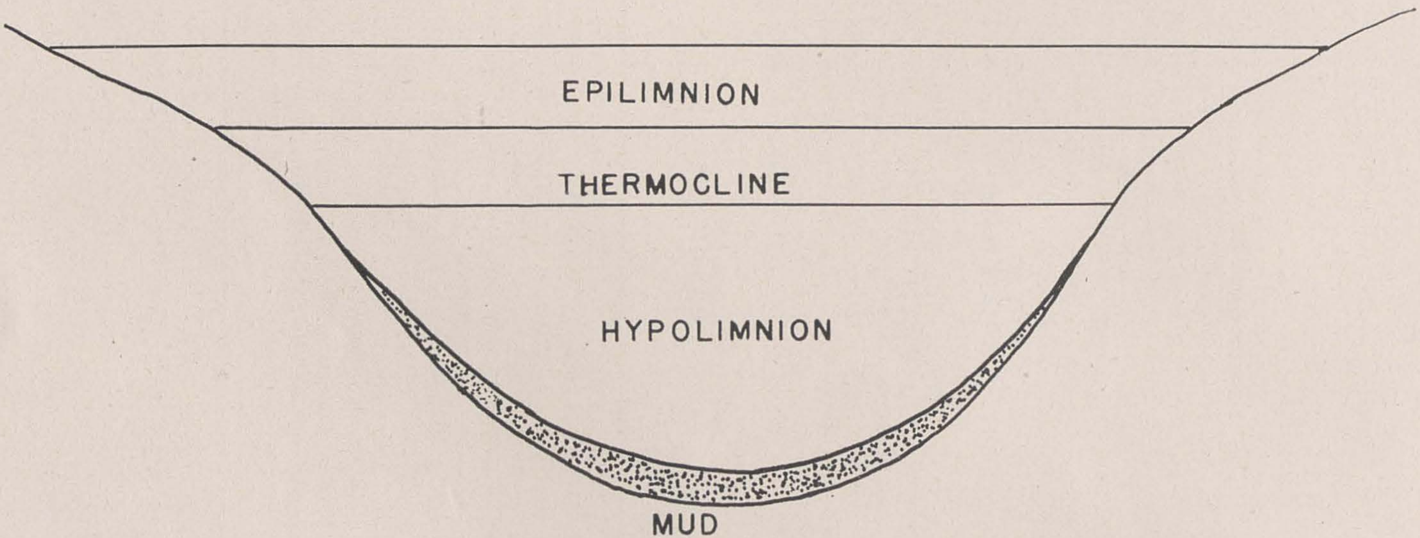


FIG. 3. Diagrammatic cross section of a typical lake, showing stratification based on temperature. Only lakes approximately thirty feet or deeper stratify in this manner.

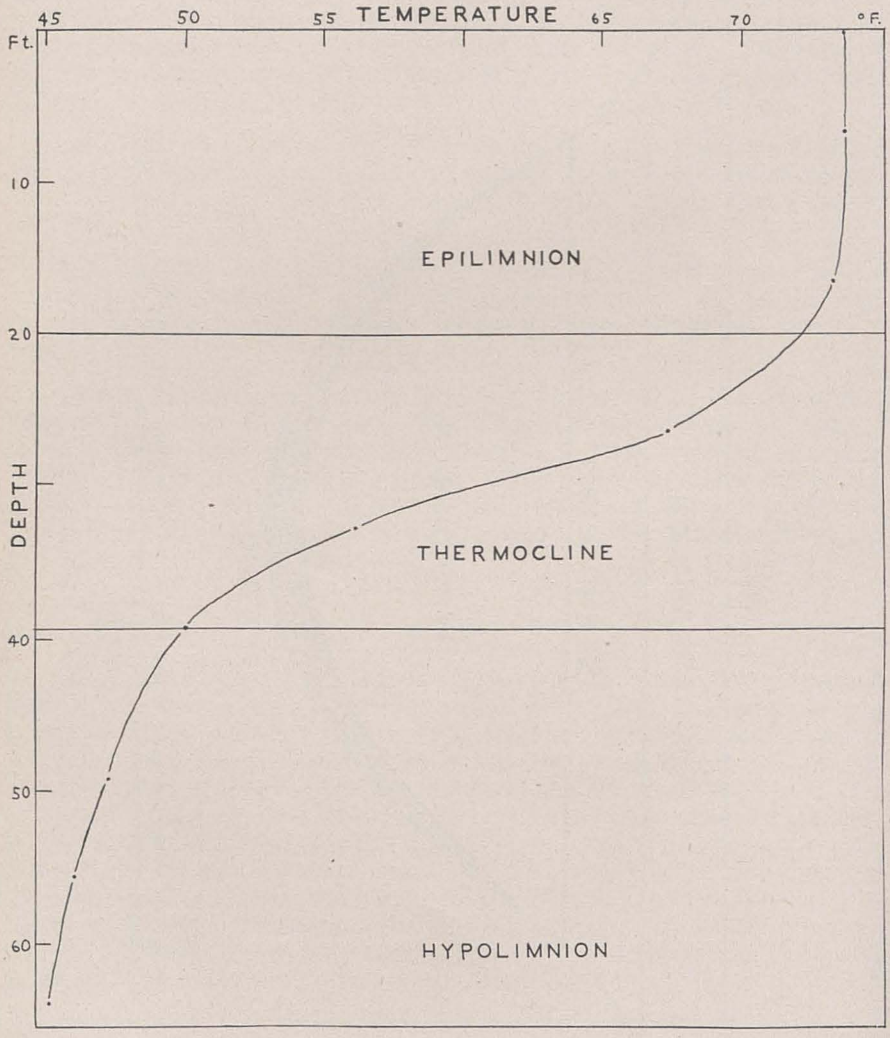


FIG. 4. A typical temperature curve (East Twin Lake, September 1, 1938).

the drainage basin of the lake. The result of this reduction in light is that the upper waters of the lake are the only layers in which the production of new food can take place. This region in which light intensity is adequate to permit photosynthesis is often referred to as the zone of production or the trophogenic zone. In the lower waters, the consumption of organic matter by animals, and especially by bacteria, exceeds production by plants. This region is called the tropholytic zone. The exact position of the compensation level which separates the two zones is difficult to fix, as different species of plants vary widely in their light requirements, and since the introduction of foreign matter such as peaty extractives changes the quality as well as reduces the intensity of the light. In other words, humic stain reduces the penetrating power of different wave lengths of light differentially. Obviously, variations in light penetration, other factors being equal, determine the lower limit at which rooted plants can grow, and thus determine the lower limits of weed beds, an important foraging ground for many fish. The lower limit of rooted vegetation in Connecticut lakes varies from about eight feet in Moodus Reservoir to about forty feet in Wononscopomuc Lake, and this is a fairly typical range for small lakes. Much greater depths for rooted plants are on record. For example, two species of moss were found growing at 400 feet in Crater Lake, Oregon,[11] probably the clearest lake in the world.

Dissolved Oxygen

The great biological importance of thermal stratification lies not only in its direct effect on aquatic life, but in the chemical changes that take place during the summer in the hypolimnion. The oxygen combined with hydrogen as water is not available to aquatic organisms. All permanently aquatic forms are dependent on oxygen dissolved in the water. Oxygen in lakes either comes from the air or from aquatic plants as a by-product of photosynthesis. Oxygen derived from the air must be mixed through the lake by the wind, as the diffusion of oxygen through still water is negligible. After thermal stratification is established, the lower layer, or hypolimnion, receives little additional oxygen by wind-generated, turbulent mixing. Unless the lake is transparent enough to support algae in the deeper layers, the endowment of oxygen present during the spring circulation is gradually depleted by the decomposition of dying plankton organisms. If the lake is deep and the amount of plankton present is comparatively small, the oxygen deficiency may not be very serious. Wononscopomuc Lake is an example of this class. However, if the lake is comparatively shallow and highly productive of plankton, the oxygen may be nearly exhausted from the hypolimnion by midsummer, and this layer, although extremely rich in bottom fauna (insect larvae, worms, etc.) becomes uninhabitable for most species of fish. Linsley Pond is an excellent example of this type of lake. Oxygen curves for these two lakes may be compared in Fig. 5.

These variations in oxygen determine, in part, the distribution and habitats of aquatic organisms, since different organisms vary considerably in the amount of oxygen they require for existence. To determine the species best suited to the various lakes,

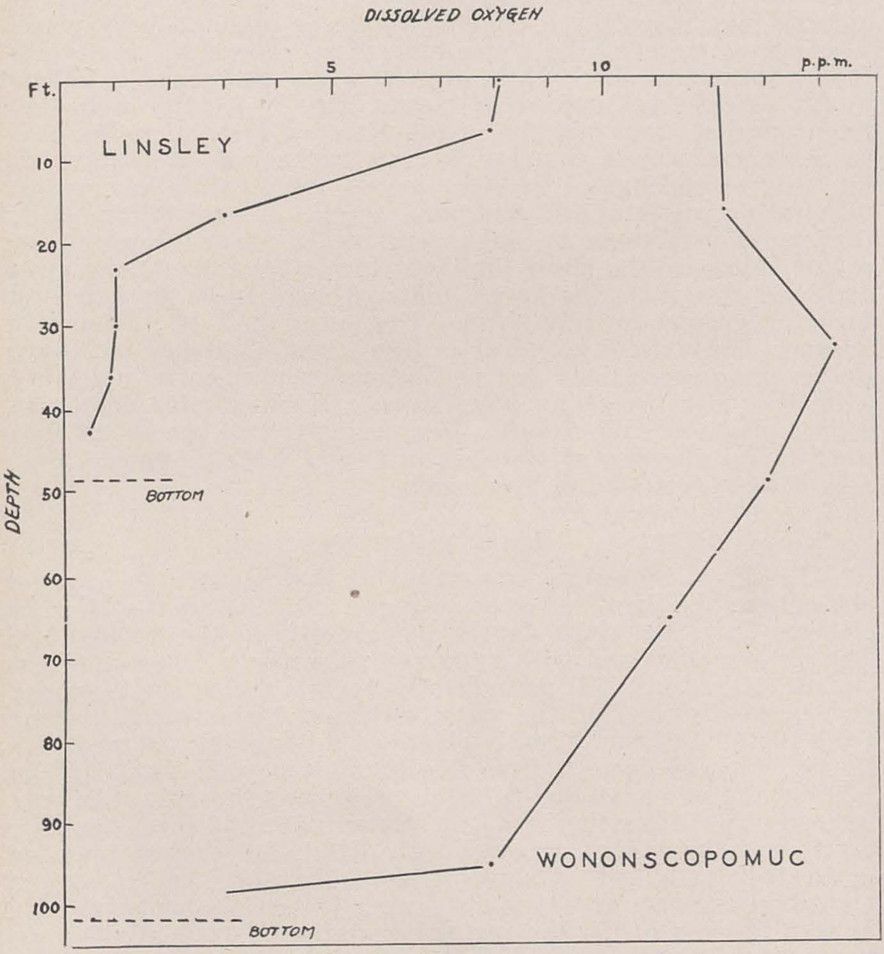


FIG. 5. Dissolved oxygen curves for Linsley Pond and Wononscopomuc Lake, showing extremely dissimilar conditions. Analysis for Linsley Pond made September 16, 1938; for Wononscopomuc, August 31, 1938.

an intelligent fish management program must take the oxygen curves and the amount of water available to various species throughout the year into consideration.

Investigations made by Riley[35] on Linsley Pond have shown the possibility of photosynthesis at all depths down to the bottom

(49 feet); but the amount of oxygen produced in the lower layer (hypolimnion) is very small and is insufficient to raise the concentration to a level that can be tolerated by most species of fish. On the other hand, several series of oxygen determinations made by the Survey on East Twin Lake show clearly that photosynthesis can occur throughout the hypolimnion in this transparent, deep lake (75 feet) in sufficient quantity to improve the habitability of the lower water for fishes.

The use of less refined methods in analyzing the oxygen content of lakes has led to the frequently expressed conclusion that some animals, particularly the mud-dwelling, "blood worm" larva of the midge, *Chironomus,* are able to live without oxygen for the several months of summer stagnation. It has been shown experimentally that this type of existence is impossible for any animal for longer than a few hours, but that *Chironomus* can survive at oxygen concentrations well below one part per million. The fact remains, however, that many Connecticut lakes, and the bottom waters of nearly all, show oxygen concentrations too low to support fish life.

Other Chemical Conditions

Lakes vary in the degree of hardness of their water and this is dependent on the amount of carbonates available in the water. This fact is frequently of great, although indirect, importance to fishing. The chemical complexities of the "bicarbonate equilibrium" need not be discussed here, but attention is often called to the fact that aquatic plants, including algae, can utilize bicarbonate as well as free carbon dioxide in photosynthesis. It will be shown later (pp. 105-108) that the soluble carbonates of lakes of low to moderate hardness have a negligible effect in determining the amount of phytoplankton. The importance of this fact cannot be over-estimated. In waters of extreme hardness, bicarbonate (which usually enters lakes as calcium bicarbonate derived from limestone in the drainage basin) has a harmful effect on plankton. Hardwater lakes, such as Wononscopomuc and East Twin in the limestone areas of Litchfield County, are characterized by the luxuriant growth of a rooted alga, *Chara,* which precipitates calcium carbonate on its stems and leaves and on the surrounding bottom. Other plants have the same property when the water is of sufficient hardness. It has been shown both experimentally and by direct observation that the chemical precipitation of calcium carbonate (marl) also leads to the precipitation of the essential nutrient element, phosphorus, which is taken from solution as insoluble calcium phosphate.[9] This leads to a phosphorus deficiency which may be responsible for a reduction in the amount of plankton. This is clearly indicated by the Connecticut data and the reports of Naumann in Sweden.[28]

Closely bound up with the bicarbonate equilibrium is the amount of free carbon dioxide dissolved in the lake waters. This compound has not been studied in Connecticut, since all other investigations have shown that in natural waters it is always adequate for photosynthesis and never present in sufficiently high quantities to be injurious to fish.

The substances of the greatest importance in the economy of lakes are the nutrient substances, phosphorus and nitrogen. These are essential to the growth of plants and, therefore, to the welfare of all life in lakes, since in any environment the plants are the producers and animals the consumers. It is, of course, realized that many other elements are essential to plant growth. However, nitrogen and phosphorus, particularly the latter in Connecticut, are most frequently deficient in natural environments, and thus act as factors limiting productivity.

From the standpoint of planktonic algae, nitrogen is somewhat the easier of the two to secure, since it is "fixed" (made available) from the air during lightning discharges and brought to the lake dissolved in rain water. Atmospheric nitrogen is also continually being "fixed" by bacteria and blue-green algae within the lake. The biological cycle of nitrogen is complicated by the fact that once a nitrogen atom has become plant or animal matter it is more difficult to remove in order to continue the cycle than is the case with phosphorus.

Fundamentally, lakes are dependent for their phosphorus supply on the phosphorus combined in the surrounding rocks, which is released by the erosive action of streams. Differences in the content of rocks and the amount of erosive action makes certain regions of the world much less productive than others, both from the standpoint of plankton production in lakes and from that of agriculture. The study of the phosphorus content of Connecticut lake waters, reported in a later chapter, indicates strongly that apart from the Connecticut Valley, where agricultural fertilization has been intensive, Connecticut waters are unusually deficient in this element. As a result, phosphorus exercises a remarkably complete control over plankton production and, through the plankton, over all of the organisms which are directly or indirectly dependent upon it. Some Connecticut lakes, such as Green Falls Reservoir and Shenipsit Lake, show the lowest contents of total phosphorus ever recorded, a fact which has to be taken into account in estimating their ability to produce fish.

Apart from the primary endowment of phosphorus in lake waters, the "internal cycle", or cycle of combination and release of phosphorus within the lake itself, is of very great importance. This might be likened to the well-known principle in economics that a small amount of capital capable of rapid turnover ("fluid assets") is much more desirable than an infinite amount of "frozen" capital. The internal cycle of phosphorus is only slowly becoming understood, but it is clear that, under certain conditions, phosphorus can readily be reclaimed from the mud, where it has been delivered by the death of planktonic organisms, and thus made accessible for a new crop of plankton (see Fig. 6). Studies made by Hutchinson[13] on Linsley Pond have made clear the importance of *iron* in improving the fluidity of the phosphorus capital, and thus gearing up the productivity of the lake beyond that which might be expected from its phosphorus content.

PLANKTON

Plankton, defined previously as the floating microscopic life of lake waters, is extremely important in the economy of lakes; the plant fraction, or phytoplankton, contains the producing members of the "balanced aquarium" and provides organic food for all the other members of the food chain in the lake, either directly or indirectly through decomposition. The zooplankton, or animal component, feeds directly upon the phytoplankton, while the mud-dwelling bottom fauna utilizes organic matter delivered to the mud in the form of dead plankton. Nutrient material is released for the benefit of rooted vegetation by the decomposition of plankton in shallow waters. A large population of sedentary animals utilize rooted vegetation for support while filtering out planktonic algae for food. The fish, which comprise the most important member of the food chain, utilize all these sources of supply, and thus are directly or indirectly dependent on plankton. In general, the smaller fish use plankton directly, the larger ones indirectly, but many large fish feed directly on zooplankton, as for example, the whitefish and the rainbow trout.

Plankton is often important for other reasons. The action of suspended microscopic life in reducing light penetration, and thus limiting the vertical extension of weed beds of higher vegetation, has been mentioned. Certain types of plankton are important because they serve as intermediate hosts for a number of fish parasites. For example, many roundworms (nematodes), spiny-headed worms, and tapeworms use plankton organisms in this fashion. Another effect, fortunately of rare occurrence, which may be of supreme importance to fishing is that in lakes supplied with large amounts of the fertilizing nutrient materials, plankton production is often excessive, giving rise to "water bloom", or scums of living and dead algae. In popular language, the lake "works". After a bloom of this sort, which usually takes place in shallow lakes at high temperatures, decomposition of the dead plankton may lead to a complete exhaustion of the dissolved oxygen within an astonishing short time, and fish caught in this way are in danger of asphyxiation. In the case of the incident at North Farms Reservoir in 1935, the circumstances were exactly these, while the final contributing cause was a very calm night, with consequent lack of renewal of oxygen by mixing. Fish died in great numbers, and apparently the only survivors were those small enough to stay in the surface film and breathe oxygen supplied by direct diffusion from the air. Similar conditions are reported from other states[31] where decomposition of a mid-winter plankton bloom has been known to asphyxiate the fish under the ice.

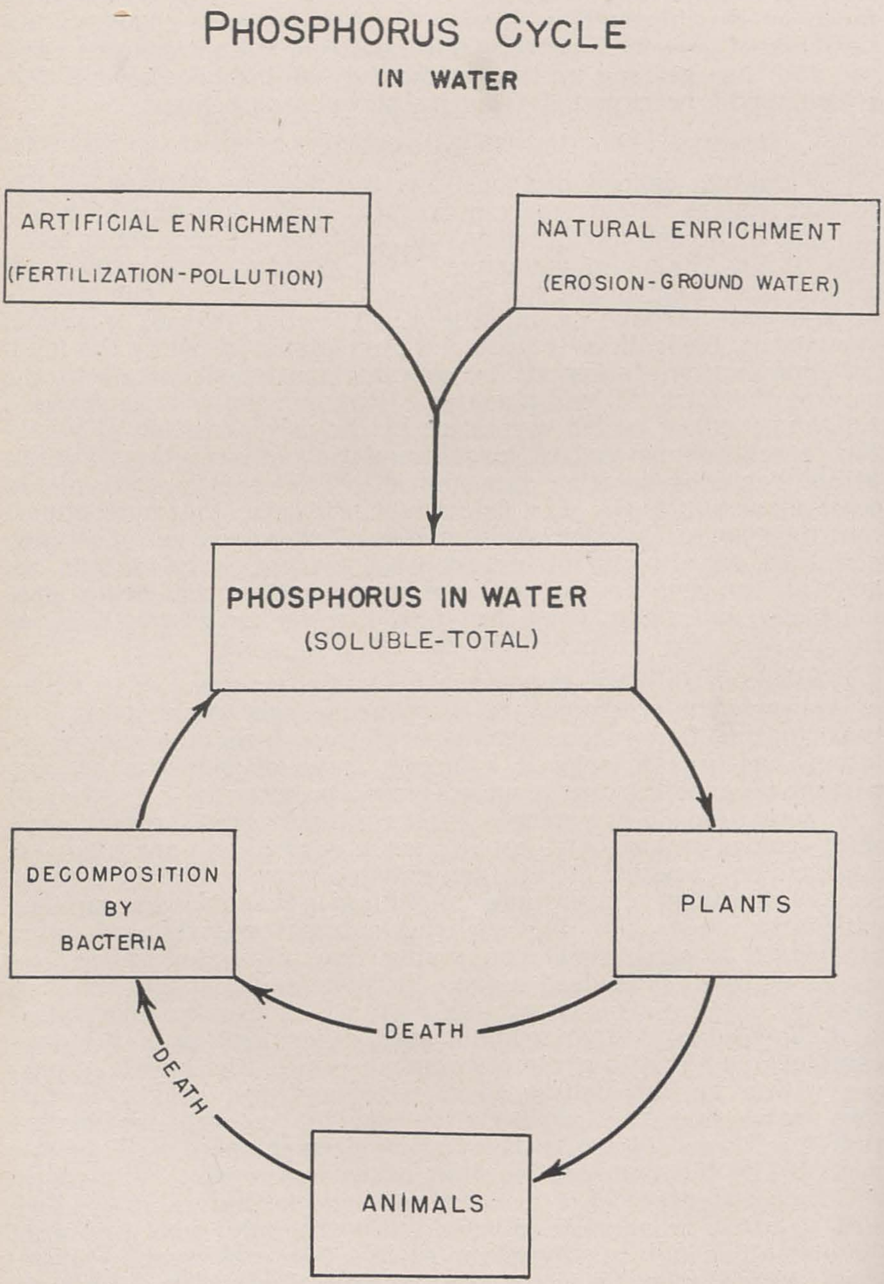


FIG. 6. The cycle of combination and release of phosphorus in lakes and ponds.

The "working" of lakes is not usually harmful to fish and is restricted to a relatively small proportion of Connecticut lakes. Indirectly, however, "working" may lead to the introduction of copper sulphate by those having proprietary interest in bathing. This pollution may cause additional harm to fishing.

Bottom Fauna

In evaluating the potential ability of a lake to produce fish, probably no single standard is so important as an estimate of the amount of bottom fauna. The estimation of bottom fauna, however, presents some of the most difficult problems encountered by the investigator, since field methods are cumbersome and laboratory work is extremely time-consuming. In the Connecticut Survey, many important facts have come to light and some hitherto unproved theories have been confirmed; yet we are still far from a complete understanding of the factors controlling variations of bottom fauna or of the exact role of bottom fauna in the economy of lakes.

A. Depth Zones

Before summarizing the essential facts concerning the distribution of bottom fauna, it is necessary to distinguish between regions of widely different environmental characteristics. The accepted division of a lake into three zones is rather arbitrary. It is often impossible to identify the limits with certainty; but certain conventions have been suggested by Eggleton[5] and others which are applicable to small, essentially uniform lakes such as those of Connecticut. These definitions refer only to stratified lakes.

The shallow water region along the shore is called the littoral zone. This extends from the surface down to the maximum depth of rooted aquatic vegetation, and is a region of high transparency, turbulent mixing, and strong wave action, particularly in the upper five to ten feet. As a result of water movements many parts of the zone, especially exposed to shoals, are barren, not only of vegetation but also of organic sediment and aquatic animals. It usually corresponds to the region of the epilimnion.

The deep water region is known as the profundal zone. This is a permanently cold, badly lighted region, lacking in rooted vegetation, and often subject to marked oxygen deficiency during summer stagnation. Its sediment is usually a rich, soft, brown or black mud. Its upper limit corresponds to the intersection of the slope and the bottom of the thermocline.

The poorly-defined zone lying between these two is the sublittoral. It may have scattered littoral vegetation, and in exceptionally transparent lakes like Wononscopomuc, a well developed zone of Charophytes (the large attached algae *Chara* and *Nitella*) may occupy the entire zone; quite frequently, on the other hand, soft, nearly typical profundal sediments may occur. A characteristic feature of this zone when molluscs are prominent in the littoral fauna, as in the hard-water Wononscopomuc and East Twin Lakes, is the presence of a bed of empty and slowly dissolving mollusc shells, called by Lundbeck[21] the "shell zone". These shells have been transported by wave action from the zone of maximum abundance of living molluscs, namely the littoral.

B. Vertical Distribution of Bottom Fauna

The littoral zone is primarily inhabited by insects which either require well-oxygenated water, like nymphs of mayflies, dragon-flies, and larvae of caddis-flies, or by those which must make frequent trips to the surface to obtain oxygen from the air, like water-bugs and aquatic beetles. The food of the littoral animals is derived from or found living upon rooted aquatic plants, or, less abundantly, it is found under rocks and stones on rocky shoals. Most molluscs are restricted to this zone by their high oxygen demand.

The profundal zone is populated by a number of mud-dwelling forms, of which the Chironomid (midge) larvae are the most important. The aquatic earthworms (Tubificidae) are likewise at home in the profundal; the food of the mud-dwellers is derived from direct consumption of the mud. In most lakes the phantom-midge larvae (*Chaoborus*) is also restricted to profundal bottoms, and where the oxygen deficiency is most marked these animals may completely dominate the fauna; 122,000 per square yard were encountered in Linsley Pond in February, 1938 (a record for this animal). *Chaoborus* is enabled to withstand a severe lack of oxygen by virtue of two pairs of air sacs which it employs to raise it to the upper waters at night. *Chaoborus* is carnivorous, and feeds on Chironomids and bottom-dwelling copepods, as does at least one Chironomid form, *Tanypus*.

The relative abundance of fauna in the different depth zones depends upon the type of the lake. It has been shown by Lundbeck,[21, 22] Miyadi,[26] the senior author, and others that the deepest lakes (those poorest in plankton and richest in oxygen in the lower layers and having muds most deficient in organic matter) are relatively poor in bottom fauna, particularly on the deepest bottoms. The shallower lakes, on the other hand, with more plankton and less oxygen in the hypolimnion and with more organic muds are quite rich in bottom fauna, and relatively richer on the deepest bottoms. Lundbeck adds to this general statement certain qualifications. Regardless of the type of lake, those rich in molluscs (usually hardwater lakes) have vastly greater quantities of bottom fauna in the littoral zone than in the profundal; very deep but plankton-productive lakes have a maximum bottom productivity in the upper profundal, but the quantity of bottom fauna falls off as the deepest bottoms are approached. However, in most lakes a sublittoral minimum is found

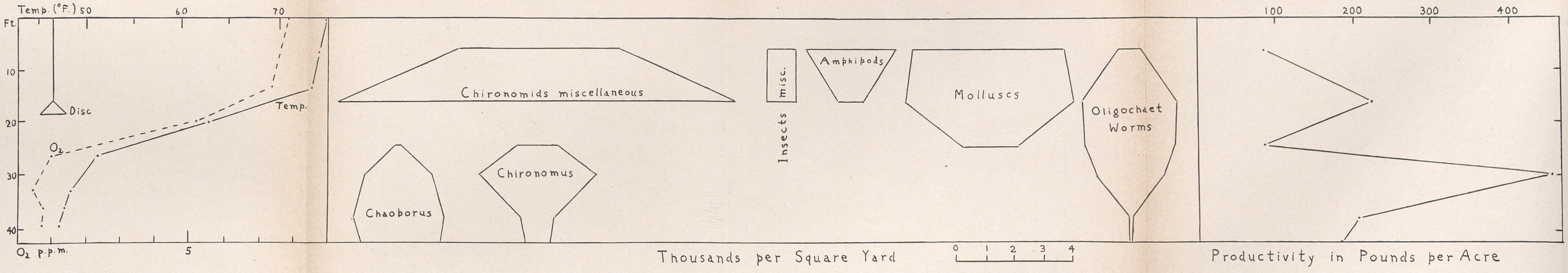


FIG. 7. Temperature, dissolved oxygen, transparency, and bottom fauna for Mt. Tom Pond, August 26, 1938. Bottom fauna polygons refer to numbers of organisms per square yard; graph at right of figure indicates total weight of organisms per acre.

Note that a smaller number of profundal organisms is responsible for a greater total productivity than in Long Pond. Concentration zone is evident at 30 feet. This is a midsummer phenomenon.

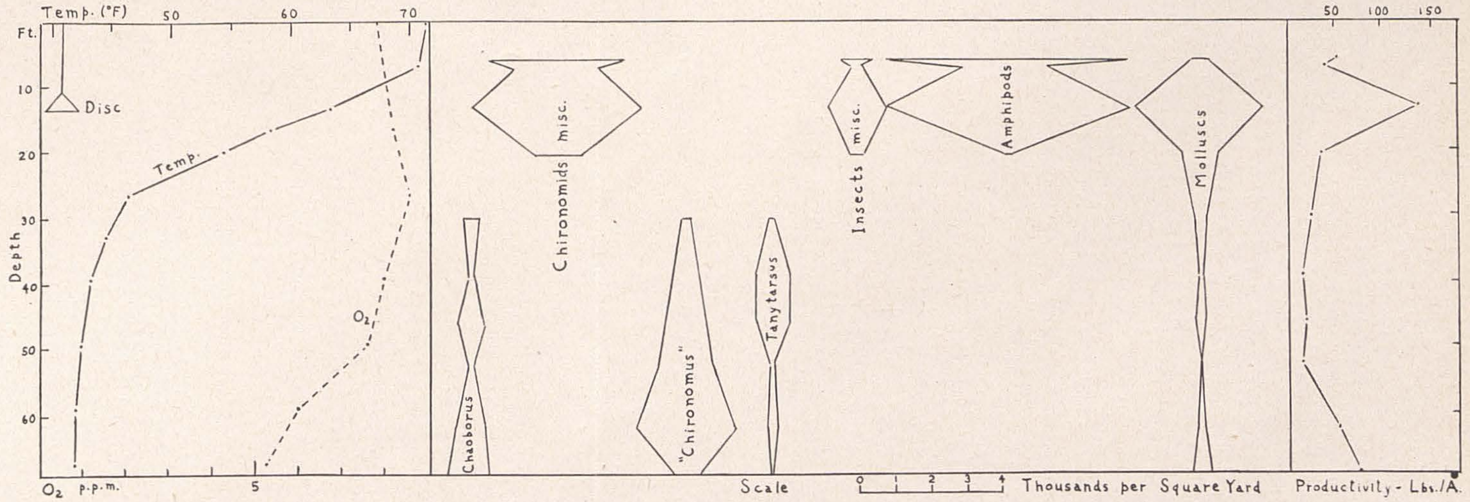


FIG. 8. Temperature, dissolved oxygen, transparency, and bottom fauna for Long Pond, Ledyard. Analysis made July 3, 1938. Note maximum weight in littoral zone in this lake.

in the vertical distribution of bottom fauna, the causes of which are not known.

As illustrations of the two types of bottom fauna distribution, Figs. 7 and 8 are presented, showing conditions in Mt. Tom Pond and Long Pond in 1938. It is hoped that a study of these figures will bring out more clearly than any description the differences in distribution just mentioned; both qualitative and quantitative differences can be seen.

That the distribution and amount of bottom fauna should vary with the seasons might be expected, and has been strikingly shown for profundal animals by Eggleton[5] and by Miyadi and Hazama[27]; a similar analysis based on material from Linsley Pond (12 series) and Lake Quassapaug (4 series) will soon be available. In general it may be said that the quantity of bottom fauna is materially reduced in summer by the emergence of the insect members of the population. This fact is unfortunate, since it prevents a consideration of the maximum productivity of bottom fauna from data obtained in a summer survey, but it is hoped that summer data will permit valid comparisons between lakes. It has also been shown by Eggleton and also the senior author that the profundal species, which are usually found in increasing numbers with increasing depth in the late winter and early spring, undertake a form of vertical migration (migration up the slope) as oxygen deficiency begins to make itself felt in the deepest water in the early summer. This "migration" is difficult to understand, but the fact remains that in midsummer a markedly productive zone is usually found in the upper profundal zone of oxygen-poor lakes, and is called the concentration zone. (See Fig. 7, p. 82a). Its importance in bringing a source of food supply within comparatively easy reach of foraging shore-inhabiting fish can be readily imagined.

Whatever the type of distribution in a lake, it is clear that the bottom fauna is more available to fish in the littoral zone, and it is the experience of every sportsman that the weedbeds are the best fishing grounds for such fish as pickerel, bass and perch. In order to obtain food in the profundal zone, a fish must grub in the mud, and cannot trust to his eyes in foraging. If the profundal is particularly rich in food, it will nearly always be unavailable for feeding during summer stagnation, since in general the more productive the lake, the greater the oxygen deficiency. Those fish that can best stand low oxygen concentrations are best fitted to make use of this provender. The yellow perch is known to make short plundering expeditions into the profundal and probably is able to take advantage of this food supply.

C. Quantity of Bottom Fauna

Although a complete mathematical description of the factors controlling productivity of bottom fauna is not yet possible, it is clear from the results of the Survey that plankton productivity is the most important of these. Of the other factors examined, nutrient content of the mud (as measured by organic nitrogen content) and the amount of oxygen present play little part. The detailed basis for this conclusion will be presented in a later chapter (pp. 110-114). That it is of the utmost importance to the fisherman may be seen from the consideration that plankton productivity is considerably easier to estimate than bottom fauna productivity. The fair degree of correlation between these two estimates makes it possible to predict, when studying a lake, that richness in plankton food will be accompanied by abundant bottom fauna. When time is short this assumption can be substituted, with a reasonable degree of safety, for estimation of bottom fauna. Moreover, pursuing this reasoning, it can be predicted, following the regional analysis of plankton productivity presented in a later chapter (pp. 99-108), that lakes in the Connecticut Valley Lowland will be more productive of bottom fauna, and hence potentially more productive of fish than those of the Connecticut Highlands.

It is necessary to add, however, that "high potential productivity" does not always result in good fishing. Though the fish yield in pounds per acre may be high, this poundage may be represented by coarse species or large populations of stunted game fish. It is also true that lakes of low potential productivity do not necessarily provide poor fishing. Many Connecticut lakes within this category provide excellent fishing, perhaps due to the fact that the available food is efficiently used by an association of suitable game and forage species. Low potential productivity is, in fact, one of the essential characteristics of most good trout lakes.

Classification of Connecticut Lakes

By way of summarizing this chapter, some general principles can be found which relate limnology to fishing. In general, ordinary lakes (not including bog lakes, glacial stream lakes, desert lakes, or tropical lakes) fall into two classes. In one class, nutrient substances (nitrogen and phosphorus), plankton, and bottom fauna are low, and the oxygen content of the hypolimnion is high. The latter condition prevails since the plankton population is too small to reduce it appreciably during decomposition. These lakes tend to be large and deep, and are called oligotrophic. Wononscopomuc Lake and East Twin Lake are examples of this class. In the other class, nutrients, plankton, and bottom fauna are high while the oxygen content of the lower layer, or hypolimnion, approaches zero. These lakes are classed as eutrophic and are generally smaller and more shallow. Linsley Pond, Ball Pond, and Mt. Tom Pond are examples of this class. The differences between the two are, in part, based on the difference in depth, since a large deep lake has relatively less area of the earth's surface in contact with its waters. Moreover, the volume of the hypolimnion is so great with respect to the amount of plankton in the upper waters that the oxygen is not seriously depleted during the summer. In oligotrophic lakes a given amount of dissolved substances and the oxygen deficit are diluted by the larger volume of water.

Fundamentally, however, the differences between the two kinds of lakes arise from the different amounts of nutrient substances available in the drainage basins. This is clearly shown by comparing lakes in different geological and geographical areas. In other words, there are two sorts of oligotrophy or eutrophy possible. Mt. Tom Pond is eutrophic because it is small and shallow, although its nutrient content is rather low, while Linsley Pond is eutrophic because, in addition to being small and shallow, it has considerably greater supplies of nitrogen and phosphorus. There are no lakes in the Connecticut Valley Lowland deep enough to be described as oligotrophic, but the oligotrophy of Wononscopomuc Lake is clearly of a different sort than that of Lake Nipigon in the sterile rocks of Ontario, or of certain mountain lakes in Norway where the nutrient substances are excessively deficient. Thus it is possible to distinguish an oligotrophy or eutrophy which is primary, or based on available nutrients from an oligotrophy or eutrophy which is secondary or morphometric[12] (the form of the lake basin). In comparing areas of widely different geological character, it is easy to distinguish the types, but within a small area primarily oligotrophic lakes may have a secondary eutrophy imposed on them, as in the case of Mt. Tom Pond, and the converse is equally likely.

Both of these sorts of oligotrophy or eutrophy are important to fishing. The primary sort imposes limits of potential productivity, and governs the *annual yield of fish per acre of lake.* But differences between oligotrophic and eutrophic lakes, whether they are of primary or secondary origin, determine *the kind of fish best suited to the lake.* Thus an oligotrophic lake, having a large volume of cold, well-oxygenated water in the hypolimnion, is admirably suited for such species as lake trout, smelt, whitefish, rainbow trout, or cisco. A eutrophic lake is not a satisfactory habitat for these species, but is better suited for perch, bass, and pickerel, which tolerate warmer water and need not spend the summer in the hypolimnion. An oligotrophic lake, having a cold, well-oxygenated epilimnion and having broader weed beds because of its greater transparency, may also be adapted to the characteristic eutrophic species. This advantage is counteracted, however; deficiency of food supply, at least in primarily oligotrophic lakes, may result in a smaller total yield of fish than in the eutrophic lake.

PART III. PROCEDURES IN A LIMNOLOGICAL SURVEY

In this chapter the methods followed will be outlined for the benefit of the non-technical reader. Technical descriptions and references to analytical methods will be found in Appendix II.

Maps and Morphometric Data

The first step in a limnological survey is to sound the lake, and from the resulting data to compute the areas and volumes at different depths and the total volume. This is important for the following reasons:

1. Certain facts about the oxygen curve and temperatures can be deduced from the maximum and mean depths. A vertical series of water samples for chemical analysis can be taken at the station of maximum depth, thus eliminating unnecessary work in sampling.

2. The volumes in conjunction with temperatures and oxygen data can be used to compute the available water for fish, such as the lake trout, preferring the hypolimnion.

3. The *total oxygen deficit* of the hypolimnion is calculated from the volumes of the different layers. When this is divided by the area of the hypolimnion the amount of oxygen used during any given time per unit area of hypolimnion surface is obtained. This gives the best index of potential productivity yet devised, as is shown in a later chapter (pp. 110-117). These values may be used to compute the probable oxygen concentration during the late summer, as oxygen values taken before summer stagnation may be misleadingly high. This prevents mistaken conclusions concerning fishery management from June oxygen data, as has frequently been done by other surveys.

4. In estimating the average amount of bottom fauna per unit area of bottom, each sample is assumed to be representative of neighboring depths. The areas covered by different depths of water, as computed from the map of soundings, are used in applying the results of the samples to the entire lake bottom.

Outline maps of the lakes (Fig. 9) were obtained from tracings of aerial survey photographs (scale: 1 inch = 600 ft.). Soundings were made with a lead weight and a wire line operated from a winch. Soundings were made between conspicuous points on the shore at intervals of ten or fifteen oar-strokes. They were later transferred to a copy of the tracing, contours drawn, and areas measured with a planimeter. From this contour map volumes were computed (see Appendix II).

Temperature and Water Samples

The importance of a study of lake temperatures has been mentioned on pages 71 and 72.

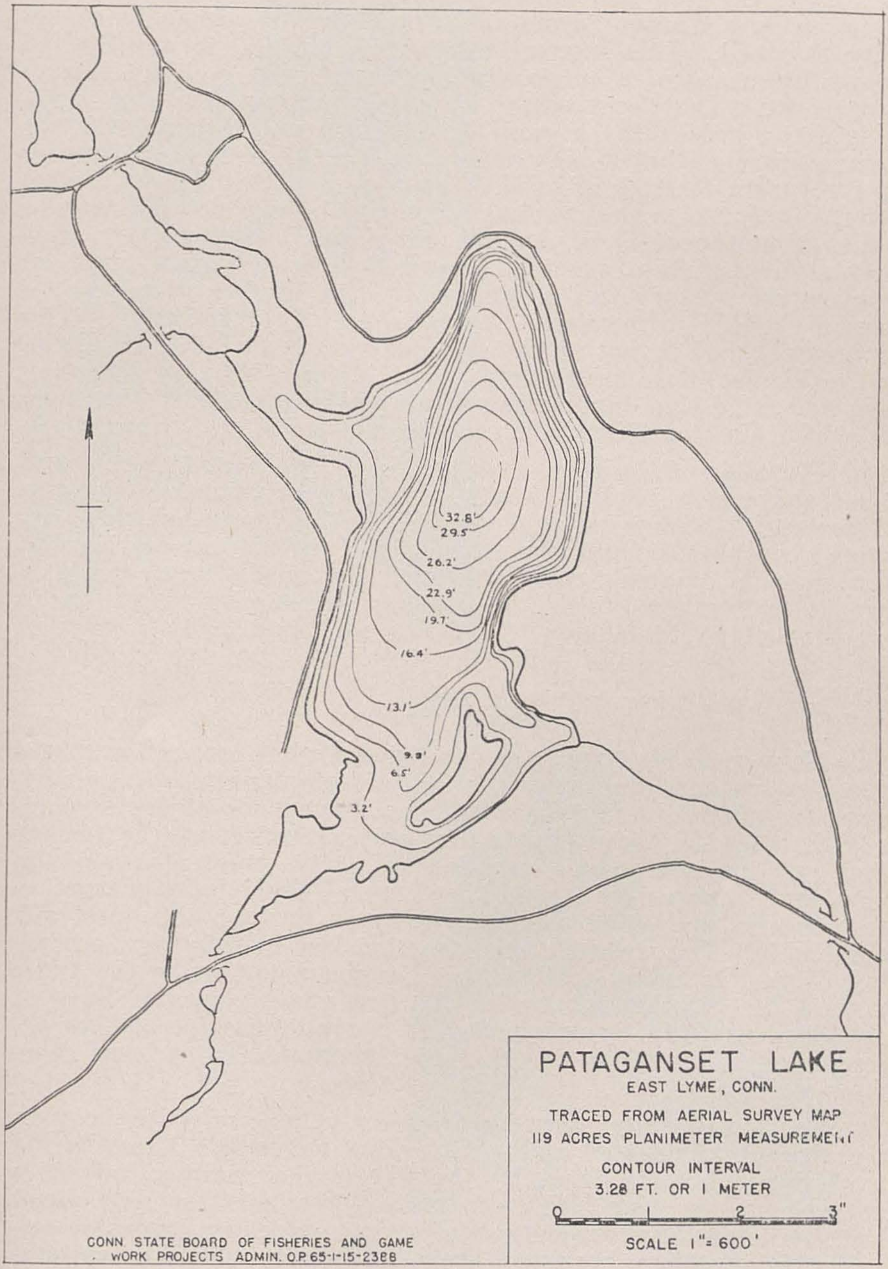


FIG. 9. Example of sounding map made on the larger bodies of water studied by the survey.

Temperatures and water samples were taken at the same time, using a Nansen reversing bottle with a reversing thermometer attached. This instrument may be lowered to any desired depth by means of a small winch provided with a depth recording device. The thermometer is so designed that turning it upside down breaks the column of mercury and thus records the temperature so that it may be read at the surface. Temperatures are accurate to 0.02° F. The advantage of the Nansen water-sampling bottle is that water samples and temperatures may be taken simultaneously at any desired depth. Methods for accurate studies of light penetration into water are too elaborate for routine use by surveys. However, for comparative purposes it is useful roughly to measure the depth of light penetration. This is accomplished by noting the depth at which a white disc (called a Secchi disc) disappears from view. Under ideal conditions of sun and wind this depth corresponds approximately to the depth at which 10% of illumination at the surface is still present.

The color of the lake, as seen against the Secchi disc at half the transparency reading, is also useful for comparative purposes. A scale of 21 colors is employed (Forel-Ule Scale) which varies from deep blue to light and dark brown waters caused by varying amounts of humic color or stain. Intermediate are the blue-greens and yellow-greens of ordinary lakes caused by various amounts of phytoplankton. With the exception of I, II and III, the entire range of the Forel-Ule Scale is encountered in Connecticut.

Plankton Analysis

Many methods have been developed for the estimation of the quantitative and qualitative composition of plankton. It is sufficient for qualitative purposes to draw a net made of fine bolting-silk through the upper layers of water, transferring the residue to a vial for microscopic examination. The usual plankton net, however, retains only a small fraction of the total plankton, as the bacteria and small algae readily pass through the finest silk obtainable. The weight of the fraction lost in this way, according to studies made in Wisconsin[3], may amount to twelve times that of the fraction retained. The net, which may be closed at any desired depth, is unsatisfactory for quantitative studies except for investigations of the larger zooplankton, such as copepods and Cladocera.

For quantitative purposes a known volume of water may be centrifuged or filtered and the residue weighed. The filtering method has been adopted by the Connecticut Survey, but it is very time-consuming and analyses are available for only about half the lakes. Filtrations made through a relatively coarse collodion filter (finer, however, than the bolting-silk) are suitable for counts of planktonic organisms. A thorough study of the plankton of Connecticut lakes, using the plankton trap and the filter-and-count method, would require the undivided attention of one trained investigator each season.

FIG. 10. One type of water sampling bottle and reversing thermometer.

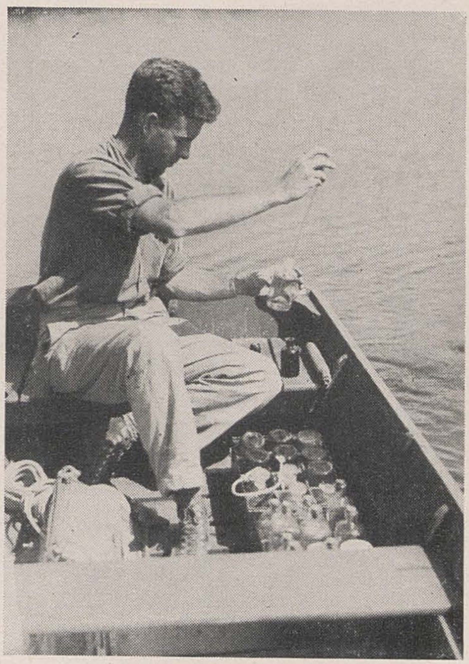


FIG. 11. Preliminary steps in determining oxygen content of water must be carried out in the field.

A far simpler method, which has proved extremely useful in the survey work, consists in measuring chemically the amount of chlorophyll present in the lake water. Chlorophyll, the green coloring matter used by plants in photosynthesis, can readily be estimated in lake waters by the methods devised by Harvey for studies in the ocean. The disadvantage of this method is that only phytoplankton is measured, and its reliability as an index of the total quantity of plankton present depends on the ratio of phytoplankton to zooplankton. This ratio has seldom been measured, but determinations made by Riley (unpublished) indicate that in Lake Quassapaug, which is probably typical of the majority of Connecticut lakes, the ratio is approximately 1 to 1. Two lakes in Austria measured by Ruttner[38] also gave comparable ratios. Strongly eutrophic lakes, however, may have different ratios; the ratio for Linsley Pond, as given by Riley,[35] averages 5.5 to 1.

Bottom Fauna

Estimation of the quantity and numerical composition of the bottom fauna is probably the most important single part of a limnological survey, and is also the most troublesome. The difficulties are in part technical, as counting and weighing is always time-consuming, and in part statistical, since very large areas are sampled by very small apparatus, and reliable figures are difficult or sometimes impossible to obtain. The data are always subject to a large error inherent in the sampling process, and this error cannot be materially reduced by taking three to five times as many samples. However, there is every reason to believe that the data fairly represent the bottom fauna of the different lakes studied, at least to the extent that the differences between figures for different lakes exceed the error inherent in the figures for each lake.

Bottom samples were collected by use of the Ekman-Birge bottom sampler (Fig. 12). This is clam-shell bucket taking an area of 36 sq. in., whose jaws are closed by the release of a catch after reaching the bottom. Samples were spaced, so far as possible, at regular intervals from the shallow water to the deepest, the intervals varying from six feet to twelve feet of depth according to the depth of the lake. The Ekman sampler is designed for soft bottoms, and is unsatisfactory in shallow water where weeds, sticks, and sand prevent its closing. For these areas a larger sampler, having an area of 81 sq. in., was devised (Fig. 13). This could be held firmly on the bottom by means of extension rods while the jaws were drawn together by a rope. The sample is washed through a fine scrim net which retains all the large organisms and varying amounts of detritus. The residue, transferred to a wide-mouth jar and preserved in formalin, is examined under the microscope and the organisms counted. The vari-

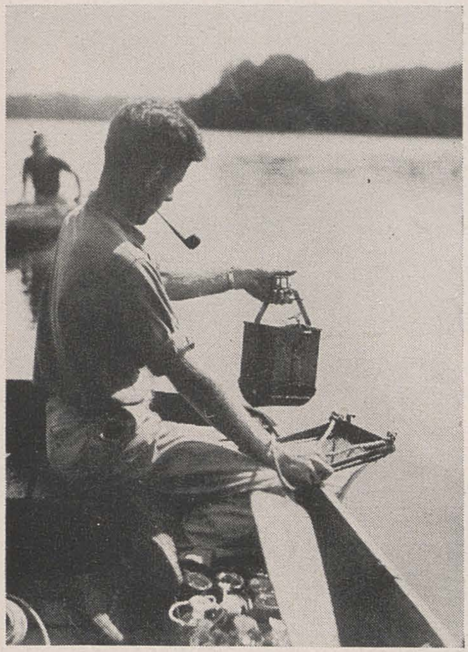


FIG. 12. The Ekman-Birge dredge is the apparatus used to obtain samples of organisms in soft mud bottoms.

FIG. 13. For sampling in shallow water over sand and gravel bottoms this type of dredge was devised.

ous groups of organisms in each bottom sample are kept in separate vials, and are weighed after the excess water has been removed by blotting on filter paper. The zoological categories used are the following:

Insects:

- Chironomidae (midge larvae)
  - *Chironomus* (Tribe Chironomariae)
  - *Tanytarsus* (Tribe Tanytarsariae)
  - *Trissocladius* (Sub-family Orthocladiinae)
  - *Tanypus* (Sub-family Tanypodinae)
  - *Ceratopogon* (Sub-family Ceratopogoninae)

  (counted separately in all but shallowest samples)
- *Chaoborus* (phantom-midge larvae)
- Insects miscellaneous

  (including *Sialis*, mayflies, dragonflies, caddisflies, and beetle larvae)

Amphipods

Asellus

Mites

Molluscs
(Including small clams or Sphaeriidae, and snails)

Oligochaets
(Family Tubificidae, earthworm allies)

Turbellaria (flatworms)

A few of the more common aquatic insects which are important as fish food and which receive some notice from anglers will be mentioned briefly.

Dragonflies and Damselflies (*Odonata*)

Large dragonfly nymphs or "perch bugs" are a favorite bait with many anglers. From these immature stages emerge the swift-winged adults so common over lakes and ponds. The nymphs occupy a variety of habitats in the littoral or shallow water areas. Some, like the large green *Anax* (the species most frequently sold by bait dealers), are clamberers among the aquatic vegetation. Others lie sprawled on the bottom or may even burrow in the mud.

The nymphs are fierce carnivores, feeding upon aquatic insects by means of a unique extensible "jaw". This is a hinged structure which is thrust out to capture food. The adults are also carnivorous and the structures aiding them in securing food are as singular as those possessed by the nymphs. A "basket" is formed by the stiff spines on the legs. The food, which consists of mosquitoes, midges, and other small flying insects, is captured in the basket while the dragonfly is on the wing. Though most common over water, adults frequently stray long distances from it.

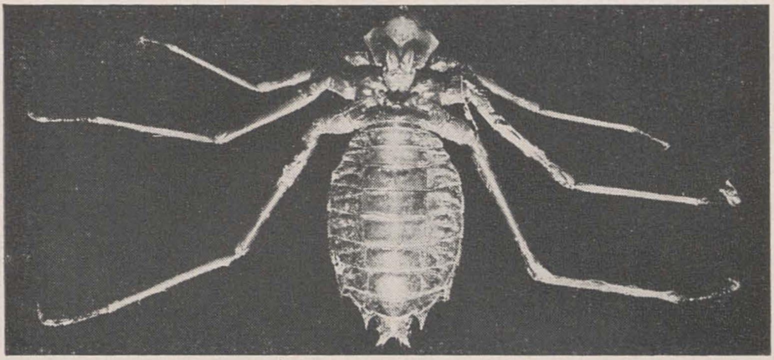


FIG. 14. Dragonfly nymph (*Didymops*). Ventral view of a sprawler on sandy shoals.

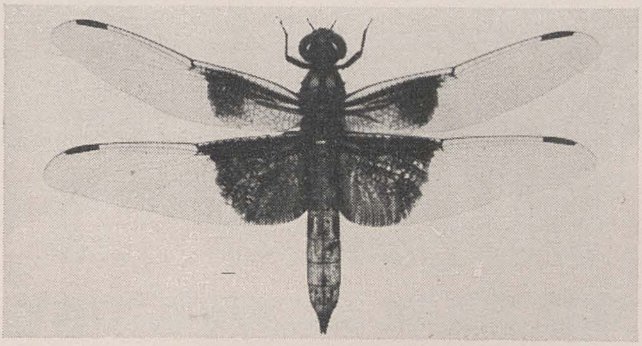


FIG. 15. Dragonfly adult (*Libellula luctuosa*).

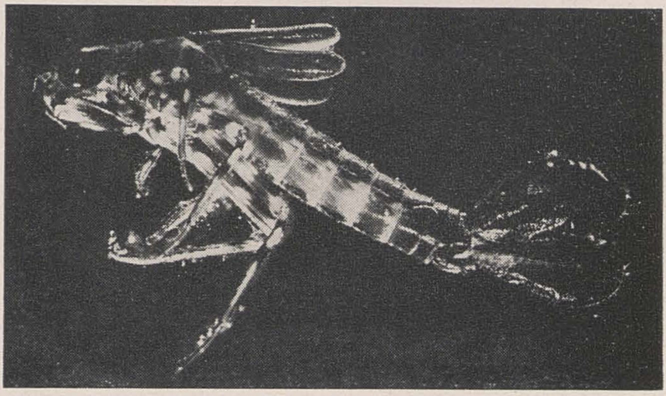


FIG. 16. Damselfly nymph (*Argia*).

FIG. 17. Case of a Limnephelid caddis worm.

FIG. 18. Nymphs of the large burrowing mayfly, *Hexagenia*, abundant in the bottom muds of many lakes and streams.

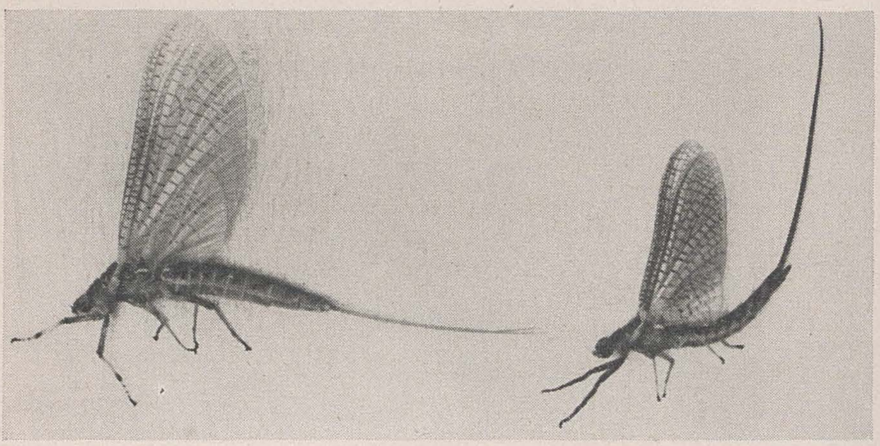


FIG. 19. Subimagoes of *Hexagenia*. Female left, male right.

FIG. 20. Larvae of midges (*Chironomus*) live in the bottom muds of lakes and ponds.

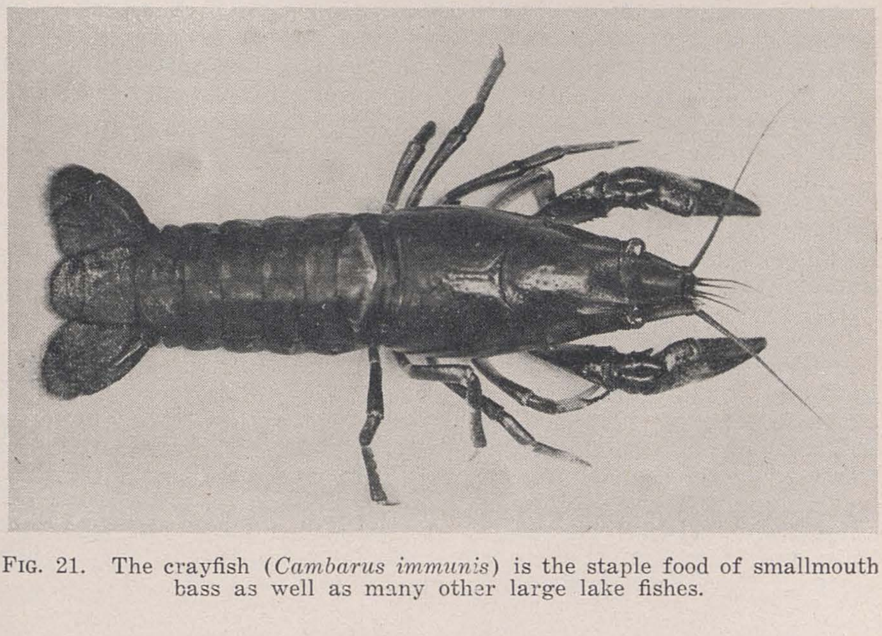


FIG. 21. The crayfish (*Cambarus immunis*) is the staple food of smallmouth bass as well as many other large lake fishes.

Mating pairs flying in tandem are often seen. The eggs are commonly laid directly in the water as the female dips the tip of her abdomen below the surface of the water during flight. Different species, however, vary markedly in their egg laying habits. The female of the big green darner, *Anax*, for example, deposits her eggs in the stems of aquatic plants, while *Cordulegaster* drops gelatinous masses of eggs over vegetation. The eggs hatch into tiny nymphs which may spend from one to three years in the water before they are ready to transform into adults. This transformation to an aerial existence takes place on the land. The fully-grown nymph crawls out of the water, perhaps only a distance of a few inches on the stem of a plant or sometimes several yards to a tree trunk or the side of a building. From the somber colored nymphal shell may emerge a brilliant metallic colored adult.

The damselflies are smaller, more slender cousins of the dragonflies and they possess similar habits and life histories. However, the damselflies seldom stray as far from water and their eggs are almost invariably laid in the stems of aquatic plants. Adult damselflies when at rest fold their wings in a vertical position, while dragonflies leave theirs unfolded in a plane at right angles to the body. The little blue damselfly, *Enallagma*, is familiar to all lake fishermen for it is a common form that persists in perching adeptly on one's rod or line.

Caddisflies (*Trichoptera*)

Caddis larvae are the "house builders" of the aquatic insect world. Each worm lives enclosed in a case built of leaves, sand grains, tiny pebbles or sticks held together by a silk-like secretion. Perhaps most remarkable is the fact that each different kind of caddis consistently builds a case of similar materials and similar shape. Indeed, it is by the case characteristics that the larvae are most easily distinguished.

The larvae walks or swims about with its head and legs extended from the case, but when disturbed a hasty retreat is made into the case. Fish feeding upon these insects eat both the worm and its case and so it is not uncommon to find a fish whose stomach holds considerable quantities of sticks and small pebbles.

Transformation of the larvae into the adult is not direct as is found in the dragonflies and mayflies. A quiescent or pupal stage is present during which the change occurs and from this there emerges a fully-formed adult caddisfly. Emergence usually takes place in the evening. The adults are small, moth-like insects, usually less than one inch in length and of brown or gray coloration. Fishermen call them "sedges". Their antennae are long and they fold their wings tent-like over their body. They take no food during their brief terrestrial sojourn.

Mayflies (*Ephemeroptera*)

The "drakes", "spinners", and "duns" of the fly-fishermen belong to this group of insects. The adults are dainty, fragile creatures who live but a day or so. Mayflies are an important fish food and in many Connecticut lakes one form alone, the large *Hexagenia*, probably outranks most other aquatic insects in this respect.

The nymphs of *Hexagenia* (Fig. 18) spend two years living in the bottom mud. They are admirably adapted for a burrowing existence by a pair of "tusks" and digging legs. They feed upon the organic ooze and are in turn preyed upon by many different kinds of fish as well as predacious insects.

Transformation into a subadult stage (subimago, Fig. 19) takes place on the surface of the water; the "hatch" usually begins at dusk and continues on into the night. At this time the nymphs and newly transformed subimagoes are quite unprotected and fish of nearly all species turn lustily to this easily attainable food. In Connecticut these hatches normally occur during the last two weeks of June and the first week of July.

In spite of depredations of fish, many of the subimagoes reach the shelter of the foliage around the water. The subimagoes of the common Connecticut lake form are of a pale, sulphur color with bodies about an inch long. They remain quietly here until, after a lapse of about a day or so, they again moult, this time to become imagoes or true adults. During the period of transformation and adulthood they eat no food, since their mouth parts are quite undeveloped.

During the evening and night of the day following their emergence from the water, the adults congregate over the lake in dense swarms in the "mating dance". They die shortly after and the water may be strewn with their bodies, another opportunity for fishes to appease their appetites.

Midges (*Diptera*)

The immature forms of midges, near relatives of the mosquitoes and punkies form the important initial insect food for many young fish. These insects are usually both abundant and available to fish and for this reason rank high as forage.

The bloodworm, *Chironomus*, found in both shallow and deep waters, is common in most Connecticut lakes. Unfortunately, those in the deep water may not be available as food since fish may be barred by lack of oxygen from entering this region. Bloodworms live on the bottom in loosely constructed silt or mud tubes. They feed upon algae and decaying vegetation. As with the caddisflies, an intermediate or pupal stage exists between larval and adult life.

Phantom midge larvae, *Chaoborus (Corethra)*, have been found to be an important food of the white perch. This form lives in the deep, often oxygen-deficient water, during the day, but migrates to the surface at night. The larvae and pupae of the phantom midge are transparent save for two pairs of opaque air sacs, one near each end of the body, which presumably aid in the vertical migration. Unlike most midge larvae they are carnivorous, feeding upon such animals as minute crustaceans and rotifers.

Dobsonflies, Fishflies and Alderflies (*Neuroptera*)

Dobson, or hellgramites (*Corydalis*), are the larvae of insects belonging to this group. They are typically found in running water, but because of their importance as a bait they were deemed worthy of mention here. The insect spends three years in the larval or hellgramite stage and during this period it is extremely predacious. Pupation then takes place under rocks or in the soil along the stream banks. The adults are large nocturnal insects with a wingspread of four or five inches but are clumsy fliers. Their life as winged adults is short and they probably do not feed during this period. The male appears particularly formidable for it possesses a large pair of curved "pincers". These, however, are largely employed as claspers during mating.

A much smaller form, the alderfly (*Sialis*), occurs in many lakes and ponds. The larvae live in the bottom mud or sand of both the shallow and deep waters, but only infrequently do they appear in fishes' stomachs. They are fierce carnivores.

The pupal period is passed on the shore of the lake and the adults which emerge during May and June are black in color and about one and one-half inches in length. They are eagerly sought by sunfish and small bass swimming near the shores. The eggs are laid usually during the middle of the day in flat places on boards, leaves, or branches overhanging the water.

Chemical Analyses

References and descriptions of the chemical techniques used by the Survey will be found in the Appendix. The nontechnical reader, interested in the reasons for the analyses made, should consult pp. 75-79. Certain analyses not mentioned elsewhere may be of more general interest and are included here.

The color of the water differs from the "color of the lake" as it measures the amount of humic or peaty stain dissolved in the water. It is compared against standards of brown color. These consist of different dilutions of potassium cobalti-platinate, and the results are reported in parts per million of platinum. Humic matter is important to the economy of lakes because it reduces light penetration and because it tends to remove oxygen from the water.

Phosphorus is reported both as soluble phosphorus, the form directly available to plankton, and as total phosphorus, which includes that present in the plankton and in humic detritus. As the soluble phosphorus tends to be used as rapidly as it is formed, a given quantity reflects the activity of "yesterday's" plankton. For this reason frequently no soluble phosphorus can be detected although the analyses is accurate to below 0.2 parts per billion. Total phosphorus gives a far better index of the phosphorus endowment of a lake, and it is usually quite constant throughout the year.

Total nitrogen (by the Kjeldahl method) cannot be reported for Connecticut lakes, as the amounts present are too low for satisfactory analyses. Soluble nitrogen in the form of nitrates is open to the same objection as soluble phosphorus as an index of nitrogen capital, but satisfactory results are obtained by determining nitrate in the winter when plankton activity is at a minimum. Analyses of winter nitrate in thirty Connecticut lakes are discussed in a later chapter.

The great importance of the oxidation-reduction potential of lake waters is discussed in a later chapter (pp. 111-115). It is shown that this value, rather than the oxygen content, is to be correlated with this characteristic type of Chironomid larva living in the bottom of the profundal zone. This determination appears to give an index of the type of the lake (whether oligotrophic or eutrophic), of the probable rate of regeneration of phosphorus, and the character of the internal phosphorus cycle.

Iron in the reduced or ferrous state is the principal element responsible for a given oxidation-reduction potential in Connecticut lake waters. Since ferric iron is almost completely insoluble in natural waters and most of the iron present is ferrous, determinations of total iron may be substituted.

The relationship of oxidation-reduction potential, ferrous iron, and lake types was first reached indirectly by consideration of the bicarbonate content of the hypolimnion of lakes. The bicarbonate not accounted for as calcium and magnesium bicarbonate was presumed to be ferrous, manganous, and ammonium bicarbonate, and regarded as an index of reducing substances. The data obtained by the Survey include some analyses of calcium, magnesium, and manganese made in 1938. These figures, in so far as they allow conclusions as to reducing substances, have been superseded by the determinations of oxidation-reduction potential and ferrous iron, and are now of interest only in other connections not so closely bound up with fishing problems.

Silica is an element important in the growth of phytoplankton since it forms the skeletons of certain algae called diatoms. It was determined on most lakes in 1938, but since it was never found to be deficient, the determination was dropped as a routine procedure.

The analysis of chlorophyll is largely a chemical one, but it has been discussed under the section entitled Plankton Analyses. In connection with this method, the amount of yellow pigment, carotin, found in phytoplankton can readily be determined. The data, however, are of little value except with a qualitative study of the various algae composing the plankton, as the chlorophyll-carotin ratio undoubtedly varies with the species.

Copper has been reported for a few lakes in which copper pollution was known or suspected. Study of the effect of this serious fish poison is still incomplete.

Organic nitrogen determinations were made on samples from most of the lakes studied. This indicates the nutrient content of the mud which is the chief food of many important members of the bottom fauna. The results are rather disappointing, partly because the data are few in number, and partly because erosion, attendant on deforestation after colonization of Connecticut, appears to have materially increased the amount of mineral detritus delivered to present-day lakes.

PART IV. LIMNOLOGICAL SUMMARY

Relation of Geology to Plankton

There is a remarkably close correlation between plankton productivity and geology in Connecticut lakes. This relationship is of fundamental importance to fishing. However, before this is discussed further, a brief sketch of the geology of Connecticut seems desirable.*

Differences in bedrock geology of Connecticut are familiar to everyone who has crossed the State by train or automobile. The eastern and western highlands of the State are divided into two regions by the broad lowlands of the Connecticut River Valley. The Connecticut River remains in this lowland until it reaches Middletown where it changes its course to follow a rocky gorge to Saybrook. The lowland continues southward, becomes narrower, and reaches sea level at New Haven. Southward extensions of the Berkshire and Taconic ranges produce subdued mountainous terrain in the northwestern corner of the State.

The rocks and the soils derived from them differ in color in the lowland and highland provinces. In general, the highland rocks are light in color, and this is particularly well shown where sand and gravel deposits are exposed in road cuts and river valleys. The lowland rocks are of two sorts: The red sandstone,

*The reader interested in a more detailed account of this subject may consult the non-technical "Walks and Rides in Central Connecticut and Massachusetts", by Longwell and Dana, or the "Manual of the Geology of Connecticut", by Rice and Gregory.

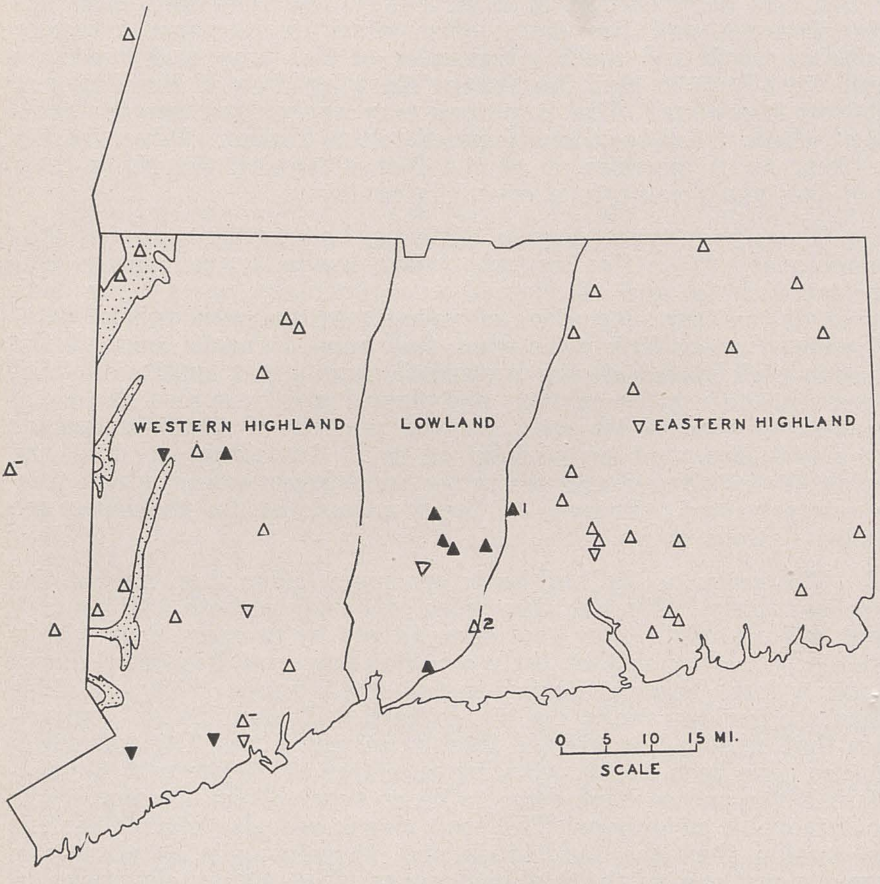
which has been eroded to a strikingly red sand and underlies the lowland, and the dark, often black trap ridges, running roughly north and south. Examples of this trap rock are East and West Rock in New Haven, the Hanging Hills of Meriden, and Talcott Mountain. The trap rock may appear red due to "rusting" where it has been long exposed to the weather. When freshly broken, as in quarries or at the foot of slopes, the black color and fine grain indicate a consolidated lava.

These rock types may be distinguished by their origin. The sandstones of the Connecticut Valley Lowland are weakly consolidated sands, and are classed as sedimentary rocks. The dark lavas of the trap ridges are of volcanic origin, although no cataclysmic eruption took place when they were formed. Instead, the molten rock moved slowly upward through great longitudinal fissures in the earth's surface and flowed gently across the plain formed by the sandstones. Several periods of those extrusions occurred separated by periods of sand deposition, so that the lavas lie both above and below the sandstones within which they are interbedded. Because of their volcanic origin the lavas are called igneous rocks.

The rocks of the highlands are much older than any of the lowland rocks. Although they were originally of both sedimentary and igneous origin, they have been altered by pressure deep within the earth's crust so that their original character has been almost entirely lost. These are called metamorphic rocks. They are older than the lowland rocks, but are so hard and insoluble by comparison that erosion has affected them relatively little. The soft sandstones have been deeply worn by ancestors of the present Connecticut River and so have come to lie at lower elevations than their metamorphic neighbors. The trap ridges are also more resistant to erosion than the sandstones and, therefore, lie at about the same elevations as the highland rocks. The higher elevations in the State lie approximately in a plane surface with a gradual slope to the southward.

One additional feature of the rock composition of Connecticut needs be mentioned. This is the occurrence of a limestone formation known as the Stockbridge marble throughout a broad belt skirting the foothills of the Berkshire Range. This rock is world-famous as "Vermont marble" and its presence in Connecticut is confined to a belt in the northwest corner of the State and to three outcrops in the lower Housatonic Valley.

During the Pleistocene, or glacial period, certain striking changes were wrought in the Connecticut landscape, but the effect of the active ice sheet was slight. It consisted in smoothing off the hills and depositing a thin layer of the poorly assorted material known as till or ground moraine. The natural lakes in Connecticut were formed during this glacial period. Some of these lakes were formed when ground moraine dammed old valleys, others when lingering blocks of ice melted out from under



Legend: — Stockbridge marble.

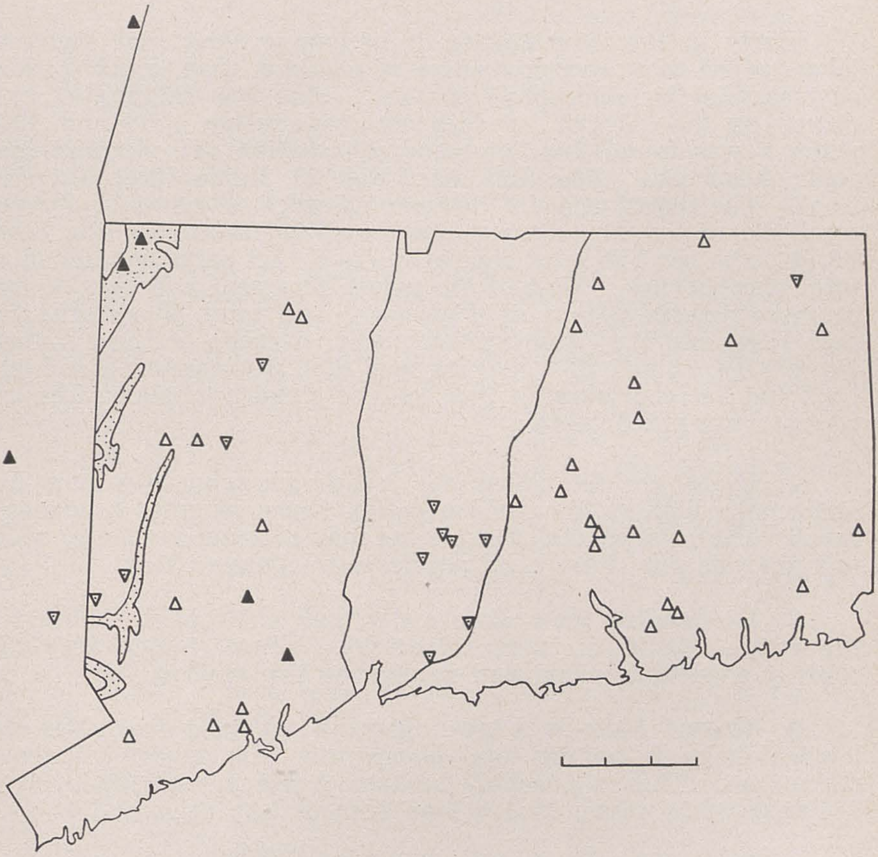
▲ — Lakes having summer chlorophyll and total phosphorus values above the state mean.

△ — Lakes having summer chlorophyll and total phosphorus values below the state mean.

▼ — Lakes having chlorophyll values above mean, phosphorus values normal for the region.

▽ — Lakes having phosphorus values abnormal for the region.

FIG. 22. Regional differences in plankton productivity and total phosphorus. See text p. 104.



Legend: — Stockbridge marble.
▲ — Hard-water lakes.
▽ — Medium hard-water lakes.
△ — Soft water lakes.

FIG. 23. Regional differences in bicarbonate content (hardness). See text p. 105.

sandy deposits washed over them by glacial streams,[7] and a few lake basins owe their origin to active scouring by moving ice.

Early in the investigation it became evident that highland lakes tended to be less productive of plankton than lowland lakes, as measured by chlorophyll content. This was thoroughly confirmed by the addition of data obtained during 1938 and 1939 when it was found that the same distribution also characterized total phosphorus. The first map, Fig. 22, shows these distributions. The distribution of summer chlorophyll values and mean total phosphorus are compared to the grand means for the State (6.74 parts per billion of chlorophyll and 14.9 parts per billion of total phosphorus). Most of the points represent averages of two or more determinations of chlorophyll and total phosphorus for each lake, and the "grand mean" is an average of these values. From Figs. 22 and 23 it may be seen that the separation of highland and lowland lakes on this basis is almost complete. The exceptions are noted below:

1. There are five lakes for which phosphorus values are abnormally high or low for the region (open inverted triangles). Small variations in total phosphorus may account for these, while one analysis may have been accidentally contaminated.

2. Three lakes show abnormally high chlorophyll values for the region (solid inverted triangles). These values are only slightly above the mean, and require no explanation.

3. Bantam Lake is a true exception, since it resembles the lowland lakes in having total phosphorus and chlorophyll above the means. This is probably because it has an unusually large drainage basin (ratio of drainage area to lake area 19.3 to 1).

4. Two lakes are lacking total phosphorus determinations (open erect triangles marked by a minus sign).

5. Two additional exceptions "prove the rule". Job's Pond (No. 1) according to the bedrock geology lies in the Eastern Highland; but actually it is surrounded by sandy red glacial material derived from the lowland rocks that was washed upon the edge of the highland during the retreat of the ice sheet.[8] The lake is without inlet other than seepage through this material and consequently it is a typical lowland lake, having chlorophyll and phosphorus contents slightly above the means.

The other exception, Lake Quonnipaug (No. 2), lies on the boundary between the highland and lowland, but has a larger drainage from the highland. It has chlorophyll and phosphorus values slightly below the means and is a typical highland lake.

The figures for chlorophyll and total phosphorus are presented in another way. The regional means given in parts per billion are as follows:

	Chlorophyll	Total Phosphorus
Lowland	18.39	31.0
E. Highland	3.47	10.8
W. Highland	5.83	13.0
Limestone	3.75	10.4

These means convincingly show that the lowland waters average well above the other provinces in chlorophyll and total phosphorus. These values have been shown to be statistically different.*

Another factor of possible importance in the production of plankton is bicarbonate (pp. 77-78). The amount of this compound in the surface waters of lakes is largely an expression of the amount of calcium carbonate, or limestone, in the drainage basin. This bicarbonate would be expected to show a regional distribution based on geological differences. The lakes studied have been divided into soft, medium-hard, and hard classes on the basis of their bicarbonate contents.[43] The plotted distribution in Connecticut is shown in Fig. 23. The hardwater lakes (solid erect triangles) are confined to the outcrops of limestone, with the exception of Lake Zoar and Lake Housatonic. These two impounded stretches of the Housatonic River drain through

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*Fisher's "t" test, as given in "Statistical Methods for Research Workers", was used in treating these data. Examining the significance of differences between the regional means for chlorophyll and total phosphorus, the following "P" values are found:

Differences for Chlorophyll:

E. Highland — Lowland	P = .01*
E. Highland — W. Highland	.02*
E. Highland — Limestone	.7
Lowland — W. Highland	.01*
Lowland — Limestone	.5
W. Highland — Limestone	.2

Differences for total phosphorus:

E. Highland — Lowland	P = .02*
E. Highland — W. Highland	.3
E. Highland — Limestone	.3
Lowland — W. Highland	.05*
Lowland — Limestone	.3
W. Highland — Limestone	.2

Significant differences are marked with an asterisk. The chlorophyll of the lowland lakes is significantly different from the two highlands and these are in turn significantly different from one another. The lowland lakes are richer than the highland in total phosphorus, but the highlands do not differ significantly from each other. The limestone lakes do not differ significantly from any of the others, possibly because of the small number of analyses.

It should be noted that in order to improve the significance of the available data certain New York lakes have been included in the analysis. Two of these, Queechy Lake and Sylvan Lake, lie in the Stockbridge marble formation; Glenida Lake resembles the Western Highland lakes.

limestone formation for most of its extent. The highland lakes are soft, almost without exception (open erect triangles). The lowland lakes are medium-hard (inverted triangles with dots), probably because thin layers of limestone are interbedded with the sandstones and lavas. Five medium-hard lakes in the western highland (including Glenida) probably owe their abnormally high bicarbonate content to lime mixed with glacial material and carried south of the limestone outcrops. The size of the drainage basin also has some influence, as Bantam Lake and Stillwater Pond probably owe their high alkalinity to large drainage areas. The presence of a medium-hard lake (Roseland Pond) in the eastern highland is more difficult to explain, but evidently the surrounding rock has a somewhat higher line content than the other highland areas.

Nitrogen, in addition to phosphorus and bicarbonate, is found to influence the production of plankton. Nitrate determinations made in the winter when plankton production is at a minimum is the best index of available nitrogen supply. Winter nitrate figures are available for thirty of the forty-nine lakes discussed in connection with other substances; the regional means are reported in parts per billion as follows:

Lowland	72.0
E. Highland	45.0
W. Highland	67.0
Limestone	25.0

Analysis of the probable significance of these differences by the "method of t" shows that none of them are significant, possibly because of the smaller body of data used. The regional distribution is also less striking than in the case of the other substances. A map is not presented, but it is clear that the lowland lakes have more nitrogen as well as more plankton and phosphorus.

The study of these data may be carried a step further. Statistical comparisons of the total phosphorus, nitrogen, and plankton values show a remarkably high degree of correlation.*

*Applying statistical methods to the present situation, it is found that the correlation coefficient between summer chlorophyll and total phosphorus in 47 lakes is 0.895. The value of the same coefficient, using thirty lakes for which winter nitrate is also known, is 0.958. The most probable value of the coefficient is found to be 0.919. This coefficient is remarkably close to 1 and goes far toward confirming the theory that chlorophyll is dependent on total phosphorus for its production.

Examining the relation between summer chlorophyll and winter nitrate (using the 30 available observations) it is found that $r = 0.605$. The strength of the relationship is not so great, but great enough to be real, and not due to chance. Nitrogen, then, also influences plankton productivity.

Bicarbonate is believed to influence plankton production by many workers, since it can be utilizied by algae as a source of carbon dioxide in photosynthesis. At first sight the Connecticut data offer no support for this assumption, since $r = .0736$, using forty-seven observations, and .0415, using thirty observations.

There is good reason to believe that this effect is not accidental, but is due to the removal of phosphorus during the precipitation of calcium carbonate in hard water lakes, as explained in Part II. A depressing effect of bicarbonate on plankton production is thereby brought about. It seems that the best case for believing bicarbonate to favor plankton productivity rests on a removal of the hardwater lakes from consideration, and when this is done $r = .418$, using forty-two observations, and .432, using twenty-seven observations.

The result of this analysis provides three variables — phosphorus, nitrogen, and bicarbonate — all of which influence plankton production to varying degrees, and all of which appear to have real and not accidental effects. The simple correlation coefficients, however, take no account of the interrelationships between the variables, and it is desirable to determine these. Thus the effect of bicarbonate may after all be fictitious, due to the fact that, in general, the medium-hard lakes also contain more nitrogen and phosphorus. That this fact is the case is shown by calculating "partial correlation coefficients"; these values measure the net effect of one or more variables when the others are held constant, or in other words when the effect of their variation is eliminated.

The correlation coefficient between chlorophyll and phosphorus when nitrogen and bicarbonate are eliminated is .922. This is written

$$r_{CP.NB} = .922$$

The variables are eliminated in successive combinations, and

$$r_{CN.PB} = .376, \text{ and}$$

$$r_{CB.NP} = .167$$

Thus the net relation with phosphorus is still very high, that with nitrogen is of border-line significance, while that of bicarbonate is definitely of no significance, when each of the variables is considered apart from the others.

It can also be shown that these three variables do not combine their effects in causing variations in chlorophyll by calculating a multiple correlation coefficient for the four variables. A multiple correlation coefficient is usually written "R" to distinguish it from a simple or partial correlation coefficient, and

$$R_{C.PNB} = .663$$

measures the combined action of phosphorus, nitrogen and bicarbonate on chlorophyll. As this value is lower than the simple correlation coefficient between chlorophyll and phosphorus, it is clear that it is an erroneous statement of the true relationships involved.

Since the observed relation of chlorophyll and bicarbonate is accidental, there is no reason to eliminate the hard-water lakes from consideration, and the partial correlation coefficients can be recalculated on the basis of thirty lakes:

$$r_{CP.N} = .893$$

$$r_{CN.P} = .402$$

The multiple correlation coefficient is now found:

$$R_{C.PN} = .964$$

This is an improvement over either of the simple correlation coefficients, between chlorophyll and either phosphorus or nitrogen, and is taken to mean that these two substances, acting in concert, are responsible for nearly all of the variation in chlorophyll from lake to lake. In fact the data show that chlorophyll can be calculated, with a high degree of confidence, from a given amount of phosphorus and nitrogen, according to the equation

$$C = .500\ P + .0421\ N - 3.05$$

This is, of course, solely applicable to the data, and cannot be used for other lakes under other conditions. The values of the coefficients in this equation show the relative importance of phosphorus and nitrogen, and the small value of the independent constant (3.05) shows the high degree of probability that any values for chlorophyll so calculated will agree with the observed values.

The amount of phytoplankton in Connecticut lakes is thus found to be controlled by the amount of total phosphorus and nitrogen in the lakes. It might be presumed that it is in this relation that the striking influence of geology lies. Though phosphorus and nitrogen are important, their quantity may be controlled by other substances, for example, iron, as has been pointed out previously. The distribution of iron may well be responsible for the basic difference between lowland and highland lakes. It should be noted that no significant differences in phosphorus content can be detected between the lowland and highland soils of Connecticut; but this study is complicated by the widespread use of fertilizers that makes it difficult to obtain a soil sample free of artificial phosphorus enrichment.

Whatever the basic cause for the influence of geology on the productivity of Connecticut lakes, this influence is of the utmost importance in fishing, since it controls the potential yield of fish in a given lake.

It is interesting to compare Connecticut lakes with some other lakes of the world with respect to their phosphorus content. Aside from lakes in desert regions, which do not provide a fair comparison, analyses are available for three other regions: northern Germany[29], Wisconsin[19], and Japan[44]. Of the three, northern Germany is by far the richest in phosphorus, while Wisconsin and Japan resemble the lakes of the Connecticut Valley Lowland. The lakes of the Connecticut Highlands are poorer in phosphorus as a group than any other region, and some of the analyses, for example those for Green Falls Reservoir and Shenipsit Lake, as previously mentioned, are lower than any values previously recorded in scientific literature. There is every reason to expect, therefore, that phosphorus will act as a limiting factor in Connecticut, shaping the limits within which any program for improvement of fishing must act.

Transparency and Color

Light penetration into Connecticut lakes is in general poor. The average depth at which the Secchi disc disappears is 14.3 feet, the maximum depth 33 feet. This rapid reduction of light obviously reduces the depth at which plants can grow, and in this way narrows important foraging grounds for fish. It is important to know whether the factors tending to reduce transparency are correlated with the amount of plankton and so may be expected to show the influence of geology, or whether other factors, less regular in their distribution, affect this important feature.

From Connecticut investigations it appears that no relationship exists between the amount of chlorophyll and the transparency (correlation coefficient, $r = -0.0776$). A negative correlation was found to exist between the seston (total suspended matter, including plankton) and the transparency, since more suspended matter would tend to reduce the transparency. This correlation ($r = -0.386$), however, was on the borderline of significance. Transparency and color of the water, on the other hand, showed a close negative relationship ($r = -0.709$).

When the interrelationship of seston and humus is taken into consideration by partial correlation coefficients, it appears that humus color is largely responsible for variations in transparency, while plankton, even when represented by total seston, is unimportant.* The relation between transparency and seston alone, apart from variations in humus, is definitely not significant. Another factor, turbidity caused by streams, is probably responsible for variations in transparency. This has not been measured and the total seston figures, in reality, represent organic matter in the total seston.

This conclusion agrees with that of Wisconsin workers.[17] However, Riley has shown that in Linsley Pond, where humus color is essentially constant, week-to-week variations in plankton are responsible for most of the observed variation of transparency. Geological features, therefore, play little part in the illumination of Connecticut lakes.

Quantity of Bottom Fauna

Samples of bottom fauna are probably the best index of the food supply directly available to fish. If it can be shown that lakes most productive of plankton are, in general, richest in bottom fauna, plankton determinations can be substituted to a certain extent for estimations of bottom fauna.

The effect of plankton upon bottom fauna, if any, must be exerted through a direct conversion of organic material to plankton to living organisms. This implies that the more plankton per unit area of lake surface, the more bottom fauna per unit area of lake bottom.

Analysis of the data from thirty-three lakes substantiates this assumption, for a relatively high correlation was found be-

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*Partial correlation coefficient between transparency and humus, seston remaining constant, was –0.536.

Partial correlation coefficient between transparency and seston, humus remaining constant, was –0.286.

tween plankton (measured by chlorophyll) and bottom fauna ($r = 0.596$). The relationship of nitrogen and oxygen to bottom fauna adds strength to this correlation*, but the influence of plankton is much greater.

The influence of plankton productivity is much greater than that of the other two variables and the predicting equation is:

$$B = 18.98\ C + 45.9\ N - 8.58\ O + 48.7$$

The same general conclusions apply when the bottom fauna of the profundal zone are considered separately. This procedure changes several of the bottom fauna values but does not materially affect the relationship mentioned above.**

Despite numerous technical and statistical difficulties, it is clear that the lakes most productive of plankton are also richest in bottom fauna. The main thesis of this chapter may, therefore, be reiterated: Geology is the primary factor in the productivity of Connecticut lakes and sets the limits of potential fish production.

Productivity of Connecticut Lakes

Earlier in this section some theoretical conclusions were drawn from general limnology in advance of the Connecticut data. It was shown that lakes are in general of two sorts, oligotrophic and eutrophic. On closer examination these terms prove to have more than one meaning. For example, some lakes in unproductive geological situations may be so shallow that they become secondarily eutrophic, while upon the other hand, some primarily eutrophic lakes are so deep that they are secondarily oligotrophic. Green Lake, Wisconsin, is an excellent example of the latter; however, such lakes do not occur in Connecticut. The generalizations developed are useful in providing standards for comparison of Connecticut lakes with those of other areas. These comparisons will be valuable in future management if they permit predictions as to potential yield of fish and optimum growth rate of particular species.

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*The correlation coefficient between bottom fauna and organic nitrogen was 0.269 and with oxygen was –0.043. The relationship of nitrogen is of doubtful significance, while that of oxygen is not significant. Multiple correlation coefficient of bottom fauna and plankton and nitrogen was 0.654 and the added consideration of oxygen increased this coefficient to 0.690.

**Much of the observed variation is still not accounted for by any factors hitherto measured, but it may be supposed that this situation arises from errors inherent in the data themselves, rather than from failure to account for some important casual factor. At any rate, it is more than likely that the evaluation of bottom fauna is subject to a much larger error than the chemical analyses previously considered. The picture is further complicated by the fact that the relationship of the variables is probably curvilinear.

Comparison of Ball Pond and Glenida Lake

These two lakes were selected with reason. Sportsmen in the vicinity of Danbury have urged the planting of rainbow trout in Ball Pond, pointing out that it was "similar" to the neighboring Glenida Lake in New York State, a lake furnishing good trout fishing. They were visited on August 9, 1939, and in addition to the routine analyses performed elsewhere, determinations of the oxidation-reduction potential were made, and ferrous iron was also reported. The figures are, therefore, directly comparable to those secured for eight other Connecticut and New York lakes in the fall of 1938.[14]

Although both are comparatively small lakes, Glenida Lake has about twice the area of Ball Pond (Glenida 172 acres, Ball 90 acres). Glenida is more than twice as deep as Ball, having a maximum depth of 108 feet, while the maximum depth of Ball is 49 feet. The volume of Glenida is about five times greater, and the mean depths are respectively 50 feet and 19 feet. The ratio of drainage area to lake area is almost exactly the same for the two lakes, 2.52 and 2.60, and the lakes have almost equally regular shorelines.

When plankton contents are considered, it is found that Ball Pond has considerably more plankton per unit volume of water than Glenida. The chlorophyll figures, giving phytoplankton only, are: Ball, 5.54 parts per billion; Glenida, 2.86 parts per billion. The total seston in all probability consists largely of plankton in both instances, since neither lake is appreciably contaminated by externally derived organic matter (humus color: Ball 15, Glenida 5). The organic matter in the seston per unit volume of Ball Pond is about three times that of Glenida: Ball, 4.2 p.p.m.; Glenida, 1.6 p.p.m. The "centrifuge plankton" reported by the New York workers[42] for Glenida is comparable to the seston determined by membrane filtration; the mean centrifuge plankton is given as 1.4 p.p.pm.

The oxygen curves for the two lakes are presented in Fig. 24, and are seen to be strikingly different. The hypolimnion of Ball Pond is virtually devoid of oxygen, the concentration in the bottom water being 0.41 p.p.m., while the hypolimnion of Glenida is well supplied with this life-supporting gas, for in spite of a steep fall as the mud is approached, the bottom water has 4.75 p.p.m. The suitability of Glenida Lake for rainbow and even for lake trout becomes clear, since these species require cold well-oxygenated water, and Ball Pond is seen to be wholly unsuited for these species.

The differences between the two lakes are further emphasized by examination of the curves for oxidation-reduction potential. This determination gives a measure of the intensity of reduction taking place in the water, due to the accumulation of such reducing substances as ferrous iron, manganous manganese,

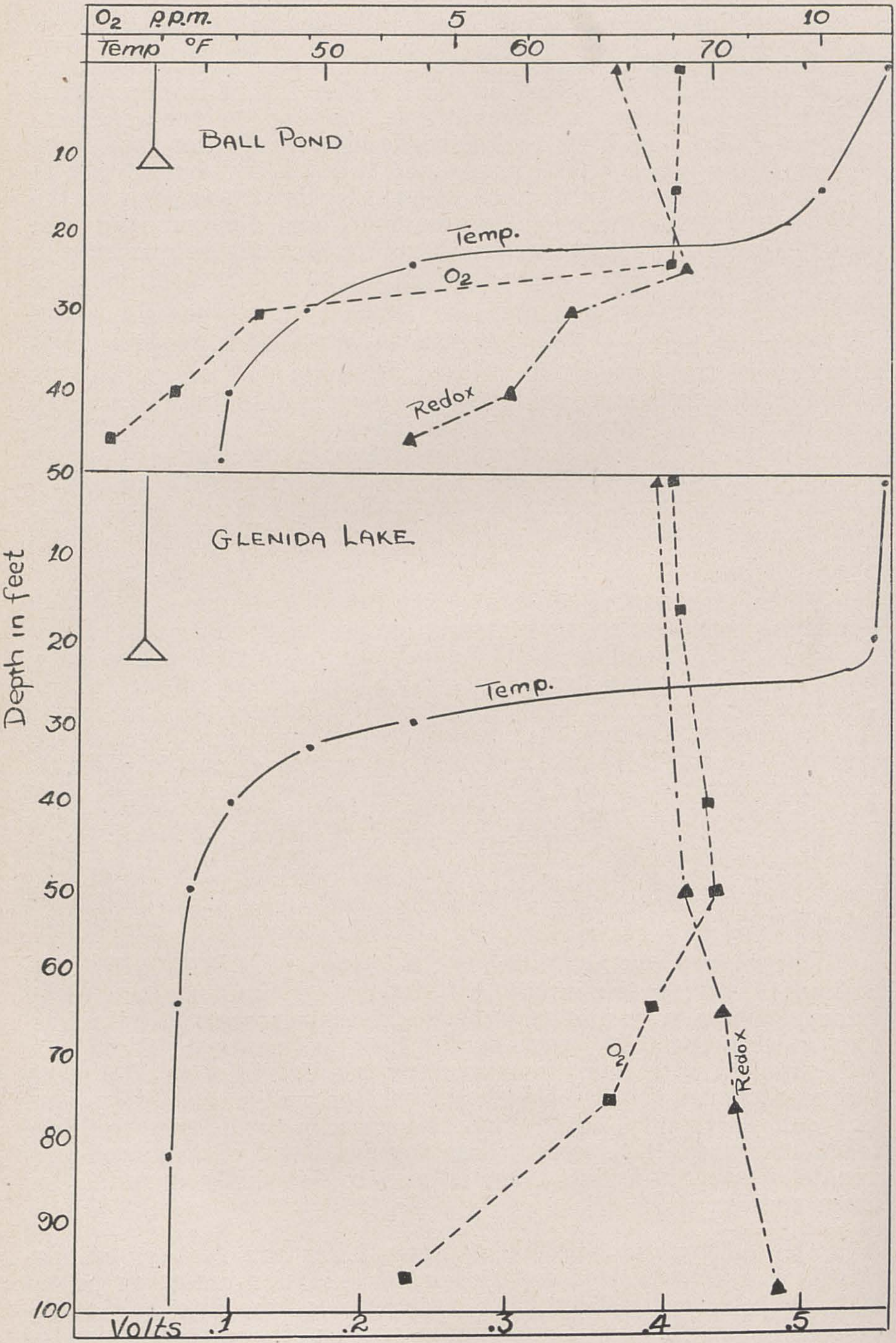

FIG. 24. Comparison of Ball Pond and Glenida Lake in respect to temperature, oxygen, transparency, oxidation-reduction potential. Analyses made August 9, 1939. Both diagrams plotted to same scale.

and ammonia — all of which will remove oxygen if present, although the value of the potential as determined is independent of the actual oxygen concentration at the time. This is particularly true when, as is the case here, the ferrous-ferric oxidation-reduction system dominates the equilibrium. The curves given for "redox" potential refer to the standard hydrogen electrode (for further information textbooks of physiology or Michaelis[25] should be consulted). It is evident that reduction proceeds much more strongly in the hypolimnion of Ball Pond than in that of Glenida Lake; the curve falls to 198 millivolts in Ball Pond, approaching the low values characteristic of Linsley Pond in September, while the potential of Glenida Lake follows an essentially straight line, even rising a little in the bottom water. This latter type of curve is characteristic of Quassapaug, Wononscopomuc, and East Twin Lakes, all of which further resemble Glenida in the form of their oxygen curves.

That ferrous iron is chiefly responsible for the observed differences in potential is seen from the values for the bottom water: Ball, 4.24 p.p.m.; Glenida, 0.15 p.p.m. All data available for Connecticut lakes[14] support the assumption that ferrous iron dominates the redox system. One lake examined, Queechy Lake, N. Y., suggests the existence of a different poising system, presumably dominated by hydrogen sulfide.

The paper cited shows that the characteristic bottom Chironomid species is determined by the form of the redox curve, rather than by that of the oxygen curve, as presumably assumed. European and Japanese lakes well supplied with oxygen in the hypolimnion are usually populated by the Chironomid genus *Tanytarsus;* those with little or no oxygen in the hypolimnion are inhabited by *Chironomus;* intermediate lakes are inhabited by *Sergentia* and *Stictochironomus* in Europe and by *Endochironomus* in Japan. When Connecticut lakes are examined, it is evident that the oxygen curve is not the controlling factor, as seen by a comparison of Job's Pond, a *Chironomus* lake well supplied with oxygen but having low values of the redox potential, with Quassapaug, a *Tanytarsus* lake with less oxygen but high values of the redox potential. Intermediate lakes, like Highland, with oxygen curves essentially similar to that of Quassapaug but with intermediate values of the redox potential, are populated by *Endochironomus,* or, in the case of East Twin lake and Wononscopomuc, by a *Chironomus** which lacks the ventral blood gills characteristic of the genus. As Ball Pond and Glenida Lake are intermediate between the eutrophic lakes of high productivity and low oxygen and the oligotrophic lakes of low productivity and high oxygen, they are called mesotrophic, and the Chironomid is provisionally referred to as "mesotrophic *Chironomus*". It now becomes significant that the characteristic Chironomid of Ball Pond is a typical *Chironomus,* that of Glenida Lake a mesotro-

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*Personal communication with Dr. O. Johannsen of Cornell University.

phic *Chironomus.* Glenida Lake thus resembles East Twin and Wononscopomuc Lakes, not only in the form of its oxygen and redox curves, but in the characteristic Chironomid, while Ball Pond resembles Linsley Pond and Mount Tom Pond, not only in the form of its oxygen and redox curves, but in its characteristic Chironomid.

The differences between the two lakes are of exactly the same nature as those between Green Lake and Lake Mendota, Wisconsin,[2] or between the North German and the subalpine lakes,[41] and, in the classical scheme of lake types, rank Glenida as an *oligotrophic* and Ball as a *eutrophic* lake. No discrepancies can be detected except the substitution of mesotrophic *Chironomus* for *Tanytarsus,* the characteristic oligotrophic Chironomid species. However, the differences between the two lakes are not so fundamental as might first appear.

When it is considered that the plankton of Ball Pond, although relatively abundant per unit volume, is confined to a small volume of water, and that the epilimnion, here regarded as the trophogenic zone (see p. 75 for definition), a fairer comparison between the two lakes is provided by the amount of plankton under unit area of lake surface. When these quantities are calculated the two lakes are found to have the same plankton productivity per unit area, 0.709 ounces per square yard.

It may also be assumed that equivalent amounts of plankton per unit area, dying and settling through the thermocline and hypolimnion and consuming oxygen by its decomposition, will consume equivalent amounts of oxygen. However, if two lakes have hypolimnia of different volumes, the original total endowment of oxygen (at the time of spring circulation) will be greater in the deeper lake, and the decomposition of equivalent amounts of plankton will result in a greater net amount of oxygen per unit volume in the deeper lake at the end of the stagnation period. In other words, the deeper lake will have an oxygen curve characteristic of oligotrophic lakes, while the shallower will have a eutrophic oxygen curve (described in Chap. II). The only fair comparison, therefore, is provided by the oxygen consumed per unit area of hypolimnion surface, and as this deficit, which may be defined as the *areal hypolimnetic oxygen deficit,* is cumulative, and increases with time, the rate of its generation may be assumed to be proportional to the amount of plankton under unit area.

The oxygen deficits per unit area for Ball Pond (Sept. 6, 1938, and Aug. 9, 1939) and Glenida Lake (Aug. 9, 1939)* are calculated according to the method of Hutchinson.[12] The increment in the deficit per day for the two lakes is found to be almost exactly the same: Ball Pond, 0.0182 per day (mean of two determinations); Glenida Lake, 0.0188 per day. The fact confirms the

*Deficits calculated from the data of the New York Survey seem impossibly high for lakes in this region.

impression derived from the quantities of plankton per unit area, and shows that the two lakes have exactly the same fundamental productivity, the differences between them being entirely determined by their differences in depth. The oligotrophy (or more exactly, mesotrophy) of Glenida Lake, therefore, is not fundamental, but *morphometric*, and correspondingly, Ball Pond may be called a *morphometrically eutrophic lake.* The data used in the comparison are set forth in Table 2.

TABLE 2. COMPARISON OF BALL POND AND GLENIDA LAKE

	Ball Pond	Glenida Lake
Area	90 acres	172 acres
Maximum depth	49 feet	108 feet
Mean depth	19 feet	50 feet
Ratio of drainage area to lake area	2.60	2.52
Shoreline development	1.35	1.19
Chlorophyll	5.54 p.p.b.	2.86 p.p.b.
Seston organic matter per unit volume	4.2 p.p.m.	1.6 p.p.m.
Seston organic matter under unit area	0.709 oz./sq. yd.	0.709 oz./sq. yd.
Oxygen concentration in bottom water	0.41 p.p.m.	4.75 p.p.m.
Oxygen deficit per unit area of hypolimnion	0.0182 per day*	0.0189 per day*
Ferrous iron	4.24 p.p.m.	0.15 p.p.m.
Oxidation-reduction potential, bottom water	0.198 volt	0.486 volt
Bottom Chironomid	*Chironomus*	mesotrophic *Chironomus*

Comparative Productivity of Connecticut Lakes

Many lakes are known whose oligotrophy is of a more fundamental sort, and arises from an excessive sterility and insolubility of the rocks surrounding them. Such lakes are found in the Alps and in the granite areas of Norway. Similarly, many lakes are fundamentally eutrophic, like the southern Wisconsin lakes, Mendota and Green (already chosen, as was done by Hutchinson, to illustrate how differences in apparent productivity can arise from differences in depth). The values chosen by Hutchinson to separate lakes on the basis of their fundamental productivity (in most cases plankton data were not available) were: *oligotrophic* — increment in areal oxygen deficit less than 0.5 per month*; *mesotrophic* — between 0.5 and 1.0 per month; and *eutrophic* — more than 1.0 per month. It is of interest, therefore, to compare the Connecticut lakes with these values, in order to determine the primary condition of Connecticut.

On Fig. 25 all available determinations of the areal hypolimnetic oxygen deficit in Connecticut lakes are plotted against

*These values are expressed in metric units; they can be thought of as "ounces of oxygen consumed per square yard of hypolimnion surface per day".

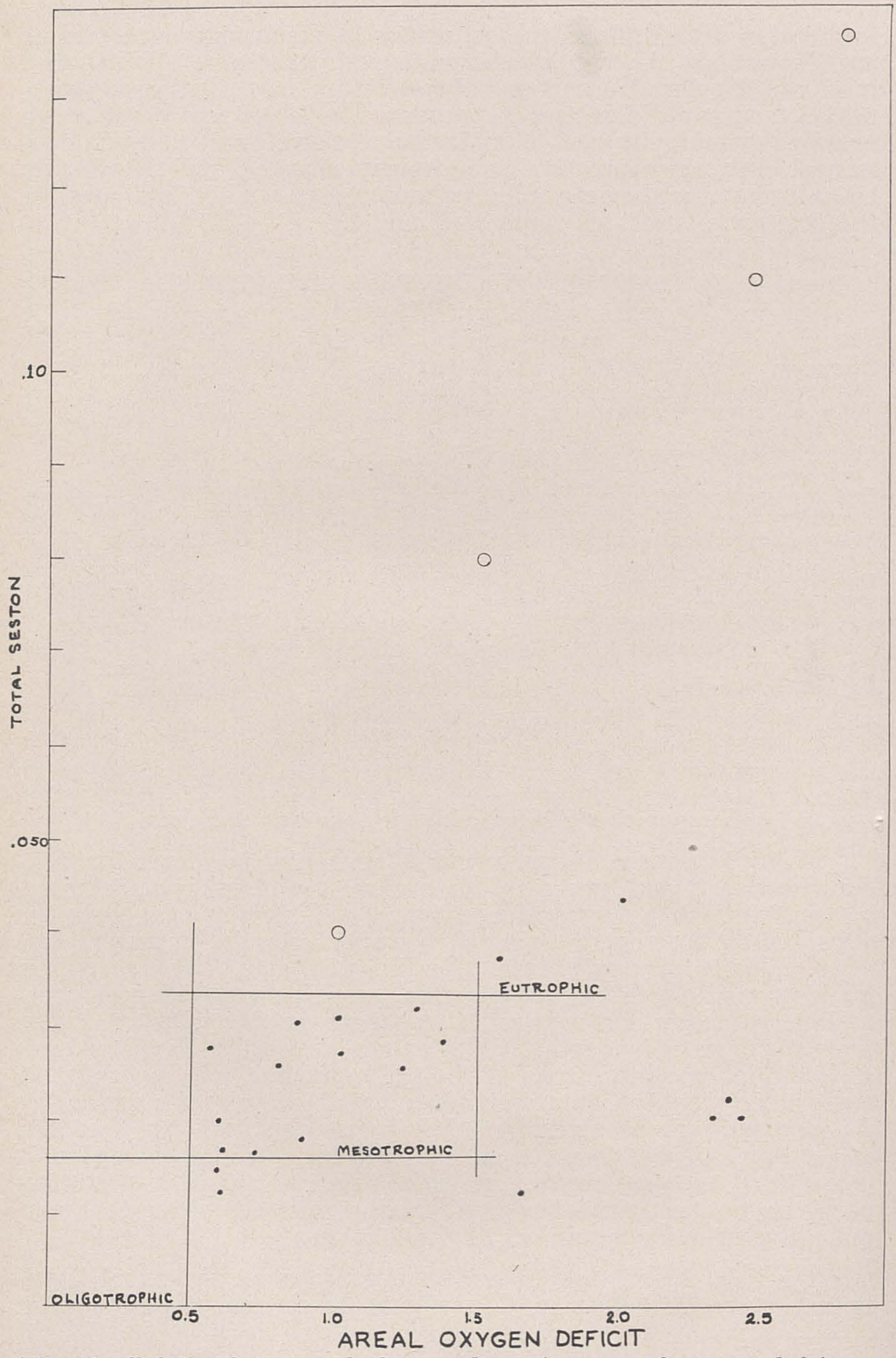

FIG. 25. Relation between *plankton under unit area* and *oxygen deficit per unit area of hypolimnion surface* in 21 Connecticut, New York, and Massachusetts lakes. Plankton figures represent total seston; both variables plotted in metric units. Large circles — four lakes used by Hutchinson (1938) in a similar comparison.

seston organic matter per unit area. Four large circles represent the four lakes used by Hutchinson in this theoretical analysis of the oxygen deficit — lakes Mendota, Green, and Black Oak in Wisconsin, and Fure Lake in Denmark, while the ruled lines correspond to the limits set by Hutchinson. As may be seen, the correlation between plankton and deficit is low; in fact, the correlation coefficient is only .130. This is unquestionably due to the fact that Connecticut lakes are too shallow to permit accurate determination of the deficit, since photosynthesis in the hypolimnion increases the oxygen values, or in other words reduces the deficit.[34, 35] To correct this condition in part, the mean maximum increment in the deficit has been plotted where more than one determination is possible, but in most cases only one series of oxygen analyses is available. Nevertheless, the box labeled "mesotrophic" includes the majority of Connecticut lakes, and this designation is undoubtedly valid. No Connecticut lake, not even the highly productive Linsley Pond, approaches the southern Wisconsin lakes in fundamental eutrophy; on the other hand, the "oligotrophic box" is empty, and probably only the Norwegian and high alpine lakes, of the known lakes of the world, are included here.

Other Features of Connecticut Lakes

It has been shown that all Connecticut lakes are fundamentally alike in potential productivity. However, within the limits of fundamental productivity imposed by the rocks of Connecticut considerable variations in real or apparent productivity are possible. The considerable spread of the points in Fig. 25 illustrates this in one sense. In another sense it may be recalled that the bottom fauna productivity, which represents the productivity as one may expect it to control and direct fishing, is not perfectly correlated with the other standards of judgment, not even with plankton. The criteria of productivity hitherto used, namely plankton crop, plankton under unit area, oxygen deficit per unit area, bottom fauna weight per unit area, and nutrient content, are, at best, individual criteria, to be taken into consideration with all the others in forming an ultimate judgment. Moreover, a difference in apparent productivity, such as is produced by a difference in depth, is not an insignificant piece of information, since it determines the form of the oxygen curve, and thus the suitability or non-suitability of a lake for a given species of fish.

As a final illustration of the economic value of a biological survey of lakes, the case of Green Falls Reservoir may be discussed. This small lake lies in the Eastern Highland close to the Rhode Island border. As might be expected from the foregoing discussion of geological influences on lake productivity, the plankton crop is low, unquestionably because the lake is excessively poor in total phosphorus. Were the lake deep, the poverty of plankton might make little difference to the fish present, for a comparison between Green Falls and Lake Quassapaug shows that the great mean depth of the latter (28.5 ft. compared with 13.4 ft. for Green Falls) permits considerable plankton to occur under unit area, although the chlorophyll values per unit volume are not very different (Quassapaug 5.62 parts per billion, Green Falls 3.06 parts per billion). Moreover, the depth of Quassapaug determines that the oxygen curve should be of the oligotrophic type, or at least that sufficient oxygen is present to support fish life at all levels throughout the summer, while the volume of deeper water in Green Falls is so small that the oxygen values fall to quite low levels (the data, obtained early in the summer, do not wholly bear out this statement, but later analyses undoubtedly would do so).

Even admitting these difficulties, a considerable number of rainbow trout might conceivably support themselves by feeding on plankton in the thermocline, where the temperature is low enough and the oxygen high enough to meet their requirements; in fact, several records show that this must have been the case. Here, however, the poverty of plankton in Green Falls makes itself felt, since the available water is of much smaller volume in Green Falls Reservoir than in Quassapaug, where rainbow trout have been successfully introduced.

But in the last analysis no lake will support trout whose bottom fauna is deficient; fish feeding directly on the bottom will find little sustenance, and fish feeding on the surface will find a paucity of insects, the larvae of which dominate the bottom fauna. The difficulty of successful rainbow trout planting in Green Falls Reservoir now becomes clear, for the bottom fauna weight per unit area is excessively small (13.7 pounds per acre as compared with 78.5 pounds per acre in Quassapaug).

These facts, which are of the utmost importance in any fish management program, illustrate the genuine value of scientific information to sportsmen.

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Section III.

The Life Histories Of Some Connecticut Fishes

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PART I. INTRODUCTION

The life history of a fish is a narrative of the events which affect or influence the fish from the moment it exists as an egg until it dies. It is a description, with both a qualitative and quantitative aspect, of an egg laid by parent fishes, of the egg's development into a tiny fish, and the growth of this tiny fish to maturity to take part in perpetuating the race. Thus a complete life history study would cover a multitude of facts: place and conditions surrounding reproduction; number, size, and characteristics of the eggs; period of egg incubation; size, development, and growth of the young fish; food, growth, enemies, parasites, habits, and habitats of the adult fish — these are some of the more pertinent points to be included in such a study. The life histories of very few fishes are completely known. Very little has been recorded about a number of common fishes and the information on those which have received most attention is widely scattered throughout the literature.

It is the purpose of this chapter to better acquaint the Connecticut angler with the lives of the fishes he seeks. It is hoped that this will both increase his pleasure in the sport and make for a more sympathetic view towards the efforts of fishery management and the natural problems with which such efforts must contend.

If life history studies need justification, it is obviously here. It hardly needs to be pointed out that if the eggs of a fish are to be secured, its breeding season must be known; if a fish is to be stocked in a stream or lake, a knowledge of its habitat is necessary; or if a fish is to be planted as food for more desirable species, its growth rate, food habits, and other characteristics should be known before such a planting can be successfully carried out. It is life history studies which contribute the solutions to these and numerous other problems. Without a thorough knowledge of the life histories of our fishes, sound and successful fishery management policies cannot arise.

Survey collections of fish have been made through the use of gill nets and seines. Much data, particularly on large fish, have been gathered from anglers' catches, the information being collected by members of the Survey party, by wardens, or volunteered by fishermen themselves.

Seining operations were confined to the shallow water of the shores, with the objective of determining the species of fish present. These collections of young game fish and minnows also gave some idea of abundance and the success of natural reproduction. Every effort was made to seine each type of environment present in the individual bodies of water and in most instances from 10 to 15 stations in each lake were sampled. The equipment for this work consisted of 6 to 20 foot minnow seines. All specimens were preserved in the field in a ten per cent solution of formalin; later when the collections were sorted, this was reduced to five per cent. These specimens, besides furnishing a permanent record of the species to be found in the waters from whence they

FIG. 1. A short quick haul with a small minnow seine is often the best way to collect in heavy weed patches.

came will be of further use in growth and food studies. A master sheet showing occurrence of species in Connecticut lakes and ponds covered by the 1937 and 1938 surveys may be found in Appendix III.

The gill nets were used to obtain specimens of the larger fish in deeper waters. Sixteen hundred feet of nets were at the disposal of the Survey, but considerable discretion was exercised in the quantity placed in any one body of water. Nets were of 100 or 200 foot lengths and varied in depth from 4 to 10 feet; several mesh sizes were used in order to capture various size groups of fish ($1\frac{1}{2}$, 3, 4, and 6 inch stretched mesh). The fish collected in this way were weighed, measured, sexed, and examined for parasites immediately following capture. The stomachs were also removed and scale samples taken for subsequent study, the details of which will be mentioned later.

At present the Department has data on over 5,000 adult fishes taken during the past five years. These include specimens taken by the Survey as well as those caught by anglers who have cooperated by voluntarily submitting measurements and scale samples from the fish they have caught. These efforts are appreciated and indicate a true desire to help on the part of the angler.

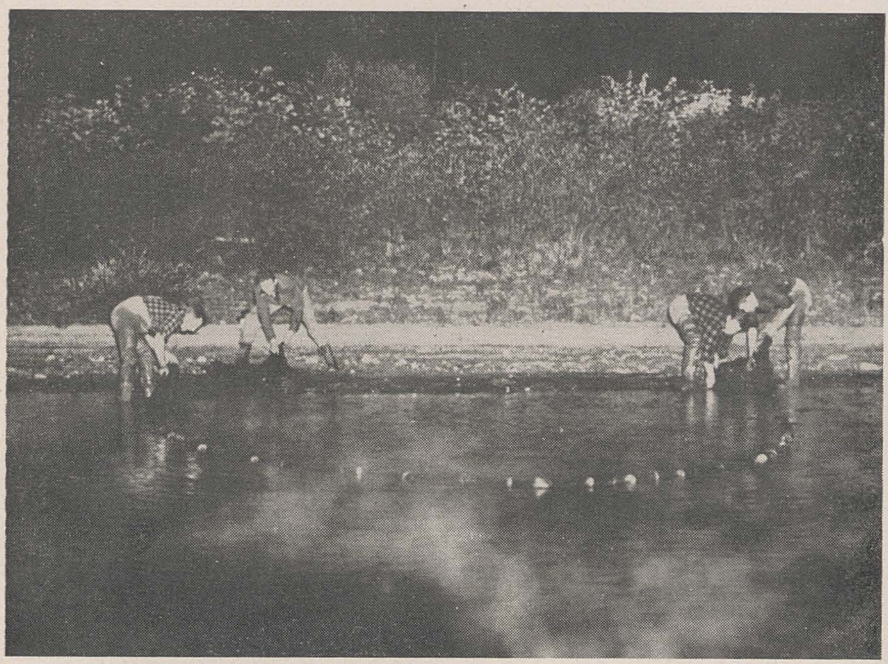

FIG. 2. Pocketing the catch after a long haul with a 100 foot seine over a sandy shoal in Bantam Lake. Night collecting is frequently more fruitful than day collecting.

Photographs of fishes used here were made from living, freshly caught, or freshly preserved specimens. Consequently they represent with a fair degree of accuracy the natural color patterns. When attempting to identify fish from the illustrations, however, it should be remembered that coloration and color patterns may vary considerably between different waters, seasons of the year, sexes, and particularly with the age of the fish. Recognition marks or distinguishing characters useful in the identification of specimens in the field have been mentioned in the titles whenever possible.

To supplement photographs as an aid to identification, a non-technical field key suitable for use by sportsmen has been included for the adults of salmonoid and centrarchid fishes found in Connecticut. Use of the keys consists simply in selecting the correct choice in each couplet (i.e. "1a" or "1b", etc.) until a selection leads to the identification of the specimen. Minnows are frequently difficult to identify, even for the trained observer, and workable non-technical keys are nearly impossible to devise. Readers will probably find direct comparison to the illustrations of sufficient aid to identify adult lake minnows in most instances. Anglers desiring to have fish identified may do so by sending them preserved in ten per cent solution of formaldehyde (obtainable at drug stores) to the State Board of Fisheries and Game.

PART II. LIFE HISTORIES

All fishermen are acquainted with some phases in the life of a few fishes, although this is usually restricted to a scattered knowledge about some of the habitats which various species frequent. In the pages which follow, an attempt has been made to gather some of the pertinent and more interesting details concerning the lives of Connecticut lake fishes. These include mention of the distribution, reproductive habits, habitats, and economic importance. In addition, a little information has been included concerning the families to which our fresh-water representatives belong.

A word might be mentioned about the extent of the fish fauna of Connecticut. As indicated by Table 1, a total of 40 species, 13 of which are introductions not occurring naturally in Connecticut waters, are now known from our lakes and ponds, and it is probable that the total number of fresh-water species in the State does not greatly exceed 50 in number. Thus the fresh-water fauna of Connecticut is small when contrasted with the 119 fishes known from the Ohio River drainage basin of Pennsylvania,[74] 150 or more species and subspecies from Illinois,[28] and 163 from Ohio.[100]

TABLE 1

CHECK LIST OF CONNECTICUT LAKE FISHES

(Complete through 1940)

Family AMIIDAE
Bowfin (*Amia calva*)

Family COREGONIDAE
Round Whitefish (*Prosopium cylindraceum quadrilaterale*)

Family SALMONIDAE

*Sockeye Salmon (*Oncorhynchus nerka*)
*Brown Trout (*Salmo trutta*)
*Rainbow Trout (*Salmo gairdnerii*)
*Lake Trout (*Cristivomer namaycush*)
Brook Trout (*Salvelinus fontinalis*)

Family OSMERIDAE

Smelt (*Osmerus mordax*)

Family ANGUILLIDAE

Common Eel (*Anguilla bostoniensis*)

Family CATOSTOMIDAE

Common Sucker (*Catostomus commersonnii commersonnii*)
Chub Sucker (*Erimyzon oblongus oblongus*)

Family CYPRINIDAE

*Carp (*Cyprinus carpio*)
*Tench (*Tinca tinca*)
*Goldfish (*Carassius auratus*)
Golden Shiner (*Notemigonus crysoleucas crysoleucas*)
Fallfish (*Leucosomus corporalis*)
Horned Dace (*Semotilus atromaculatus atromaculatus*)
Black-nosed Dace (*Rhinichthys atratulus atratulus*)
Bridled Minnow (*Notropis bifrenatus*)
Spot-tail Minnow (*Notropis hudsonius amarus*)
Common Shiner (*Notropis cornutus cornutus*)
Cut-lips Minnow (*Exoglossum maxillingua*)

Family AMEIURIDAE

Common Bullhead (*Ameiurus nebulosus nebulosus*)

Family ESOCIDAE

Grass Pickerel (*Esox americanus*)
Chain Pickerel (*Esox niger*)
*Northern Pike (*Esox lucius*)

Family CYPRINODONTIDAE

Barred Killifish (*Fundulus diaphanus diaphanus*)

Family CENTRARCHIDAE

*Largemouth Black Bass (*Huro salmoides*)
*Smallmouth Black Bass (*Micropterus dolomieu*)
*Calico Bass (*Pomoxis nigro-maculatus*)
*Bluegill Sunfish (*Lepomis macrochirus*)
Red-bellied Sunfish (*Lepomis auritus*)
Common Sunfish (*Lepomis gibbosus*)
Rock Bass (*Ambloplites rupestris*)
Banded Sunfish (*Enneacanthus obesus*)

Family PERCIDAE
- *Pike-perch (*Stizostedion vitreum*)
- Yellow Perch (*Perca flavescens*)
- Johnny Darter (*Boleosoma nigrum*)
- Fusiform Darter (*Hololepis fusiformis* subsp.?)

Family MORONIDAE
- White Perch (*Morone americana*)

Introduced Species	13
Native Species	17
Total	40

*Indicates species which have been introduced.

The Bowfins (Amiidae)

The bowfin are a primitive family of fishes with only one species found in North America, the bowfins or dogfish (*Amia calva*). The Survey has not yet collected any specimens of this fish in Connecticut, but in past years it has been taken from Lake Zoar, a pond in Sandy Hook*, and in quarry holes in Portland.

During the breeding season the bowfin clears away a spot in the vegetation to form a nest and the male fish guards the eggs and young for a considerable period after they have left the nest.[28]

The fish is of little value as food, although it is eaten to a certain extent in the south. Maximum size is around two feet.[28]

The Lake Herrings and Whitefishes (Coregonidae)

These are fishes found in the northern hemisphere in lakes providing the cold water habitat which they require. Of the three genera, *Coregonus* (whitefishes), *Leucichthys* (lake herrings or cicoes), and *Prosopium* (round whitefish or frostfish), only the latter occurs in Connecticut.

The family has close affinity with the trout and salmons, both from a structural and from environmental aspects, but the coregonids are much more restricted to lakes. The largest of them, the Lake Superior whitefish (*Coregonus clupeaformis*) attains a size of ten to twelve pounds and is of considerable commercial value. For this reason it has received much attention from fish culturists.

By virtue of the fact that trout, particularly the lake trout (*Cristovomer namaycush*), inhabit the same waters as these fishes and utilize them as food, they are of considerable value as forage. Whitefishes themselves, in general, feed upon small organisms found in the water.

*Correspondence with Dr. A. E. Parr of Peabody Museum, Yale University, dated February 12, 1940.

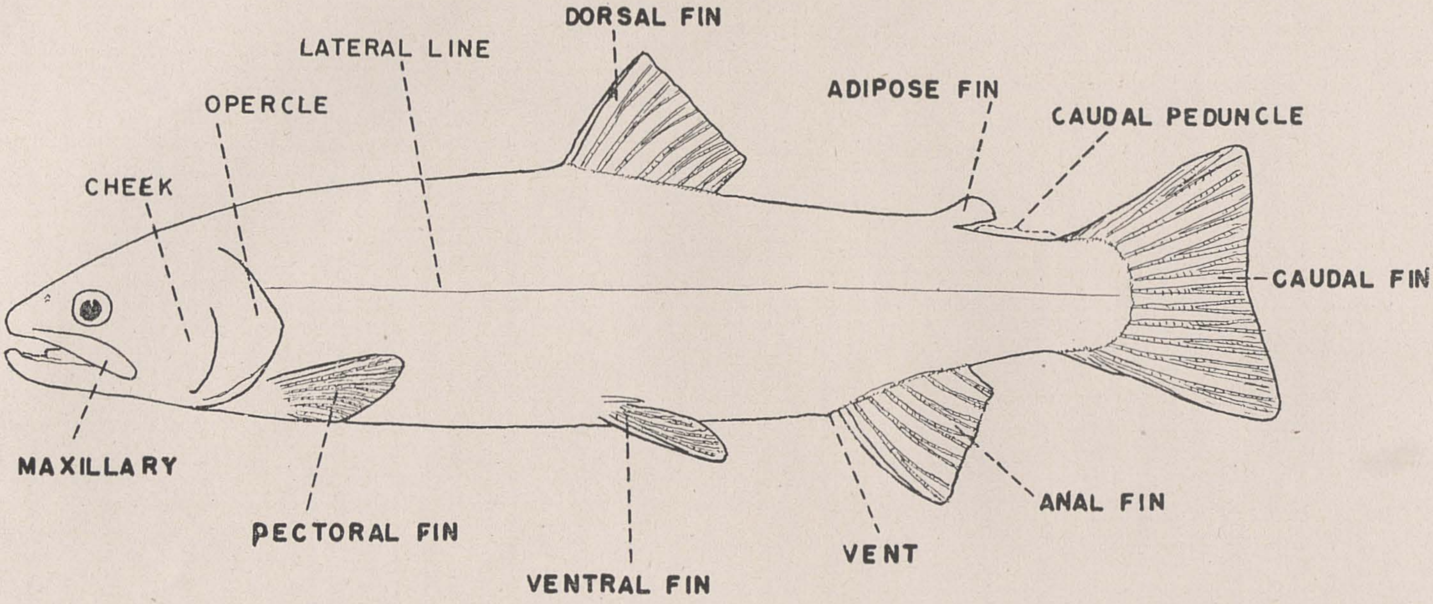

FIG. 3. Diagram indicating terms frequently used in describing fish.

Round Whitefish (*Prosopium cylindraceum quadrilaterale*)

Distribution

This coregonid has the widest distribution of any of the fishes in the family, occurring from New England west through the Great Lakes to Alaska and parts of Russia.[12] In Connecticut it is known only from the northwestern section where it inhabits East Twin Lake.

Habits and Habitat

Nothing is known of the breeding habits of this fish in Connecticut other than that spawning presumably occurs sometime between October and December.

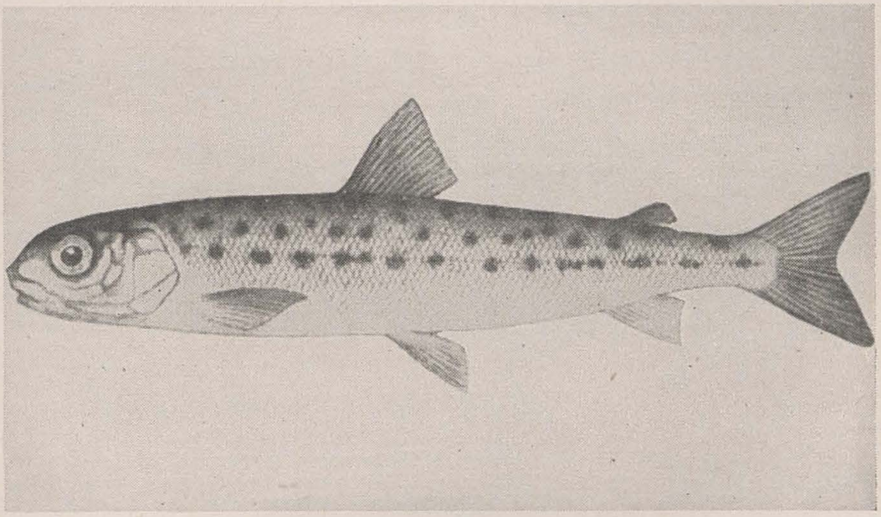

FIG. 4. Round whitefish fingerling (*Prosopium cylindraceum quadrilaterale*). Drawing of a young fish from Lake Nipigon, Canada. Young possess three rows of dusky spots along the sides.
Courtesy Ontario Fish. Res. Lab.

Specimens 13 to 15½ inches long were found in 40 to 60 feet of water and in association with sockeye salmon, yellow and white perch. The round whitefish is quite abundant in the lake.

The stomachs of fifteen Twin Lake specimens taken on August 9th, 1939, were examined and found to contain the following (percentage estimation by volume): 53 per cent midge larvae and pupae (of which 22 per cent was represented by *Chaoborus*), 35 per cent sowbugs (*Asellus*), 7 per cent snails (largely *Physa*), 4 per cent water fleas (*Daphnia*), and 1 per cent *Hyalella*. Six fish taken on August 31, 1940, had been feeding almost exclusively on larvae of the phantom midge (*Chaoborus*); two specimens had, in addition, eaten a few midge larvae and small clams.

Reference to other sections of this report will show that East Twin Lake is quite different in several important respects from other impounded waters of the State, and it is because of these differences (primarily cool, deep waters, well-oxygenated at all depths) that this species thrives here.

Economic Role

Since the round whitefish does not take a hook readily, it cannot be classed as a game species. In many parts of its range, however, it is highly esteemed as food and it is taken in large

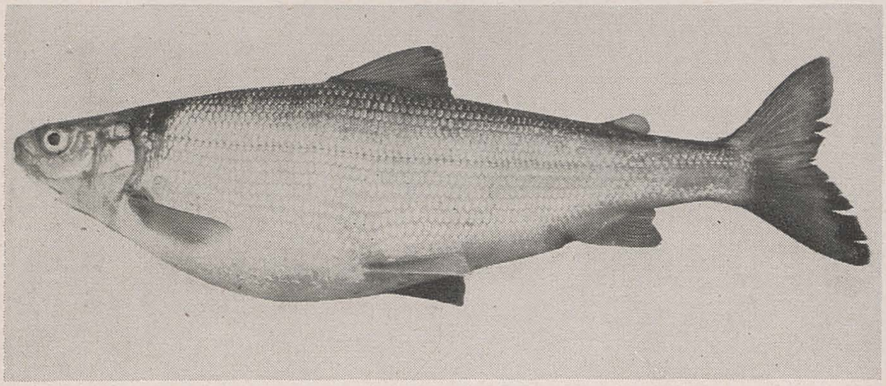

FIG. 5. Round whitefish (*Prosopium cylindraceum quadrilaterale*). Known in Connecticut only from East Twin Lake, Salisbury. Adult male 14½ inches long. Abdomen abnormally large because of distended air bladder.

numbers by gill netting.[53] It was formerly the policy of this Department to allow gill-netting for the round whitefish in East Twin Lake and large numbers were taken by this method.

THE SALMONS AND TROUTS (Salmonidae)

Members of the Salmonidae are probably the best known and most highly regarded of sport fishes. Like the whitefishes they are typically of northern distribution in lakes and streams where the waters remain cool the year around. All of them are more or less migratory in nature, and in some instances this instinct, if it is such, is very remarkably developed.

The family is divided into three main groups: the Pacific salmons (*Oncorhynchus*), the true trouts (*Salmo*), the charrs (*Salvelinus* and *Cristivomer*).

Of these the Pacific salmons are unique in that all die after their initial spawning, none, so far as known, ever surviving to reproduce a second time; there are five North American species, all originally found only in Pacific waters. They live in the

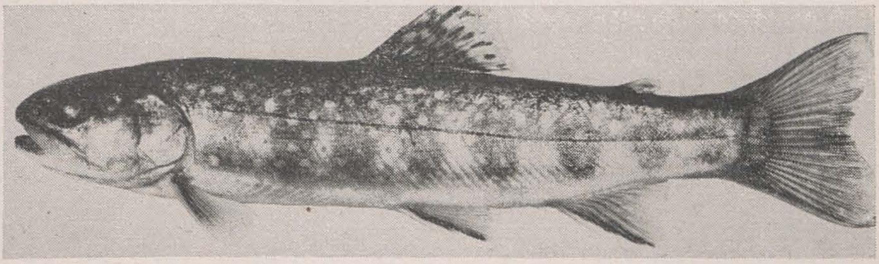

FIG. 6. Brook trout (*Salvelinus f. fontinalis*). This fish is now the only salmonoid native to Connecticut, the Atlantic salmon have long disappeared. White and black margined belly fins and absence of black spots on the body distinguish the "brookie". Specimen 4¾ inches long.

ocean before spawning and then run up into fresh water to spawn and die. Curiously enough, one species, the sockeye or red salman (*Oncorhynchus nerka*), has been successfully introduced into one Connecticut lake, East Twin, where it is now present in considerable numbers.

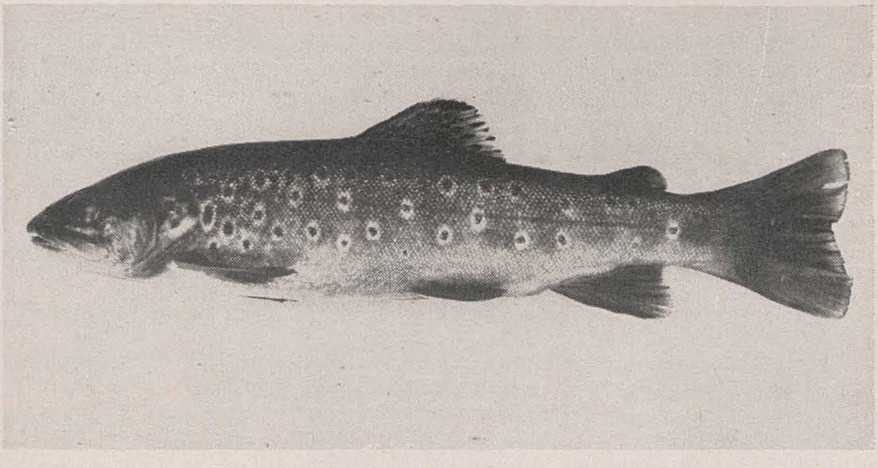

FIG. 7. Brown trout (*Salmo trutta*). Introduced from Europe in the last century, the brown trout has done well in many streams no longer suitable for the more fastidious brook trout. Black and orange or yellow spots serve as recognition marks. Specimen, 9 inches long, from Burlington Hatchery Brook, Burlington.

The genus *Salmo* includes the Atlantic salmon and the landlocked salmon (*Salmo salar salar* and *Salmo salar sebago*) of the east, the brown trout (*Salmo trutta*) introduced from Europe, the variable rainbow and rainbow-steelhead strains (*Salmo gairdnerii*) and others, and the cutthroats (*Salmo clarkii*). Connecticut waters have long since been depleted of the once abundant Altantic salmon, while the land-locked never existed here,[56] although many fruitless efforts have been made to introduce it. Both the brown and rainbow trouts have become established in the streams through artificial planting, and the rainbow has been introduced into a score or more lakes and ponds.

The brook trout (*Salvelinus fontinalis fontinalis*) (Fig. 6) is the familiar native representative of the charrs, although its once widespread distribution throughout the State has been largely localized to areas where cool stream conditions still prevail. It has recently been planted in Moriarty's and West Hill Ponds, and occurs naturally in some small spring ponds.

Of the several other species of charrs, one other occurs here and that is the lake trout (*Cristivomer namaycush*). It is not native, and is found naturally in New England only in Maine, New Hampshire, and Vermont.[56]

The range of all members of this, as well as the preceding family (Coregonidae), is quite restricted by temperature and oxygen requirements. The oxygen demands apply particularly to lake-dwelling species which must resort to deep water for low temperatures, but may be barred from doing so by low oxygen content.

The Salmonidae assume great economic importance, both from a food and sporting standpoint. However, with the disappearance of the Atlantic salmon, Connecticut lost its only claim to the food fisheries. In sport fishing, nevertheless, salmonoids are still very important.

Field Key to Adult Trouts of Connecticut

1a. Tip of the longest ray of anal fin, when folded back along body, not reaching base of last ray . . . . . SOCKEYE SALMON (Figs. 9, 10).

1b. Tip of the longest ray of anal fin, when folded back along body, reaching base of last ray.

- 2a. Light spots on dark background, never with black spots on body; scales minute, small specimens appearing scaleless. (the Charrs)
  - 3a. Pink or vermillion spots present, ventral and anal fin strongly margined with white and dark brown . . . . . BROOK TROUT (Fig. 6).
  - 3b. Reddish spots absent, with many irregular grayish or yellowish spots . . . . . LAKE TROUT (Figs. 13, 14).
- 2b. Black spots on light background; scales larger, plainly visible.
  - 4a. Reddish or orange spots usually present; adipose fin usually margined with orange . . . . . BROWN TROUT (Fig. 7).
  - 4b. With black spots only, usually with pink or purple lateral band; adipose fin margined with black . . . . . RAINBOW TROUT (Figs. 11, 12).

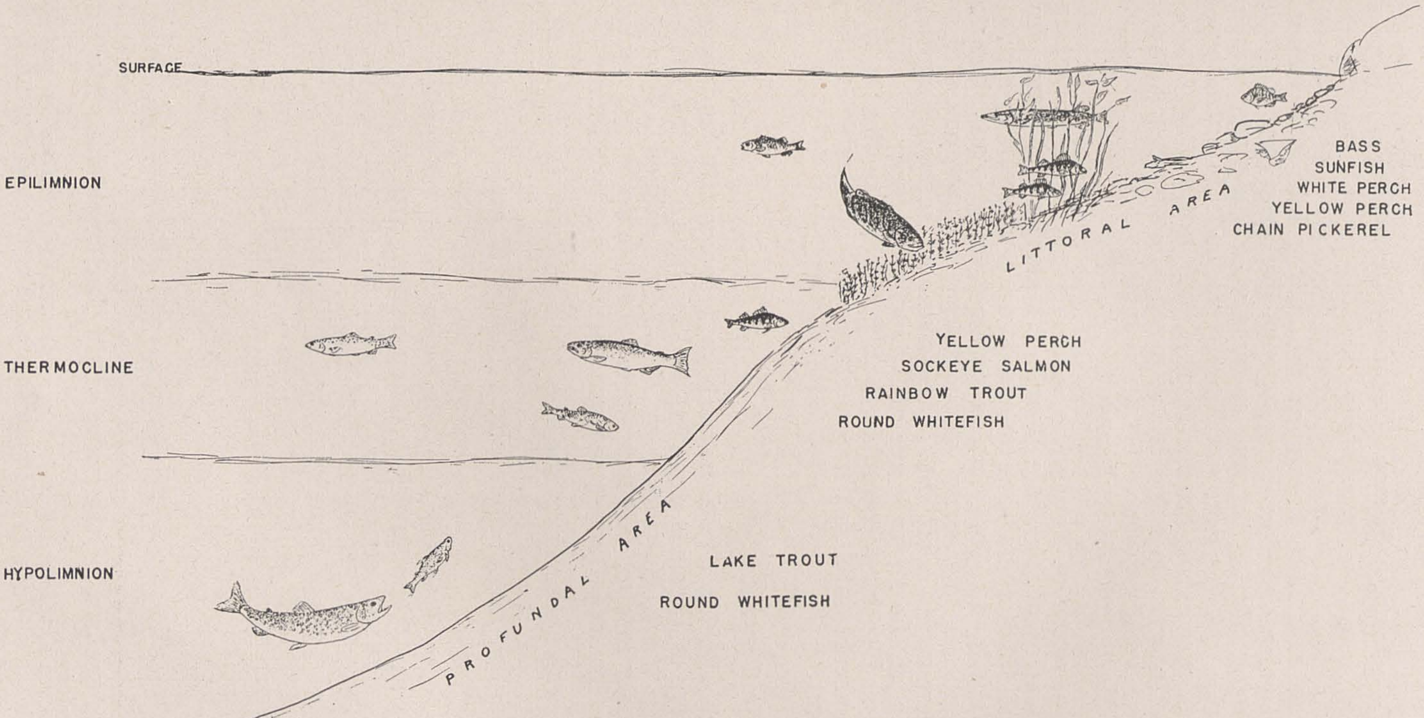

FIG. 8. Typical mid-summer habitats of some fishes living in relatively deep Connecticut lakes such as Wononscopomuc, East Twin Lake, and West Hill Pond. Explanation of limnological terms may be found on p. 72.

Sockeye Salmon (*Oncorhynchus nerka*)*

Distribution

The sockeye, also known as the red or blueback salmon, is found native on the Pacific coast from Monterey Bay, California, to the Bering Strait,[20] as well as land-locked in many of the inland lakes.[71] Many attempts have been made to introduce this and other species of Pacific salmon into various parts of the world, but success in establishing a sea-run population has been limited to three regions: certain coastal waters of Chile, New Zealand, Maine and New Brunswick.[20]

The presence of the fish in East Twin Lake was first called to the attention of the State Board of Fisheries and Game during the fall of 1936 when large numbers were reported spawning in localized shallows. Considerable public interest was immediately aroused and the "discovery" of the salmon was the cause of widespread newspaper comment. Circumstances surrounding the introduction of the sockeye are still indefinite; several individuals have claimed to be responsible, but the difficulty lies in getting reliable specific information on shipments of Pacific salmon to Connecticut.

Taxonomic Consideration

On the Pacific Coast the sockeye is frequently land-locked in lakes where it becomes dwarfed and is known as the little redfish, silver trout, Kokannee, or Kennerly's salmon. Except for the disparity in size, this land-locked form is apparently quite inseparable from the larger sea-run form.

The sea-run sockeye has the most commercial value of the five species of Pacific salmon, although it is one of the smaller ones, attaining a maximum size of about 12 pounds and averaging about 6.[71]

The dwarfed sockeye, on the other hand, is smaller, for in some British Columbia lakes its maximum size is only 7 or 8 inches.[22] It has been considered as a separate species (*O. kennerlyi*) or as a subspecies (*O. nerka kennerlyi*). Recently, however, the smaller sockeye has been classified with the larger form[82] since environment seems to be the principal factor accounting for the size differences and no genetic difference has yet been shown.

Reproduction

Upon the approach of the breeding season, many fishes exhibit marked changes in coloration and form. This is particularly striking in the case of the males of the Pacific salmon. Male sock-

*Specimens have been examined by several men including the late W. C. Kendall, W. C. Schroeder, J. Nichols, C. McC. Mottley, and Bureau of Fisheries representatives.

eyes taken from East Twin Lake in October are spectacularly colored with bottle green heads and blood red sides. These are to be contrasted with fish taken just three months before whose livery consisted of silvery sides, greenish backs, and heads faintly flecked with black. Changes in form are apparent at this time (Fig. 10). During the breeding season this change in form has reached an extreme and the males possess deep bodies and grotesquely elongated and hooked snouts. The hooked snout, popularly thought to be an aid to males engaged in combat, probably serves only slightly for this purpose.[66, 93]

Twin Lake sockeyes mature during their fourth growing season and spawn during the following fall. Specimens whose gonads exhibited signs of sexual maturity were from 14 to 16½ inches long, while an immature female 12⅜ inches long was two years old and in its third growing season. These observations correspond to the age of the sea-run Pacific coast sockeyes which mature in their fourth or fifth years depending upon the age at which they migrated to the sea.[30]

After a long period of feeding spent in the ocean, the sea-run sockeye exhibits a marked migration into fresh-water rivers for the purpose of breeding. Spawning takes place on shores of the lakes found at the headwaters of rivers or in the streams feeding them.[53] Land-locked forms behave in a similar manner though their migration is necessarily of a much more limited nature.

Spawning on East Twin Lake, as far as is known, takes place only in the shallows of a localized area on the east shore of the lake and in a small spring tributary entering at this point.

The breeding season in Connecticut extends from mid-October through November. Many eggs were stripped artificially on October 30, 1936. During the following year large numbers of fish were found on the spawning grounds on October 22nd (water temperature 53° F.) and these numbers gradually dwindled until December 3rd when the last fish were noted. In 1938, October 28th marked the first appearance of the sockeyes.

The courtship, nest-building, and spawning of the little redfish has been well described in Pacific coast streams[85] and is not unlike that mentioned for the rainbow trout (p. 139). Only females usually engage in nest building activities. Well-defined courtship antics precede or accompany spawning, in which the male noses the female or swims back and forth over her. Both sexes defend their nest against invaders, although the appearance of a larger male may cause the defending male to leave.[84]

L. M. Thorpe made some interesting observations on courtship behavior of Twin Lake sockeyes on November 11, 1939. This was immediately following a sudden drop in temperature and on this date the water over the spawning ground was 33° F. (air 10° F.). No spawning or nest-building activities were observed, although the females occupied well-defined nests and a large number of males were moving about in the spawning area. Females frequently left their nests to contact passing males, often nudging them markedly along the sides and rarely nipping them about the region of the vent. The females did not tolerate the presence of others of the same sex within their nests, but often as many as six males would attend a single female. Once within the nest the male salmon also apparently tried to stimulate the female by nosing the regions about the vent. Many of the males exhibited frayed caudal fins as though they had been actively engaged in nest building along with the females.

As mentioned previously, all Pacific salmons spawn once and then die. In their native waters, the spawning grounds are cluttered with dead or dying salmon. For some reason, as yet not evident, such conditions are not to be found in East Twin Lake, although it is not inferred that the sockeyes do not die. It is simply observed that throughout the breeding season, even at its height, when an estimated several thousand fish are on the grounds, only a few dead ones are to be found. It is possible and probable that the spent fish retreat to deeper water before they succumb and thus effectively escape notice.

Habits and Habitat

The young land-locked sockeyes migrate into the lakes after hatching, if they did not hatch there. In sea-run forms this is paralleled by migration to the ocean after a variable length of lake life; some move down to the ocean shortly after hatching, while others remain in the lakes for a year or two.[30] The ocean affords excellent feeding opportunities and here the salmon remain until they reach sexual maturity.

Pacific coast lakes containing sockeyes seem to exhibit the same general combinations of conditions required by other salmonoid fishes, such as cold, deep, and well-oxygenated waters. East Twin Lake is one of the few Connecticut waters which furnish these conditions. Sockeyes taken in August by the Survey were found in 40 to 60 feet of water along with the round whitefish and a few white and yellow perch.

The food of the lake sockeye appears to be largely microcrustacea throughout its entire life.[82, 23] Five sockeyes in their fourth growing season taken from East Twin Lake on August 9, 1939, held the following organisms (estimation by volume): Cladocera, 60 per cent; *Chaoborus* larvae and pupae, 30 per cent; other midge larvae, 5 per cent; Ostracods, 5 per cent. In addition, three other specimens whose stomachs were empty had remains of Cladocera in their intestines. These specimens were from 14 to 16½ inches long. Seventeen sockeyes of similar size taken on August 31, 1940, had been feeding almost exclusively on Cladocera (*Daphnia*), a few larvae and pupae of midges comprising about 3 per cent of the food.

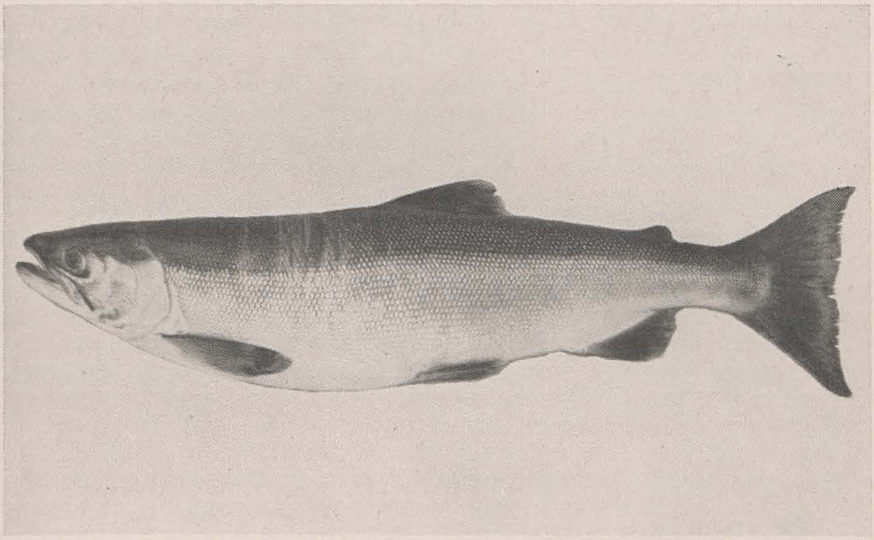

FIG. 9. Sockeye salmon female (*Oncorhynchus nerka*). Artificially introduced into East Twin Lake, Salisbury, from the Pacific Coast. Color pattern of this maturing female is typical of immature fish of both sexes. Specimen, 16¼ inches long, taken August 31, 1940.

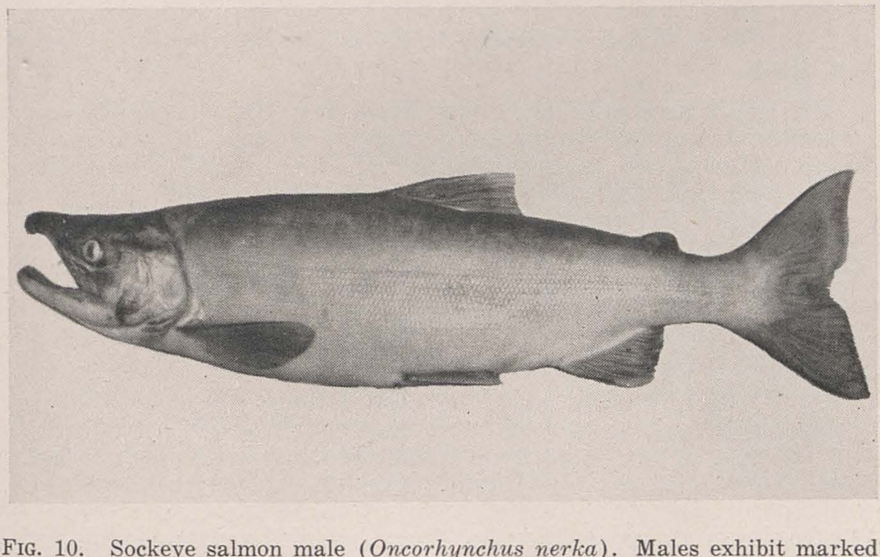

FIG. 10. Sockeye salmon male (*Oncorhynchus nerka*). Males exhibit marked color and body form changes with the approach of the breeding season. This specimen, 16½ inches long, also taken August 31, 1940, already differs greatly from the female above.

Mature sockeyes take no food during the breeding season and may cease feeding for some time prior to it.[30]

Economic Role

The presence of a self-sustaining population of sockeye salmon in the waters of a Connecticut lake has little intrinsic value to anglers because of the restricted distribution of the fish.

Until the spring of 1941, Twin Lakes fishermen have had little success angling for these fish, although on the Pacific coast, land-locked sockeyes are frequently sought by anglers. This is particularly true in Washington where they are known as "silver trout". The sockeye is taken in several ways by western anglers.* In general, the methods used depend on where the salmon are living, a logical rule followed by most fishermen. During the summer when surface temperatures are intolerable, the fish repair to deep water and the fishermen troll for them with a series of spoons or spinners accompanied by a baited hook. This lure is known by various names, probably best in Connecticut as the "Davis rig". When the surface waters are cool, as in the spring and fall, the sockeyes feed freely near the surface and may be taken on artificial flies or almost any other lure or bait. Whatever methods may be employed, one precaution is necessary. The sockeye salmon has a tender mouth and it is thus requisite to use extreme care in setting the hook and in playing the fish to prevent the hook from tearing out.

The dwarf sockeye salmon in some waters of the west is considered as a forage fish, particularly for the rainbow trout.[22, 23]

Rainbow Trout (*Salmo gairdnerii*)

Distribution

The rainbow is a Pacific Coast trout, first introduced into eastern waters in 1874 by an early American fish culturist, Seth Greene. From the early activities of the United States Fish Hatchery in California, 15,000 eggs of the famed McCloud River rainbows were shipped to Connecticut in 1883 and 1884.[98] In its native range this trout lives in coastal streams and lakes from Alaska south as far as northern Lower California, frequently descending to spend part of its life in the ocean. There are also a few isolated forms to be found in the high mountains.

Taxonomic Consideration

The differences between the many subspecies of western trouts have long been a source of argument and confusion to both scientist and layman, in particular, the well-known rainbow-steelhead controversy. At present, it seems to be the general concensus of opinion among authorities that the rainbow trouts are rep-

*Information on angling methods for sockeyes suggested by Dr. C. McC. Mottley, Department of Limnology and Fisheries, Cornell University.

resented by but a single species, *Salmo gairdnerii*, which is subject to considerable variation perhaps due to various environmental conditions under which it may be found. For instance, it has been shown that rainbow trout growing at different altitudes differ noticeably in the number of scales along the lateral line, a character used in separating the several species of these trout.[65] These cannot be considered as species unless they are inherently different from one another.

Rainbow and steelhead trout are considered as one species, since the steelhead is a sea-run rainbow which attains a larger size than inland forms owing to physical variations brought about by sea life.[88] In conclusion, then, the accepted classification would be that one in which but a single species, *gairdnerii*, is recognized with several varieties (subspecies) to be found in the various parts of its range.[83, 67]

Reproduction

Most rainbows are spring spawners, becoming mature in Connecticut waters in late March or April.

Lake dwelling forms, as well as the sea-run "steelheads", migrate at this time into streams where spawning takes place. Individuals already inhabiting streams may not show such a definite movement.

A spawning nest or redd, as it is often called, is built usually by the female fish in the gravel, typically at the foot of a pool just before the water breaks up into riffles. These are built in a haphazard manner and are scarcely comparable to the nests of sunfish. In the case of a large fish the nest may be three or more feet in length.

Pertinent observations have been made on the nest-building and spawning behavior.[34, 70] The nest is a depression several inches deep and is excavated principally by the use of the tail. The gravel is loosened by powerful caudal strokes delivered as the female lies on her side and it is carried downstream by the current where it piles up below the nest.

When the redd is completed, and this may require a number of hours, the female is ready to deposit the eggs. During the spawning act she is accompanied by one or more males. As the pair lie in the deeper part of the depression, the male appears to be tightly pressed against the female in a lateral position. Eggs and sperm are released simultaneously during a vibratory movement of their bodies. The spawning act lasts about two seconds, the male participant leaving immediately afterwards. After spawning, the female turns to the task of covering up the eggs which have settled to the bottom of the depression; this also is accomplished by the use of the tail with which the female digs in the gravel at the sides of the nest and upstream from it. The loosened gravel is again carried downstream by the current to cover the eggs to a depth of several inches. If all of her eggs have not yet been extruded, the female begins construction of another nest, and spawning again takes place.

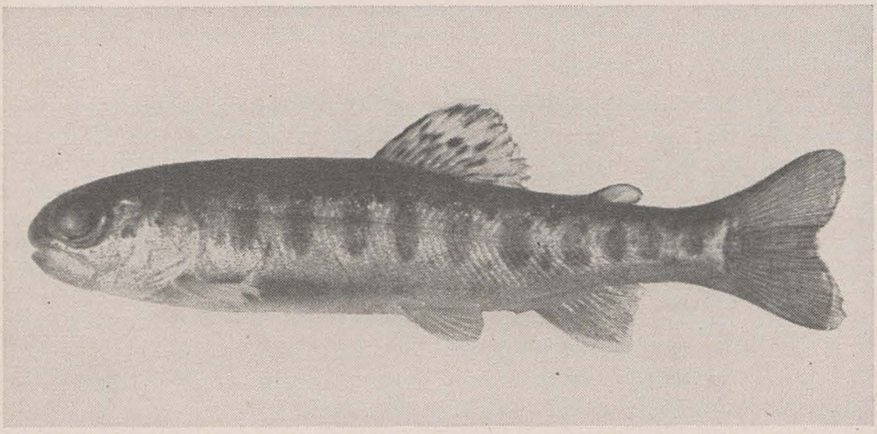

FIG. 11. Rainbow trout fingerling (*Salmo gairdnerii*). The young of nearly all salmonoid fishes possess dusky vertical bands or "parr" marks. Black spots and a black margined adipose fin are recognition characters of the rainbow trout. Juvenile, 3 inches long, from inlet to Skaneateles Lake, New York.

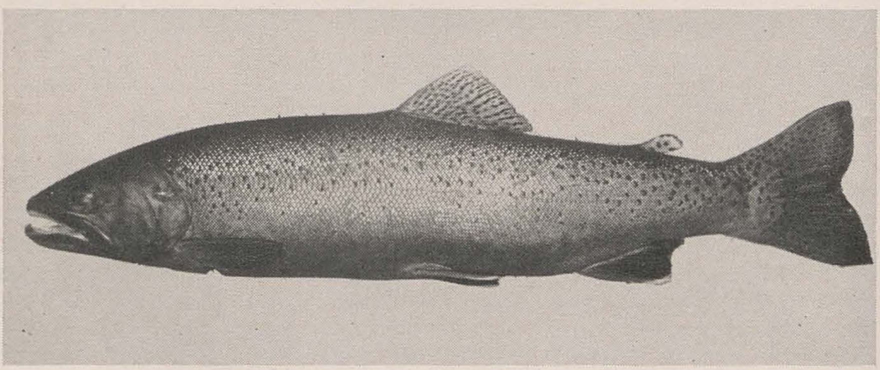

FIG. 12. Rainbow trout adult (*Salmo gairdnerii*). Rainbow trout in lakes generally become more silvery than stream fish and immatures lose most of their black spots. Mature male, 18 inches long, taken from inlet to Skaneateles Lake, New York.

As is the case with other trout and salmon, the task of spawning is arduous and the anal, ventral, and caudal fins of the females become frayed and broken as a result of their digging activities. During the period intervening between breeding seasons, these are replaced.

At present there is no definite information concerning the successful reproduction of rainbows which are land-locked in lakes. Running waters seem to be necessary.

The eggs of the rainbow trout are large, as is generally the case in salmonoids, being about six millimeters in diameter (four to the linear inch). They are a beautiful orange or pinkish color. As indicated previously, the female deserts the nest after covering the eggs and this is the extent of parental care.

Young trout are particularly burdened with a large amount of yolk and this seriously impedes any swimming attempts. They remain buried in the gravel in which they have hatched until the yolk is absorbed. When this is accomplished, they work their way up into the open water of the stream and eventually play a conspicuous role in the complex organization of the watery world.

In the case of lake rainbows the young fish may drop downstream into the lake itself after a variable length of stream life or a few may remain as permanent residents of the running water. The Survey has no records of young rainbows being taken in any of the Connecticut lakes.

Habits and Habitat

Only a few Connecticut lakes present the conditions usually conceded necessary for rainbow trout, even when the problem of satisfactory natural reproduction is neglected. Over a period of several years many lakes and ponds have been stocked. Information collected on most of these show all but a few to be quite unfit for rainbow trout. By the simple expedient of determining the suitability of these waters prior to stocking, considerable money could have been saved. On the other hand, lakes which the Survey showed to be suitable for trout were, significantly enough, the ones from which a reasonable return of planted trout was realized. Though high oxygen content of the bottom waters in lakes is generally considered essential to the well-being of trout, a number of British Columbia lakes have been shown to exhibit low mid-summer oxygen concentration and yet have supported large populations of rainbow trout.[76] By many costly trial and error experiments, it appears definite that the British Columbia lakes of this type are not comparable to Connecticut conditions in suitability for rainbow trout.

All Connecticut waters successful in supporting this trout exhibit the following characteristics: they are relatively deep with average depths from 29 to 36 feet and maximum depths of 60 to 100 feet; at the time of the Survey they were thermally stratified and possessed oxygen values of 3 to 4 p.p.m. in the deeper waters; all have relatively clear water (minimum Secchi reading 20 feet).

Information on the food of rainbow trout in lakes and ponds is meager. In a study of the food of 250 lake rainbows in British

Columbia, Mottley and Mottley[68] found fresh-water shrimps (*Gammarus*) to be of primary importance although various aquatic insects formed a conspicuous item in their diet. Rainbows from a lake in Utah also had been feeding predominantly on crustaceans, principally shrimps; about 40 per cent (by volume) of the food of the 39 specimens examined consisted of crustacea, 30 per cent was plant material of various kinds, 20 per cent consisted of mollusks, and the remaining 10 per cent was made up of insects and other organisms.[44]

The Survey has examined the stomach of 43 lake specimens from three different waters. Seven fish averaging 14½ inches (13 - 15 inches) taken from Wononscopomuc Lake on August 22 contained only plankton crustacea. Twenty-four specimens from Quassapaug Lake also had been feeding predominantly on plankton crustacea, and midge larvae (Chironomidae) were second in importance; these fish were taken during the last week of July and ranged from 10 to 15 inches in total length (average 13 inches). The remaining 12 fish were taken from Green Falls Reservoir during the first week of July and ranged from 8 to 10 inches in length (average 9 inches) and differed markedly in food habits from those taken from the two preceding lakes. Insects, both aquatic and terrestrial, constituted nearly their entire food. Two interesting points may be noted in the case of the Green Falls fish: a large share of the total number of insects eaten were terrestrial in origin (about 20 per cent, based on counts of the organisms) and of the total number of insects taken, about 80 per cent was surface food, that is, it had to be captured at the water's surface.

Consideration of the limnological data on these three lakes showed Wononscopomuc and Quassapaug Lakes to be suitable for trout, since fish have access to all depths of the water. Green Falls Reservoir data, on the other hand, showed that trout presumably would be confined to about ten feet of water because of insufficient oxygen below that depth. The data on Green Falls were taken on June 28, 1938, and conditions undoubtedly would have become worse as the season advanced. In spite of heavy stocking, Green Falls Reservoir[4] has never proven a successful trout water.

In West Hill Pond the rainbows are known at times to feed extensively on the surface even during the summer months. During quiet evenings when large numbers of insects are emerging, the entire surface of the water may be disturbed continually by the movements of rising trout.

Economic Role

No one familiar with the fish will question the high ranking game qualities of the rainbow trout under suitable conditions. But there are definite reasons why this trout cannot show up to its greatest advantage in the best lakes the State has to offer.

Since rainbow trout are not known to reproduce successfully in lakes, ideal conditions would necessarily include a suitable stream in which spawning could take place. In not one of the Connecticut lakes which may in itself be satisfactory, can such a stream be found. Maintenance of all rainbow trout fishing immediately becomes dependent on artificial stocking.

Nor do the difficulties of maintaining a population of rainbows end here, for their migratory habits make it nearly impossible to keep the fish within the confines of the lake unless conditions are especially favorable. They leave the lake waters during the spawning season particularly and move down the outlets or up the inlets. Screening these avenues of escape is usually difficult and often unsatisfactory.

Lake Trout (*Cristovomer namaycush*)

Distribution

This fish, the largest of the family with the exception of the Pacific king salmon (*Oncorhynchus tschawytcha*), is abundant in the Great Lakes and its range extends northward from northern New England to British Columbia and Alaska.[53] The date of introduction is not known, but many plants were made in Connecticut lakes during and slightly preceding the first decade of 1900. At the present time the lake trout is caught to an appreciable extent only in Wononscopomuc Lake, although formerly they apparently were not uncommon in East Twin Lake.

Reproduction

The lake trout spawns in the fall, probably in late October and November in this region.[56] At that time the fish move into spawning areas in the lake at depths which may vary from 3 feet[37] to 120 feet and eggs have been found deposited in gravel or "honeycomb" rocks.[97] Nothing has been recorded concerning spawning activities.

Habits and Habitat

Little is known about the habits of the young fish. Greeley[37] found sac fry in the gravel on May 9th, but later stages were not obtained; Kendall[56] mentions taking several fingerlings about two inches long in a spring tributary of the First Connecticut Lake.

Adult lake trout are well known inhabitants of the cold deep water of lakes, although in the spring when the waters are cooler throughout they may move into shallow water to feed. Most of the lake trout caught at the present time range from 5 to 15 pounds but specimens of 80 pounds have been recorded.[69] The laker is a voracious feeder, living principally on such fishes as the smelt, lake herring, and whitefish.[56] A single Connecticut specimen from Wononscopomuc Lake had been examined for food; this fish, taken on August 22, 1939, was 14 inches long and it had been feeding entirely on plankton crustacea.

Economic Role

In the Great Lakes region the lake trout is still a fish of con-

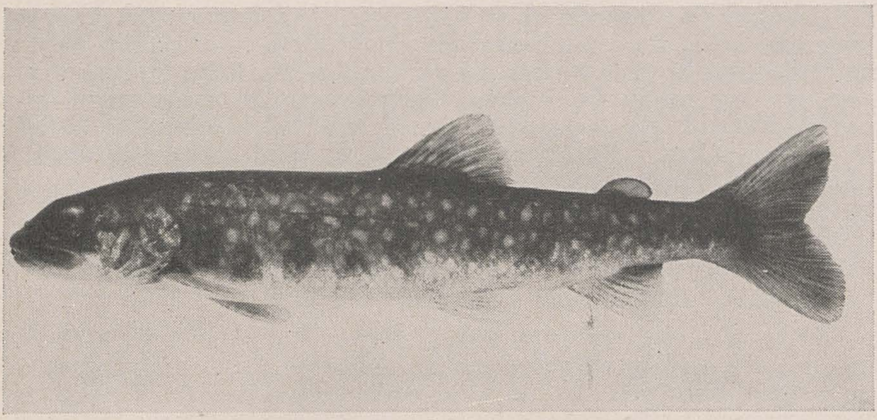

FIG. 13. Lake trout fingerling (*Cristovomer namaycush*). Little is known about the life of the young lake trout under natural conditions. Juvenile, 5 inches long, from New York State Fish Hatchery, Bath.

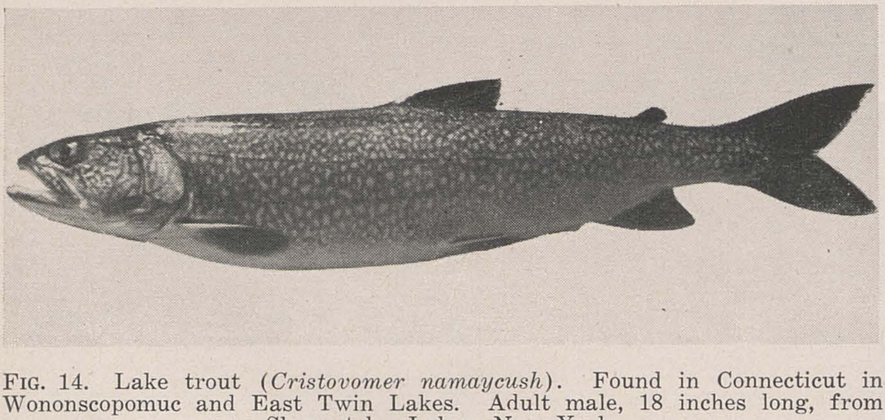

FIG. 14. Lake trout (*Cristovomer namaycush*). Found in Connecticut in Wononscopomuc and East Twin Lakes. Adult male, 18 inches long, from Skaneateles Lakes, New York.
Photo by H. John Rayner

siderable economic value as a food, but in New England it is not abundant enough to be classed as anything but a sport fish.

In Connecticut it seems highly desirable to foster the species in the one or two lakes which are suitable for it. At present the species maintains itself by natural reproduction in Wononscopomuc Lake. Data on the cropping of this species are not available, but natural reproduction probably should be supplemented by artificial stocking.

The Smelts (Osmeridae)

Smelts are a group of small fishes closely allied to the salmon family. Like the latter they are also migratory, ascending fresh-water streams to spawn; they are found along the Atlantic coast from Nova Scotia to Virginia and are frequently land-locked in inland lakes[52] where their range has recently been extended by artificial stocking. So far as is known these fresh-water smelts occur as natives on this continent only in New Hampshire and Maine.[58]

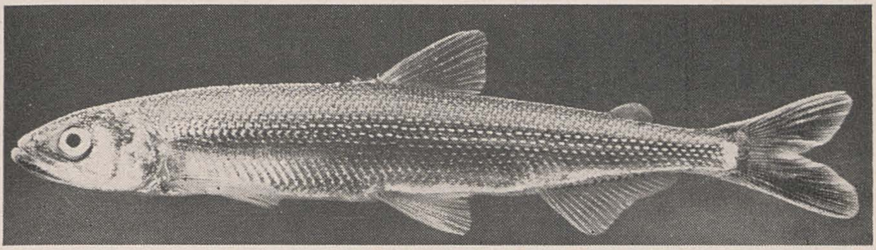

Fig. 15. Smelt (*Osmerus mordax*). Male, about 7 inches long, in breeding condition from Owasco Lake, New York. Note tubercles covering body. *Photo by W. F. Royce*

One species, *Osmerus mordax*, is found in the waters of Long Island Sound from whence it enters coastal streams in the spring to spawn. Lake forms likewise run up the tributaries in March and April.[58] Spawning occurs at night in rapidly running water. Here the closely milling groups of fish deposit their adhesive eggs on the stones and gravel. During the spawning act the tubercle-covered male smelt drives the female into the bottom or shoreward; about 50 eggs are deposited at each spawning. The incubation period is ten days at a temperature of about 60° F.[45]

Eggs taken from marine smelt have been hatched and the young widely distributed in lakes throughout the State, only, however, with infrequent success. This fish is known to be established in Crystal and Shenipsit Lakes and fishermen catch many through the ice during winter fishing.

The smelt attains a size of 6 to 12 inches and in some waters two distinct races may be separated by size differences.[40] It is a distinctly carnivorous fish, feeding on plankton crustacea, insect larvae, and small fishes.

Smelt are excellent eating, but aside from being directly useful, in many lakes they form an important forage fish. This is particularly true in many of the northern Maine lakes which contain land-locked salmon (*Salmo salar sebago*).

True Eels (Anguillidae)

There is only one genus in this family of fishes and it has representatives distributed in the fresh and salt waters of most of the world with the exception of the Pacific coast of North America and the islands of the Pacific.

The snake-like form of the eel is well-known to fishermen. Many will be surprised to learn that eels have scales, although they are small and embedded in the skin and thus readily escape notice.

Common Eel (*Anguilla bostoniensis*)

Distribution

The American eel is found in the coastwise waters of the Atlantic and Gulf states. In Connecticut, although not much is known of its distribution, it occurs in many inland lakes as well as in the larger streams.

Reproduction

The eel possesses a fascinating life story. Among the fishes it is unique in that it spends most of its time in fresh-water and migrates to the sea to lay its eggs.

In the spring the eels leave the fresh waters and migrate to the ocean waters between Bermuda and the West Indies. Spawning takes place in deep water and then the parent fishes apparently die.

Young eels differ so greatly from their parents that for a number of years their connection with adult forms was unsuspected, and scientists classified them separately as Leptocephali. They are transparent, glass-like little animals which are carried by the ocean currents back to the vicinity of coastal rivers. After about a year of larval life in the sea, the young transform into fish bearing a resemblance to their parents and move into fresh-water streams.[64]

The migration of these young eels or elvers, as they are called, occurs in Rhode Island in April and May[96] and probably takes place in Connecticut waters at the same time. Vast numbers participate in this upstream movement. It is said that only the female eels move up into the fresh water, the males remaining in the estuaries.[87]

Habits and Habitat

Eels in fresh water are inhabitants of muddy bottoms and are largely nocturnal in their activities. A few small eels (four inches long) were taken in the weeds along the shores of Beardsley Park Pond and Rogers Lake.

The eel is omnivorous in its food habits, feeding voraciously on other fishes, insect larvae and adults, crayfish, and aquatic plants.[1] Eels are fond of the eggs of fishes and during the shad runs may kill many females merely to feed upon the ovaries.[53] During their feeding activities they overturn large and small rocks in their search for food.[51] Eels may also feed on the surface during the early morning or evening, sucking in the floating insects.[14]

Economic Role

Eels have but little commercial importance in Connecticut, but in other coastal states and in the Mississippi Valley they support a small fishery.

Where eels are numerous they undoubtedly are an important predator on the eggs and young of desirable species.[1]

The Suckers (Catostomidae)

The suckers are primarily fishes of the Mississippi Valley, although various members of the group occur in all parts of North America. There are fifteen genera and about sixty species including such forms as the buffaloes, red horses, quillbacks, and suckers.[53]

The members of the family exhibit considerable similarity in habits; they are largely sluggish fishes which feed on the bottom. Breeding occurs in the spring, when an upstream migration usually takes place; the males, and in some instances the females, of many species develop breeding tubercles on various parts of their bodies at this time.[28]

None are highly regarded as food, but suckers assume some commercial importance in certain sections of the country, notably the Mississippi Valley and Great Lakes.[28]

Two representatives may be found in Connecticut lakes: the common sucker (*Catostomus commersonnii commersonnii*) and the northern chub sucker (*Erimyzon oblongus oblongus*); the former is more frequently encountered.

Common Sucker (*Catostomus commersonnii commersonnii*)

Distribution

Jordan[52] calls this the commonest of the suckers and gives its range as Canada south to Florida and as far west as Montana. In Connecticut it appears in nearly every stream and it has been found in most of the lakes and ponds studied.

Reproduction

The "sucker run" is familiar to many fishermen as an upstream movement of mature fish in the spring. In Connecticut the height of the breeding season is usually in late April, although spawning may be extended for a month or so earlier or later.

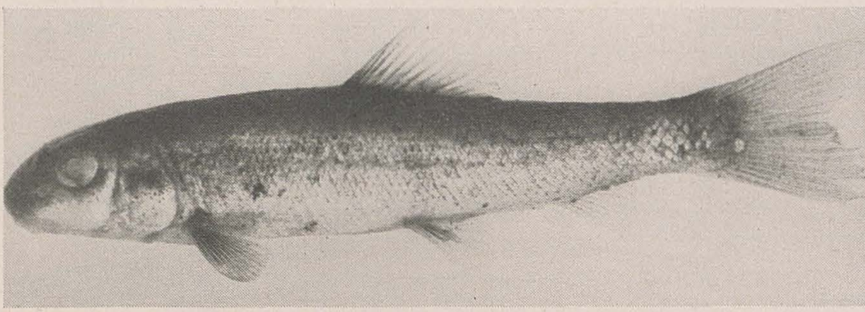

FIG. 16. Young common suckers possess blotches along the sides which are absent in the adults. Specimen, 3 inches long, from Farmington River, Simsbury.

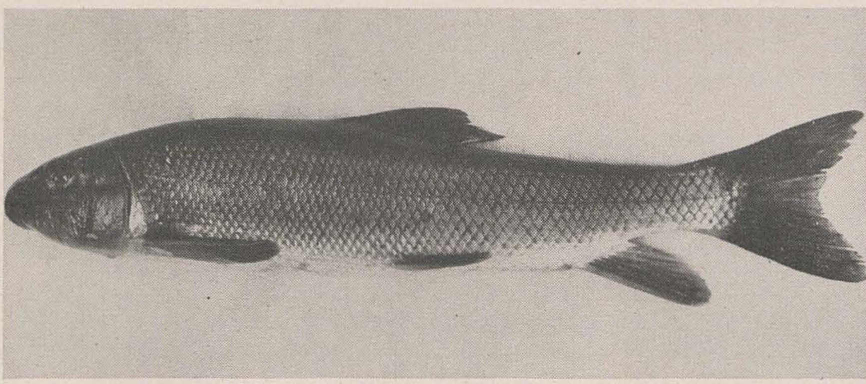

FIG. 17. Adult common sucker, 15 inches long, from Long Meadow Pond, Bethlehem.

For instance, a large ripe female was taken from a small inlet to Green Falls Reservoir on July 2, 1938.

The spawning migration or run occurs largely at night, the lake suckers traveling up the tributaries for a variable distance. Spawning may take place within a short distance of the lake itself or in the upper reaches of the stream. Upstream movement of the fish apparently begins as the water temperature approaches 40° F., and spawning seems to reach a height when water temperatures are above 50° F.

At this season of the year the male suckers develop prominent tubercles on the anal fin and lower part of the tail, as well as less conspicuous ones on the upper sides of the paired fins, the dorsal fin, and on the scales of the body itself. During spawning, changes in coloration also take place in both sexes. A dusky band bordered above by a light stripe becomes apparent along the sides, and the body takes on a bronze sheen. Other changes may take place in the male at the moment of spawning.

Spawning occurs both during the night and day, usually taking place in gravel riffles where the water is relatively shallow. No nest is built. A courtship act has been described[80] in which the female swims into the spawning area and assumes a position of rest on the bottom. As the males in the vicinity approach, she moves hurriedly forward as though bent on escape. Then she again takes up a resting position until the males close in and the procedure is repeated. This continues for a variable number of times until males are allowed to take up the spawning position.

During the spawning act the female is attended by one or more males and frequently, when the water is shallow and several males are in attendance, considerable splashing results as the males swim frantically about for a position alongside of the female. Detailed observations of the spawning position[80] show that two males usually participate, one closely pressed on either side of the female. The tubercles of the male aid in the maintenance of these positions. While the fish are in this position, eggs and milt are released during a strong vibratory movement of the posterior parts of the body. The same movements also cause considerable bottom disturbances which serve to help cover the eggs. The actual spawning act lasts about one and one-half seconds.[80]

If the male's supply of milt is exhausted during the spawning act, then the female again swims on to spawn with other males.[80] Spent fish drop back downstream to the lake or retire to the deep pools of the stream.

Sucker eggs are slightly adhesive and about 4 millimeters in diameter (about 6 to the linear inch). The incubation period is rather short, occupying around 21 days at a temperature of 50° F.[90] The newly hatched young are about 8 millimeters (0.3 inches) long.[79] Large numbers of the eggs are destroyed by the numerous small minnows which crowd about the spawning areas of the suckers.

The fact that many young suckers can be found in lakes at a considerable distance from tributaries supports the idea that suckers may also spawn successfully in the still waters of lakes. Lakes Zoar and Housatonic are examples within the State where very young suckers may be found along the shores far from tributaries; suckers have been reported to spawn in shoal areas of Alexander Lake. The possibility of suckers spawning in lakes has been noted elsewhere.[2, 79, 32]

Habits and Habitat

Most young suckers presumably drop down into the lakes after a short period of stream life and then they may often be seen or collected along the shores. In Lake Zoar and Lake Housatonic young suckers about one inch long were found in prodigious numbers along the shores in late June of 1939.

The youngest suckers seem to prefer shallow water with a scarcity of vegetation and muddy bottoms. Observations elsewhere indicate that suckers a little over an inch in length move into the vegetation.[50]

The food of young suckers in lakes and ponds has been studied and found to be such small organisms as rotifers, Cladocera, small insect larvae, diatoms, desmids, and filamentous algae.[19, 13]

Larger suckers inhabit the deeper waters of many lakes, but this is by no means a general rule. There may be a tendency for them to move into the shallows to feed under the cover of darkness.[89] The species is very tolerant of temperature and may be found both in the deep waters of cold lakes and in shallow ponds which reach relatively high temperatures.

Large lake suckers feed on a variety of foods, including many kinds of aquatic insect larvae, crustaceans, mollusks, and algae, particularly those forms which may be found in the bottom ooze.[1]

Two exceptionally large common suckers were taken from East Twin Lake on August 9, 1939. One specimen had a total length of 25 inches (standard length, 56 cm.) and weighed 6 pounds and 15 ounces; the second was 21¾ inches long (standard length, 46 cm.) and weighed 4 pounds. Both of these fish were egg-bound females.

Economic Role

The common sucker is of some direct value as food. The tendency of the fish to become soft as warm weather approaches and its large number of small bones makes it quite unattractive as a table fish. Nearly all suckers taken for food are captured during the spawning migrations of March and April when the flesh is relatively firm.

Suckers are frequently accused of being spawn-eaters, thus destroying large numbers of more valuable game fishes. There is undisputable evidence that this may sometimes be the case. Lake suckers have been reported eating the eggs of lake trout or whitefish while these species were on the breeding grounds.[4, 41] On the other hand, one hundred suckers taken from a Canadian lake over the spawning grounds of whitefish showed no evidences of feeding upon the eggs.[7] Variable evidence may also be found concerning the predatory habits of suckers on trout eggs in streams.[34, 8]

Adverse evidence, however, does not necessarily condemn the sucker without reservation. It must be remembered that young suckers undoubtedly form an important food item for predatory fishes and that in this role they may greatly outbalance the harm done by eating spawn. It is doubtful if suckers could break through the guard of black basses guarding the spawning nests. Yellow perch are extremely prolific and can apparently hold their own under almost any conditions. Chain pickerel spread their eggs broadcast, and both pickerel and the yellow perch spawn at a time when suckers, themselves, are usually up in the streams breeding. Aside from this, there is some evidence that spawning suckers feed very little,[86] although it has also been noted that breeding males in streams feed regularly while females are not in the spawning riffles.[80]

It is also important to recall that the association of common suckers with many of our pond and stream species is a natural one and it is probable that, save for situations where suckers are unduly successful, a balance will be maintained between the suckers and more desirable species. It is quite conceivable, however, that food or game species in waters over-populated with suckers might suffer as a consequence. Anglers are often prone to advance such an argument after they have seen a large sucker run and exaggerated ideas of dense populations easily result. This is because they fail to realize that during the breeding season fishes usually are concentrated into the relatively small areas used for spawning, but during the remainder of the year they are more or less scattered throughout an entire lake.

Chub Sucker (*Erimyzon oblongus oblongus*)

Distribution

The chub sucker is widely distributed along the Atlantic drainage from New England south to Virginia.[46] Occurrence in Connecticut is restricted when compared with the common sucker, but complete information on its distribution is not yet available.

Reproduction

This sucker is reported to breed in late April in Connecticut and the season in other regions such as Illinois and New York has been stated to be April and May.[28, 103] Little has been written concerning the breeding or other habits of this fish. It is said to migrate into tributaries to spawn.[1] Males develop a few prominent tubercles on the head.

Habits and Habitat

Young chub suckers are frequently taken in small schools over vegetation about the shore, but little is known about the life history of this fish.

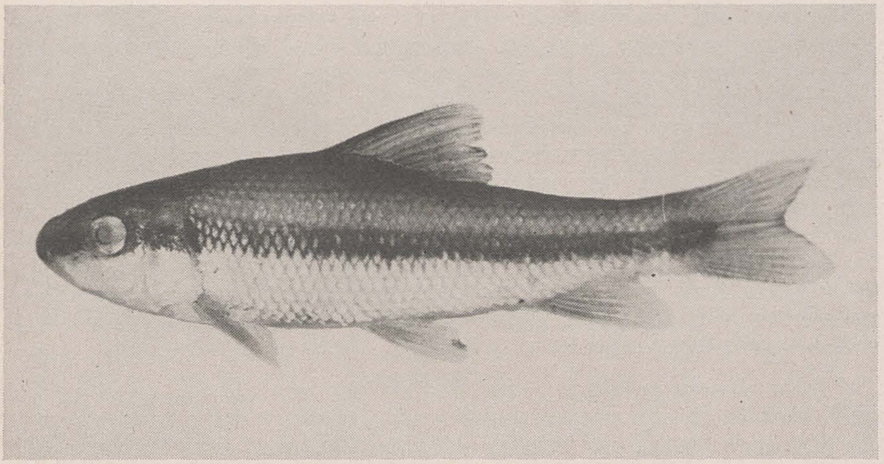

FIG. 18. Chub sucker (*Erimyzon o. oblongus*). In young the black lateral band is always very conspicuous and when in the water a light dorsal stripe makes them easily recognizable. Young of year, 2½ inches long, from Old Marsh Reservoir, Bristol.

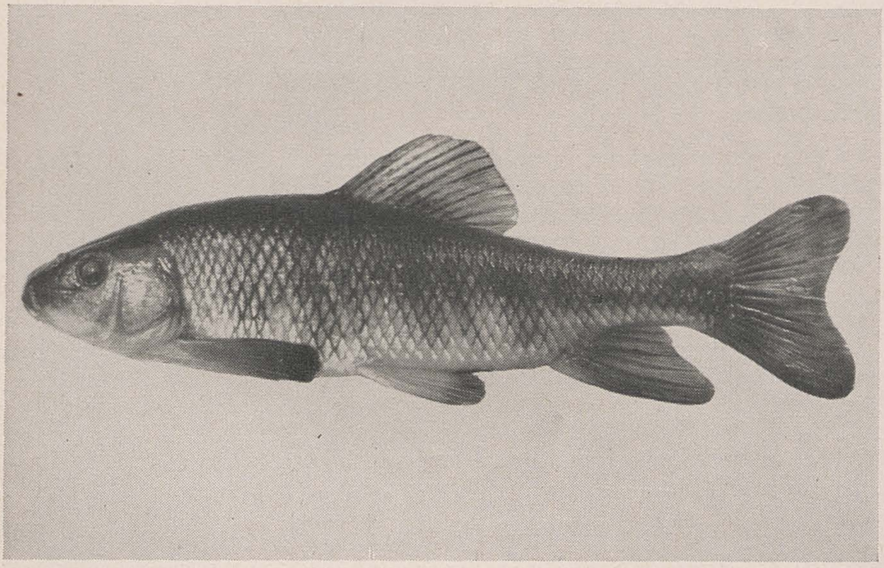

FIG. 19. Chub sucker adult. (*Erimyzon o. oblongus*). The lateral band becomes obscured with age and large specimens are deep through the pectoral region. Note absence of laterol line. Adult female, 7½ inches long, from Cornell Experimental Hatchery, Ithaca, New York.

The food consists of such organisms as insect larvae, aquatic plants, and minute crustaceans and this would indicate that it is probably largely a bottom feeder.[1]

Economic Role

Chub suckers may be important as forage for other fishes. "Next to the golden shiner, it is perhaps the most important fish of the smaller lakes, and is a frequent associate of pickerel, perch, and large-mouth bass."[37] This is probably not true, however, for most of the Connecticut lakes examined.

The Minnows (*Cyprinidae*)

The word "minnow" connotes to the layman any of the small fishes found in the shallow waters, whether they be the young of perch, bass, or shiners. In a stricter sense, the term is reserved for the family of Cyprinidae, which, although composed largely of small fishes, contains minnows, such as the carp and squawfish (*Ptychocheilus*), weighing 50 pounds or more. The family also includes the groups known variously as shiners, dace, and chubs.

There are about 1,000 species distributed over North America and the Old World. About 225 are found in American waters,[53] although Connecticut lakes can boast but 11 species. Four of them are more typically found in streams and for this reason will be only mentioned here; these include the horned dace, the black-nosed dace, the common shiner (Fig. 26), and the cut-lips minnow. Of the seven remaining lake forms, three are European introductions: the goldfish, the carp, and the tench. This leaves the golden shiner, the bridled minnow, spot-tail minnow, and the fallfish as native minnows commonly found in Connecticut lakes.

Because of their small size, the minnows as a group occupy an important niche in the food chain of many piscivorous fishes. They assume this important role because of a few characteristics usually typical of them. Minnows are very abundant in most waters; they are usually available to predatory species and they convert small organisms into fish flesh which may be eaten by small fishes. Because of their importance, knowledge of their life histories is necessary before effective fishery management is possible. Unfortunately, the lure of studying larger and more conspicuous fish has left the life story of these diminutive species comparatively unknown. The minnows will justly receive more attention when it is realized that without them many of our larger fish might cease to thrive or even disappear.

The breeding habits of Cyprinids are variable, ranging from species which build distinct nests, such as the fallfish and horned dace, to species which scatter their eggs widely like the carp and golden shiner. A few individuals may participate in the spawning act or it may take place while the fish are in a large school.

Two species not discussed separately in the pages following will be briefly mentioned here:

Goldfish (*Carassius auratus*) have not been taken in any of the lakes yet surveyed, but they are known to be established in a few small ponds. They spawn in May as the temperature approaches 55° F. Spawning takes place over aquatic plants to which the eggs firmly adhere. Several males wildly chase the female through the water, the female scattering eggs as she goes and often leaping clear of the water.[26] Goldfish are normally of olivaceous coloration; the brightly colored specimens typical of pet shops are selected varieties which have been domesticated for commercial purposes.

The tench (*Tinca tinca*) (Fig. 20) is known only from Winnemaug Lake (Wattles Pond) and the history of its introduction there is unknown. This cyprinid is an Asiatic species which was early introduced into Europe from whence it found its way to America; it is present only in a few localities in this country, however. The tench "thrives in shallow, marshy lakes and ponds" and is a hardy fish "capable of living in water of low oxygen content and of remaining alive, covered with mud, in freezing temperatures."[15] Tench have been cultivated at the Cornell University Experimental Hatchery in Ithaca, New York, for a number of years and they spawn there in June.

Carp (*Cyprinus carpio*)

Distribution

The carp is one of the four fish found in Connecticut waters which has become naturalized from the Old World. It is found only in a few localities here, principally the Connecticut and Housatonic Rivers (Lake Zoar and Lake Housatonic) and in Candlewood Lake.

The advent of the carp in the United States dates back to 1876 when the first successful introduction was made by the United States Fish Commission. From the descendants of these fish, which came from Germany, the carp has been distributed to all parts of the country. Even in Europe this fish was not indigenous but was introduced from Asia at an early date; its abundance on the Continent was mentioned as early as 350 B.C. by Aristotle.[61]

Reproduction

In Connecticut carp probably spawn in May and June. Breeding takes place in shallow weedy areas and the eggs are spread broadcast in a manner similar to goldfish. A female may be accompanied by several males, and spawning groups swim about near the surface often with their backs out of the water. Eggs and sperm are shed amidst considerable splashing.[28, 18]

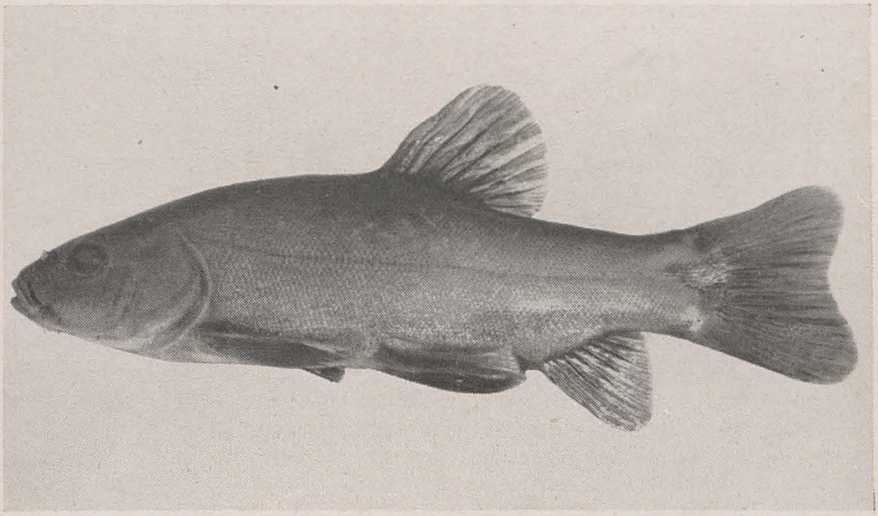

FIG. 20. Tench (*Tinca tinca*). An Asiatic fish of olivaceous coloration known in Connecticut only from Wattles (Winnemaug) Pond, Watertown. Specimen, 7 inches long, from Cornell Experimental Hatchery, Ithaca, N. Y.

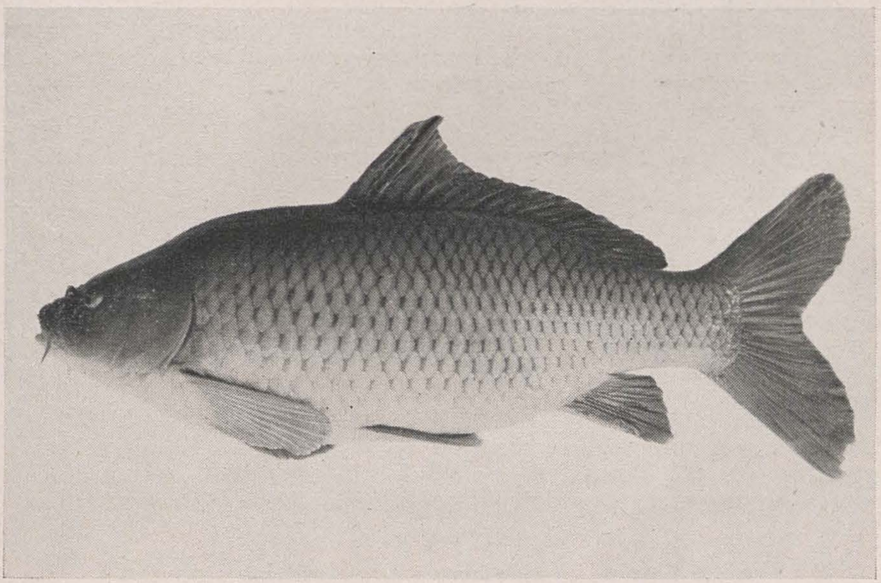

FIG. 21. Carp (*Cyprinus carpio*). Another Asiatic fish introduced from Europe in 1876. Adult, 25 inches long weighing 4¾ pounds, from Cornell Experimental Hatchery, Ithaca, New York.

Carp eggs are very small and are strongly adhesive. At a temperature of about 69° F. they hatch in four or five days.[63]

Taxonomic Consideration

There are three easily recognized races or varieties of carp, commonly known as the leather, mirror, and the scale carp. The leather carp lacks scales and possesses a smooth soft skin; the mirror carp is distinguished by the three or four rows of large scales along the sides, while the scale carp is completely covered with scales.

Habits and Habitat

The carp prefers warm weedy shallows, but it can survive in a wide range of conditions. It is omnivorous in feeding habits, the important foods being insect larvae, plankton, and aquatic plants.[1] Of 169 stomachs examined from various New York waters, 56 per cent of the contents consisted of plant material, 37 per cent of animal, and 6 per cent was silt.[92] Carp do not appear to be predacious on other fishes or their spawn. In their feeding activities they frequently uproot considerable quantities of aquatic vegetation and often muddy the water in so doing.

Economic Importance

The limited range of the carp in Connecticut waters makes it relatively unimportant in the economy of our fishes. In Lake Zoar and in the Connecticut River a limited amount of commercial fishing is carried on. In none of our waters is the carp to be regarded as beneficial and further extension of its range is decidedly undesirable.

In many regions, however, the carp has gained a successful foothold and has attracted considerable attention. The New York State Conservation Department has conducted investigations on the species over a period of years and has contributed much valuable information on the relationships and control of the carp. The main objections to the carp lie in the destruction of rooted aquatic vegetation, the roiling of the water, the frequent disturbance of the spawning grounds of other fish, and food competition with more desirable species.

In America the carp is not highly regarded as food although in the larger cities there may be no small demand for carp. In many parts of Europe the carp is an important food and is raised commercially under well-developed fish cultural methods.

Golden Shiner (*Notemigonus crysoleucas crysoleucas*)

Distribution

This minnow occupies a wide range in the eastern half of the United States and is known to bait dealers and fishermen as the pond shiner. In the southern and western parts of its range other subspecies are recognized. The golden shiner is the most

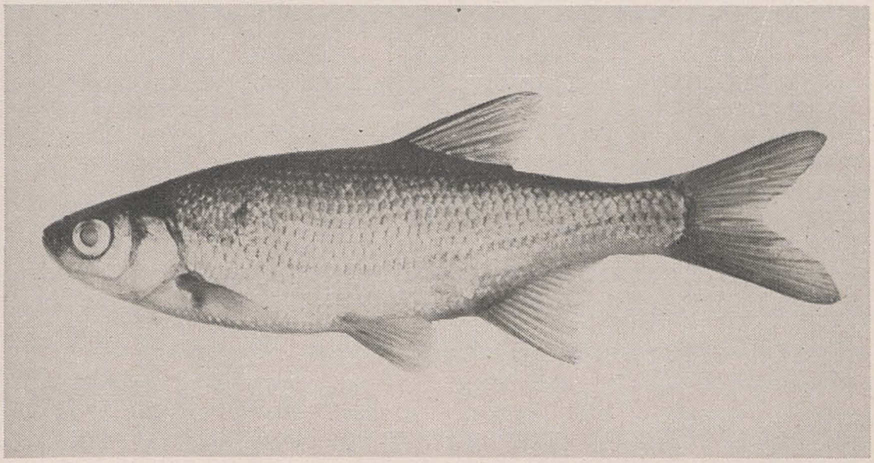

FIG. 22. Golden shiner (*Notemigonus c. crysoleucas*). The deep, compressed body and decurved lateral line make this minnow easily recognizable among Connecticut cyprinids. Young lack the golden color and possess a dusky lateral band. Specimen, 2½ inches long, from Kelley Pond.

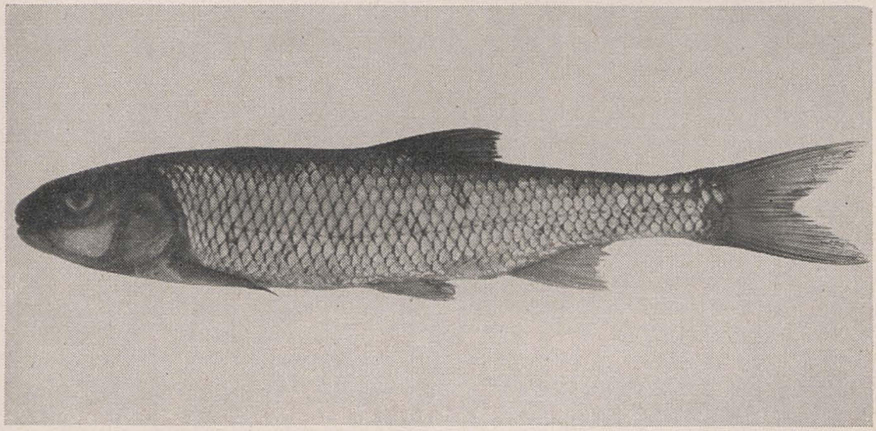

FIG. 23. Fallfish (*Leucosomus corporalis*). Most common in streams, it is also present in many lakes where it grows to a large size. Young possess a black lateral band which the silvery adults lack. Adult, 7 inches long, from Eight Mile River, North Lyme.

common Connecticut lake minnow, and although its abundance varies considerably, the species is present in nearly all lakes and ponds.

Reproduction

In Connecticut waters the breeding season of the golden shiner is quite extended, running from mid-June through mid-August and reaching a peak in many waters during July. About seventy-five specimens from two lakes sexed after August 15, 1939, were in a spent condition.

Spawning takes place over beds of submerged vegetation and the eggs are spread broadcast. "One or two males may pursue a single female who swims in and out of the vegetation, the males nosing the female on the cheeks, opercles, and along the sides of the abdomen. The eggs are emitted while the female is swimming and adhere firmly to whatever object they fall upon."[26] In lakes with an absence of marginal vegetation the eggs are probably laid in the weed beds which grow in the deeper water. Ripe golden shiners have been taken near the bottom in from ten to fifteen feet of water over dense beds of *Nitella* in Waumgumbaug Lake and Samp Mortar Reservoir.

Habits and Habitat

Golden shiners are typically fish of the weeds, but the smaller young not infrequently may be found in the open waters of shallows, although usually not far from vegetation. This minnow exhibits a very marked schooling tendency throughout life and in the case of young fish these schools may reach considerable size.

In lakes such as Columbia and Waumgumbaug, where the shorelines are largely rocky and devoid of vegetation, most of the young remain in the deeper waters where vegetation may be found. In most Connecticut waters the larger fish desert the shallows and may be taken in prodigious numbers at depths of ten to twenty feet. In Tyler Lake, where there is a rank growth of pond weed (*Potamogeton amplifolius*) over the entire bottom, schools of great size may be seen moving about among the weeds throughout the lake.

Brush piles placed along rocky shorelines in Columbia Lake have been repeatedly successful in attracting schools of golden shiners during their first year of life. Many hours of observation show these areas of food concentration to be constantly frequented by bass and pickerel, most often fish under twelve inches in length.

The food of the golden shiner is largely plankton crustacea, although aquatic insects, mollusks, and algae appear as conspicuous articles of food.[49, 1]

Economic Role

There is no doubt that this minnow is the most valuable of all forage fish in Connecticut waters. In many lakes it is extremely abundant and in others in which natural conditions do not favor reproduction, it appears to be scarce.

Young golden shiners have been observed to form the first fish food of young smallmouth bass. The extended breeding season of the shiner is important in this respect since it means that a supply of tiny minnows is constantly available to young game fish of the year.

Golden shiners are extensively used as a bait minnow.

Fallfish (*Leucosomus corporalis*)

Distribution

The fallfish or chub, as it is locally called, occurs east of the Alleghanies from Quebec to Virginia.[53] Although the species is by no means rare in Connecticut lakes, the fallfish is far more common in the streams of the State.

Reproduction

The breeding season is in the spring, probably during May in Connecticut. At this season of the year the male fish are highly colored, becoming rosy along the sides and on the fins. Tubercles are present on the head.

The fallfish is a nest-builder. The nest consists of a pile of pebbles or stones in the shoal areas of lakes and quiet pools of streams and it may reach a considerable size. Two nests observed in Columbia Lake were fully three to four feet in diameter and about two feet high; much larger ones have been recorded.[102] One or more males may be involved in the construction of the nest, the fish actually carrying stones in their mouths and depositing them on the nest.

Spawning has been described in the case of fallfish in a stream.[35] A female approached the nest and was "met by the male and held in a brief spawning clasp, terminating by an upward toss of the female so that her snout often broke the surface with a splash. Spawning was followed by further gathering of stones by the male."

The eggs are non-adhesive and hatch in from seven to nine days at a temperature of about 60° F.[3] Fallfish fry apparently remain near the nest for a short period after hatching.[33, 36]

Habits and Habitat

Young fallfish may be taken around the shores of lakes, frequently in association with schools of other minnows or killifishes. Fish of two to four inches do not appear to remain in large schools, but are found in a number of scattered groups consisting of a few individuals.

Large fallfish frequent the deep waters, and in Connecticut lakes thus far surveyed apparently are not very abundant. They also travel in small schools. On a number of successsive years, schools of large fallfish were found in the waters near a public beach in Columbia Lake; these fish afforded considerable amusement to picnickers, who were in the habit of feeding them bread.

The food of the fallfish consists largely of aquatic insects, although a variety of organisms may be eaten.[1] They are infrequently caught by fishermen and are known to take a plug or artificial fly as well as natural lures.

The fallfish is the largest minnow native to Connecticut waters. In the smaller streams it attains a maximum size of 10 to 15 inches, but in the rivers and lakes it may become a sizeable fish. One specimen taken by the Survey from Shenipsit Lake was 17½ inches long and weighed 2 pounds.

Economic Role

Young fallfish undoubtedly serve as food for bass and pickerel, but the large numbers of insects eaten by this species may make it a serious competitor of more desirable species. Concerning its status in New York waters, Greeley[37] says, "Despite the value of the small individuals as bait and as forage for bass, the chub is to be considered detrimental to production of game fish in many waters. The large chubs so outnumber game fish as to be serious competitors for the available food."

Fallfish have little food value. Thoreau has said of its eating qualities, ". . . . it tastes like brown paper salted."

Bridled Minnow (*Notropis bifrenatus*)

Distribution

This small minnow is found in several of the lakes surveyed. Its range includes the Ontario drainage, New England, western New York, and Delaware.

Habits and Habitat

Bridled minnows breed in Connecticut during June and part of July. Their spawning has not yet been observed, but it probably occurs in weedy areas. Ripe males are bright yellow below the black lateral band in contrast to the more somber straw color of the females. Gravid females are noticeable because of their distended bellies.

This minnow has not been taken except in weedy areas. Like most of the other minnows it is a schooling fish, though these schools are only of moderate size.

Economic Role

The extent to which the bridled minnow serves as forage is somewhat indefinite; its abundance in Connecticut falls considerably below that of the golden shiner, but since it inhabits relatively shallow water throughout life, this minnow may be an important food for young bass and pickerel.

This species has been noted feeding upon the eggs of the common sunfish when the male sunfish were removed from their nests.

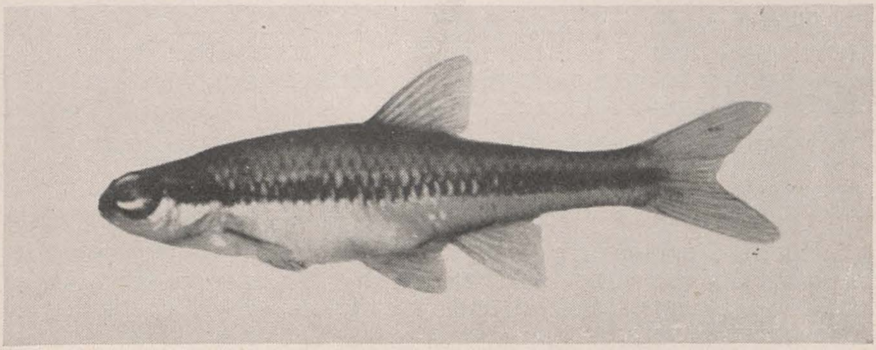

FIG. 24. Bridled minnow (*Notropis bifrenatus*). The well-defined black lateral band is conspicuous throughout life. Back is straw-colored while below the black stripe the sides are yellowish to white. Mature adult, about 2 inches long, from Kelley Pond.

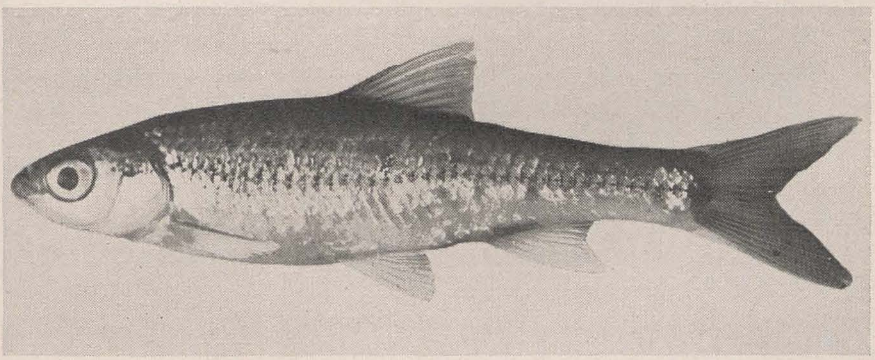

FIG. 25. Spot-tail minnow (*Notropis hudsonius amarus*). Called "river bait" by most fishermen, it is most abundant in the larger streams of Connecticut.

Spot-tail Minnow (*Notropis hudsonius amarus*)

Distribution

This species, commonly known as "river bait" in Connecticut, is found from the Great Lakes and New England south; in other parts of its range it is represented by other subspecies.

The spot-tail is most abundant in those Connecticut lakes impounded on large rivers and it is possible that in others where it occurs, introduction has been effected by bait fishermen.

Habits and Habitat

Although the breeding season of the spot-tail minnow in Connecticut is not definitely known, it is probably during May, since young taken during mid-June are nearly an inch long. Breeding in this species takes place in shoal areas or creek mouths,[32] while the fish are in a school.[39]

The spot-tail is usually found in large schools in the shallows where vegetation is scant or lacking. In Lake Zoar young spot-tail minnows in June were found in beds of *Elodea,* whereas the adults were found over mud flats.

Food consists of insects, crustaceans, and vegetation.[1]

Economic Role

Spot-tail minnows are one of the most frequently used bait fishes in Connecticut. As forage fish they are undoubtedly of considerable importance in such waters as the Housatonic and Connecticut Rivers.

The Catfishes (Ameiuridae)

This is a large family of fishes found particularly in the fresh-water rivers of tropical South America and Africa. The total number of species is about 1,000, 30 of which may be found in the United States.[53]

Many of the catfishes thrive in muddy water, spending most of the time upon the bottom from whence they obtain a large share of their food. The variation in size of American species is considerable, ranging from the blue cats of the Mississippi River, which may reach a weight of 150 pounds to the mad-toms and stonecats, which never weigh more than a few ounces.[28]

The catfishes are of commercial value as food, particularly the large species of the Mississippi Valley.[55]

One species is to be found in Connecticut lakes and this one is familiar to all fishermen as the bullhead or hornpout (*Ameiurus nebulosus nebulosus*).

Common Bullhead (*Ameiurus nebulosus nebulosus*)

Distribution

In Connecticut the bullhead may be found in all lakes and ponds and is usually very common. The range in the United States is from New England west to the Dakotas and south to Virginia and Texas.[52]

Reproduction

Bullheads breed in Connecticut in late May and June, and by the middle of the latter month the jet black young may commonly be seen along the lake shores. Ripe females have occasionally been taken as late as July 21st.

The parental care given by the bullhead to its eggs and young rivals that of the sunfishes. A nest consisting of a shallow depression or cleared spot is built, usually wholly or partially sheltered by logs, rocks, or vegetation. Here the adhesive eggs are laid in cream-colored clusters; they are about three millimeters in diameter (eight to the linear inch).[31]

One or both of the parent fish remain to guard the eggs and young. Besides warding off any intruders, the fish show devoted interest in the progeny themselves, constantly fanning the eggs or, strikingly enough, even sucking them into their mouths and then blowing them out. These operations serve to aerate the eggs as well as to keep them clean.[31]

The eggs hatch in five days at a temperature of 77° F. Young bullheads keep together in a dense school and the parent fishes frequently stir them or even mouth the young in a manner similar to that which they practice in the case of the eggs. The old fish appear to stay with the young until the latter begin to swim freely;[31] young fish from Columbia Lake averaging twelve millimeters (0.5 inches) in total length, and young of nearly twice that size in two additional instances, still had attendant adults.

Habits and Habitat

Young bullheads often remain together in a school throughout their first summer. They may be found in relatively shallow waters, invariably in vegetation or other suitable shelter and usually over more or less muddy bottom. A board partially stranded on the beach or a large flat rock may harbor a dozen or more of these little black fish. On several occasions small bullheads have been observed taking advantage of the cover provided by the small particles of semi-floating debris found near the water line of sandy wave-swept shores.

Water-fleas form the first food of young bullheads, although tiny midge larvae may compose a conspicuous part of their early diet. As the fish grow, larger organisms of greater size are eaten, particularly the larval stages of aquatic insects, ostracods, and other crustaceans.[75]

Both the young and adults are largely nocturnal in their habits, showing a marked increase in activity with the approach of darkness. This is reflected by the efforts of anglers, who fish for them largely at night. The bullhead spends a goodly share of its time in deep water, ordinarily over bottoms of mud or submerged vegetation.

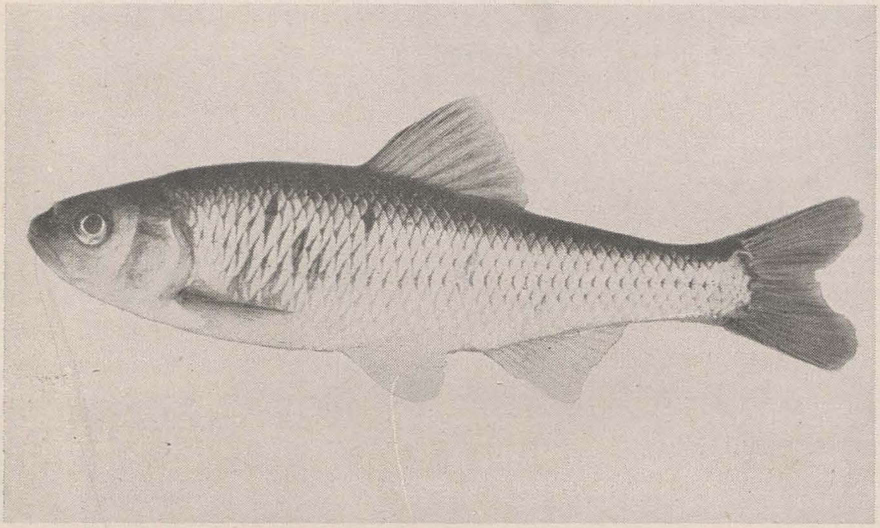

FIG. 26. Common or redfin shiner (*Notropis c. cornutus*). Only infrequently found in lakes, but a common stream minnow. The belly fins of adults are vermillion during the breeding season in the spring. Adult, 5 inches long, from inlet to Skaneateles Lake, New York.

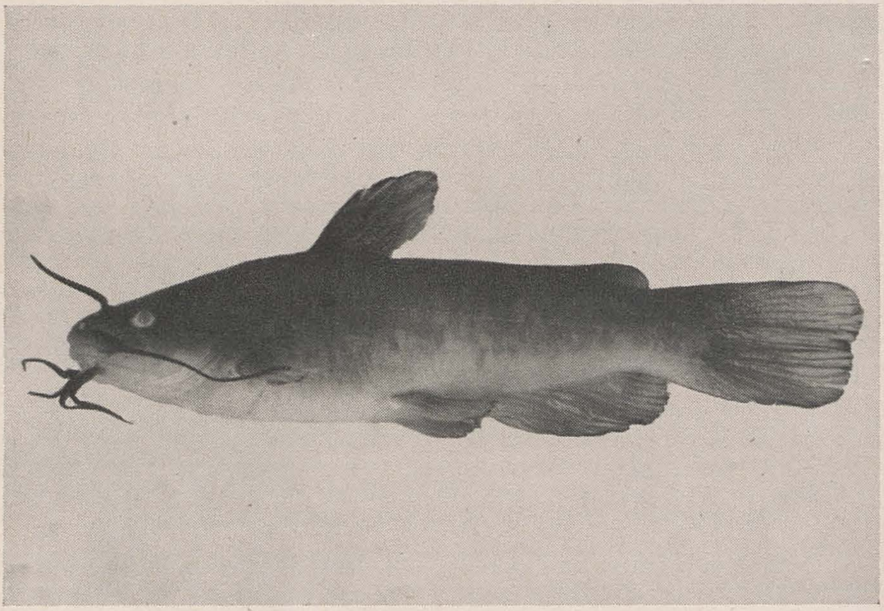

FIG. 27. Common bullhead (*Ameiurus n. nebulosus*). Coloration may range from jet black to dusky bronze depending upon the water in which they live. Young resemble adults. Juvenile, 4½ inches long, from Bantam Lake, Litchfield.

Because the bullhead is an omnivorous feeder it may be found eating anything from plant material to fishes, although in keeping with their bottom feeding habits, insect larvae and mollusks form a considerable part of their diet. Fish taken from the mouths of tributaries swollen by rains have been gorged with earthworms and some have been found to leave their bottom haunts to feed on the surface when mayflies (*Hexagenia*) are emerging.

This fish is well equipped for its nocturnal quest for food through the medium of four pairs of barbels or "feelers". Taste buds located on the tips of these allow the fish to "taste", or perhaps more properly in this case, to locate the food without having to see it first, as opposed to such fishes as bass, pickerel, and trout. Any angler who watches a feeding bullhead and pays particular attention to the movements of the barbels and its resultant successes in the capture of food, may easily verify this for himself.

On the basis of a complete check of anglers' catches, it would appear that during the breeding period either the fish slack off in their feeding, or methods used by the fishermen fail to catch them at this time. In Winchester Lake large numbers of bullheads are taken in May, but during the succeeding month the catch drops markedly despite greater fishing effort and increases in the take of perch and pickerel. The catch rises again in July.[95]

The spines possessed by bullheads will cause painful recollections to many anglers. The use to which these apparently formidable weapons are put in dealing with other water animals is not definitely established. One infrequently finds that predacious fishes which have attempted to swallow young bullheads have come to grief when the erect pectoral spines became entangled in such a way that it was impossible for the predator to either swallow or disgorge his catch. In a few catfishes poison glands are associated with these spines, but in the common bullhead such glands appear to be rudimentary.[77]

Only a few Connecticut fishes, the bowfin, carp, tench, and eel, equal the common bullhead in tenacity of life. If kept moist, they will live for several hours out of water without apparent ill effects. This is because the bullhead still possesses accessory breathing structures which allow it to make some use of its air bladder as a sort of "lung" in respiration. The fish can thus maintain life for a limited period of time by breathing atmospheric air rather than air dissolved in water. This adaptation may be used to explain why bullheads, as well as the other species previously mentioned, may be the only species to thrive in muddy, warm, and often foul waters of low oxygen content. It is said that in ponds which go dry, the bullheads will bury themselves in the mud and thus encased will survive for several weeks.[21]

Economic Role

There is no doubt about the importance of bullheads as food for man. Even in places such as Connecticut where commercial fishing for them is prohibited, they are food on many tables. As a food species it occupies a leading place among Connecticut lake fishes.

Like the sucker, the bullhead has also earned the reputation of being a spawn-eater. And again, like the sucker, this reputation is not entirely ungrounded. The eggs of several species, including the cisco,[91] lake trout,[4] and herring[55] have been found in the stomachs of bullheads. Other studies present negative evidence.[17, 28] When one considers the situation, it is difficult to understand how any fish would pass up such morsels as spawn or young fishes if its feeding habits were such as to bring the fish in contact with them. In many cases difficulty would be encountered in proving that the bullhead or other so-called egg-predators actually move to the spawning grounds of other fishes for the sole purpose of feeding on their eggs.

The Pikes (Esocidae)

This family includes the familiar chain pickerel (*Esox niger*) as well as the great northern pike (*Esox lucius*), muskellunge (*Esox masquinongy*), represented by three species or subspecies, and two small species (*Esox americanus* and *Esox vermiculatus*). The chain pickerel and one of the smaller species, the grass pickerel (*Esox americanus*), were originally found native here and the great northern pike (Fig. 28) has been introduced in one or two localities. It is known to be caught, however, only from the Connecticut River.

The little grass pickerel (Figs. 29, 32) attains a maximum size of around twelve inches[57] and is not commonly found in lakes. The species is worthless from the point of view of the angler and may do considerable harm, particularly in trout streams.

All of the pikes are more or less similar in habits and all draw quite heavily on other fishes for food. The muskellunge or "musky" attains the greatest size and may reach a length of eight feet and weight of 100 pounds.[53]

Chain Pickerel (*Esox niger*)

Distribution

The pickerel is everywhere common in the State and, as has been mentioned previously, probably occurs in all impounded waters. An interesting note on the original distribution of the chain pickerel in Connecticut may be found in the Salisbury town records, which state that no pickerel were to be found in the lakes in that vicinity (presumably highlands of the northwest corner of

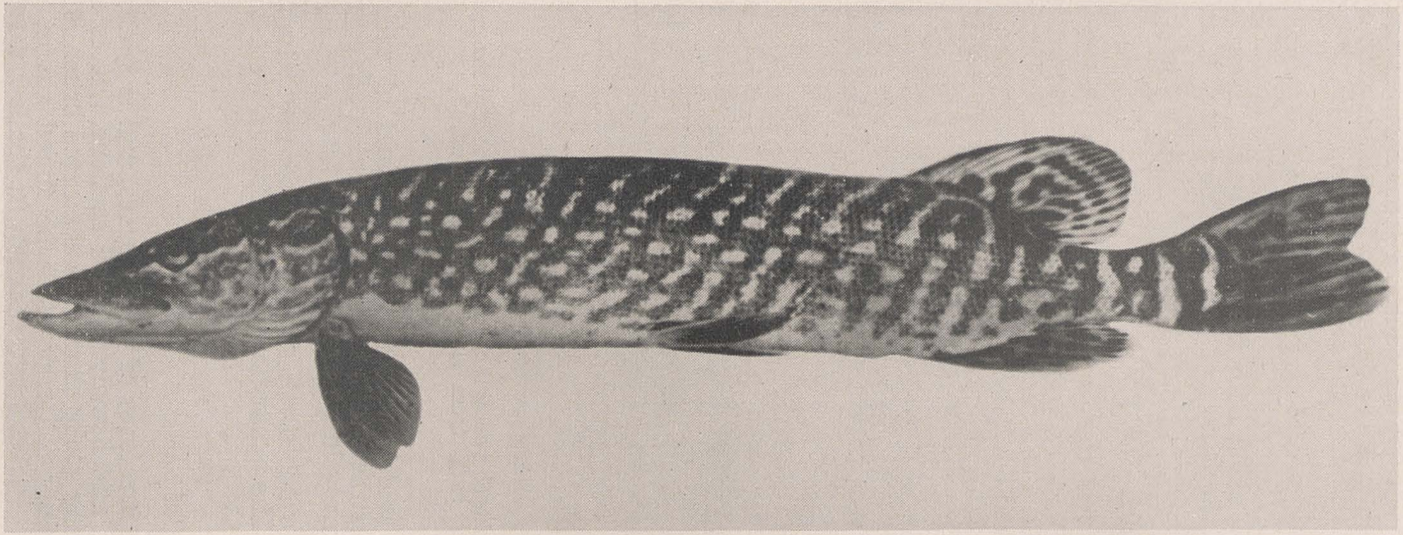

FIG. 28. Northern pike (*Esox lucius*). Found by introduction in the Connecticut River, the pike may be distinguished from the chain pickerel by color pattern and absence of scales upon lower half of the opercle.
Photo by George C. Embody

the State) prior to their introduction from Bantam Lake in 1812. Its general distribution is confined to the region east of the Alleghany Mountains from Maine to northern Florida.[99]

Reproduction

This species, along with the yellow perch, is one of the first fish to spawn in the lakes and ponds of the State. Kendall[57] gives the time in Massachusetts as May and it probably occurs here during April or May. Spawning takes place as the water temperatures approach 47° F.[25]

Embody[25] notes that breeding places are shallows, over remains of dead vegetation in marshes. The spawning act of the northern pike and chain pickerel were stated as being much alike and were described as follows: "A female accompanied by one or more males, swims about in a meandering path. Eggs and milt

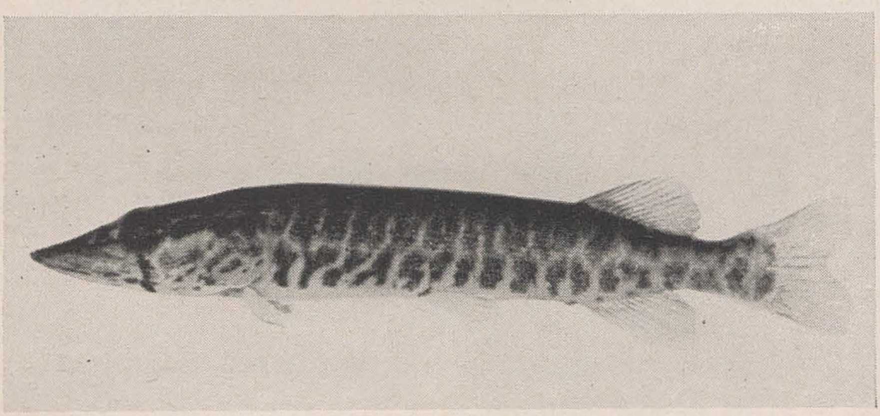

FIG. 29. Grass pickerel young (*Esox americanus*). Specimen, 2½ inches long, from Mudge Pond, Sharon.

are cast during widely varying intervals and at each emission violent lashings of their tails tend to distribute both eggs and milt over a comparatively large area."

The eggs are adhesive[63] and, of course, no attempt is made to guard them. The incubation period is from a week to ten days depending upon the water temperature.

Habits and Habitat

The pickerel is a lover of weedy areas, and is typically found in both sparsely and heavily weeded sections. It is not infrequently found along rocky shores if submerged brush is available, and scattered young fish may often be found almost anywhere along the shores. Pickerel are common in shallow weeded areas,

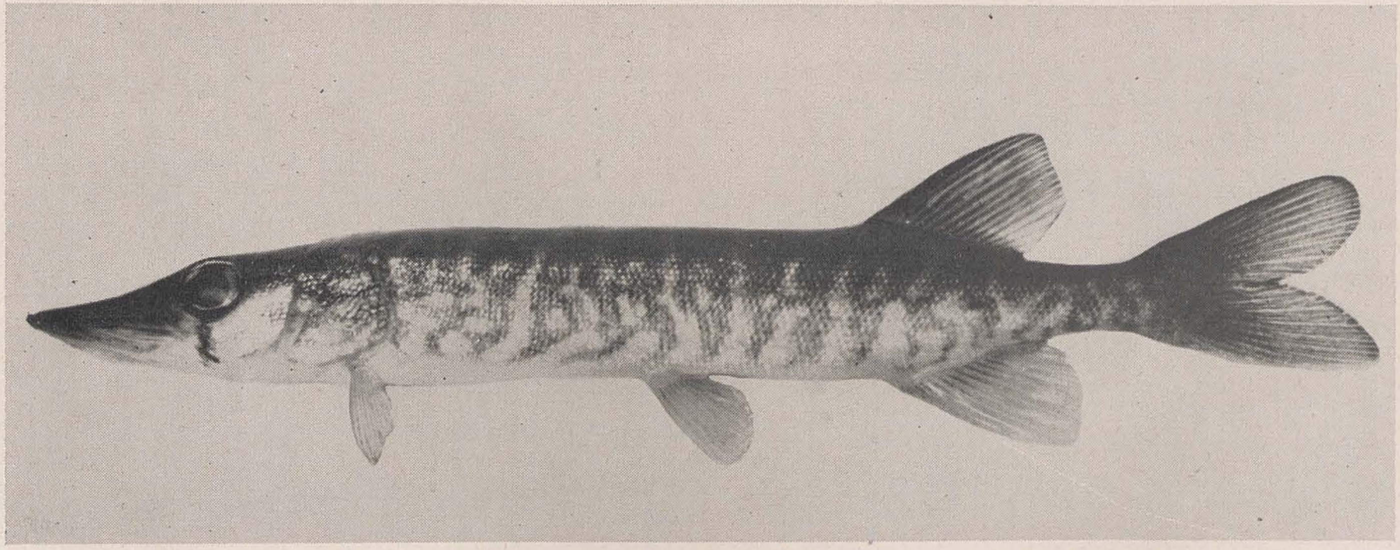

FIG. 30. Chain pickerel (*Esox niger*). Color pattern of young is variable, but usually takes the form of vertical bars. Young may be recognized from the grass pickerel by their slender appearance and longer snout. Yearling, 6 inches long, from Kelley Pond.

especially at night, but if these are lacking, the fish spend most of their time in deep waters, presumably over submerged weed-beds.

The feeding of this fish (and of others in the family) differs from such fish as the bass and perch, in that it typically waits for its prey to swim by rather than actively foraging for it. Thus we find that fishes of various species make up the usual food taken by the pickerel, although the frequent inclusion of such organisms as crayfish, and dragonfly nymphs indicates some foraging activity.

Forty-three specimens taken from waters throughout the State have been examined for food. While these numbers are scarcely large enough to draw extended conclusions, the results show the general feeding tendencies of this predatory fish. The important items were small fishes, which occurred in 27 individuals, and crayfish, which occurred in 13. Yellow perch appeared to be the fish most utilized, but almost all species known to occur in Connecticut lakes appeared one or more times. One pickerel, 3¼ inches long, had glutted itself on 21 golden shiner fry, while still another, 9¼ inches long, had eaten 18 small bullheads and 2 tadpoles. Most of the specimens examined were over ten inches in length and the majority were yearling fishes.

A motionless pickerel lying in submerged brush or vegetation is a familiar sight, and patient observation may be rewarded by seeing an unwitting small fish seized as it swims by. This is done by a swift lunge on the part of the pickerel. The prey is ordinarily seized and held crosswise in the mouth. While the victim struggles the pickerel may swim slowly about and soon with somewhat jerky movements begins to manipulate the smaller fish until it is grasped head first. Then with another series of jerky movements, the prey is ingested, the speed with which this occurs depending upon the relative sizes of predator and prey. Not infrequently the fish being swallowed is so large that its captor is forced to swim about with the victim's tail still extending from its mouth. Sometimes pickerel will be seen lying perfectly motionless while numbers of small fishes swim carelessly in front of them.

The maximum size attained by the chain pickerel is somewhat confusing since many reported large specimens turn out to be northern pike. Thus we have an early record of a pickerel from the Hockanum River near Hartford, which was 38 inches long and weighed 14 pounds.[5] However, the fact that the northern pike had already been introduced into the Connecticut River casts an element of doubt on the record.[57] There are two authentic records of chain pickerel from Columbia Lake which reached a length of 29 inches, one of which weighed 6½ pounds.

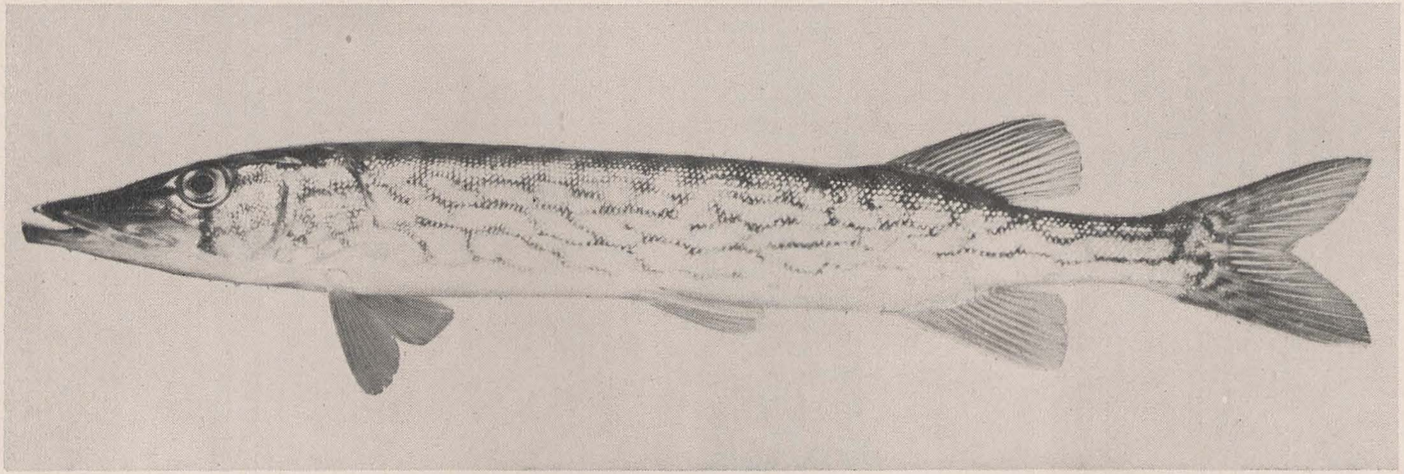

FIG. 31. Chain pickerel (*Esox niger*). Adult showing typical chain-like markings. Specimen, about 10 inches long, from Cornell Experimental Hatchery, Ithaca, New York.

Photo by W. F. Royce

Economic Role

The favored place which the chain pickerel once occupied among game fishes has been more or less taken over by the black basses. However, most anglers prize a good pickerel.

Pickerel, in most of the waters studied, do not appear to be very abundant, but whether or not this can be attributed to the introduction of black bass (since the bass occurs in most of these same waters) as the story of many old anglers goes, is still a question. It is true that in many ponds in which there are no bass, pickerel are noticeably more common. The introduction of bass may in some way seriously disturb the old original pickerel, perch, sunfish, and bullhead populations, but if so, the pickerel appears to have been the only one to have noticeably suffered adversely.

At present no pickerel are distributed artificially save a few adults seined from the Connecticut River.

The Killifishes (Cyprinodontidae)

Killifishes are mostly small fishes of fresh and brackish waters. One species, the salt-water mummichog (*Fundulus heteroclitus*), is familiar to Connecticut anglers as a bait fish. The fresh-water killifish (*Fundulus diaphanus diaphanus*) is perhaps not as well known, but is found under favorable conditions throughout the waters of the State.

The "mosquito fish" (*Gambusia affinis*), found farther south, is a member of this group which has won itself a widespread reputation as an important agent in the destruction of mosquitoes. It is also of interest because it brings forth its young alive.

Barred Killifish (*Fundulus diaphanus diaphanus*)

Distribution

The range of the barred killifish extends throughout eastern United States, west through the Great Lakes to Colorado and south to northern Indiana.[52] In the western parts of its range it is replaced by another subspecies, *Fundulus d. menona.*

In Connecticut it occurs in all parts of the State, being rather restricted, however, by relatively narrow habitat preferences.

Reproduction

The breeding season of this little fish extends from the middle of June through the middle of August. During this period the males take on a bright coloration. Particularly noticeable is the brilliant yellow on the lower gill-cover (branchiostegal) membranes.

Spawning was observed at Bantam Lake on August 7, 1939. This occurred in about eight inches of water over a sandy bottom with scattered beds of a scant growth of fresh-water eelgrass (*Vallisneria*). The temperature of the water at the time of observation (2 P. M.) was 90° F.

A school of forty or fifty large killifish (two to three inches in total length) ranged back and forth along twenty feet of shoreline, spawning for periods of five to ten minutes when they came over favorable beds of *Vallisneria*. Some confusion was noted in the school as males darted about after females or chased one another.

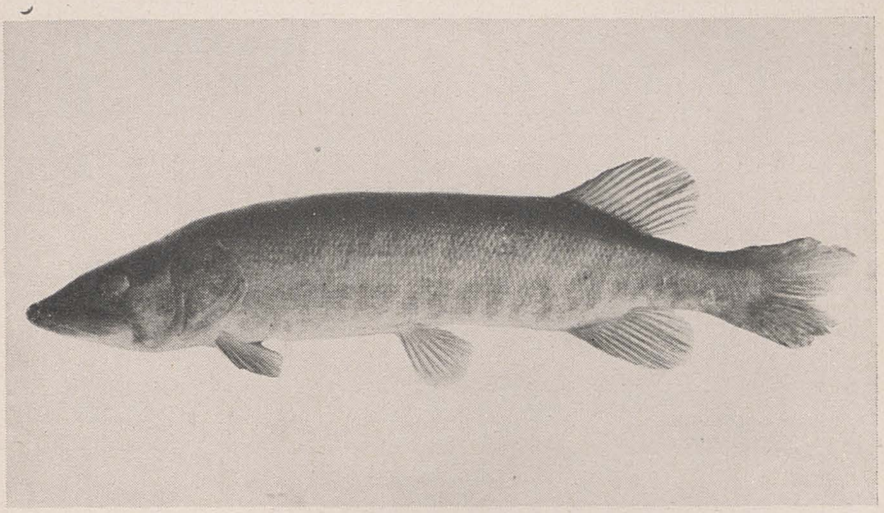

FIG. 32. Grass pickerel (*Esox americanus*). The chunky form, eye position, and the vertical barring of color pattern help to distinguish this useless species from the chain pickerel. Adult, 9 inches long, from Pocotopaug Lake, East Hampton.

The spawning act was initiated when a male singled out a female and after a short chase halted her and assumed a position parallel to her. After a momentary pause the pair arced swiftly downward, turning on their sides enroute. With his body uppermost and curved, the male appeared to press the female in contact with the sandy bottom among the weeds, and for a brief instant, perhaps two to four seconds, a rapid vibration was noted, causing a cloud of sand to arise. At this time the eggs and sperm were presumably shed.

Then the male, plainly evident with the light reflecting from his brightly barred sides and erected anal fin, sprang upward to release his mate who assumed a normal position in a bit less spectacular manner. The male immediately swam about in search of another mate in the event that spawning had occurred in a school.

Spawning by individual pairs not in a school was similar except that the male played a more noticeable and active part in driving off intruding males. This was done by rushing at them with the anal fin prominently spread and with characteristic careening and wobbling motions.

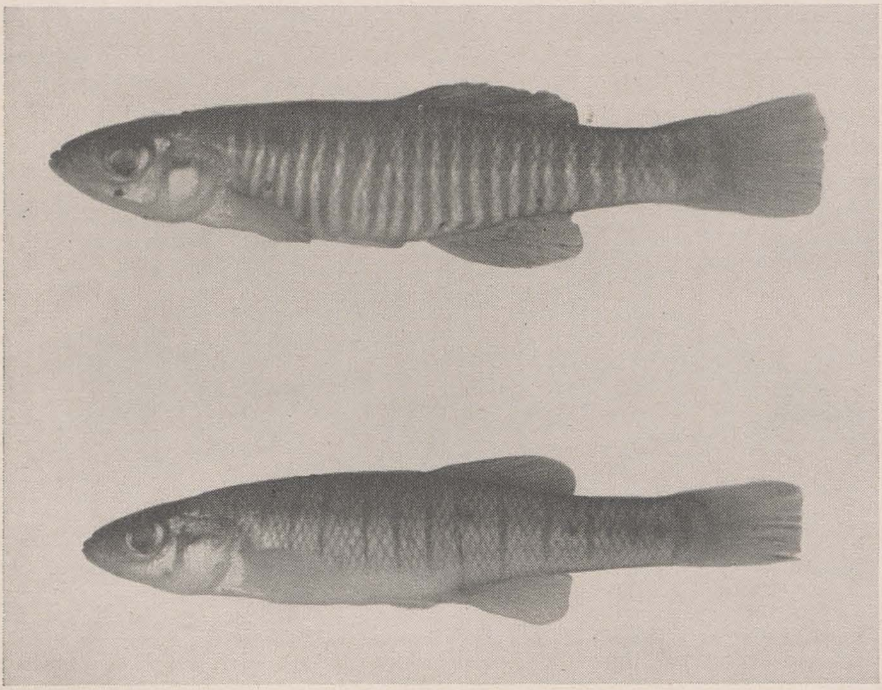

FIG. 33. Barred killifish (*Fundulus d. diaphanus*). The male (above) is striking in livery of olive and iridescent bars with a bright yellow wash on pectoral region. Female (below) is more subdued, has fewer bars, and usually possesses a rosy sheen along the sides. Black spots are parasites. Adults in breeding condition, about 3 inches long, from Bantam Lake, Litchfield.

It has been recorded that the eggs upon extrusion remain attached by threads to the genital papilla of the female; at the completion of the spawning act these threads, which appear to be adhesive, serve to entangle the eggs among the weeds.[81]

Water-hardened eggs average a little over 2 millimeters in diameter (12 to the linear inch) and one female measuring 3 inches in total length contained about 200 well developed eggs of this size, besides numerous smaller undeveloped ones in the wall of the ovary.

Habits and Habitat

The barred killifish shows a distinct preference for fine gravel or sandy shallows, and it is not often found in abundance except under these conditions; if found in other situations, it is because other bottom conditions are tolerated rather than a change into deeper water environment. The smallest fish are often found in very shallow water, only one-quarter to one-half inch in depth, and even the largest specimens seldom venture out into water over a foot in depth. Small killifish may also be found among the low weeds which extend for a short distance into the shallows where they grow on the inner beach zone.

As already mentioned, this species typically travels about in schools, the size of which may vary from four or five individuals up to perhaps a hundred or more. It is noteworthy that along shallows of considerable extent there will be numerous small schools distributed along the area rather than a few extremely large ones. There is usually a segregation of size groups so that the fish comprising a school will be about the same size.

The mouth of the killifish is upturned (superior in position), an adaptation for surface feeding.

Since it is found in shallow water, the killifish can be preyed upon only by fishes of such size as to be able to pursue them successfully there. For this reason fish predators are largely pickerel and yearling (or younger) small and largemouth bass. The bass, particularly, make spectacular raids upon the schools, the little fish driving wildly ahead, often skipping across the water's surface in their frantic efforts to escape and reach the haven of shallower water.

The maximum size of the species is about four inches.

Economic Role

The barred killifish must be considered a forage fish of limited value, by virtue of its shallow water habitat, for here it is available as food only to those fish small enough to pursue it. In lakes where they are abundant they are an important item in the food chain of predatory species, for observation in such waters show them to be subject to almost constant attack.

The habitat of the species during periods when ice covers the water is not known, but it may be that they become more available at this time.

As a bait fish, anglers use them to a considerably less extent than other species, although at times they form a good lure. They are not particularly hardy on a hook.

The Bass and Sunfishes (Centrarchidae)*

The sunfishes are a rather large group of spiny rayed fishes

*The proposed revision of certain genera of the Centrarchidae by Bailey[6] is followed here.

with such familiar local representatives as the pumpkinseed, calico, and black basses. The group is particularly characteristic of North American fishes. Eleven genera and about 30 species are known, 8 of which occur in Connecticut. Of these probably only 4 were found here as natives: the red-bellied sunfish (*Lepomis auritus*), pumpkinseed (*Lepomis gibbosus*), banded sunfish (*Enneacanthus obesus*), and the rock bass (*Ambloplites rupestris*). The remainder, the smallmouth black bass (*Micropterus dolomieu*), largemouth black bass (*Huro salmoides*), calico bass (*Pomoxis nigro-maculatus*), and the bluegill sunfish (*Lepomis macrochirus*) have become well established in most instances through introduction and subsequent distribution by early fish cultural efforts.

All of the centrarchids are nest-builders and give more or less parental care to their eggs and young. Spawning usually takes place in the late spring, though in the case of the pumpkinseed and red-bellied sunfish, it may extend well into the summer months.

Several important game fishes are found in this family, and in this respect it ranks with the trout and salmon family in supplying sport fishing in Connecticut.

Field Key to Adult Bass and Sunfish of Connecticut

1a. Dorsal fin much longer along base than anal fin.
- 2a. Body form elongate (Figs. 39, 40).
  - 3a. Maxillary bone not extending beyond center of eye; vertical barring frequently present . . . . SMALLMOUTH BASS (Figs. 34, 39).
  - 3b. Maxillary extending beyond center of eye; black lateral band frequently present . . . . LARGEMOUTH BASS (Figs. 35, 40).
- 2b. Body form comparatively short and deep (Figs. 41-46).
  - 4a. Anal spines 3 or 4.
    - 5a. Ear flap present.
      - 6a. Flap dark blue without vermillion tip.
        - 7a. Dusky blotch at posterior base of soft dorsal; gill rakers comparatively long and slender . . . BLUE-GILL SUNFISH (Fig. 43).
        - 7b. No dusky blotch; gill rakers comparatively short and blunt . . RED-BELLIED SUNFISH (Fig. 44).
      - 6b. Vermillion tip present . . . PUMPKINSEED (Fig. 45).
    - 5b. Ear flap absent; body and fins with round light blue spots; nine spines in dorsal fin . . . BLUE-SPOTTED SUNFISH
  - 4b. Anal spines 6 . . . . ROCK BASS (Fig. 46).

1b. Dorsal fin not longer than the anal fin . . CALICO BASS (Figs. 41, 42).

Smallmouth Black Bass (*Micropterus dolomieu*)

Distribution

It will probably be a surprise to most Connecticut anglers to learn that the smallmouth bass is not native to the waters of the State. In its natural range the fish came no closer to Connecticut than the St. Lawrence River and the Finger Lakes region of New York State.

The records of an early Connecticut naturalist, James Linsley,[60] indicate that the smallmouth was present in the Housatonic River in 1844 and thus introduction into the State presumably

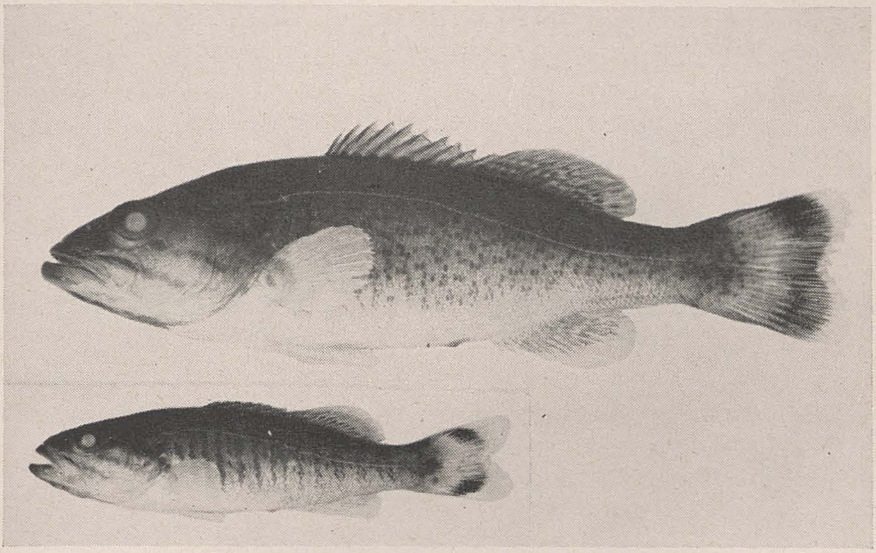

FIG. 34. Smallmouth bass young (*Micropterus dolomieu*). Inset shows prominent barring present in early juvenile color pattern (young of year, 2½ inches long) while in larger and older specimen (4¾ inches long, taken September 13, 1940) bars have become diffuse. Black banded and white tipped tail make young easily recognizable in the water. Specimens from Bantam Lake, Litchfield.

took place at some time prior to then. Stocking records show that they were being widely distributed around 1870.

Reproduction

Probably most smallmouth bass in Connecticut waters are mature by the time they reach an age of three to five years (and a length of nine to thirteen inches). Scales from specimens of male bass guarding nests have shown all of them to be at least three years old. Breeding activities of bass extend from the middle of May to the middle of June in the latitude of Connecticut, varying slightly with the various bodies of water and with the nature of the season. Spawning temperatures range from 59° to 65° F.[48]

As the lake waters warm and approach the spawning temperatures, the male bass takes up his task of building a nest or spawning bed. This is normally and preferably in gravel found along the shoreline or shoal areas. The beds of thirteen bass observed in Columbia Lake on May 22, 1937 were, with but one exception, in water from three to four feet deep, the exception

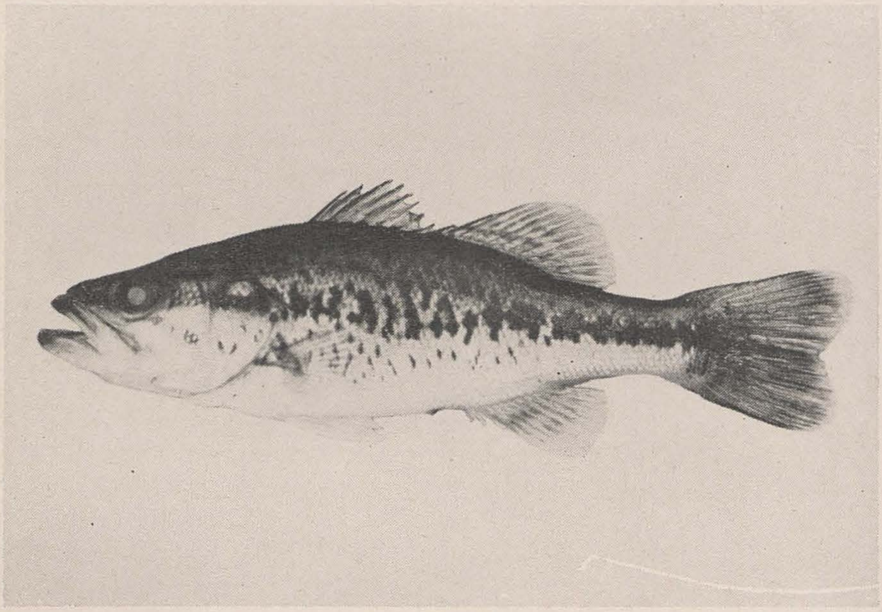

FIG. 35. Largemouth bass young (*Huro salmoides*). Young of the year showing black lateral band typical of the largemouth. Juvenile, 3¾ inches long from Bantam Lake, Litchfield.

being in twelve inches of water. They are reported in water over twelve feet.[10]

The nest is built solely by the male, mainly by the use of his tail fin; it is a shallow depression from which all sediment and debris has been swept away and varies in size with that of the male constructing it. Nests of several ten to twelve inch fish averaged eighteen inches in diameter, but much larger ones are built by larger fish. During and following the construction of this bed, it and the immediate vicinity becomes the private territory of the adult bass and he guards these areas carefully and pugnaciously against all intruders — save ripe females.

The appearance of a female leads to a courtship act in which the male gives short chase to his prospective mate, repeating this several times until she is finally induced to come to the nest and spawn.

The spawning act is essentially the same as that described in detail for the red-bellied sunfish. Eggs and milt are shed as the pair of fish swim about the nest with their vents approximate, the male remaining upright and the female swimming partially or completely upon her side. During the act the female becomes markedly darker and more mottled in color than her mate, while the eye of the male takes on a more reddish color.[78]

When all of her ripe eggs have been shed, the female leaves or is driven from the nest while the male maintains a vigilant watch over the eggs. He will, however, spawn with one or more females if they approach the nest within a short period following his initial spawning.[78]

The eggs are relatively small, measuring about 2.5 millimeters in diameter (10 to the linear inch). They are adhesive and stick firmly to the gravel in the bottom of the nest. The incubation period depends directly upon the water temperature, but occupies about 14 days with a temperature of 64° to 70° F.[10]

Meanwhile, the male bass has kept the eggs free from suffocating sediment and well-aerated by a gentle fanning motion of his tail and pectoral fins. Even with this care many eggs are destroyed by water mold which attacks dead animal matter and spreads from infertile eggs which die soon after spawning. Short trips are made from the bed, as if to reconnoiter in the immediate vicinity, but this period is never more than a few seconds. No fish or other possible enemies, such as crayfish, are tolerated in the vicinity of the nest.

It is a well-known fact to anglers that during the period of nest guarding the male bass will strike with rare abandon at any sort of lure presented to him. Doubtless this is often from a sense of protecting his progeny rather than a desire to feed. However, the male bass, under certain conditions at least, does take food while guarding the nest. Bass with nests in less than three feet of water were observed to feed quite regularly and with the eagerness of rising trout upon adult alderflies (*Sialis*) falling upon the water within a radius of about four feet. Food analysis of one male showed his stomach to be crammed with both adults and nymphs of aquatic insects (Columbia Lake, June, 1937).

Bass fry are about five millimeters (0.2 inches) long upon hatching and are at first colorless, but pigmentation progresses rapidly and soon they become almost jet black in color. They need take no food at this time since they are nourished by the contents of a yolk sac located in the abdominal region and so they have no need to move about.

When this supply has been nearly exhausted, the length of time again depending upon the water temperature, the young bass must begin active foraging for themselves. Accordingly they rise up in a compact swarm in the open water above the nest and here minute crustaceans or "water fleas" form their first item of diet. The attendant parent meanwhile keeps nervous watch of his charges, swimming about the school as if to keep it intact as well as ward off enemies, which indeed, would make short work of destroying the helpless fry. Gradually the feeding fry begin to break up and become scattered along the shoreline. On one nest observed in Columbia Lake two days after rising (June

FIG. 36. Rocky shore such as this are typical of most good smallmouth bass lakes. Columbia Lake, Columbia.

3, 1937) the fry had become scattered from ten to fifteen feet from the nest; three days later they were distributed over a still greater extent of shore and the attendant male was still attempting to keep proper guard; on June 10th, or nine days after rising, the male deserted the nest and young. At this time the fry averaged 18 millimeters (0.7 inches) in total length.

From the time their parent leaves them to shift for themselves the young bass become increasingly adept at taking care of themselves, making effective escape when threatened by danger to the protection of crevices between or under rocks on the bottom.

Their diet gradually changes from small crustaceans to include large quantities of small insects and finally as they approach two or three inches in length, includes the young of other fishes and small crayfish.

Habits and Habitat

Whereas Connecticut fishermen know the smallmouth as typically a lake fish, in other parts of its range, notably southern and

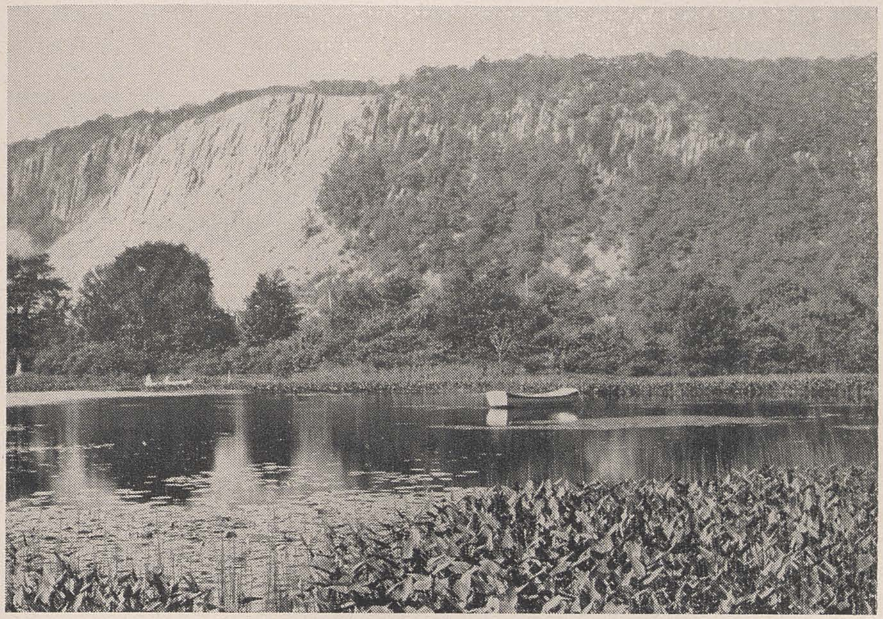

FIG. 37. Largemouth bass prefer dense weedy areas in which to forage and take shelter. Chain pickerel also haunt this type of habitat.

Mississippi Valley regions, it is common in streams. Bass fishing of this sort in Connecticut may be found to a notable degree only in a few of the larger streams. An explanation of this change in habitat preference has been given based on the influence of temperature.[48] Being a warm-water fish, the northern smallmouth finds the lakes which warm rapidly more to its liking than the cooler streams of the same region; in the southern parts of its range, such as the Ozark Mountains of Missouri, the extremely high summer water temperatures become quite intolerable and the smallmouth becomes a rapid-water stream fish. Regions between these two extremes are to be found in which there is good smallmouth fishing in both streams and lakes.

Yearling smallmouth are often quite common around the shores but after their second growing season retreat is usually made to deeper water, although fish up to nine to twelve inches are by no means rare in the shallows of most lakes. Small bass may frequently be seen harassing schools of small fishes in the shallows; this is particularly true of the barred killifish, schools of which are frequently driven to the very shallowest parts of their sandy shore habitats in order to escape pursuing bass.

It is well-known that the smallmouth is a lover of rocky shores (Fig. 36), but this is sometimes more apparent than real. For although the shoreline is rocky in most Connecticut smallmouth bass lakes, below the zone of wave action grow luxuriant beds of submerged vegetation, usually *Chara* or *Nitella*. These are frequently out of view from an observer on the surface and so are not evident under superficial examination. In these weedbeds the bass forage, along with other species, upon the crayfish and young fish living there. On rocky bottoms they hunt for the crayfish hidden beneath the rocks.

Belding,[11] in a study of a number of bass lakes in Massachusetts, concluded that the best smallmouth lakes had an average area of one hundred eighty-five acres, were relatively clear, had but a scant growth of vegetation, and a depth of at least thirty feet. Our observations agree in nearly all cases with one notable exception: the best bass waters in the State would average considerably higher in area. A temperature maximum of around 85° F. has been given for waters ideally suited to the species.[26]

Bass are not usually considered as a schooling fish, but fishing and gill-netting experience seem to indicate that they at least tend to congregate in localized areas at some times. Bass taken in gill nets were noticeably bunched together, that is, several bass would be taken in ten or fifteen feet of net and only occasionally would an individual bass appear. Anglers know that certain "spots" consistently produce good bass fishing whereas areas only short distances away seldom prove fruitful.

It has been reported in the literature that the staple food of adult smallmouth bass is crayfish. The examination of several series of stomachs from different Connecticut lakes bears this out conclusively. Two species of crayfish are known to occur in Connecticut bass waters: *Cambarus immunis* and *Cambarus limosus*, of which the latter species is by far the more common. Most of Connecticut's better bass waters have been found to have an abundant supply of one or both of these important bass forage organisms.

Seasonal abundance and availability, however, fill important niches in the diet of the smallmouth. During late June they feed on the emerging mayfly, *Hexagenia*, and earlier on the alderfly, *Sialis;* several specimens taken at this time have been glutted with yellow perch fingerlings. On one lake (Columbia) in August all size groups of bass up to twelve inches were observed feeding heavily on a two-winged fly (Diptera) which emerged over a period of several days. Bass taken over sandy areas have been found with their stomachs filled with dragonfly nymphs especially suited for living there (*Didymops* and *Macromia*).

Economic Role

Although not native to the waters of the State, the species has readily adapted itself to conditions found here and under favorable circumstances has become well established. It is difficult to suggest the effects of such an introduction upon the native species, particularly chain pickerel and yellow perch. In most smallmouth lakes, however, good to excellent yellow perch fishing is the rule, so there has been no apparent serious conflict between these species. Reports from a number of local sources indicate that pickerel fishing generally declined sharply with the introduction of either species of black bass, but scientific backing of such an effect is at present lacking.

No one will dispute the fact that the smallmouth bass is the most highly prized of Connecticut's warm-water fishes. It must be considered as one of the few valuable additions to the native fish fauna found in the fresh waters of the State and although it is not to be stocked with any less discrimination than other species, the management of Connecticut's smallmouth bass waters should receive careful attention.

Largemouth Black Bass (*Huro salmoides*)

Distribution

The natural range of the largemouth bass is more southern than that of the smallmouth, predominating in the Gulf States but extending well up into the Mississippi drainage as well. Its introduction into Connecticut waters probably came at about the time of or shortly after that of the smallmouth.

Taxonomic Consideration

Because of the difficulties anglers sometimes have in distinguishing between these two basses, it might be found helpful to mention distinguishing characteristics at this point. The best external character for the use of the angler is the length of the maxillary bone, the elongated structure forming the margin of the upper jaw. In the smallmouth this bone extends backwards to about the center of the pupil of the eye, whereas in the largemouth it extends for a short distance beyond the eye (Fig. 38). In very young specimens this difference will not hold, but fishermen need not be concerned with this. Of course, to the eye of a trained observer the two species are easily separated, but it is unfortunate from the point of view of the layman that some

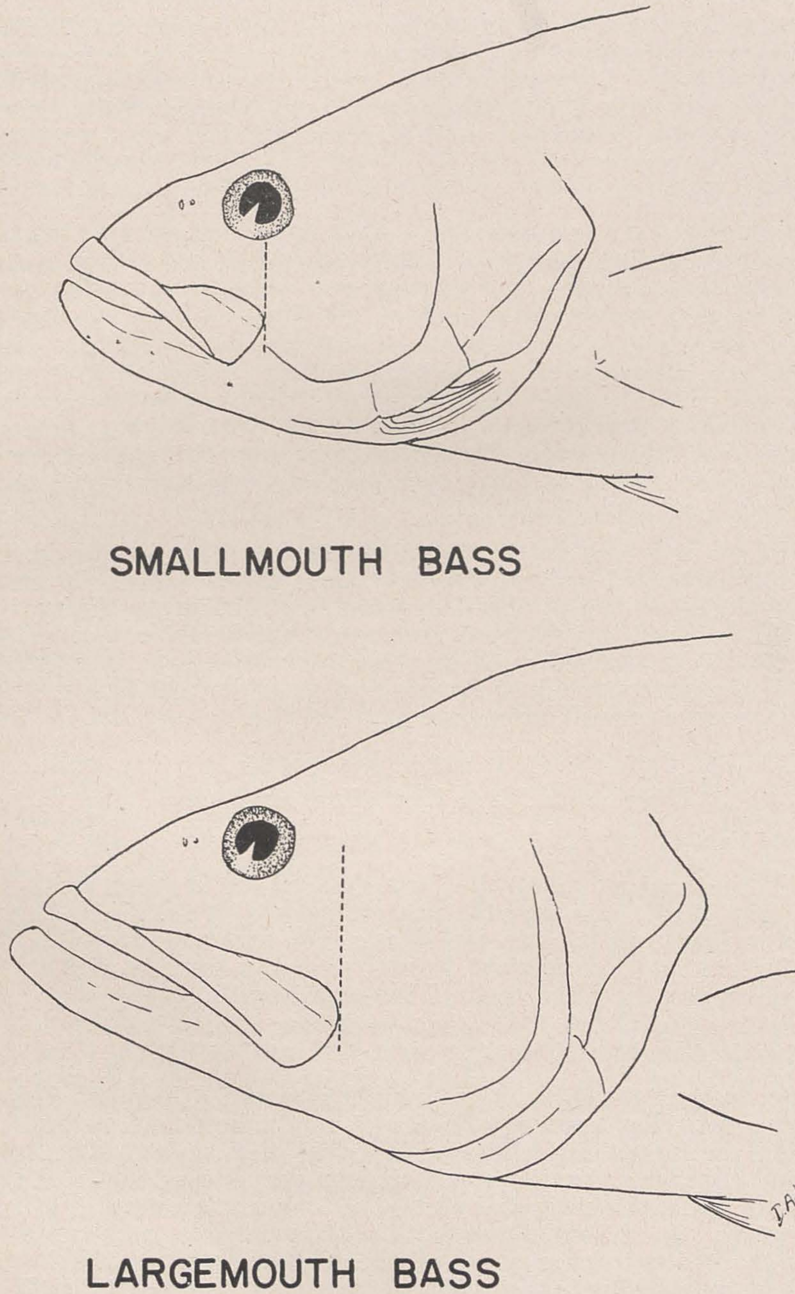

FIG. 38. Sketch of large and smallmouth bass heads showing differential characteristics in the maxillary bone. In smallmouth the maxillary does not extend beyond the center of the eye (indicated by dotted line) while in adult largemouth this bone extends beyond the center of the eye.

easily recognizable difference such as shape or coloration cannot be used. Largemouth bass have a much more greenish cast than smallmouth and usually specimens of twelve inches or under have a distinct dusky lateral band, while smallmouth may have transverse bars.

Reproduction

Our data on the age at which largemouth bass become sexually mature is meager, but it is probable that they mature at the same age or length as do smallmouth. Recent studies on some largemouth bass in Illinois[94] showed most of the fish mature at three years with a total length of about ten inches.

Dates of breeding are also lacking for the State but in other regions spawning follows rather closely that of the smallmouth, which would be from the middle of May to the middle of June in Connecticut. Spawning temperatures are given as 64° to 73° F.[101]

As is the case with other sunfishes, the male bass builds the nest, but in this respect it is not as restricted or particular as the smallmouth in the material in which the nest is built. Nests may be found, under varying local conditions, in almost any sort of bottom. Often times it is simply upon the roots of aquatic plants from which some of the bottom ooze and detritus has been swept, or it may be upon dead leaves, either over a muddy or a gravel bottom. If over gravel, such as the smallmouth might use, the stones will be swept clean, but no depression is scooped out.[78] It is generally built in shallow water about two feet in depth.[16]

No complete description of the spawning act of the largemouth black bass has yet been given. However, it is similar to that of the smallmouth and has been observed to take place at dusk by Reighard,[78] thus differing from most centrarchids which spawn during the daylight.

The eggs are smaller than those of the smallmouth, averaging 1.5 millimeters in diameter (17 to the linear inch). The male remains on guard until they hatch and continues to care for the young for a period of time afterward. The swarm of fry differs from smallmouth in that the fry remain in a compact school for a much longer period before scattering.[78]

Habits and Habitat

Both the young and adults are typically found in weedy mud-bottom habitats — a patch of lily pads or clump of pondweeds is often the hide-out of a big largemouth (Fig. 37). Thus this species is at home in an environment generally considered as quite unacceptable to the smallmouth bass. On the other hand, it will thrive in some lakes which are preeminently smallmouth waters by all standards, as Lake Pocotopaug, for example.

Small ponds of the weedy type often produce good large-mouth fishing. The water may be stained brown, as it frequently is in weedy situations, and summer maximums of 90° F. or over

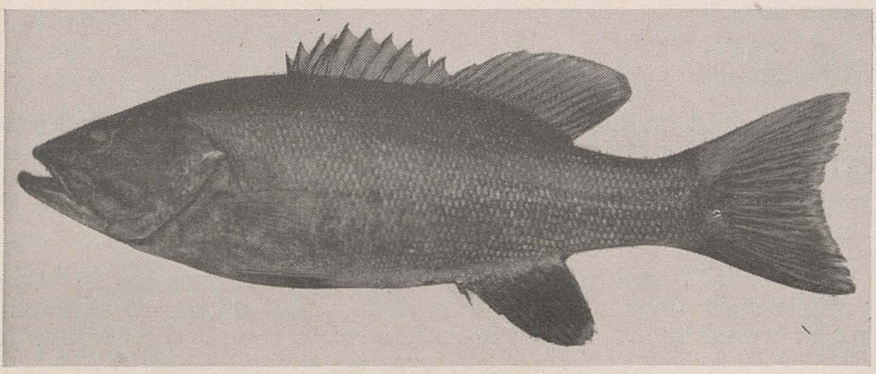

FIG. 39. Smallmouth bass adult (*Micropterus dolomieu*). Coloration varies from dark olive to bronze depending upon age and environment. Dark vertical barring often present may be retained or lost at will, although in large specimens barring tends to be obscured. Adult male, 12 inches long, from Columbia Lake, Columbia.

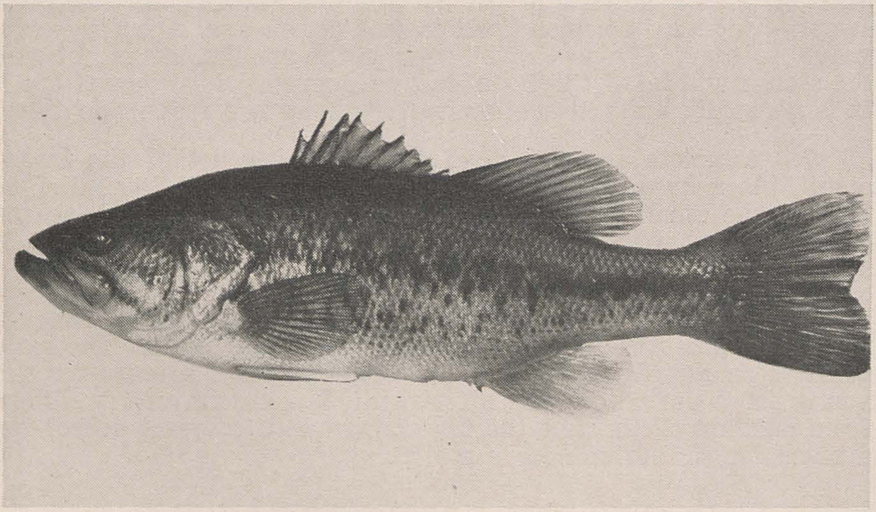

FIG. 40. Largemouth bass adult (*Huro salmoides*). With advancing age the lateral band becomes more obscure and in large specimens may disappear completely. Adult male, 9 inches long, from Cornell Experimental Hatchery, Ithaca, New York.

do not limit the territory inhabited by this bass.[26] Thus waters best adapted to the species are those most closely duplicating conditions found in its natural range.

Only a few Connecticut largemouth bass have been examined for food, but these seem to indicate rather closely allied food habits with the smallmouth. Of the 26 individuals examined, 15 had eaten a total of 23 crayfish, while 9 had consumed 13 small fishes (including yellow perch, sunfish, calico bass and smallmouth bass). All specimens were over ten inches in length.

Economic Role

The largemouth bass does not enjoy as complete a distribution as the smallmouth in Connecticut lakes and this must be regarded as fortunate since the majority of the larger waters suitable for bass stocking are better suited for smallmouth.

It is easy to note from the foregoing brief description that the largemouth bass is not particularly specialized in its environmental or reproductive requirements and consequently it has become established, frequently to the point where it could be classed as successful, in waters not ideally suited for it. Indiscriminate stocking or failure to distinguish between the two species of black bass sometimes leads to the introduction of the largemouth into waters which should have been reserved for other species. The proposed planting of this species in Connecticut waters where they do not already exist should consequently always be regarded with skepticism, for even though the environmental conditions may be favorable, the reservation of waters for management and production of pickerel or perch may be more desirable in the long run.

Anglers of this section of the country will generally concede the superior game qualities of the smallmouth, but the largemouth does have a place in Connecticut's fishing although just how necessary and desirable this may be is somewhat controversial.

Calico Bass (*Pomoxis nigro-maculatus*)

Distribution

The calico bass is another mid-western and southern introduction, although its range is somewhat more northern than a closely related species, the crappie (*Pomoxis annularis*). The latter species is not yet known from the State although it is conceivable that it may have been brought in with the calico bass.

Reproduction

Spawning probably occurs in May at a temperature similar to that of the black basses; in southern Wisconsin lakes the calico spawns at about 68° F.[72] The nests are constructed in sand or gravel and may be in vegetation. The eggs adhere to the bottom of the nest or upon the aquatic plants in which the nest is built.[16]

Habits and Habitat

The calico bass is a weed-loving fish. Adults are found over

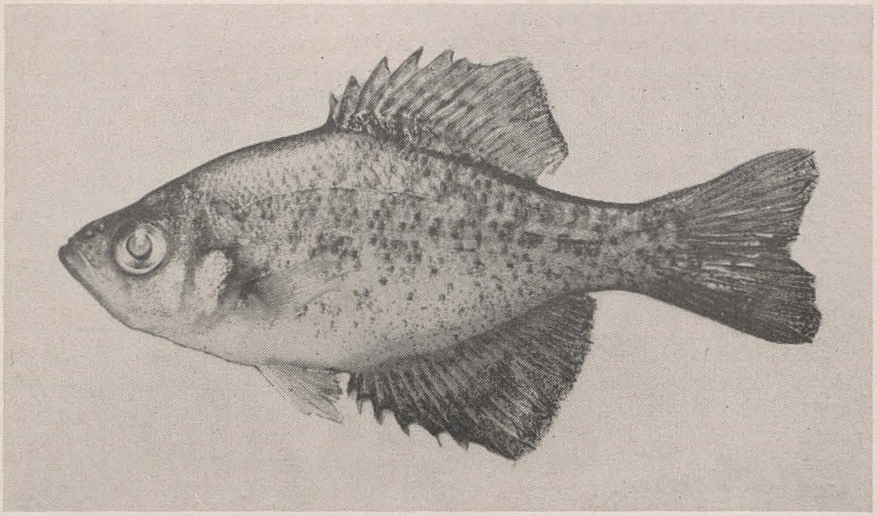

FIG. 41. Calico bass (*Pomoxis nigro-maculatus*). Young of year, specimen 3 inches long, from Bantam Lake, Litchfield.

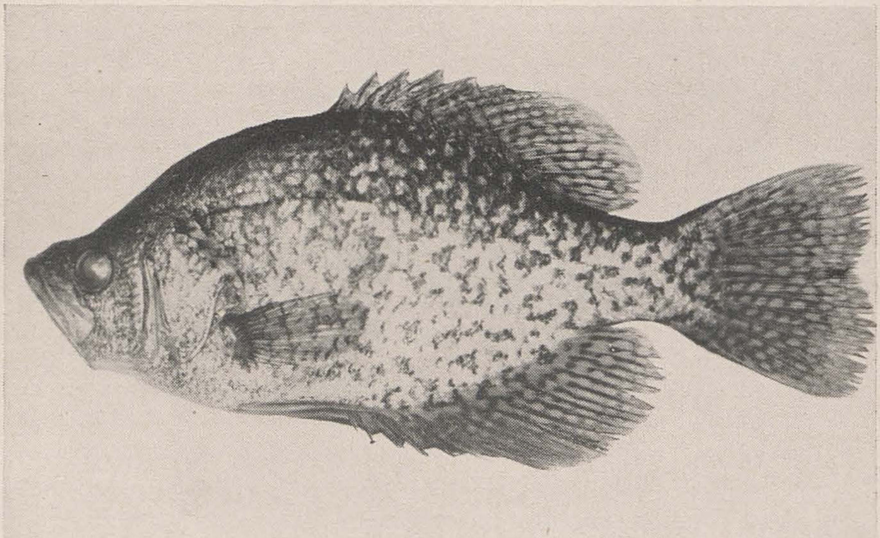

FIG. 42. Calico bass adult (*Pomoxis nigro-maculatus*). The closely related crappie, not known from Connecticut, has but little color on the anal fin and a line extended perpendicularly from the end of the maxillary bone towards the back falls before the dorsal fin. Adult, 9½ inches long, from Bantam Lake, Litchfield.

beds of submerged or floating vegetation and the young inhabit weeds growing along the shore. We have found young in beds of *Elodea, Vallisneria, Potamogeton,* and *Nuphar* and upon one occasion in a heavy growth of filamentous algae over sandy bottom.

Here in the weeds they feed extensively on aquatic insects and young fishes. Twenty-two fish from 7 to 13½ inches long have been examined from various waters. Of these, 15 individuals held insects, 10 had eaten other fishes, and 4 had also been feeding on plankton crustacea. The insects eaten included both larval and adult forms of beetles, dragon and damselflies, mayflies and two-winged flies (Diptera). In Wisconsin, 276 specimens examined throughout the year had fed chiefly on insects (largely immature stages) water-fleas, amphipods, and fishes.[72]

Economic Role

Inadvertent stocking has placed this fish in many waters where it should not be. In some lakes the calico has done well and furnishes a fair amount of sport. It takes an artificial fly but its game qualities are rather limited. Added pressure upon fish forage and a possible tendency to prey on more desirable species are the main objections to the general distribution of the calico bass in Connecticut.

Bluegill Sunfish (*Lepomis macrochirus*)

This sunfish has a native range similar to the previously mentioned centrarchids and it reaches a peak of abundance in the region of such states as Illinois and Indiana. The bluegill is the largest and most gamey of the sunfishes and reaches a length of about twelve inches. It is uncommon throughout the lakes of the State.

The bluegill breeds in May and June in other localities[16] and probably spawning dates for Connecticut fall within this range. Ripe specimens were taken from Columbia Lake in late June, 1940.

The nests are built on fine gravel over shoal areas and usually in colonies.[43]

Adults live in the weed zone[43] where they travel in schools feeding upon insect larvae, large and small crustaceans and small mollusks.[28] As high as 24 per cent aquatic vegetation in the stomachs of some fish has been reported, "too large a quantity to have been swallowed accidentally with the animals eaten."[28] Algae and higher aquatic vegetation have been markedly present in nearly all stomachs of specimens taken from Connecticut waters.

Red-bellied Sunfish (*Lepomis auritus*)

Distribution

The red-bellied sunfish is one of the four fish in the family native to Connecticut waters. It is not as common or abundant as the pumpkinseed, but it is well scattered throughout the State. The range extends from Maine to Louisiana, but it is not found west of the Allegheny Mountains.[52]

Reproduction

Over a four year period the earliest date of nest building observed at Columbia Lake was June 1, 1939 (the water temperature two days previous was 71° F.), but by the following week many nests with eggs were evident. Spawning was observed on June 9, 1939 with a water temperature of 72° F. Females taken on June 30 of the same year from Lake Housatonic were gravid (water temperature 72° F.). Breeding activities continue well into July, tapering off during the first two weeks of August.

Red-bellied nests are in shallow water, often only eight or ten inches deep, although some have been noted in as much as three feet. Several males frequently build their nests in a "colony". The nests are quite attractive, for they are evenly scooped out and composed of fine gravel in the center with a rim of sand at the periphery. They range from eight to fourteen inches in diameter.

The following observation on the spawning of the red-bellied sunfish was made in Columbia Lake on June 9, 1939 with a water temperature of 72° F. The male fish was approximately four inches long and the female about three; the nest was from eight to ten inches in diameter.

The male nosed about under large rocks near the nest and finally drove out a female. The female was considerably darker in general color than the male and the vertical barring was particularly prominent. The male presented a light "translucent" appearance and barring was nearly absent. The female required some coaxing before submitting to the nest; she would dash off for short distances closely followed by the male who always succeeded in heading her off and turning her back towards the bed.

Once in the nest the male nosed and nipped his mate in the region of the vent. The pair then proceeded to swim across the nest, with the female rolling over on her side until she was swimming parallel with the bottom. The male kept a normal vertical position. With a rapid vibration motion of her body the eggs were extruded as the female swam over the bed; the male at the same time accompanied her but did not show any readily apparent signs of excitation except for a noticeable extension of the ear flaps on the gill covers. Their positions were such that the vents of both participants were in close approximation. The pair

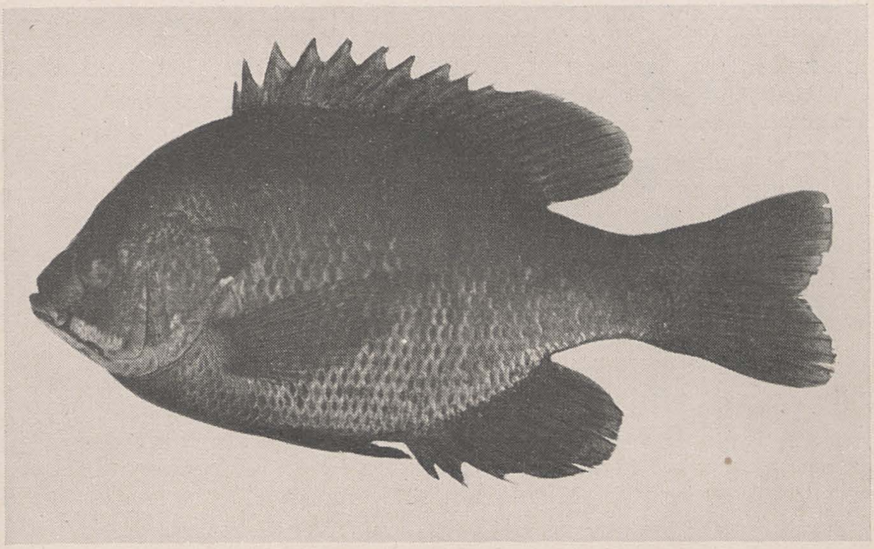

FIG. 43. Bluegill sunfish (*Lepomis macrochirus*). The bluegill can be separated from other Connecticut sunfishes by the dusky blotch on the posterior base of the soft dorsal fin, not clearly evident in this picture, or by the relatively long, slender gill rakers. Adult male, 7 inches long, from Mudge Pond, Sharon.

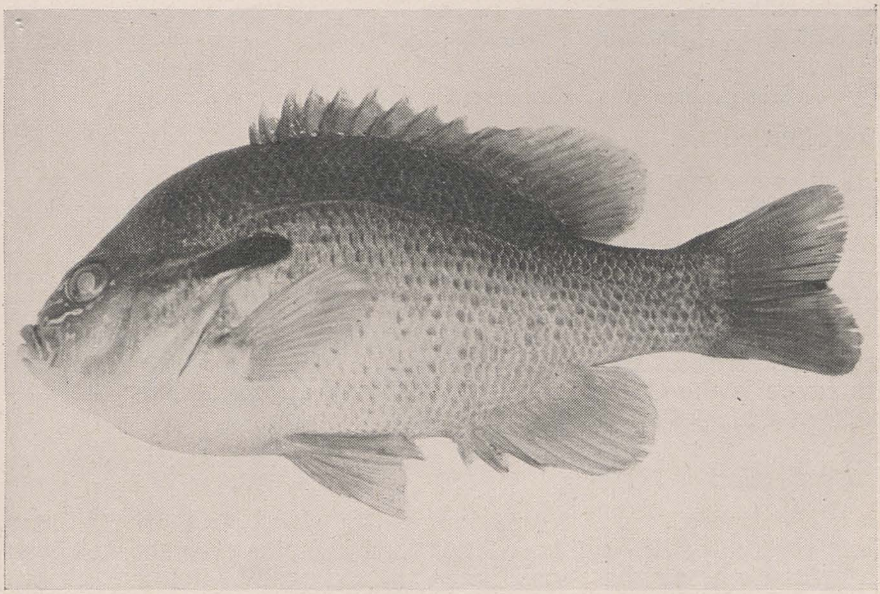

FIG. 44. Red-bellied sunfish (*Lepomis auritus*). The dark blue ear flap of this sunfish lacks the vermilion tip of the pumpkinseed and the tip of the pectoral fin is rounded while in the pumpkinseed it is pointed. Adult breeding male, 5¾ inches long, from Bantam Lake, Litchfield.

then turned and proceeded back and forth across the nest several times; this was followed by a moment of inactivity during which the male kept close escort of his mate. Spawning occupied about two minutes, after which the female retreated to the shelter of nearby rocks.

These observations took place at 11 A. M. At 3 P. M. spawning again took place, this time the period occupying about five minutes. Another female was seen close by and was chased by the spawning male, but she did not offer to follow him to the nest. After both spawnings the male fed regularly on the adults of the alderfly (*Sialis*) which were continually falling into the water in the vicinity.

The eggs are adhesive and stick to the gravel and to one another, sometimes in large clusters.

On June 13, 1939 sac fry were found in the nest described above; they were about six millimeters long. Three days later no young fish were present and the male fish had deserted the nest.

Habits and Habitat

Young red-bellied sunfish have been taken or observed over scant submerged vegetation, mud, or rock bottom. Large specimens may be found along the shores, usually over rocky or gravel bottoms and often in deeper water. The young remain together in schools for the duration of the first summer, but larger ones do not show a marked tendency to school.

Pumpkinseed or Common Sunfish (*Lepomis gibbosus*)

Distribution

The common sunfish, best known in Connecticut as the pumpkinseed or Johnny roach, is probably the most evident species to be seen along the shores of our lakes and ponds. It is a brilliantly colored fish always ready to nibble at a worm and so has well earned the reputation of being a "small boy's" fish.

This sunfish is one of the few typical centrarchids of the northeastern section of the country. The southern boundary of its range is the Carolinas on the east and approximately the latitude of Chicago on the west.[52]

Reproduction

The pumpkinseed begins spawning about two weeks later than the red-bellied sunfish. At Columbia Lake they are not even in evidence along the shores when the first red-bellied sunfish are inshore working upon their nests. In the same lake one nest has been noted as early as June 8, 1938 and some spawning occurred four days later. Scattered observations made throughout the State agree, in general, with the above observation. While females

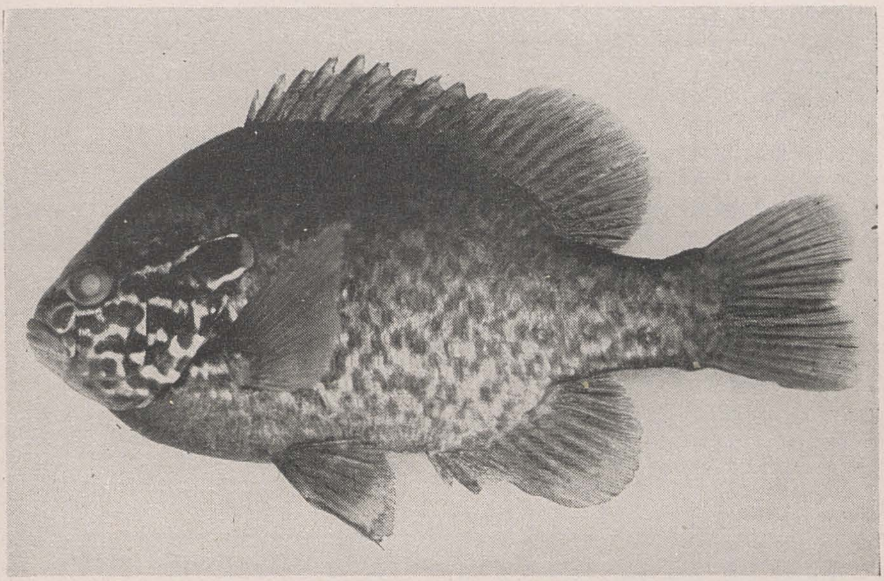

FIG. 45. Pumpkinseed (*Lepomis gibbosus*). A common fish in waters throughout Connecticut. Ear flap is dark with a livid vermilion tip in adults. Adult breeding male, 6½ inches long, from Kelley Pond.

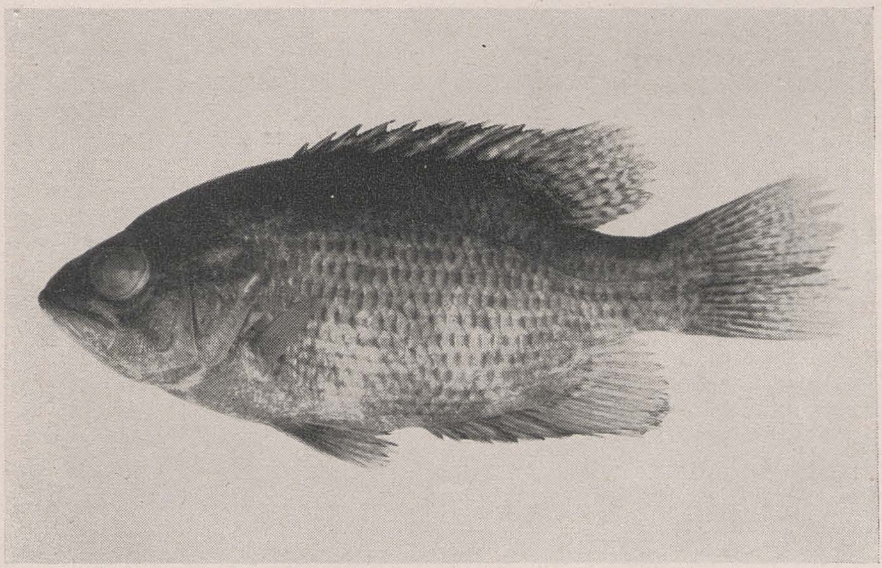

FIG. 46. Rock Bass (*Ambloplites rupestris*). Young possess a few prominent irregular vertical bands which become more obscure with age. Older specimens exhibit broken lateral bands along the scale rows. Picture shows indications of both color patterns. Iris of eye in adults is reddish. Specimen, 6 inches long, from Highland Lake, Winchester.

of both species were taken from Candlewood Lake on July 9, 1939, those of the pumpkinseed were not yet ripe, while red-bellied females were gravid and males were guarding nests. The peak of spawning of the pumpkinseed is reached during the middle of July and temperatures at which males were guarding nests or gravid females were taken ranged from 71° to 80° F. Two exceptions were found to this, one at Pataganset Lake and one at Ball Pond where with water temperatures at 68° and 62° F., respectively, males were guarding nests or gravid females were taken.

Of twenty-two females examined from four lakes between August 15 and 19, 1939, all except one were spent females. The breeding season of the pumpkinseed may be said to extend from about the middle of June to the middle of August.

The nests are commonly built in colonies and are sometimes very abundant along shore where spawning conditions are ideal. Occasionally two beds are started by one male but usually only one is completed and utilized. The males make frequent sallies towards the nest of a neighbor, but the ostensible aggression is immediately halted by the bold front of the other male. Nests are made in fine gravel or sand, or in the absence of these, even in mud. In one instance in a small pond where the entire bottom was a dense growth of weeds, circular areas had been cleared and nesting was proceeding as usual on the gravel found below. The majority of beds are constructed in water less than three feet in depth.

Spawning has been observed several times and the procedure does not differ appreciably from that described for the red-bellied sunfish. The female is decidedly darker than the male although not as brightly colored. The eggs and sperm, in the spawnings observed, were emitted for periods of three to eight seconds with a few seconds interval between emissions. Spawning continued for ten minutes in one instance and for over fifteen minutes in another. As soon as the female has left the nest, the male becomes decidedly more nervous and erratic in his nest-guarding activities. Spawning pairs were quite unconcerned about nearby movements of a boat; when the male was purposely attracted from the bed, the female remained motionless over the nest until he returned.

As is the case with other sunfishes, the male is a plucky defender of his eggs and young and will not hesitate to attack intruders many times his size. Once he is removed from the nest, the progeny are greedily devoured by enemies. This was well illustrated in Pataganset Lake when a male sunfish guarding eggs was seined from his nest. Almost immediately a score or more small fishes rushed into the emptied nest and began feeding with avarice upon the eggs; these predators included barred killifish and the bridled minnow.

Habits and Habitat

The common sunfish feeds predominantly upon insects, small crustaceans, and snails. Fishes are conspicuously lacking from their diet.[1] The scattered young of the smallmouth bass frequent the areas utilized by breeding sunfishes but none have ever been observed to have been eaten by them although bass are not tolerated in the vicinity of the nest. The stomach contents of six guarding males showed nothing but insect remains.

The pumpkinseed lives both in weedy and rocky habitats, but seems to prefer the latter; it may often be seen on the edges of weeds rather than in them. Young sunfish live in the vegetation more than the larger specimens. This sunfish is common in the shallow water, but also frequents the deeper water and large specimens may be caught here while angling for bass or perch. Young sunfish remain together in schools and adults are often seen in small groups.

Rock Bass (*Ambloplites rupestris*)

Like other centrarchids, the main center of distribution and abundance of the rock bass is the Mississippi Valley, but unlike others previously mentioned, it ranges farther eastward to include parts of New England. It is a common, although not abundant fish in the State. The rock bass attains a maximum length of ten to twelve inches.[53]

No local data are available on the spawning dates but in other localities spawning extends from the middle of May on into June.[16] Nests are made in shallow water in sand, gravel, or marl, and may be in the presence of vegetation.[53, 43]

Adults live both over weedy and rocky bottoms and young rock bass have been taken in beds of submerged vegetation along the shore. The food of larger specimens consists mainly of insects, crayfish and some small fish.[1]

Banded Sunfish (*Enneacanthus obesus*)

Jordan[52] records the range of this beautiful little sunfish as coastwise from Massachusetts to Florida and it has more recently been found in New Hampshire waters.[42] We have found it in only two of the thirty-eight lakes studied, Green Falls Reservoir and Rogers Lake.

Little has been written about the life history of the banded sunfish. The Green Falls specimens were taken in a shallow cove near the inlet where the bottom was muddy and there was a sparse growth of submerged vegetation.

The Perches and Darters (Percidae)

The family is divided into two subfamilies, the Percinae and the Etheostominae of which the great majority of the approximately one hundred twenty-five species[28] belongs to the latter group and are little known to anyone save students of fishes. Connecticut lakes boast but four members of this family and one of these is an introduction. Two of them belong to the Percinae and are the well known yellow perch (*Perca flavescens*) and the wall-eyed pike (*Stizostedion vitreum*); the other two are darters belonging to the Etheostominae and are little known to anglers: the Johnny darter (*Boleosoma nigrum olmstedi*) and the fusiform darter (*Hololepis fusiformis*).

The yellow perch is common everywhere in the State, while the introduced wall-eye or pike-perch is nowhere common. Only in a few places has the wall-eye responded to artificial stocking to a point where at least a few fish are caught.

Our two darters are poor representatives of a group of fishes which contain some of the most brilliantly colored of North American fishes. All are small, the largest species scarcely reaching eight inches in length and most of them are less than three to four inches long. The majority of the darters are stream forms.

Wall-eyed Pike (*Stizostedion vitreum*)

Distribution

The species has been unsuccessfully introduced into a number of lakes, but results have been forthcoming in only one. A number of very large specimens have been taken from Candlewood Lake during the ice fishing season, but few are caught in the summer months. The wall-eye is very abundant in the Great Lakes and extends south through the Mississippi Valley to Alabama and Virginia.[28, 52]

Reproduction

There is no evidence to indicate successful natural reproduction of the species in Connecticut waters. No young fish have been taken nor have there been any reports of spawning fish. Fishing for them has been so poor in lakes where they have taken a slight hold that it is conceivable that it is merely the result of a vigorous stocking program. The species is migratory in the sense that it runs into large tributaries to spawn in the early spring; it has been stated that spawning will take place in lakes if access to streams is prevented.[9, 62]

The following observations on the spawning act were made by Hankinson.[1] No nests are built. Spawning takes place over sand or gravel in moderately rapid water at a temperature of

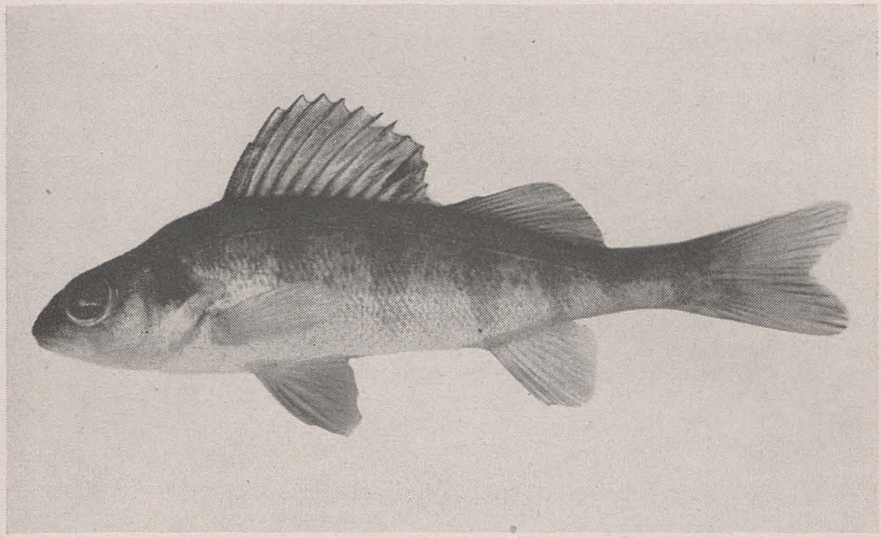

FIG. 47. Yellow perch (*Perca flavescens*). Easily recognized by the prominent regular vertical bars which the young early acquire and which are retained throughout life. Specimen, 5 inches long, from Irving's Pond.

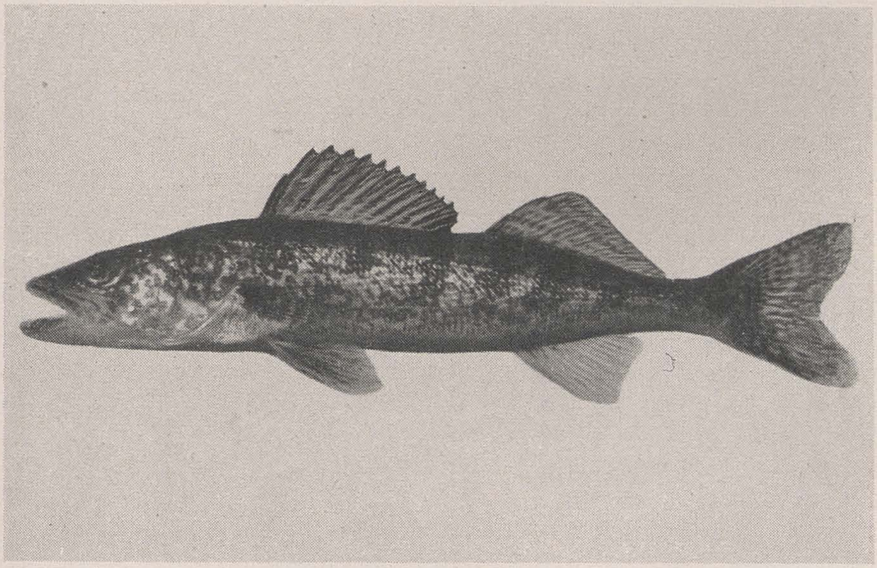

FIG. 48. Wall-eyed pike (*Stizostedion vitreum*). Spiny rays readily separate this fish from the true pikes (*Esox*) while the elongate form and canine teeth distinguish it from the related yellow perch. Specimen, about 10 inches long from Cornell Experimental Hatchery, Ithaca, New York.

Photo by W. F. Royce

about 50° F. "From two to five or six males would gather about a single female near the bottom, and then the whole group would rise to near the surface. Then it would descend as if exhausted." The eggs and sperm are shed at this time.

The eggs are small, about 2 millimeters in diameter (about 13 to the linear inch)[97] and the females carry from 200,000 to 300,000, depending upon their size.[9] The eggs are very adhesive. At a temperature of 48° F. the eggs hatch in 18 to 20 days.[97]

The young wall-eyes are extremely cannabalistic and as soon as the yolk-sac has been absorbed, at least when the fry are in the confines of a hatchery tank, will feed upon one another with rare abandon. For this reason they must be stocked as sac fry as soon as possible after hatching.[59, 97]

Habits and Habitat

The larger fish apparently inhabit the shallower waters in the spring, gradually moving out into deep water as the season advances and spending the winter in the very deep water.[1] Rocky bottoms are favored habitats, although not infrequently wall-eyes are found living in the weed zone or making short foraging trips there.

Pike perch feed largely upon small fishes, but other organisms such as crayfish and aquatic insects do form a small proportion of their food.[28, 1]

Economic Role

Lack of suitable spawning conditions has undoubtedly been one of the obstacles preventing the acclimatization of the wall-eyed pike in Connecticut. In situations such as Lake Zoar where a large stream forms the inlets, this may not be a legitimate reason. Other conditions in the lake or concerned with stocking are probably unfavorable to their success. Since continued fishing for wall-eyes is apparently solely dependent on artificial stocking, and since past plantings of millions of fry have resulted in negligible results, there is no reason why further effort should be made to establish the species in any of the waters of Connecticut, except possibly the lake mentioned.

Yellow Perch (*Perca flavescens*)

Distribution

The yellow perch ranges from southern Canada south to the Carolinas and westward to the upper Mississippi valley.[52] In Connecticut it may be found in nearly every pond or lake and it is often the most abundant species present.

Reproduction

The yellow perch spawns during April and May when the water temperature ranges between 44° and 54° F.[97, 63, 72] For a number of years the Department has secured eggs in March from the coves of the Connecticut River for use in stocking.

Spawning takes place in relatively shallow weedy situations[24] and at night[63] although spawning has also been reported over gravel.[28] No description of the spawning act has yet been published but the egg masses are quite commonly observed entwined among aquatic plants or submerged brush.

The eggs are unique among fresh-water fishes in that they are laid in a gelatinous matrix in accordion-like strings. These swell considerably upon contact with the water, becoming from one to eight feet long, depending upon the size of the fish depositing the egg-string.[97] The egg strings are grayish-white in color, semi-buoyant, and non-adhesive in character and are woven in and around the aquatic plants or brush where they are deposited. The eggs have an average diameter of slightly under 2 millimeters (about 13 to the linear inch) and an 8 ounce female carries from 10,000 to 15,000 eggs[26] and larger specimens many more. The yellow perch is a very prolific fish.

Once the eggs are laid, they are deserted by the parent fishes and left to incubate; this period occupies 27 days at a temperature of 47° F.[59] Many of the eggs or egg masses may be eaten by enemies or totally destroyed when they are washed up on beaches[63] or otherwise exposed.

The young fish which hatch in two to four weeks[97] are about 5.6 millimeters long[27] (0.2 inches) and they swim about freely in large schools as their yolk-sac is not as burdensome as in most species.[63]

Habits and Habitat

Schools of young perch characteristically spend their first summer near or in weedy areas along shore or less commonly in open water which may be quite some distance from shore or weeds. Probably many of them also live in submerged beds of vegetation in deep water, especially in lakes whose shorelines are bare of marginal vegetation. One large school observed at Columbia Lake remained in a localized area during several weeks' observations; this school was over a rocky shoreline in water from three to five feet deep.

The examined stomachs of young perch averaging 32 millimeters (about 1¼ inches) in total length, held only plankton crustacea.

Young yellow perch are extensively used as forage by many other carnivorous fishes, including larger individuals of their own species.

The best perch fishing lakes appear to be those which exhibit many of the characteristics of good smallmouth bass waters. From the standpoint of producing large numbers of catchable fish (nine to twelve inches), those waters with considerable areas of rocky shoreline and extensive beds of submerged vegetation (*Chara* or *Nitella*) show up better than those which are largely weedy in nature.

The yellow perch is a fish which retains its schooling habit throughout life, though individuals are frequently seen. Many anglers are aware of these schooling habits both by observation and experience, for to have a school of feeding perch about one's boat provides exciting sport.

During the period of calm usually prevailing on our lakes in the early morning, schools of yellow perch may be seen cruising about very near the surface, the tips of their dorsal fins just breaking the water's surface. The schooling fish are unusually wary at this time, and but a slight disturbance will cause them to immediately sound, often with considerable surface disturbance.

Schools of feeding yellow perch may sometimes be seen in shallow water where they cruise slowly over weed beds, picking up organisms living on the vegetation or chasing small fishes. Their diet is diversified, but in many Connecticut lakes crayfish are the most important item of the larger individuals. This is supplemented by aquatic insects, mollusks, small crustaceans, and fishes. Adult perch are sometimes taken with their stomachs full of plankton crustacea. The perch continues to feed through the winter months.

During the season at which the large mayfly, *Hexagenia*, emerges (usually the latter part of June or early July in Connecticut lakes), the yellow perch glut themselves upon the subadults. From the time the hatch begins each evening and far into the night, the fish feed tirelessly upon the subadults as they are about to leave the water; it is of interest to note that of the some thirty stomachs which have been examined from such feeding fish, only on rare occasions are the nymphs to be found, feeding activity apparently being directed solely toward surface food. The yellow perch provides interesting sport when taken at this time on trout tackle with a large dry-fly, to which it will usually respond readily.

Specimens are frequently taken in deep water. Many large yellow perch were taken in association with rainbow trout in Wononscopomuc Lake and some were found with the round whitefish and sockeye salmon in East Twin Lake. Two specimens were taken on the bottom in forty-five feet of water in Mount Tom Pond where the oxygen value was less than one part per million. Such movements into deep poorly oxygenated waters have been noted elsewhere.[73]

Economic Role

The yellow perch is one of the more valuable species sought by Connecticut anglers. The main reasons for this are three-fold: first, the species is everywhere abundant; second, it may be easily caught by the angler; and third, it is an important forage item for other fishes. To these might be added its excellent eating qualities.

The perch can properly be considered to play the important role of a "buffer" species in the waters of the State. Most anglers feel that they have had a successful day's fishing if they catch two or three bass supplemented by eight or ten yellow perch. In this way the species serves to relieve pressure on other less successful fishes. Of the anglers' catches examined by the Survey during the 1938 season, over twice as many perch were checked as any other one species. One fisherman's record over a two-year period showed more than twice as many yellow perch were caught as bass and pickerel combined.

Winter fishing has been blamed for eventually causing poor perch fishing in many waters. There is no tangible proof for this, although it is known that large numbers of yellow perch are frequently taken through the ice. On the other hand, complete catch records kept on fishing in Stillwater Pond in Torrington for a period of four years show that of the 6,685 yellow perch caught, only 470, or about seven per cent, were taken by ice fishing.

Under almost any circumstances the species is very successful, at least if numbers of individuals are used as a criterion. This may work to extremes and an over-population accompanied by stunting results. The reasons for this are not yet well-defined. An excellent example of a stunted perch population is found in Alexander Lake, Killingly, where prodigious numbers of fish from six to seven inches are present and but few larger ones. In such cases the fish are worthless to the angler. The introduction of yellow perch into trout waters has sometimes resulted in a large stunted population which eventually appreciably reduced the trout population; this has happened in a number of the cold Adirondack trout lakes.[32]

Johnny Darter (*Boleosoma nigrum olmstedi*)

Distribution

The Johnny darter is not uncommon in some of our lakes and it is abundant in many streams. It has a wide distribution in the northeastern section of the country, this particular subspecies ranging along the Atlantic drainage from Quebec to New Jersey.[52]

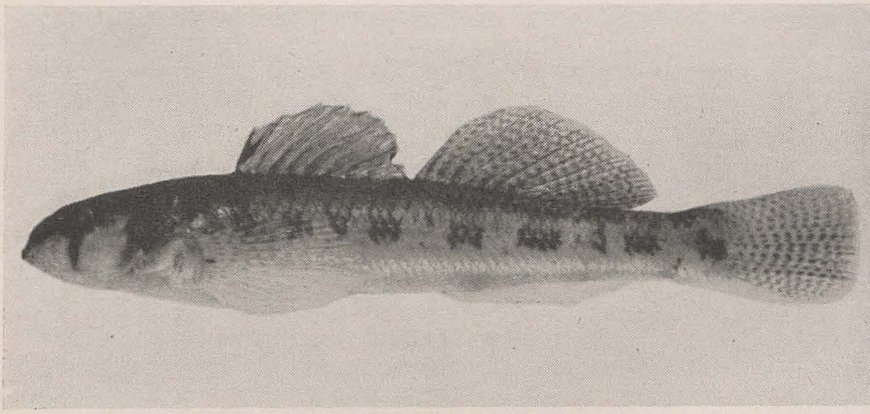

FIG. 49. Johnny Darter (*Boleosoma nigrum olmstedi*). Dark brown X or W-shaped markings on the sides are recognition characters for this small fish commonly found in both streams and lakes. Adult, 3 inches long, from Cayuga Lake, New York.

FIG. 50. Racking Gill nets.

Reproduction

Breeding occurs in the late spring in May and June[43] and the eggs, which are adhesive, are laid on the underside of flat stones. Here the male stands guard, driving away all intruders until the eggs hatch.[43]

Habits and Habitat

This fish is typically found over sandy shallows, although on a few occasions we have found it in regions with sparse growths of submerged vegetation.

Fusiform Darter (*Hololepis fusiformis*)

This little darter has only been collected from one Connecticut water, Pataganset Lake in East Lyme. It was found here over muddy bottom among floating marginal vegetation.

The exact taxonomic status of the Connecticut species of the fusiform darter has not yet been determined.[47]

The River Basses (*Moronidae*)

Two genera of this family occur in Connecticut and both of them are familiar sport fish: the white perch (*Morone americana*) and the striped bass (*Roccus lineatus*). The white perch frequents brackish waters but has become land-locked in the fresh waters of coastal ponds. The striped bass is strictly a marine fish of coastwise distribution, although it enters fresh-water rivers for the purpose of spawning.

White Perch (*Morone americana*)

Distribution

The range of the white perch extends from Nova Scotia to Florida in coastal waters, both marine and fresh. The natural distribution of the species in Connecticut, however, has been greatly extended inland so that at present it is found scattered in lakes in all parts of the State.

Reproduction

Various sources in the literature indicate April and May as the spawning seasons of this fish in brackish or salt waters.[63, 97, 38]

Fresh-water forms were found to spawn through June and July in some Maine lakes[29] and Greeley[38] states that ripe specimens were taken from inland lakes as late as July 1. Some 150 specimens taken from six Connecticut lakes between June 19 and July 9, 1939 were in a near-ripe, ripe, or occasionally spent condition. Over 300 specimens examined after August 1st revealed only spent fish. This information apparently leads to the conclusion that marine forms spawn much earlier than those "land-locked" in fresh waters.

Spawning is reported for marine white perch as taking place in the fresh waters of rivers on sand and gravel bars in a manner similar to that of striped bass.[97] Foster[29] notes that the fish entered inlets of the lakes in schools to spawn but apparently spawned along the shoreline of the lake as well. We have taken ripe fish in lakes in from ten to twenty feet of water along rocky

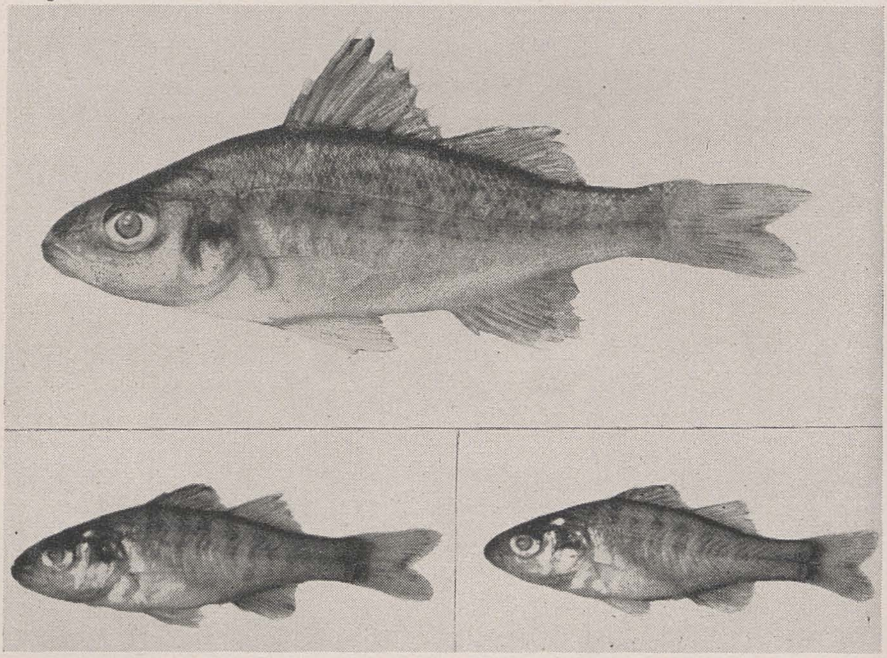

FIG. 51. White perch young (*Morone americana*). Young of the year showing dusky vertical bars lacking in older fish. Upper specimen, 2¾ inches long, taken September 13, 1940; insets, about 1 inch in length, taken July 25, 1940. All specimens from Bantam Lake, Litchfield.

or gravel shores. A spawning run is reported to occur in the inlet of Bantam Lake.

The eggs of the white perch are very small (about one millimeter in diameter or 25 to the linear inch) and quite adhesive. When the water temperature is about 60° F. the eggs hatch in from 48 to 52 hours.[63]

Habits and Habitat

Young white perch of about one inch in length have been collected in large numbers during the evening over sandy shoals in Bantam Lake. Associated with them were young yellow perch, red-bellied sunfish, and barred killifish. These fish exhibited a marked inshore nocturnal migration, for during the day none could be found in these same areas. Considerably smaller young (8 to 13 millimeters) were collected by trawl at about the same time of year (late July) in 8 to 12 feet of water over mud bottom.

Adult white perch have most frequently been taken by gill nets in ten to twenty feet of water over bottoms with a scarcity of vegetative growth. In Bantam Lake large white perch are known to move inshore to feed at night.

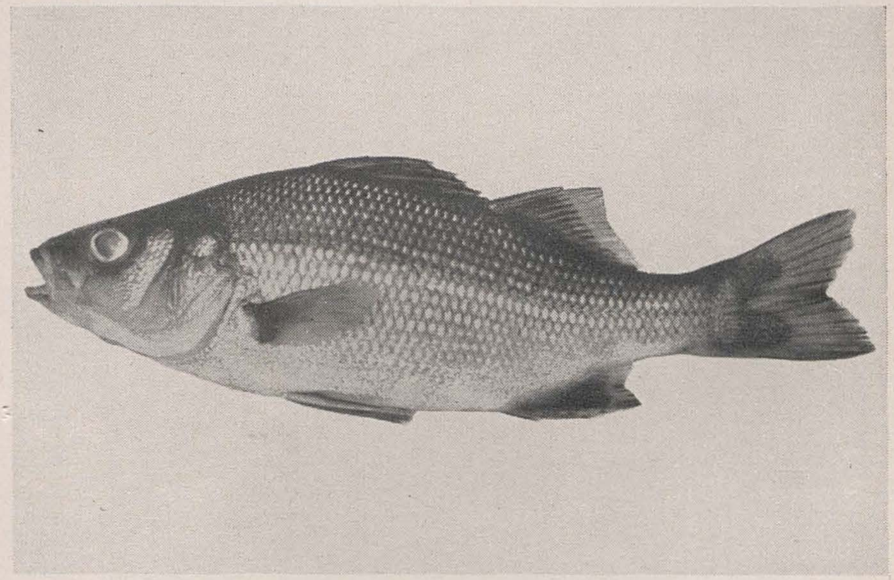

FIG. 52. White perch adult (*Morone americana*). Adults exhibit broken lateral bands along scale rows. Adult, 8½ inches long, from Bantam, Lake, Litchfield.

A fairly comprehensive study of the food habits during the summer months of 1939 indicates a rather unique diet among adult fishes. A total of 220 stomachs examined from fish captured at night from Candlewood (July 10th), Bantam (August 5th), and Waramaug (August 19th) Lakes showed similar results: about 90 per cent (by volume) consisted of the larvae and pupae of the phantom midge (*Chaoborus*) and other midges (Chironomidae). The remaining 10 percent was scattered among such food items as small fishes, other insect larvae, water-fleas (Cladocera), and a few other small crustaceans. The fish from Candle-

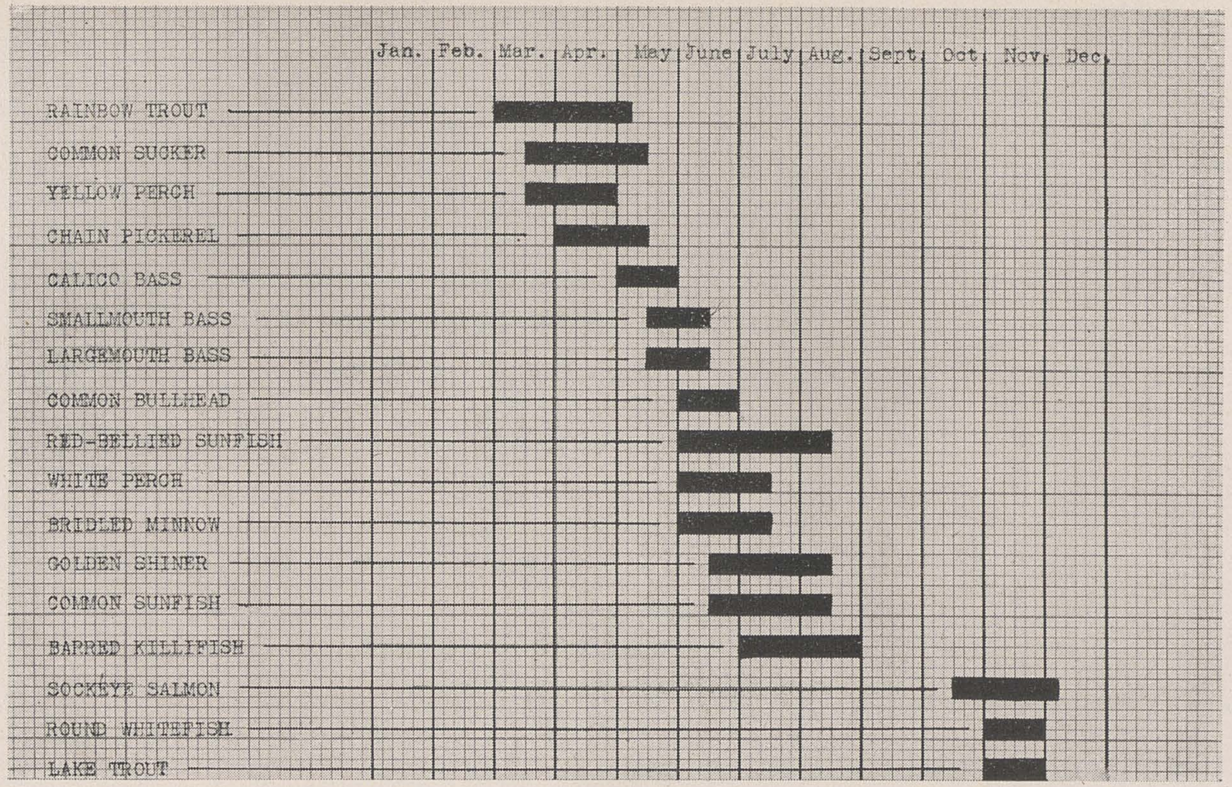

FIG. 53. Seasonal succession of the breeding seasons of some Connecticut fishes. The periods may be advanced or extended somewhat according to geographic locality or seasonal variability.

wood and Waramaug Lakes were all about nine or ten inches long while those from Bantam averaged two to three inches smaller. Nine larger specimens (8 - 9 inches) taken from Bantam Lake in July, 1940, had been feeding almost exclusively on young fish (fingerling yellow and white perch, and largemouth bass).

On the other hand, 32 specimens examined from Ball Pond (June 23rd) had been feeding largely on water-fleas (60 percent). Small fishes were second in importance, forming about 15 percent of the food at that time.

White perch examined from six New York lakes[38] (117 specimens) had been feeding heavily on *Chaoborus* and other midges in four lakes, predominantly on Cladocera in another, and on alderflies in the remaining one.

The large amounts of midge larvae and pupae eaten indicate that white perch may feed to a considerable extent on the bottom. On other occasions they may feed in the open waters for such pelagic organisms as Cladocera or migrating phantom midge larvae or invade the shallows to feed upon small fishes. No other adult Connecticut warm-water fish is known to consistently utilize midge larvae and pupae in such large quantities.

White perch travel in schools and may at times move close to the surface in a manner similar to yellow perch.

Economic Role

In five of the ten lakes where the white perch has been taken by the Survey, it has been very abundant. This is especially evident in Candlewood Lake where anglers literally take tons of white perch each year. They exist in prodigious numbers in Bantam Lake, but seldom reach a length of over seven or eight inches and thus a large part of the total population is not available to the angler. The tendency of this species to over-run its environment makes it a hazardous one to toy with in stocking and the introduction of white perch into waters where it is not already present is to be scrupulously avoided.

Food studies suggest that large white perch may not seriously compete with other large game fishes during the summer months, but it is difficult to conceive of situations where dense populations would not adversely affect more desirable species. Information on the relation of the white perch to the eggs or young of other fish is meagre, but schools of white perch have been charged with eating the eggs of the smallmouth bass.[10] On the other hand, the species is an excellent food fish and in waters where it attains good size, affords considerable sport to many anglers.

PART III. THE FOOD OF FISHES

General Interest

It is the indifferent angler who does not frequently examine with interest the stomachs of the fish he catches. Some fishermen possess surprising knowledge about the food habits of a few of the common game species and it often turns out that those with such an inquisitive twist of mind are the consistently successful ones. The fishermen who win the reputation of being "experts" display some knowledge of the habits of the fish they try to capture, and what could be of more direct importance than the fishes' food? No angler should conclude, however, that once armed with a knowledge of the food of fishes, his angling problems will be solved, for the intricate factors affecting their habits are many, and although food is of primary importance, no one can predict with certainty what the results of these interacting factors on feeding habits may be. In the last analysis, it is the uncertainties of fishing that make for excitement and suspense.

To give the angler an insight into the food habits of the common Connecticut lake fishes, Table 2 has been compiled from data collected in the State as well as other regions. It should be emphasized that any evaluation of relative amounts of organisms used as food is of the roughest sort and merely suggests, in the light of our present knowledge, what we might expect fish to be feeding upon. Further, it is futile to make a generalization about the food of a fish from a single set of observations because, as will be pointed out presently, of a number of variable factors which influence the food or feeding of fish. Stomach analysis from a series of specimens taken from a lake on one day represent only what the fish were feeding upon under those particular circumstances. Of course, it does no harm to extend the information to other situations so long as no factual significance is attributed to it in the new situation. Here it becomes merely a valuable idea as to what may be expected in the way of food.

Changes in Food Habits

Variations in the food of fishes often may be easily traced to certain conditions in the environment or in the fish. Perhaps the most fundamental of these is the marked difference in the food habits of young and adult fish (Fig. 54). Obviously when a young fish first begins to feed actively it can utilize only those organisms which are of such a size as to be easily ingested. For this reason the young of all fishes are markedly similar in their food habits since they draw on the minute free-floating population of the water, the plankton, for their initial food. The angler can easily demonstrate the presence of these little plants and animals by dipping up a glassful of lake water and holding it up to the light. The greenish specks and erratically moving forms are the plants

TABLE 2
A GENERAL SUMMARY OF THE FOOD HABITS OF SOME ADULT CONNECTICUT LAKE FISHES

Species	Fish	Crayfish	Plankton Crustacea	Mollusks	Insect Nymphs	Insect Adults	Plants
Round Whitefish			x	x	xxx		
Sockeye Salmon			xxx		x		
Rainbow Trout	x		xxx		xxx	x	
Lake Trout	xxx						
Smelt	xx		xx		xxx		
Common Eel	xx	xx		xx	xx		xx
Common Sucker			x	xx	xxx		xx
European Carp		x	x	xxx	xxx		xxx
Golden Shiner			xxx	x	x		xxx
Common Bullhead	x	xx	x	xx	xxx		x
Chain Pickerel	xxx	x					
Northern Pike	xxx						
Largemouth Bass	xxx	xxx			x		
Smallmouth Bass	xx	xxx			x		
Red-bellied Sunfish				x	xxx	x	
Common Sunfish				x	xxx	x	
Bluegill Sunfish		x	xx	xx	xxx		xxx
Rock Bass	x	xx		x	xxx		
Calico Bass	xx		xx	x	xxx	x	
Yellow Perch	xx	xx	x	xx	xxx	x	
Wall-eyed Pike	xxx	x			x		
White Perch	x		xx		xxx		

The symbol xxx designates food of primary importance; xx and x are foods of respectively lesser importance. Absence of checks does not infer that the organism is never eaten by the fish. The above grouping is necessarily of the most approximate nature and it is also flexible to the extent that the food habits of fishes vary with size, season, and the body of water in which they live. The interest and value lies in pointing out to the angler the food groups upon which the common Connecticut fishes draw most heavily. The relative specialization in diet among species may also be noted to advantage. Wherever possible, data from Connecticut lakes has been used, but in many cases the chart also includes a compilation from various sources.

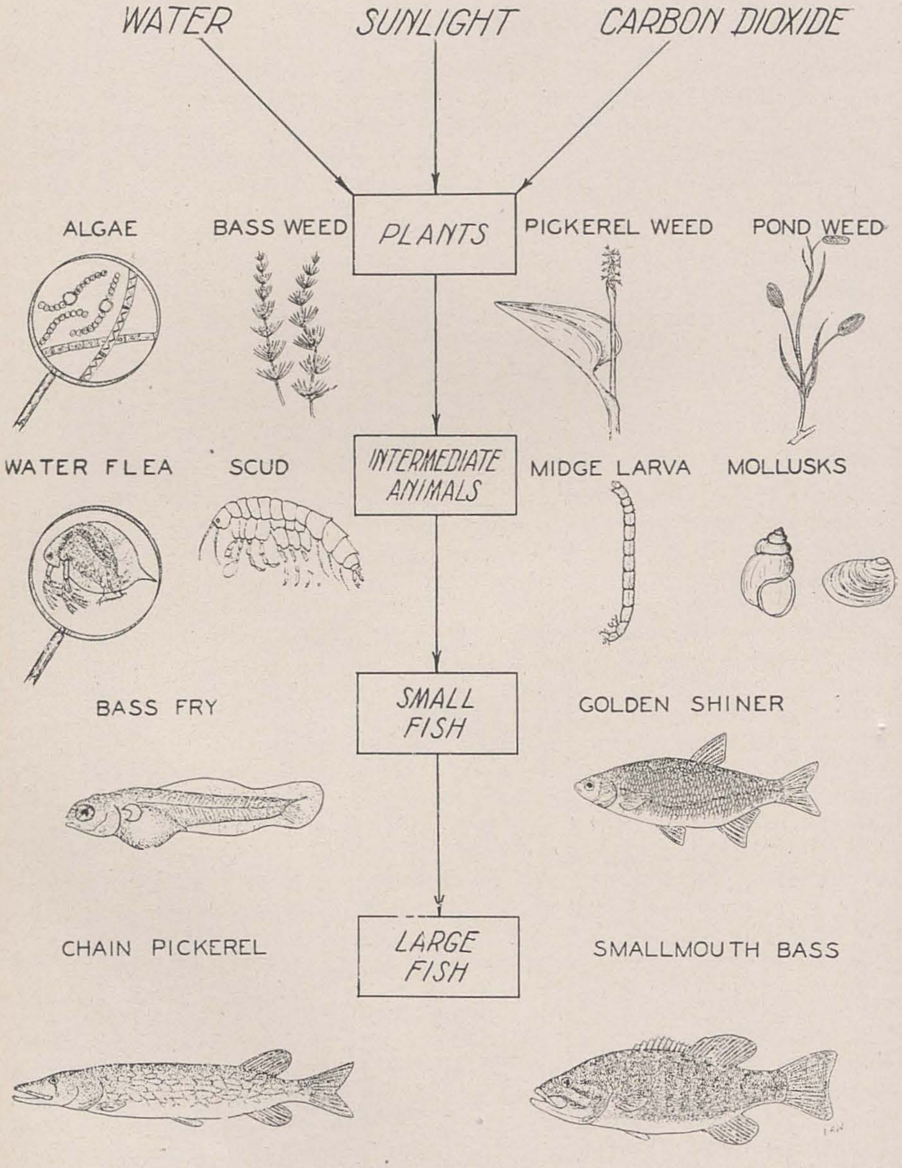

FIG. 54. A simplified food chain showing possible interrelationships resulting in game fish production.

and animals, of which the latter represent the direct food of most young fishes. As will be mentioned later, large fish of some species are able to feed extensively upon these tiny organisms by virtue of special "straining" devices which they possess.

As the fish grow, larger organisms may be accommodated in the diet and there is a gradual shift in food habits away from plankton to include such forms as small insect larvae, scuds, young fishes, and so on.

From this intermediate stage some species pass into a final state in which they feed largely on one or two organisms. Thus the pikes may feed almost exclusively on other fishes, large and smallmouth bass characteristically feed on crayfish and fish, and the trout of our streams subsist largely on insects. Other species like the bullhead and yellow perch feed on almost any of the organisms known to be eaten by fishes. Non-specialized diets may in part help to explain the general success of these species.

The food habits of a fish may also be determined by the availability of the food. Thus those organisms which are most easily secured and are abundant are the ones most likely to be eaten. Availability of some foods may be seasonal as in the case of the June emergence of the mayfly, *Hexagenia*, or it might be determined by the habitat in which the fish was living. For example, yellow perch in the open waters might feed on plankton crustacea, while perch in the weed beds might be feeding on aquatic insects, mollusks, or young fish.

Fishermen are well acquainted with the fact that on occasions fish appear to exercise selectivity in the kinds of baits upon which they may be caught. Bass may be taking crayfish well on one fishing trip while a subsequent one to the same waters may find hellgramites (*Corydalis*) or minnows to be the better baits. This selectivity is also supported by direct observations on feeding fish as well as by examining the stomach contents, but it is not easily explained. Why should yellow perch feed on the subadults of the emerging *Hexagenia* mayfly to the exclusion of the nymphs swimming up through the water all about the perch? And why should a school of white perch taken from Ball Pond during a tremendous hatch of midges have been feeding on plankton crustacea rather than on the myriads of midge pupae about them? In each of these instances it would appear that availability or abundance played little part in determining the food.

Factors Influencing the Feeding of Fish

Inability to catch fish often causes anglers to call up the old alibi, "they have too much food". Fishermen seldom stop to think that an abundance of food is one of the factors which is important in furnishing large numbers of catchable fish. Having a full stomach may be a reason why fish refuse to bite, but if so, it is only one of many which might be suggested as influencing their feeding activities.

It is well known that water temperature has a profound effect in this respect, though the temperature in itself may only be of indirect consequence. During the winter period when waters are extremely cold, many species require little or no food and may pass the winter in a dormant torpor. As the water warms in the spring and the activities of the fish increase, however, more and more food is required to satisfy the bodily demands. Extreme rises in temperature will also cause fish to cease feeding. Stream species are much more subject to high temperature experiences since the smaller volume of water responds with relative rapidity to changes in air temperature. Extended periods of heat may influence lake conditions, however, and in some manner affect the feeding of lake fishes. It should be pointed out in this respect that the various species of fish differ widely in their responses to changing temperatures. Some, like the trout, decrease their activities as water temperatures climb into the seventies, while on the other extreme, bullheads do not appear to suffer adversely from temperatures considerably above this. Unfortunately there is but scanty knowledge of the relation of temperature to the lives of our warm-water species.

Temperature variations are also responsible for many other changes that take place in the water, any one or several of which might affect the feeding of fish. Reactions in nature can seldom be identified with any single stimulus but are rather the results of numerous interacting forces. To illustrate, in a simple case, a rise in water temperature means that water can dissolve less of the life-sustaining atmospheric oxygen. Since most fish are sensitive to changes in the oxygen content of the water, such changes might induce fish to cease feeding activities.

Light is another factor which may be cited as having an evident affect upon feeding. In general, most fish are more active during the dimly lighted hours or in darkness, a fact well-known to anglers who always anticipate increased success during evening or early morning efforts. This increased nocturnal activity is quite generally conceded to be explained by the fact that fish feel more secure from attack from enemies and thus use the cover of darkness in which to feed extensively. It may be that the better "luck" experienced on cloudy days might also find an explanation here.

Cloudy weather is often associated with rain, and rain, in the minds of the majority of anglers, means better fishing. In streams it is not difficult to find possible explanations. The rain washes many land insects, earthworms, and other animals into the stream and increased stream flow may dislodge water animals; this sudden appearance of an abundance of food may stimulate the fish to an active period of feeding. Such possibilities are not so evident in the case of those species residing twenty or more feet below the surface in lakes. It is often suggested that a rain brings an increased oxygen supply and this is responsible for the fishes' activity. However this may be, fishing is often as good or better during a slow drizzle than when the water has been beaten by a brisk shower. Possibly one might look to accompanying cloudiness rather than directly to the rain itself for an explanation.

The old angling sages bespoke the potency of the wind direction, extolling those from the south and west and belittling those of the north and east. There appears to be abundant evidence that wind direction does have an important effect upon feeding, reasons for which are here again difficult to ascertain.

Other theories seeking to explain the feeding activities of fishes in some measure or other include barometric pressure and the lunar cycle. In conclusion, it is desirable to restate once again the idea that feeding habits are likely to be the result of several directly or indirectly related factors, of which only a few have been mentioned.

Feeding Structures

Differing as they do in food habits, fish might also be expected to show differences in the structures which assist them in obtaining food, or looking at it from a different viewpoint, in the structures which determine their foods. This is found to be the case.

Fish do not use their teeth for chewing as anglers know, although they may often "mouth" food before actually swallowing it. The teeth of fishes are variously modified to fit the needs of each particular group, but in any event they serve as organs for grasping and the retention of food. Thus the teeth of the pikes are long and needle-like — efficient tools for capturing the slippery fish upon which they feed. Sharply contrasting with these are the tiny rough rows of teeth found in bass, perch, and bullheads.

Assisting the teeth are certain structures found in the throat called pharyngeal teeth. The presence of these can easily be verified when one pushes a finger deep into the gullet of a fish like the bass and feels the hard rough areas located here. The pharyngeal teeth, with which are associated powerful muscles, function as an accessory means of food retention as well as a crushing organ. This crushing function is strikingly developed in the sheepshead or fresh-water drum (*Aplodinotus*), a large fish of the Mississippi Valley, which feeds almost exclusively upon fresh-water clams. Here the pharyngeal teeth are two powerful toothed plates which effectively break the shells of the mollusks. In the minnows these throat teeth consist of two elongated structures bearing long, sharp or blunt teeth which project into the gullet.

It may be puzzling to understand just how certain large fish can feed upon the tiny microscopic organisms suspended in the water. The fact is that many fish possess efficient "strainers" which retain these organisms within the mouth cavity as water is taken in and passed out over the gills. These strainers or gill rakers, as they are properly called, consist of a row of projections along the gill arch itself and are easily seen lying on the inside margin opposite the red gill filaments. Though gill rakers are found in all fishes, in those in which they serve most efficiently as straining organs, the rakers themselves are long, slender and closely set. The best Connecticut examples may be found in the shad (*Alosa*) and the alewife or buckeye (*Pomobolus pseudoharengus*); however, many other of our fishes use them more or less consistently for feeding on plankton, as a glance at Table 2 indicates.

PART IV. THE GROWTH OF FISHES

The excellence of fishing waters is generally judged by two factors: the numbers of fish caught and the size of these fish. Though both of these factors exhibit a complicated interrelationship, only that concerned with size will be discussed here. A more detailed report on the growth of Connecticut fishes is anticipated in the future and only subjects of particular interest to fishermen will be mentioned in this section.

Growth in fish, as in other cold-blooded animals, is continuous throughout life. In this respect it differs markedly from growth in warm-bloods which attain a maximum size in a relatively short period of time, and then, to a greater or lesser extent, cease growing. However, continuous growth is not regular for the rate in general decreases with age. Season, abundance of food, reproduction, and other factors also contribute to this irregularity. In north temperate regions such as New England where marked seasonal temperature variations occur, the fish grow most rapidly during the summer when the waters are warm, and most slowly in winter. In some species growth virtually ceases when the waters are cold. Fish like yellow perch and pickerel, which feed continuously throughout the winter months, probably grow to a certain extent during this period, while bass and sunfish, which are more or less dormant, grow very little or perhaps not at all.

Variability is one of the important characteristics of growth. Different species of fish obviously exhibit different rates of growth and attain different maximum sizes. An eighteen-inch smallmouth bass is not uncommon, but a yellow perch of the same size is unheard of. Such interspecific variations in growth, inherent within the species themselves, are one of the factors which necessitates individual management for each species of fish.

Growth may also vary within the species. Thus fifteen three-year old smallmouth bass taken from Columbia Lake on July 26, 1939 ranged in total length from ten to twelve inches. Of added interest to fishery managers are possible differences in growth between different bodies of water. Do bass in one lake grow faster than those in another? There is need for critical comparative growth rate studies, for growth variations among lakes is another one of the criteria upon which one may base sound management policies. Examples of extreme differences in growth rate may be found in yellow perch populations. Many Connecticut lakes produce large numbers of nine to twelve-inch perch, while in others fish of the same age group scarcely reach the legal length of seven inches. It is immediately apparent that management practices should not be identical in these two cases. The legal length of seven inches which appears adequate with the faster growing fish is totally unfit for the "stunted" population.

The maximum size of a species is of interest to anglers in that it forms the basis for "big fish" stories. Environmental conditions have such a profound effect upon growth, however, that the maximum size of a species in different localities may vary widely. To use an extreme example, brook trout in many small northern spring streams may attain a maximum size of barely six or seven inches, weighing only a few ounces, while the same species living in ponds may reach a weight of several pounds. Table 3 presents information on the largest specimens of some Connecticut lake fishes on record in the files of the State Board of Fisheries and Game. Larger examples of some species may be known to anglers, but in most cases these records probably approximate the maximum size attainable in Connecticut waters.

A Method of Studying Growth

In many fishes growth may be studied by an examination of the scales, for on each scale is written a sort of "diary" of the fish's life. In the popular sense the scale records the periods of fast and slow growth or of growth cessation, and various structures found on the scale may be taken as an indication of certain events in the fish's life.

The scale of a fish as seen with the naked eye lies loosely embedded in a pocket in the skin in such a manner that each one overlaps the scale following. However, scales are not as yet formed when the fish hatches from the egg. The size at which they first appear varies among different species of fish; in the rainbow trout this is about one and one-half inches, while in the smallmouth bass it is at a length of about one inch.

The scale first appears as a tiny plate. This steadily increases in size as the fish continues to grow. Growth of the scale occurs at the margin and is characterized by concentric lines of increasing diameter. In ideal cases these concentric rings or circuli are widely spaced when the fish grows rapidly and crowded

TABLE 3

LARGEST SPECIMENS OF SOME CONNECTICUT LAKE FISHES ON RECORD IN THE FILES OF THE STATE BOARD OF FISHERIES AND GAME. (COMPLETE THROUGH 1940).

Species	Lake	Total Length	Standard Length	Weight	Age
Round Whitefish	East Twin	15½″	34.8 cm.	1 lb. 11 oz.	VI
Sockeye Salmon	East Twin	17½″	39.3 cm.	1 lb. 14 oz.	III
Lake Trout	Wononscopomuc	36″		17 lbs. 12 oz.	
Lake Trout	Wononscopomuc	39″		29 lbs. 8 oz.	
Common Sucker	East Twin	25″	56.8 cm.	6 lbs. 15 oz.	VI
Chub Sucker	Mudge	13⅞″	30.0 cm.	1 lb. 11 oz.	V
Golden Shiner	Samp Mortar	9¾″	20.3 cm.	7 oz.	VI
Fallfish	Shenipsit	17½″	36.0 cm.	2 lbs.	VI
Tench	Wattles	14 9/16″	30.3 cm.		
Common Bullhead	Bantam	13⅞″	30.2 cm.	1 lb. 7½ oz.	
Chain Pickerel	Columbia	29″		6 lbs. 8 oz	
Northern Pike	Conn. River	34″	75.0 cm.	9 lbs.	V
Largemouth Bass	Moodus	24″	53.3 cm.	7 lbs. 8 oz.	XII
Largemouth Bass	Pocotopaug	23″		8 lbs. 3 oz.	XIV
Smallmouth Bass	Waumgumbaug	22″	48.2 cm.	5 lbs. 12 oz.	XI
Red-bellied Sunfish	Wangum	9⅜″	19.6 cm.	11 oz.	VIII
Common Sunfish	Hall's Pond	10¾″	23.0 cm.	1 lb. 1½ oz.	VII
Rock Bass	East Twin	10⅝″	21.9 cm.	1 lb. 1 oz.	VII
Pike Perch	Candlewood	28″	62.3 cm.	8 lbs.	VII
Yellow Perch	Norwich Pond	15″	33.5 cm.	1 lb. 10½ oz.	
White Perch	Alexander	16″	34.9 cm.	2 lbs. 8 oz.	

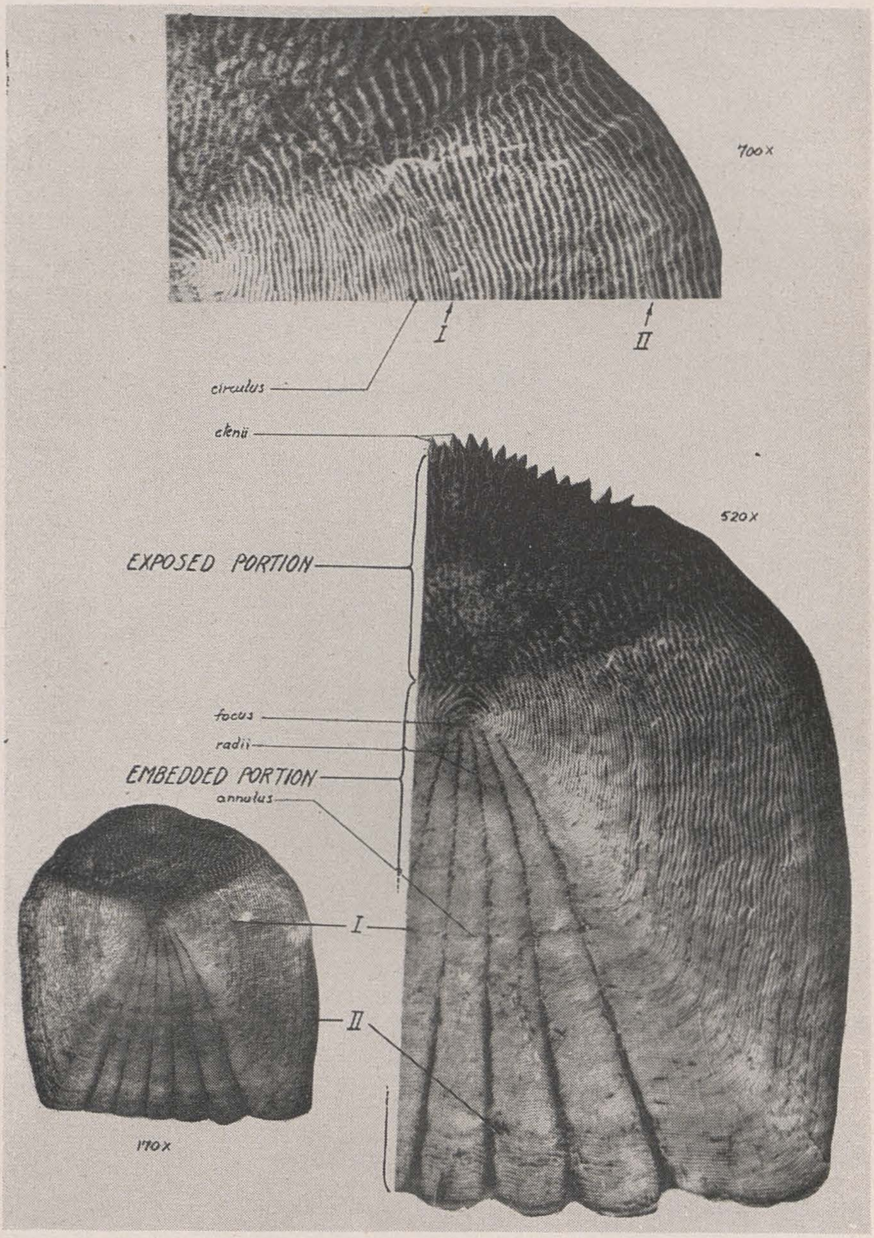

FIG. 55. Smallmouth bass scale at three different magnifications showing two year marks (annuli) indicated by Roman numerals.

together during periods of slow growth. When growth ceases, there is a corresponding cessation in the formation of circuli at the margin of the scale. Such a characteristic mark forms on the scales of some fish during the winter and is called an annular ring (annulus). By the simple expedient of counting the annuli, the age of the fish may be determined (Figs. 55 - 57).

Many of the complicating factors which surround scale studies have been omitted from the foregoing discussion. For example, the spawning period of many fishes is frequently accompanied by marked erosion on the scale margin, thus leaving a record on the scale. The so-called annuli of some adult fishes

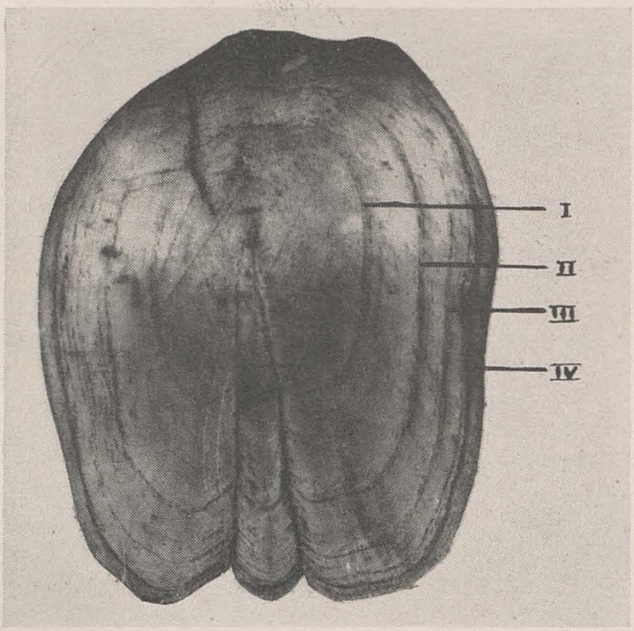

FIG. 56. Scale from a chain pickerel showing four annuli. Scales of pickerel, along with those of trout, suckers, minnows and eels, differ from those of perch and bass in the absence of the small spines (ctenii) on the anterior portion.

are actually spawning marks or perhaps may be coincident with them.

Unfortunately, the information proven in the case of a few well-studied fish such as the Pacific salmons has been accepted without question as applicable to other species, many of which are but distantly related. While the broad principles of the scale method may be so applied, it is desirable to make special studies of at least one representative within each group of fishes before attempting to interpret scale structures in terms of a fish's life history.

In the event that a fish accidentally loses a scale, another is immediately formed to replace it. These regenerated scales have blank centers and are, of course, worthless for age determination.

It was previously mentioned (p. 124) that scale samples were obtained from all but the smallest specimens. Before study, a few selected scales from each fish were made into a permanent mount. These mounts consisted of impressions of the scale in celluloid strips, following methods developed by the United States Bureau of Fisheries. Each mount was given a number correspond-

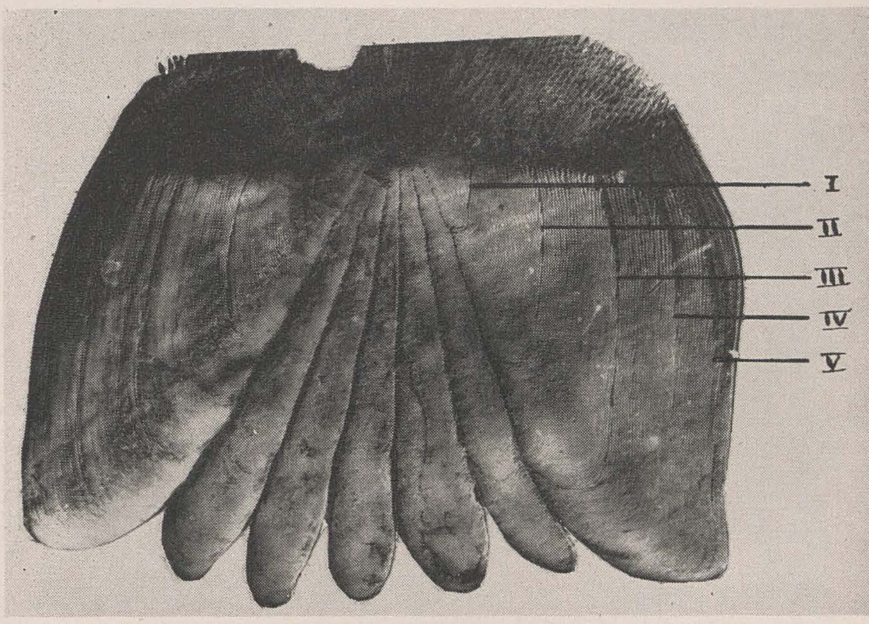

FIG. 57. Scale from a yellow perch showing five annuli.

ing to that of the specimen and filed for future study and reference.

Growth Curves

From data gathered and studied as has been outlined, the growth curves in Figs. 58 to 60 have been constructed. They represent what might be termed the "average" growth of the four species mentioned in the larger Connecticut fishing waters. The curves, with the exception of that of the chain pickerel, are based on lakes which furnished good fishing and whose growth

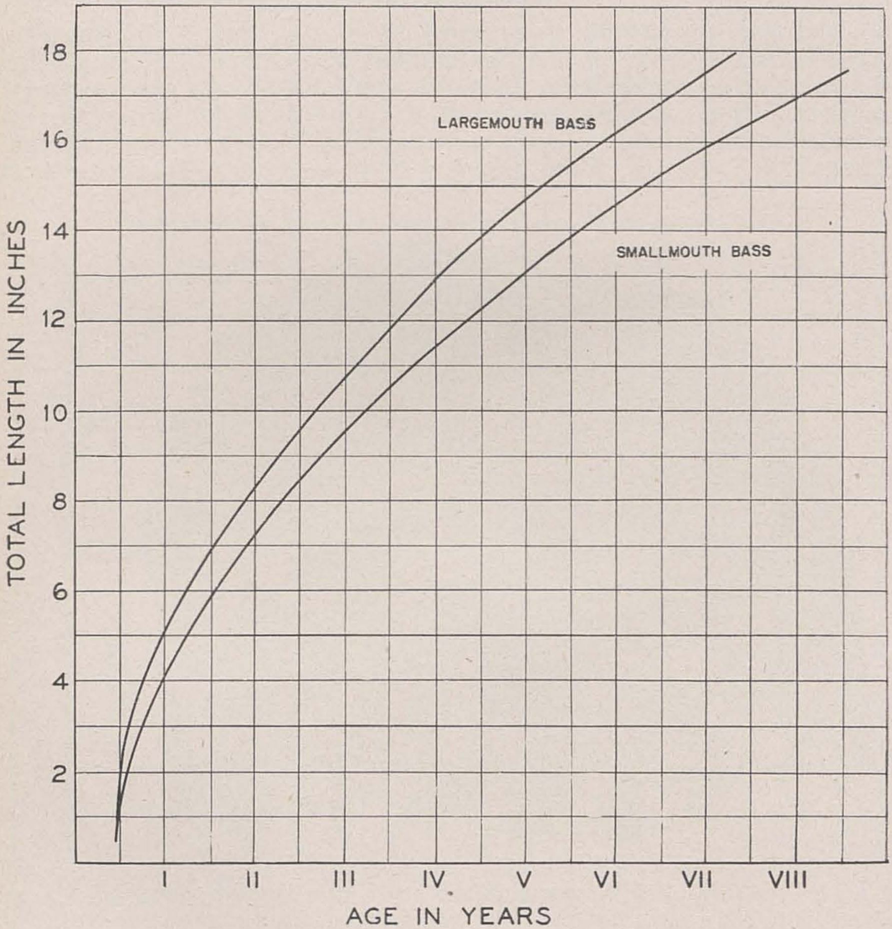

FIG. 58. Growth curves of large and smallmouth bass. The curve for smallmouth is based on data from 172 specimens from Stillwater Pond, Columbia, Waumgumbaug, and Shenipsit Lakes; that of the largemouth on 142 specimens from waters throughout Connecticut.

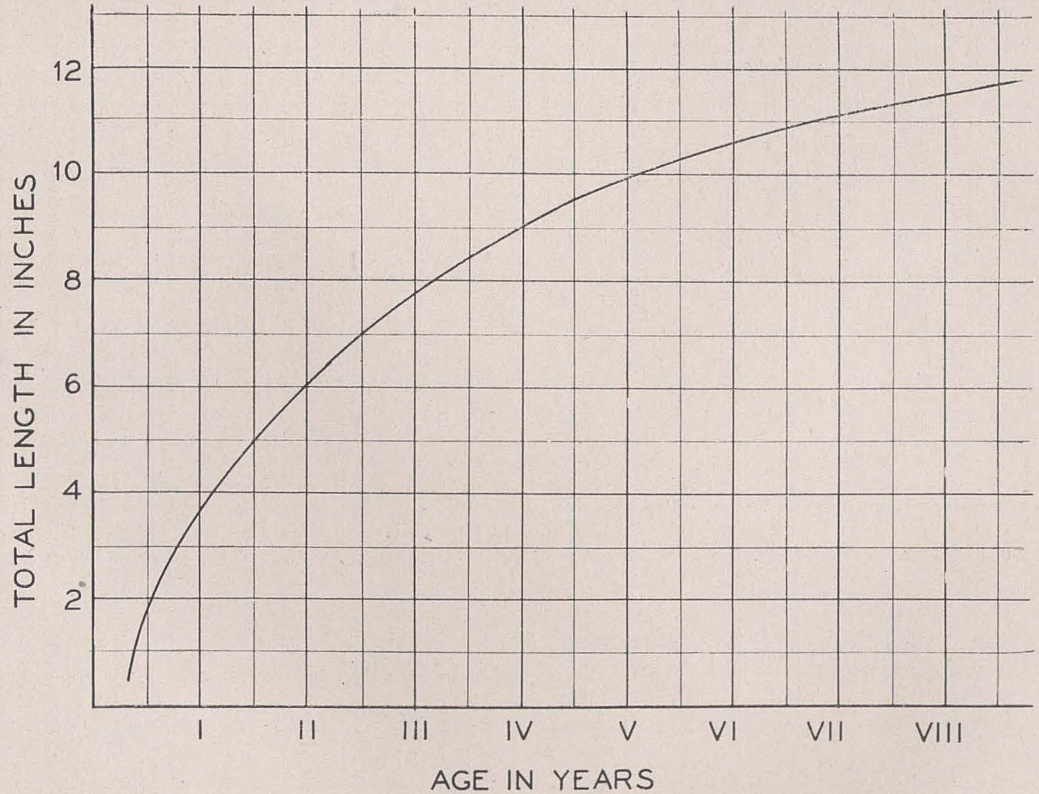

FIG. 59. Growth curve of yellow perch. Based on data from 224 specimens from Columbia, Candlewood, Quassapaug, Waumgumbaug, and Wononscopomuc Lakes.

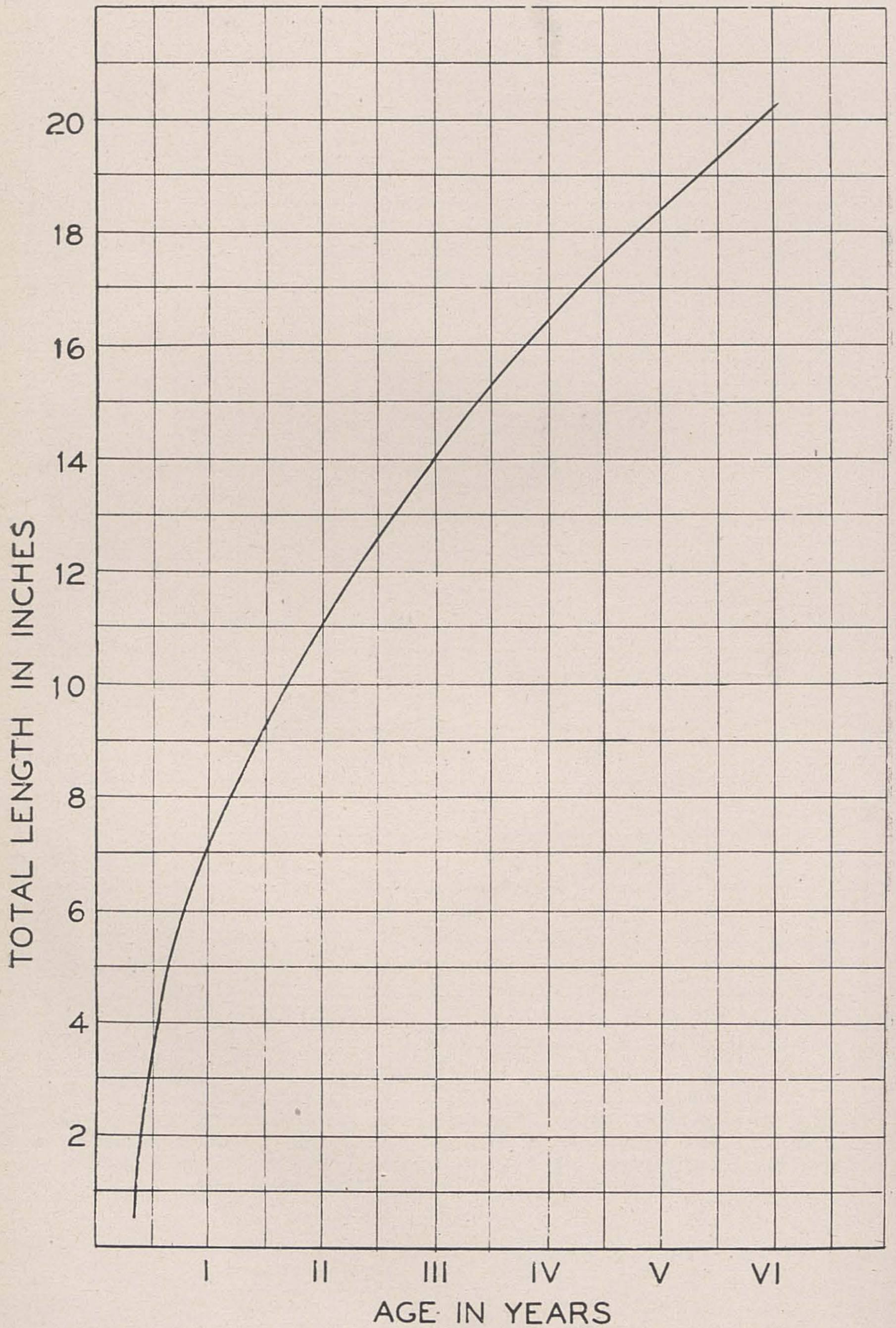

FIG. 60. Growth curve of the chain pickerel. Based on data from 118 specimens from waters throughout Connecticut.

rates fall intermediate between the slowest and the fastest growth observed among the waters studied. It is in this sense that the curves represent an "average" growth. The growth curve for chain pickerel includes data from waters throughout the State.

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Section IV.

Studies on the Parasites of Fresh-Water Fishes of Connecticut*

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PART I. PARASITISM AND THE FISH CROP

Introduction

Disease annually takes its toll regardless of whether one is dealing with man or the lower plants and animals. Because of its importance, human disease has quite naturally received considerable emphasis and numerous workers have devoted their lives to its study. In more recent years, however, scientists have turned their attention to the ailments of the lower plants and animals as it has become more evident that these likewise play an important role in the economy of nature.

The importance of a knowledge of fish diseases and the causative organisms concerned has been recognized by numerous groups interested in conservation, as well as in the formulation of sound stocking policies and production of good fish crops. Such a study of fish diseases has quite logically been included as a part of the biological survey programs of those progressive states that are interested in securing as complete a picture as possible of all of the factors affecting the fish in a given body of water. New York, Ohio, and Michigan may be mentioned as examples. More recently Connecticut has stepped into the lead in New England in this respect since it is the first state of this group to attempt to secure adequate data on fish parasites in connection with a study of the fish crop, or yield, of its various lakes and ponds.

Some General Effects of Parasitism

Many parasites do little damage to the host when present in small numbers. This is particularly true in the case of intestinal forms. However, when several different species of parasites are involved or when a single type is present in considerable numbers in a given location, definite harm may result. It is perhaps worthwhile to outline the various ways in which parasites may affect their hosts. This will be followed by a more detailed consideration of parasitism in the fresh-water fishes of Connecticut in an attempt to learn more of this relationship.

*The assistance of Mr. William C. Dimick is gratefully acknowledged.

Blood Poisoning in Fishes

Bacteria and their near relatives constitute the most frequently encountered source of blood poisoning in the higher mammals. The dread streptococcus infection of the blood stream that appears as the result of an infected wound serves as an example of this type of disease in man. It is probable that any parasite that is small enough (and properly adapted for such an existence) may invade the blood stream and so develop there, or in some of the tissues or organs in which it finally becomes lodged.

There are comparatively few known bacterial diseases of fishes. This is largely due, in the writer's opinion, not so much to the lack of disease-causing bacteria among fishes, as to the lack of bacteriological training on the part of those persons studying them. Another obvious difficulty centers around the greater amount of equipment needed to pursue bacteriological problems in the field. Probably the most widespread and important parasite known to produce blood poisoning of one sort or another is the furunculosis, a disease of fish caused by *Bacterium salmonicida.* This organism attacks trout particularly, where it appears to produce typical lesions which are recognizable by experienced hatcherymen. The causative organism of furunculosis apparently may infect the blood stream alone, or it may become established in various organs of the body. Either type of infection may result in the death of the fish. Fortunately, the trout raised in Connecticut have been relatively free from this disease, although sporadic outbreaks have been encountered. Much careful bacteriological work is still needed on this and other bacterial groups infecting fish.

The Edibility of Heavily Parasitized Fish

A second way in which parasites of various sorts may affect their host is by rendering them more or less inedible. Sportsmen all too frequently encounter fresh-water fish heavily infected with various larval parasites and Connecticut fishermen are no exception. Almost everyone has seen minnows, pan or game fish liberally sprinkled with "boils", black or yellow "grubs", or perhaps such forms as the "red roundworms". A heavy infection with almost any type of flesh-inhabiting parasites results in fish being classified by the sportsmen as "unfit for food". The numerous inquiries made of fish and game wardens and the number of letters received at the State office will attest to this fact. Some areas have been spoiled as fishing resorts because it became known that the fish in these regions were usually "grubby". This is understandable, since fish peppered with black, yellow, white or red parasites are anything but esthetic and desirable as articles of food.

In some parts of the country it might be wiser to discard infected fish. Northern Minnesota, for example, is an endemic center of the broad tapeworm of man (*Diphyllobothrium latum*). The larval stage of this occurs in a soft, white, connective-tissue cyst in the flesh of various fish, including northern pike (*Esox lucius*) and the wall-eyed pike (*Stizostedion vitreum*). Fortunately this form has not been found in the fishes of Connecticut lakes and ponds, although the "stage is set" for its introduction, since the necessary intermediate hosts are present.

Here in Connecticut round wart-like cysts may be caused by a protozoan (Fig. 1) while larval tapeworms (*Ligula intestinalis*) occur in the body cavity of minnows and suckers (Fig. 2). Black grubs, about the size of pin heads, are probably most frequently encountered by Connecticut fishermen (Fig. 3). Other important flesh-inhabiting parasites that render fish unattractive as food are the red roundworm that are found in large and smallmouth bass, rock bass, sunfish, and yellow perch. The latter also harbors in some localities the large yellow grub, or small forms encysted in the flesh about the size of a grain of sand (Fig. 4). The latter have been called sand grain grubs by the sportsmen.

This brief account indicates how a variety of parasites located on the scales and fins or in the flesh may be responsible for discarding what otherwise appears to be a perfectly edible fish. Actually it is highly improbable (although experimental proof is lacking) that these fish parasites occurring in Connecticut and described above are capable of becoming established in man. Even if some were, ample protection is afforded by *thoroughly cooking the fish* which may then be eaten with impunity.

General Emaciation and Debility

Most parasitologists are intrigued by the adaptations of parasites to their hosts and their environment. It should be borne in mind that the parasite's existence is usually an elaborate compromise between the host and the parasite, the latter exacting its daily toll while not sufficiently injuring the former to cause its death. This is true of the tissue-invading protozoa as well as the vast group of parasites that mature in the digestive tract, gall bladder, and other organs of their host. The intestinal parasitic worms all have one advantage over their hosts — they have the first chance at the potential food which is partially broken down by the digestive enzymes of their host prior to absorption from the intestine. Small wonder then that a heavy infection with intestinal parasites places a heavy burden upon the host. This may result in generally debilitated or emaciated fishes. Such an effect is rather difficult to demonstrate experimentally, since heavy experimentally-produced infections often result in death of the host. With some parasites the host appears to be "slowed down" so that it is more readily caught by the animal serving as the next link in the chain. Several instances of this sort may be mentioned. A heavy infection with the yellow grub (*Clinostomum marginatum*) serves as one example. This parasite matures in the great blue heron and other fish-eating birds. Heavily infected fish swim more slowly, an observation subsequently checked by activity studies on heavily infected and normal fish. Another example occurs in the case of minnows infected with the larval tapeworm (*Ligula intestinalis*) where it again has been observed that infected fish swim more slowly and are consequently caught more readily by the fish-eating bird which serves as the final host (see Fig. 2). Another instance will be found in the larval tapeworm belonging to the genus *Shistocephalus*. This becomes

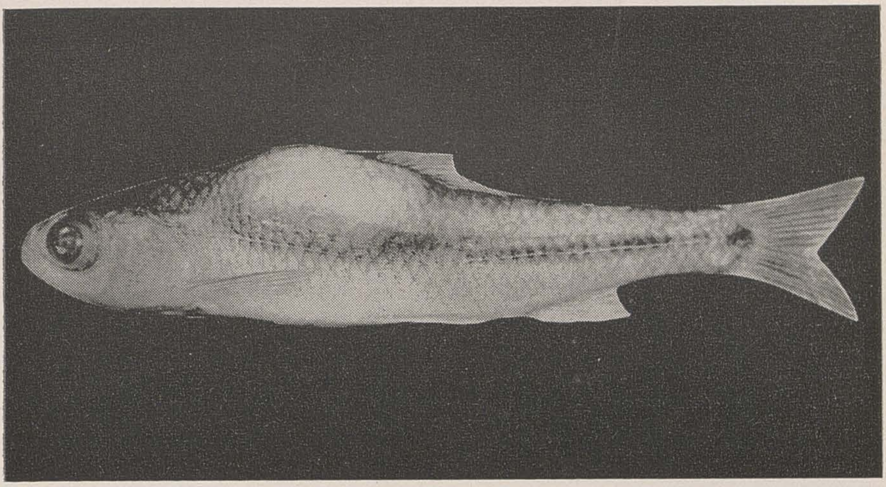

FIG. 1A. A minnow (*Notropis hudsonius*) infected by cysts of one-celled parasites belonging to the Microsporidia. Fig. 1B shows a single cyst.

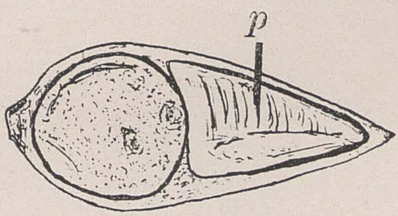

FIG. 1B. Free-hand drawing from preserved specimens of a single cyst from the infected minnow. Magnified about 2000 times. p — polar filament.

lodged in the valves of the heart of the whitefish host — the round whitefish (*Prosopium cylindraceum quadrilaterale*) or other coregonids. It gradually kills most infected fishes. Before dying they invariably rise to the surface of the water where they swim sluggishly. Many of these are caught by the gulls which constitute the final host.[16]

Any number of different groups of parasites might serve as examples of this type of effect. A fairly common one which often may have a still more severe type of reaction on the host is the protozoan *Ichthyophthirius multifiliis*. This produces minute ulcer-like sores (Fig. 5) which may definitely affect the health of the fish and frequently kills young fish.[37]

While these constitute rather extreme examples they serve to illustrate the point that parasites may produce a noticeable effect upon their host. Undoubtedly, moderate infections have a definite, but less readily detectable effect.

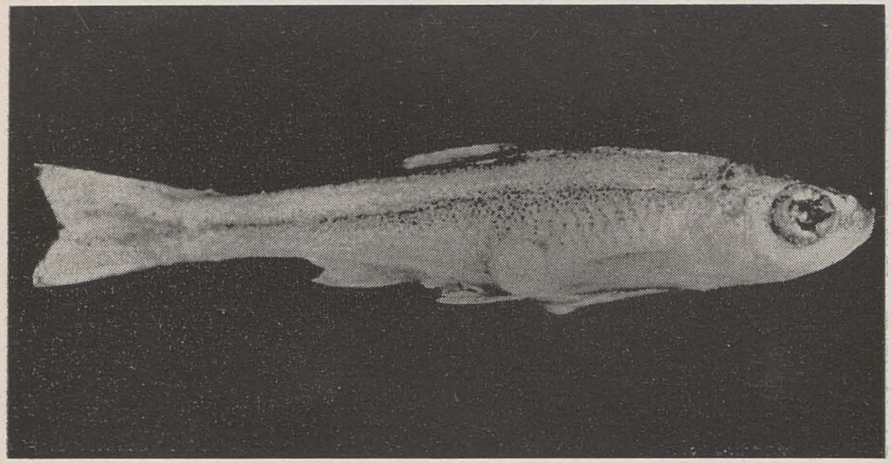

FIG. 1C. Another minnow (*Notropis cornutus*) infected with cysts of another type of one-celled parasite belonging to the Myxosporidia. Fig. 1D shows a single cyst.

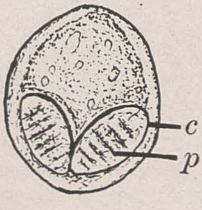

FIG. 1D. Free-hand drawing from preserved specimens of a single cyst from the infected minnow. Magnified about 2000 times. c — capsule; p — polar filament.

Loss of Weight

Presumably, heavy infections of almost any parasite will have a deleterious effect upon its host. In one case a group of four-inch smallmouth bass were experimentally infected with the larval stage of the black grub of bass (*Uvulifer ambloplitis*) and infections ranging up to 708 parasites per fish were secured.

These heavy infections caused a statistically significant loss of weight in the parasitized fish.[21]

It appears probable that other observed cases in nature were attributable to similar heavy infections. In Montana, Essex and Hunter[4] encountered "horse-shoe nail" rainbow trout — so named because of the big head and thin bodies. These, when compared with other uninfected fish from the same locality, were found to harbor both larval tapeworms and trematodes not possessed by the healthy fish. As they all came from different parts of the same mountain lake where food conditions were good, it is believed that the heavy burden of parasites was responsible for the emaciated condition of the heavily parasitized fish. While the infected fishes weighed less when compared with uninfected ones of the same length, it is regrettable that scales were not also saved, thus insuring comparisons of identical age groups.

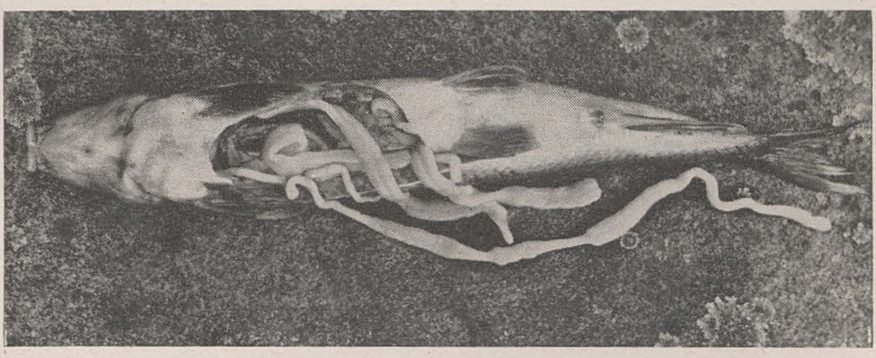

FIG. 2. A common sucker (*Catostomus commersonnii*) infected with *Ligula*. Minute crustacea carry this larval tapeworm (*Ligula intestinalis*) which develops to considerable size in the body cavity of the fish host. Fish eating birds serve as the final host.

Stunting

Other effects of heavy parasitic infections include retardation of growth. Actually, this may be a sufficiently striking deformity to cause marked structural changes. Hubbs[9] in a study of a cyprinid fish (*Platygobio gracilis*) describes the changes apparently due to parasitism. It is probable that many other less striking cases have passed unnoticed.

Sterility

From the standpoint of the sportsman and the fish culturist, one of the most important results of parasitism is the sterilization of the host. This is known to occur in the case of heavy

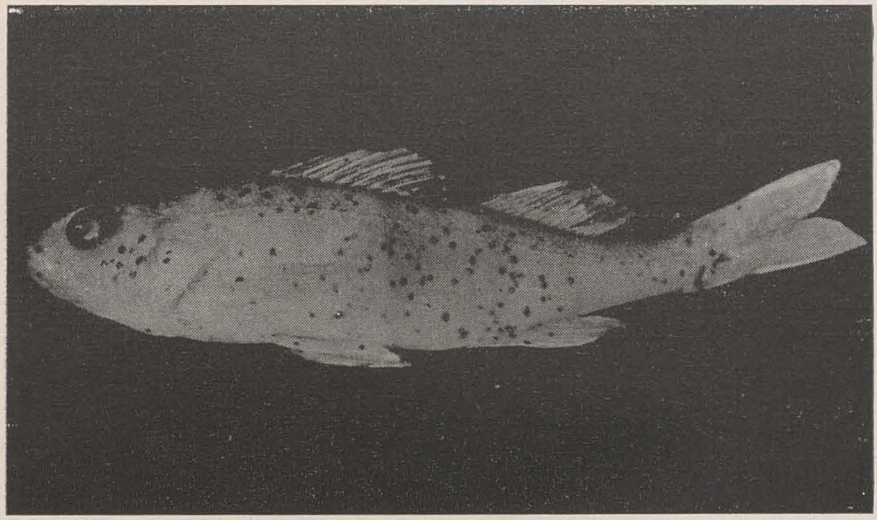

FIG. 3A. A yellow perch moderately infected with black grubs. Several species of the black grubs (larval Strigeids) infect Connecticut fishes. Heavy infections may injure the fish. Figure 3B shows a cyst in detail.

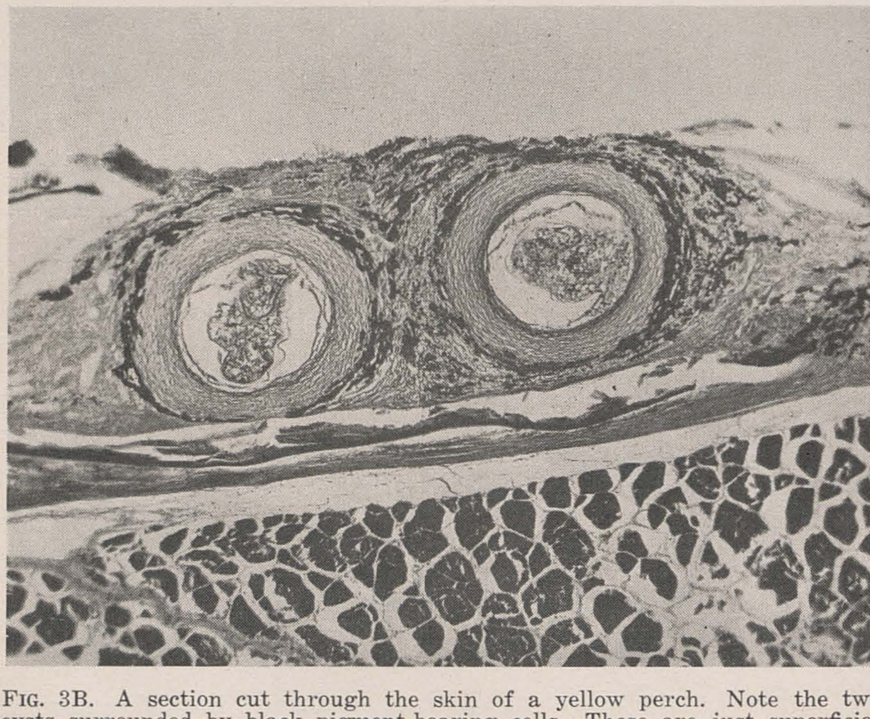

FIG. 3B. A section cut through the skin of a yellow perch. Note the two cysts surrounded by black pigment-bearing cells. These are just superficial to the scale itself and cause a pimply feeling when one's fingers are rubbed over the surface. Magnified 79 times.

infections of the reproductive organs by plerocercoid larvae of the bass tapeworm (*Proteocephalus ambloplitis*) (Fig. 6). This condition was noted by Rich[29] in the report of the Division of Scientific Inquiry of the Bureau of Fisheries and by Emmeline Moore.[25, 26] The life cycle of this parasite has been studied by

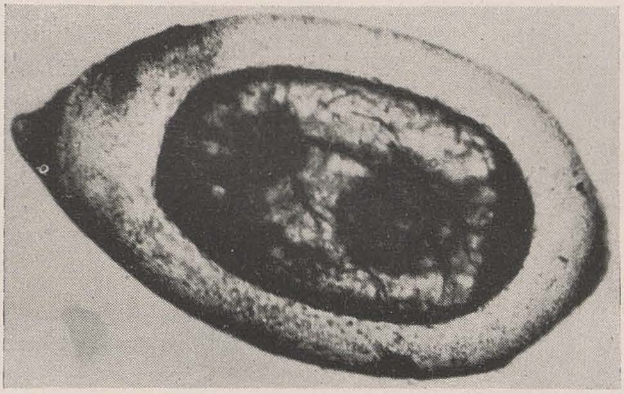

FIG. 4. A cyst of the sand grain grub, the metacercaria stage of a larval Strigeid occurring in the flesh of the yellow perch.

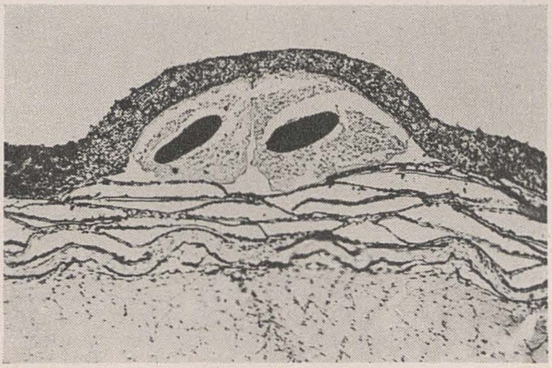

FIG. 5. This protozoan (*Ichthyophthirius multifiiliis*) may occur in epidemic proportions in trout hatcheries where it causes severe losses. Epidemics in wild fish are rare. This section shows two individuals beneath the epidermis of fingerling trout. (Courtesy of Dr. L. Wolf.)

Bangham[1, 2] and experimentally demonstrated by Hunter[12] and Hunter and Hunter.[15, 16] Several important questions still remain unanswered. Thus it is not known whether sterility is due solely to (1) the mechanical destruction of reproductive tissue by the meandering parasite and subsequent proliferation of connective tissue, or (2) to chemical substances elaborated by the parasite, or (3) to a combination of both.

Unfortunately, the bass tapeworm was found to be quite widely scattered throughout the bass and other fishes in many of the lakes and ponds surveyed in Connecticut during 1939. Some waters contain only lightly infected fish, while others carry a heavy burden of parasites. Further discussion of these points will be found later, together with a more detailed consideration of fish infected with the bass tapeworm.

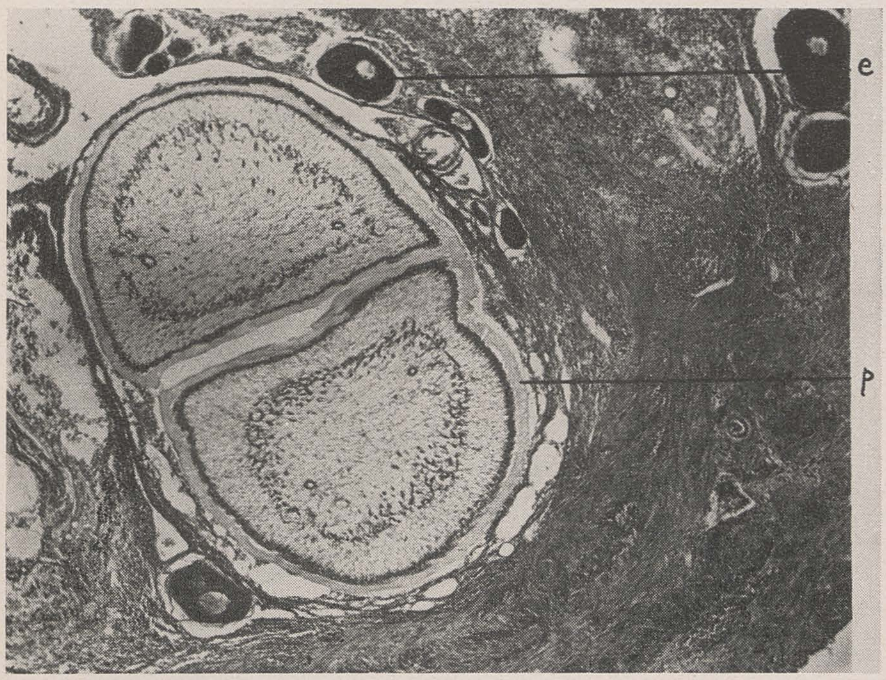

FIG. 6. Section of an ovary of a smallmouth bass showing eggs and plerocercoid larvae of the bass tapeworm (*Proteocephalus ambloplitis*). Note the mature eggs. This bass was taken in July and it had not yet spawned. E = egg; p = parasite.

SOME ECONOMICALLY IMPORTANT PARASITES IN CONNECTICUT FISHES

Viruses, Bacteria, and Protozoa

Fish parasites fall into several different groups — for viruses, bacteria, protozoa, worms, leeches, and arthropods all account for the destruction of their share of fish populations each year. While viruses and bacteria are an important factor in the economy of fish populations, much damage escapes notice, as the taking of bacterial cultures is seldom feasible in a routine study of fish. Likewise, it is impracticable to hope to detect light infections by small numbers of the more infinitesimal protozoa. Heavy infestations, or infections by the larger forms of protozoa together with the worms and other large parasites are more easily detected. Each group, however, contains a number of important forms that may well affect the host adversely if present in sufficient numbers.

Probably one of the more intensively studied and still inadequately known parasites is the bacterium causing furunculosis. While the disease may frequently be recognized by the lesions on the fish, it may often be overlooked since the organism infests the blood stream and consequently death may be caused by a general septacemia and may, therefore, pass undetected. A number of protozoa likewise exact their toll, one of the more common being *Ichthyophthirius multifiliis,* which invades the tissues of its host producing the often fatal "ich". This disease, together with *Costia,* which infects trout,[8] all too frequently reaches epidemic proportions in hatcheries.

Arthropods and Leeches

Neither leeches nor parasitic arthropods ordinarily constitute a major problem in regulating Connecticut fresh-water fisheries. Many fish harbor an occasional leech. Rare, indeed, is the leech that apparently causes the death of its host. Thompson[30] records an epidemic of these organisms on the red-mouth buffalo (*Ictiobus cyprinella*) in the Rock River in Illinois. So far as the author is aware, no such epidemics occurred on the fishes of the watersheds upon which he worked in New York. During 1938, L. M. Thorpe of the Connecticut State Board of Fisheries and Game reported great numbers of yellow perch dying in Hayward Lake or Shaw Pond. The physical conditions of the pond were studied. Oxygen and other physical conditions appeared to be satisfactory. Some of the fish were examined and there appeared to be a dearth of parasitic worms. There was, however, an epidemic of leeches (Fig. 7). Numbers were seen on various yellow perch. It appears possible that this loss was in some way associated with the leech which may have been the direct or the indirect cause of death of the perch.

Fish lice or other parasitic arthropods do not seem to occur on the fresh-water fishes of Connecticut to any extent and so do not constitute a major problem.

Worms

A wide variety of parasitic worms, both external and internal, infest practically all species of fresh-water fishes. These organisms, because of complex life cycles requiring several hosts, are often of more importance outside the hatchery than in it. This does not hold for a number of the ectoparasitic flatworms

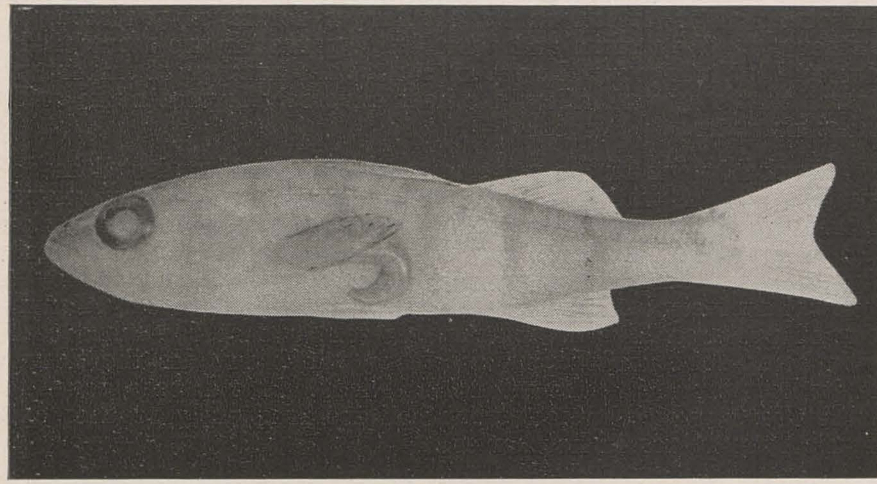

FIG. 7. Photo of a leech infecting the yellow perch in Connecticut.

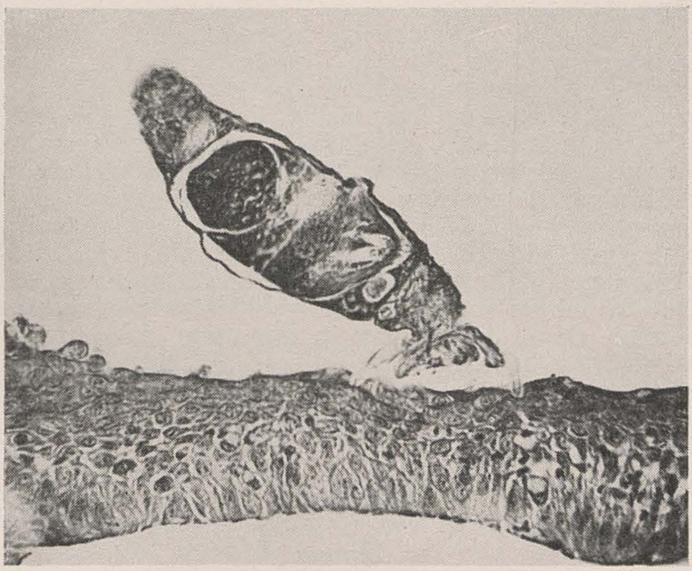

FIG. 8. Section of the skin of a brook trout fingerling infected by an ectoparasite of the Gyrodactyloidea. These parasites may cause heavy damage. Note the hooks by means of which the parasite attaches itself to its host. (Courtesy of Dr. L. Wolf.)

(Gyrodactyloidea) (Fig. 8) that attach themselves to the gills or fins of their host. Many of the more important internal parasites occur in the flesh or viscera and represent larval stages in a cycle that can only be completed in a larger fish or in some fish-eating vertebrate, usually a bird or mammal.

The Bass Tapeworm (Proteocephalus ambloplitis)

The bass tapeworm (*Proteocephalus ambloplitis*) serves as an example of one of the most important parasitic worms found in Connecticut fishes. The life cycle of this parasite is now well known as it involves a tissue-invading larval form, while the adult inhabits the intestine of at least six species of fish (Fig. 9).[17] Segments of the adult worm pass from the intestine of the fish and the contained eggs are liberated from the proglottid (segment) upon immersion in water. When these eggs are eaten by minute copepods the parasites hatch and the young procercoid larvae migrate into the body cavity of the copepod and develop there for at least two weeks. Practically any species of fish may eat these infected copepods. The parasite thus introduced into the fish bores through the wall of the digestive tract and migrates into the mesenteries and viscera, finally coming to rest in the mesenteries, liver, spleen, or reproductive organs. In cases of severe infestation of the gonads, sterility results. A suitable period of growth is required in the second intermediate host. Maturity may be reached when a larger bass or other final host ingests the infected fish, bringing the larval tapeworm back to the digestive tract of the larger fish where it grows to maturity, thus completing the cycle.

*The Black Grubs or Larval Strigeids**

Connecticut fresh-water fishes harbor a fairly large variety of encysted flukes or trematodes. Some species occur as black grubs in and on the host; many of these parasites belong to that large group known as the Strigeids. Many different species of parasites are represented by black grubs on different species of fishes and even though they all look alike superficially, their life cycles are usually quite different in detail. The parasites themselves are not black; the colored pigment is deposited in and about the host cyst which surrounds the larval worm and the so-called inner cyst of parasitic origin. These resting, encysted parasites are known as metacercariae and they occur in nearly every species of fish examined by the Lake and Pond Survey.

The life cycle of these forms is quite interesting and, while variations occur and the details have not been demonstrated experimentally in all cases, it is believed that they follow the same general pattern (Fig. 10). A fish-eating bird or mammal eats

*In the case of some species the term designating the metacercaria is used since the writer believes further experimental work is necessary to reveal the true relationships of some of these Strigeids.

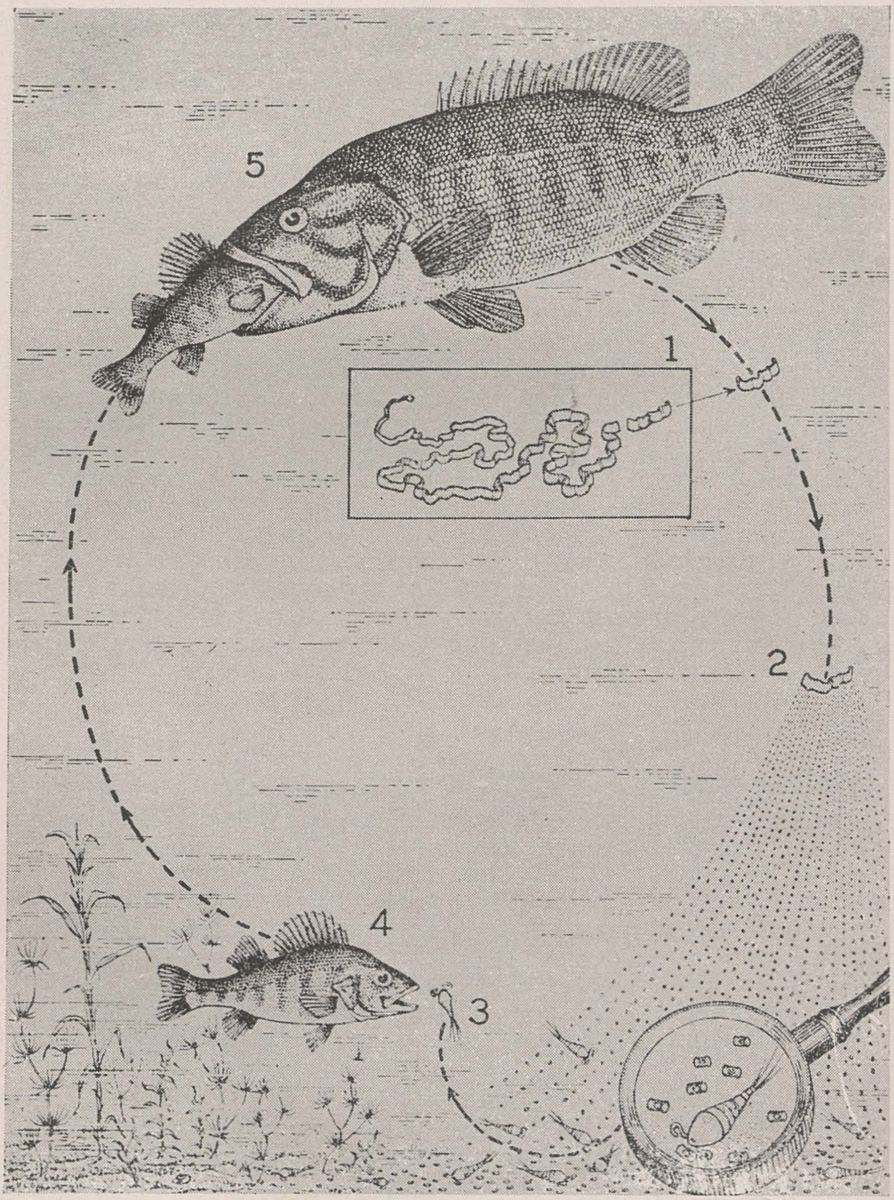

FIG. 9. Diagram of the life cycle of the bass tapeworm (*Proteocephalus ambloplitis*). (After Hunter and Hunter through the courtesy of the New York State Conservation Dept.)

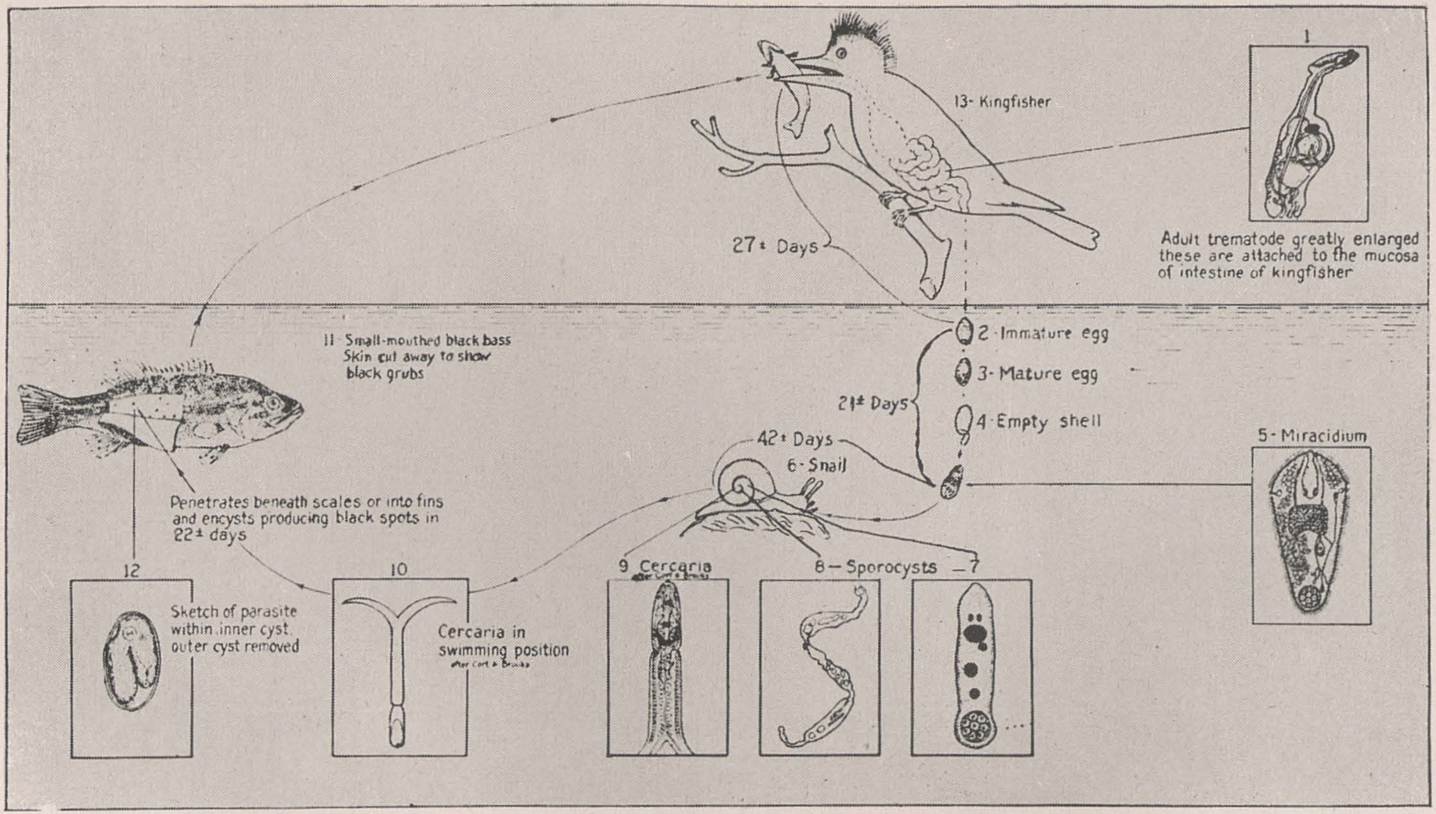

Fig. 10. Diagram of the life cycle of the black grub of bass (*Uvulifer ambloplitis*). (After Hunter and Hunter through the courtesy of the New York State Conservation Department.)

the infected fish, thus bringing the parasite into the intestine of the final host where it matures. After the parasites reach sexual maturity, eggs are passed with the droppings of the host. If these eggs reach water they hatch after a proper developmental

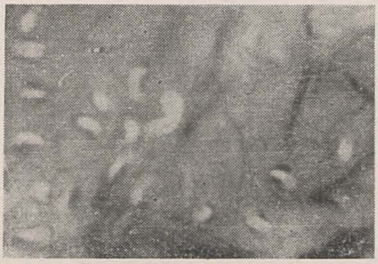

FIG. 11A. Photo showing a portion of the liver of a common sunfish heavily infected with metacercariae of the white grub of the liver, *Posthodiplostomum minimum.*

period into free-swimming miracidia. These free-swimming larval parasites must find and penetrate a particular species of snail. Several generations are produced within the body of the snail, culminating in another free-living organism, recognizable as a fork-tailed cercaria. This form penetrates and comes to rest beneath the scales or in the deeper layers of the muscles of the fish. The parasite secretes a thin, inner cyst. The fish responds by producing an outer cyst of connective tissue in which appears the black-pigment-containing cells that give it the name of black grub.

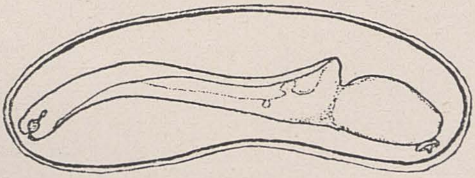

FIG. 11B. Freehand drawing of a side view of the white grub of the liver within its cyst.

The White Grub of Liver (Posthodiplostomum minimum)

Although this Strigeid fluke is not particularly prevalent in all of the fishes discussed in this report, nevertheless, it is one of the most widespread and economically important parasites encountered. In the first place the liver, which is the normal site of the infection, is sometimes almost completely destroyed (Fig. 11). Experimental infections have led to the death of the fish and examinations have revealed that the spleen, kidneys, and even reproductive organs were heavily parasitized. Several workers[5, 14, 22] have contributed to a knowledge of its life cycle and ecology. These authors have shown that the worm matures in the great blue heron. Eggs of this parasite are shed in the droppings of the bird and, after a developmental period, hatch and

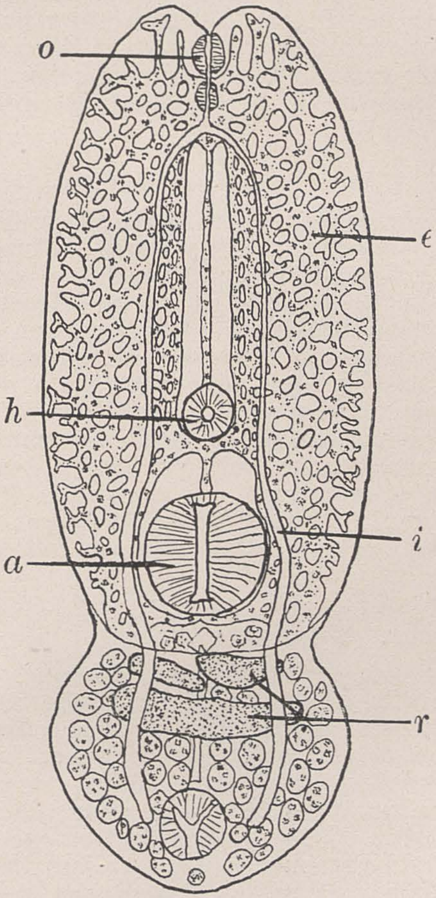

FIG. 11C. Freehand line drawing of a white grub of the liver dissected from its cyst. Most of the details seen in the figure are only observable under the microscope. a — acetabulum; e — excretory system; h — holdfast; i — intestine; o — oral sucker; r — rudiments of reproductive organs.

penetrate a snail. Here, after several generations, cercariae are produced; these penetrate beneath the scales of fish and eventually reach their destination in the liver and associated organs (Fig. 12). If sufficient tissue is destroyed, the host will die. This has been demonstrated in the laboratory.[14]

The Sand Grain Grub (Tetracotyle sp.)

Still another offending parasite is the Tetracotylid-like Strigeid larva that encysts in the flesh of the yellow perch and probably other species of fishes. This form occurs as a yellowish or whitish cyst between bundles of muscles (Fig. 4) and has apparently been found by various workers.[10, 31] This is believed to be similar to the forms reported from the pericardial cavity of several species of fish by Hughes. It apparently belongs to the larval group of the *Tetracotylids*, although it has not been identified further and its life cycle is at present unknown. The presence of this parasite in quantity in the flesh of fish renders them definitely unpalatable.

The Yellow Grub (Clinostomum marginatum)

Another closely related parasite is the yellow grub of fish (*Clinostomum marginatum*). This worm matures in the mouth of the great blue heron and other fish-eating birds (Fig. 13). The eggs are shed from the parasite as the bird feeds, the water furnishing the necessary stimulus for the liberation of the parasite's eggs. These eggs hatch in the space of a few hours, liberating miracidia which actively seek and penetrate a particular species of snail. Development of several generations follow in the snail, terminating in the production of a free-swimming, fork-tailed, cercaria. This organism actively penetrates beneath the scales and into the flesh of practically all species of fresh-water fishes except trout, where it develops within a loose connective tissue cyst in the muscles. This resting stage is called a metacercaria (Fig. 14).

The Red Roundworm (Eustrongylides sp.)

Whenever the life cycles of these fish parasites are known, it becomes possible to control them in hatcheries and to predict whether or not control measures would be effective in nature. The first step always necessitates a thorough knowledge of the life cycle. The weakest link in the chain can then be detected and studies on the practicability of further control investigated. The fresh-water fishes of Connecticut harbor one important parasite that occurs fairly frequently and renders the infected fishes unattractive as food. This is a larval red roundworm which occurs in the viscera or flesh of many of our game fishes (Fig. 15). It has been previously reported from New York State as *Eustrongylides sp.*[14, 27] However, no experimental work has been performed on the life cycle of this parasite. The larval stages of this roundworm are found not only in eels and minnows but in the flesh and viscera of many yellow perch, bass, sunfish, calico bass, and pickerel. In all of these fishes the parasite eventually dies unless the fish host is eaten by the proper final host. In cases where the parasitized fish is not eaten the fish does not completely resorb the parasite, which remains as a hard mass of degenerated tissue, still encapsulated by the host cyst.

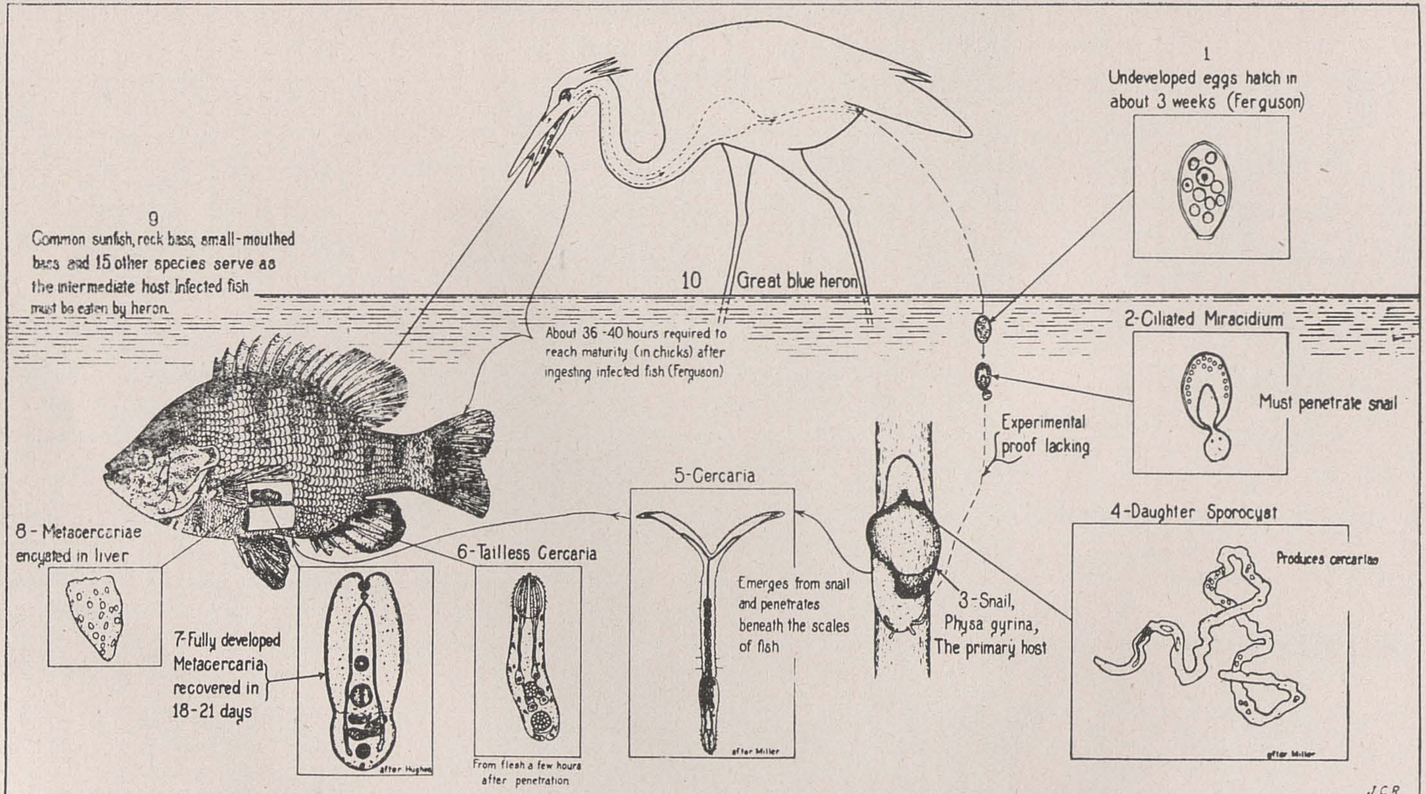

Fig. 12. Diagram of the life cycle of the white grub of the liver (*Posthodiplostomum minimum*). (After Hunter through the courtesy of the New York State Conservation Department.)

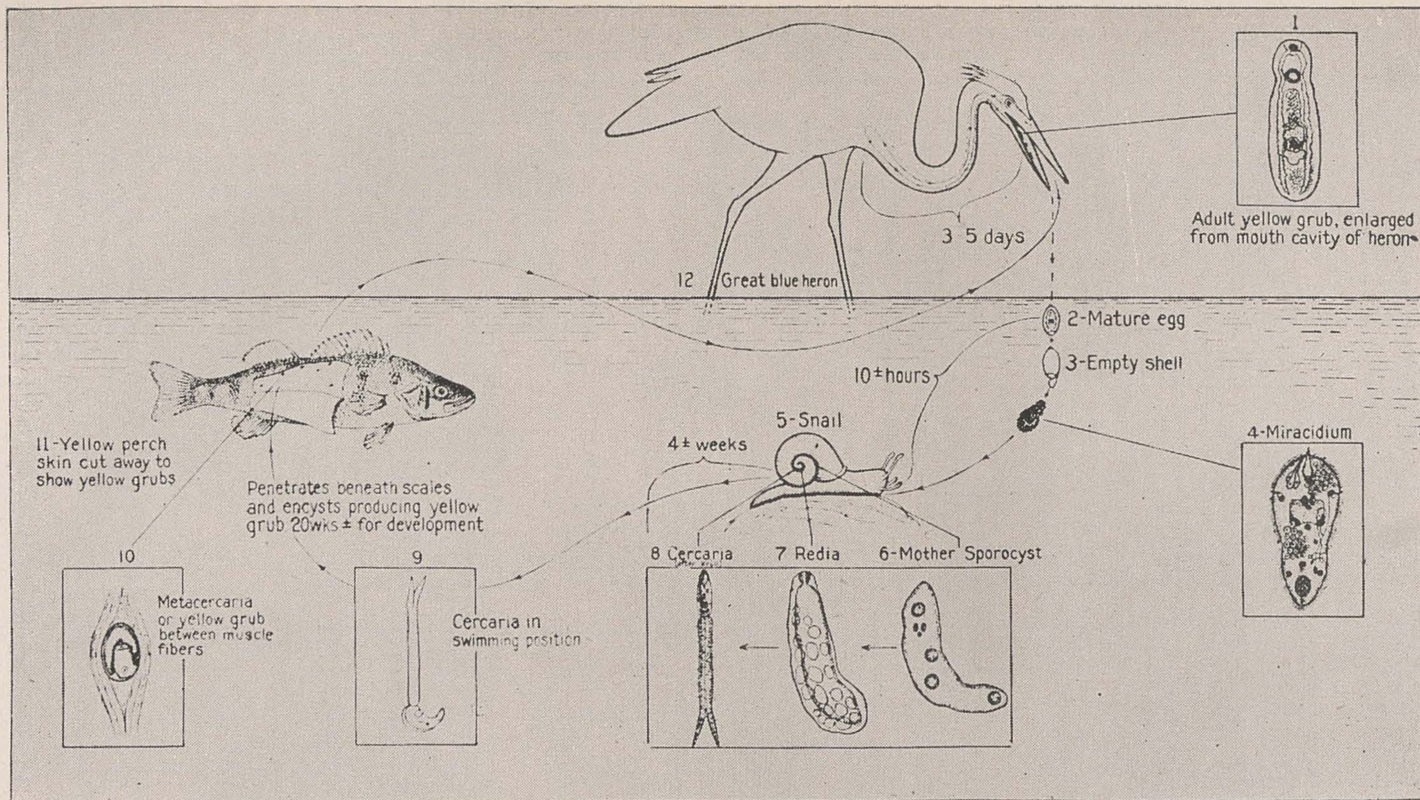

FIG 13. Diagram of the life cycle of the yellow grub of fish (*Clinostomum marginatum*). (After Hunter and Hunter through the courtesy of the New York State Conservation Department.)

The Eye Grub (Diplostomum sp.)

As this paper was going to press it was found that the life history of the eye grub of trout had been described by Ferguson and Hayford.[7] Whether or not the cycle described by them proves to be identical with the larval form encountered in the lens and humors of the eyes of the various fresh-water fishes of Connecticut can only be determined upon further experimental work. In any event it is sufficiently close to the form described by these two workers to warrant inclusion here (Fig. 16B).

This parasite was encountered by Ferguson and Hayford in rainbow brook, and brown trout, as well as common suckers,

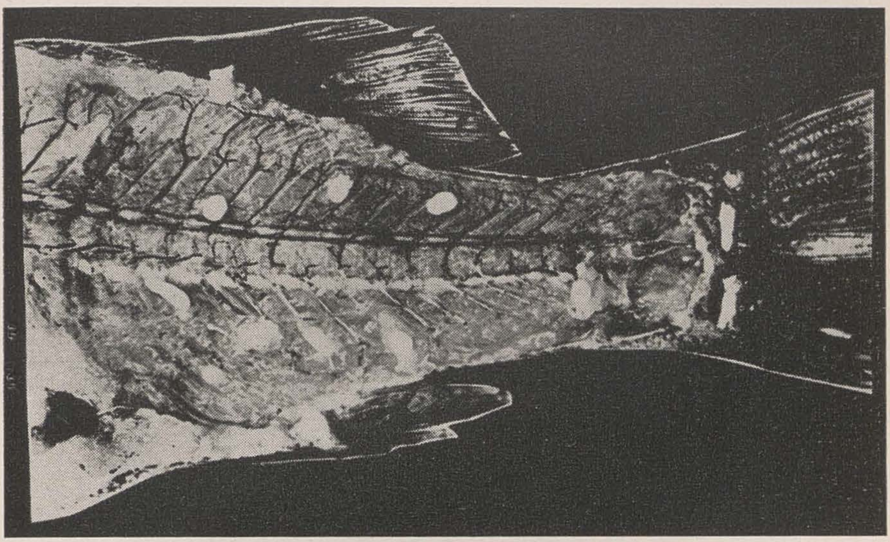

FIG. 14. Photo of yellow perch with a portion of flesh removed to show metacercaria of yellow grub.

bluegill sunfish, smallmouth bass, and forage minnows. In some cases the infections were sufficiently severe as to cause blindness. Further experiments have included the smallmouth bass, Oswego bass, common sunfish, and blackhead minnows. There is apparently some doubt in this first report as to whether one or more species are involved. Further experimental study will be necessary to determine this point. It has been shown, however, that in cases of severe infections it is possible to bring about the death of the fish host. Whether or not this occurs in nature is not known at this time.

The life cycle of this parasite, and probably its close relatives, may well start with the infected fish. Ferguson and Hay-

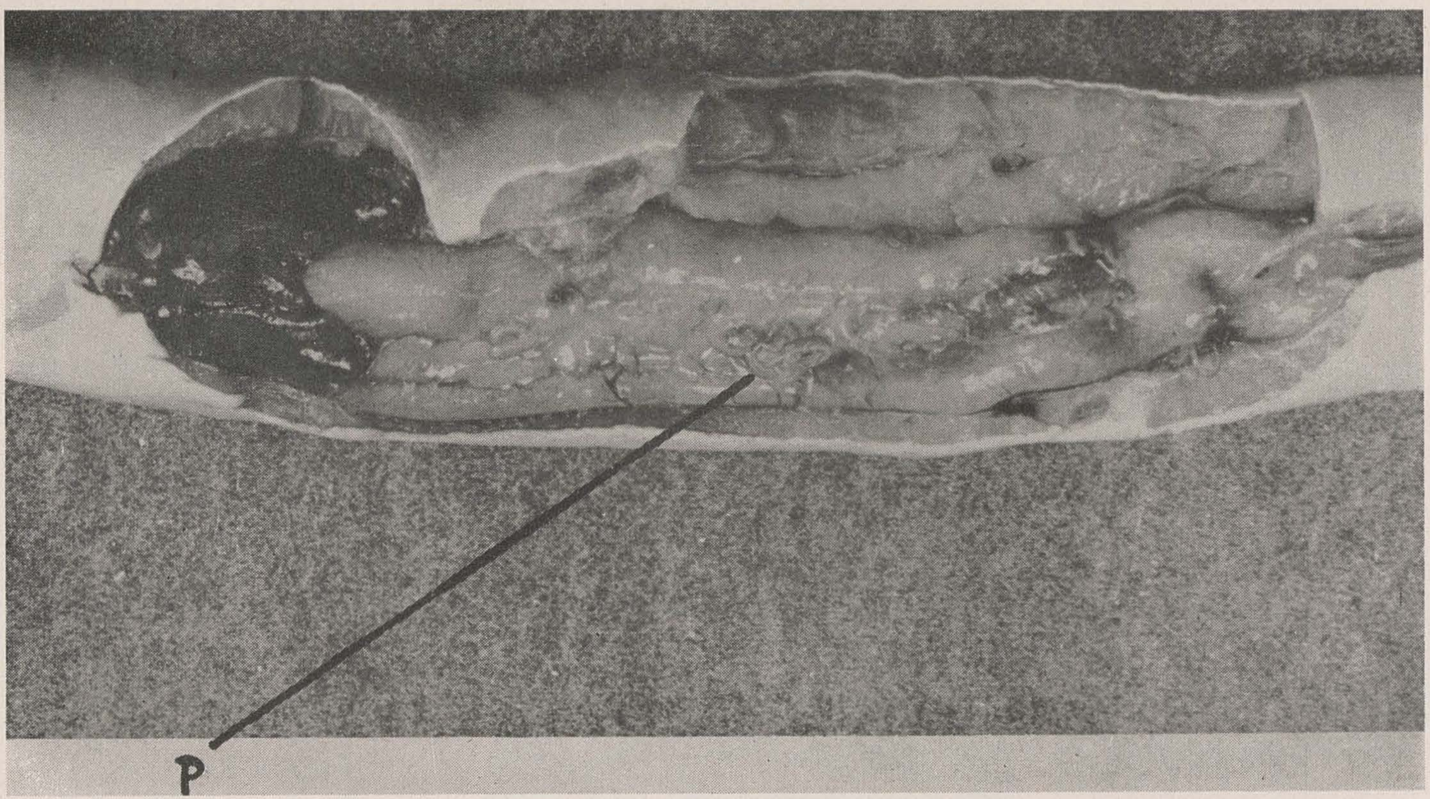

FIG. 15. Photo of the larval red roundworm of fish (*Eustrongylides sp.*) in the flesh of the eel. P = parasite.

ford[7] have shown that young laughing gulls serve as the final host. The parasites develop in the intestine of the gull and the eggs that are dropped require a developmental period of two or three weeks in water before they hatch. The larval stage, or miracidium, penetrates several species of snails of the genus *Lymnaea* where further development takes place. A new generation of sporocysts is produced in the liver of the snail which liberates fork-tailed cercariae. These in turn penetrate the fish host and apparently become localized in the eye. The subsequent metamorphosis requires a period of about six weeks after penetrating the fish. The life cycle of this parasite will be found in Fig. 16B.

For the sake of clarity the more important characteristics of these parasites are summarized in Table I. In this table occurs the common name of the organism, a general description of the parasite, the species of fish in which it may be found, together with some indication of its economic importance.

PART II. PARASITES OF THE FISHES OF LAKES AND PONDS IN CONNECTICUT

Having investigated several aspects of parasitism in Connecticut fresh-water fishes, it remains to consider parasitism of certain species in specific lakes. The sportsmen in Connecticut, as well as the State Board of Fisheries and Game, are now concerned with the question as to whether or not the perch, bass, or trout in certain lakes are more heavily infected than are comparable specimens from other lakes in the state. This is only one aspect of the problem. Another important feature is a study of the parasite index of the fishes in a given pond or lake and a comparison of that figure with one representing the state average. Properly interpreted data on the degree of parasitism is an essential part of a program designed to improve fishing. In some cases this factor alone may be of sufficient importance to cause a change in fish regulations or even of stocking policy.

Perhaps a few words of explanation concerning the parasite index are in order. Each fish was examined for parasites and the intensity, or degree of infection, with each species of parasite recorded. In each case four categories were used so that information was recorded indicating whether the fish was uninfected, lightly, moderately, or heavily infected. A light infection was represented by 1 - 9, a moderate infection by 10 - 49, and a heavy one by over 50 parasites of a given species. Arbitrary values (based upon actual counts and averages) were assigned.*

*These were: uninfected = 0, light = 5, medium = 30, heavy = 150 parasites per fish.

TABLE I. DESCRIPTIVE SUMMARY OF THE MORE IMPORTANT PARASITES OF FRESH-WATER FISHES IN CONNECTICUT

Common Name of Parasite	Scientific Name	Description and Location	Species of Fish Infected	Importance
1. Black grub of Bass	*Uvulifer amblo-plitis*	Small cysts about the size of a pin head. Occurs on fins and in flesh.	Most species of sunfish, rock bass, small and largemouth bass.	Severe infections may kill young fish or cause a significant loss of weight.
2. Black grub of Perch	*Crassiphiala bulboglossa* *Neascus sp.*	Small cysts about the size of a pin head occurring on or just under the scales. Sufficient numbers may be present in severe infections to give the impression of roughness when the fish is touched.	Yellow perch, chain pickerel, barred killifish and probably others.	No experimental evidence. Probably same as 1.
3. Black grubs	*Neascus sp.*	Same as in 2.	Other species of fish.	Unknown.
4. Sand grain grubs	*Tetracotyle sp.*	In flesh as minute but hard white or yellow cysts.	Yellow perch.	Unknown.

5. White grub of liver	*Posthodiplostomum minimum*	These white cysts occur in the liver and sometimes kidney, spleen or gonads. They are about the size of a white headed pin.	Nearly all species of fish.	Destroys liver and other tissue. May kill the fish in cases of severe infections.
6. Eye grub	*Diplostomulum scheuringi* *Diplostomulum sp.*	In lens, aqueous or vitreous humor of eye.	Nearly all species of fish.	Unknown. Parasites in lens may produce blindness. Heavy infections may kill fish.
7. Yellow grub	*Clinostomum marginatum*	In flesh, on gills or gill cover.	Nearly all species of fish.	Apparently may cause emaciation.
8. Red roundworm	*Eustrongylides sp.*	In flesh, may cause sores. Dead parasites occur in hard nodules.	Eels, bass, sunfish, yellow perch.	Unknown. Heavy infections make unfit for food.
9. Bass tapeworm	*Proteocephalus ambloplitis*	In mesenteries, liver, spleen or reproductive system. Sometimes makes fish soft and flabby.	Nearly all species of fish.	May cause sterility in bass.

Thus, by including all available data from Connecticut pond fishes, it was possible to secure an arbitrary figure representing the degree of infection within the state for each species of parasite of importance in a given species of fish. This *state index* was used as a basis for comparison. A figure for various lakes and ponds was determined in a similar way and a comparison of the two sets of figures indicated whether the situation as regards a given parasite was better or worse than the state average. An example will serve. In the case of the smallmouth bass, the state index for the bass tapeworm (*Proteocephalus ambloplitis*) was 29. Data gathered from bass in Taunton Pond yielded an average of 127. This exceedingly high figure indicates that an excessive infection is present in smallmouth bass from this body of water. The question may well be raised as to the advisability of planting more smallmouth bass in this pond. This point will be mentioned later.

With this explanation of the procedure in mind several species of fishes that are important to Connecticut sportsmen will now be considered.

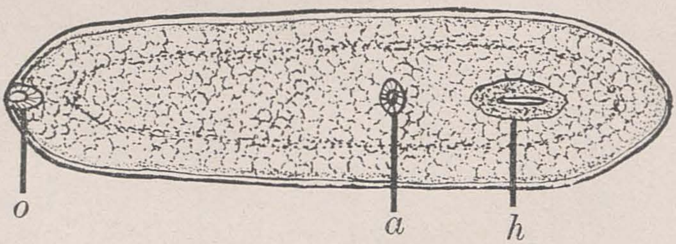

FIG. 16A. Free-hand drawing from preserved specimen of the larval eye grub (*Diplostomum scheuringi*) from the humor of the eye of the common sunfish. a — acetabulum; h — holdfast organ; o — oral sucker.

THE COMMON SUNFISH (*Lepomis gibbosus*)

This attractive little pan fish is deservedly popular, particularly with the youngsters. Aside from any part they play in the economics of the larger species, they deserve consideration here. The common sunfish supports a number of parasites as will be realized from the total of 87.1 per cent infection representing 17 species of parasites. This figure compares with 14 species of worms from the common sunfish in Oneida Lake and 13 species of parasites (including leeches and protozoa) from those examined from Lake Erie. Furthermore, this fish is usually fairly heavily infected by a number of important parasites. The white grub of the liver, black grubs, eye grubs (Fig. 16), yellow grubs, bass tapeworm, and the red roundworm are all present in varying degrees in this species from the different lakes. These parasites are known respectively as *Posthodiplostomum mini-*

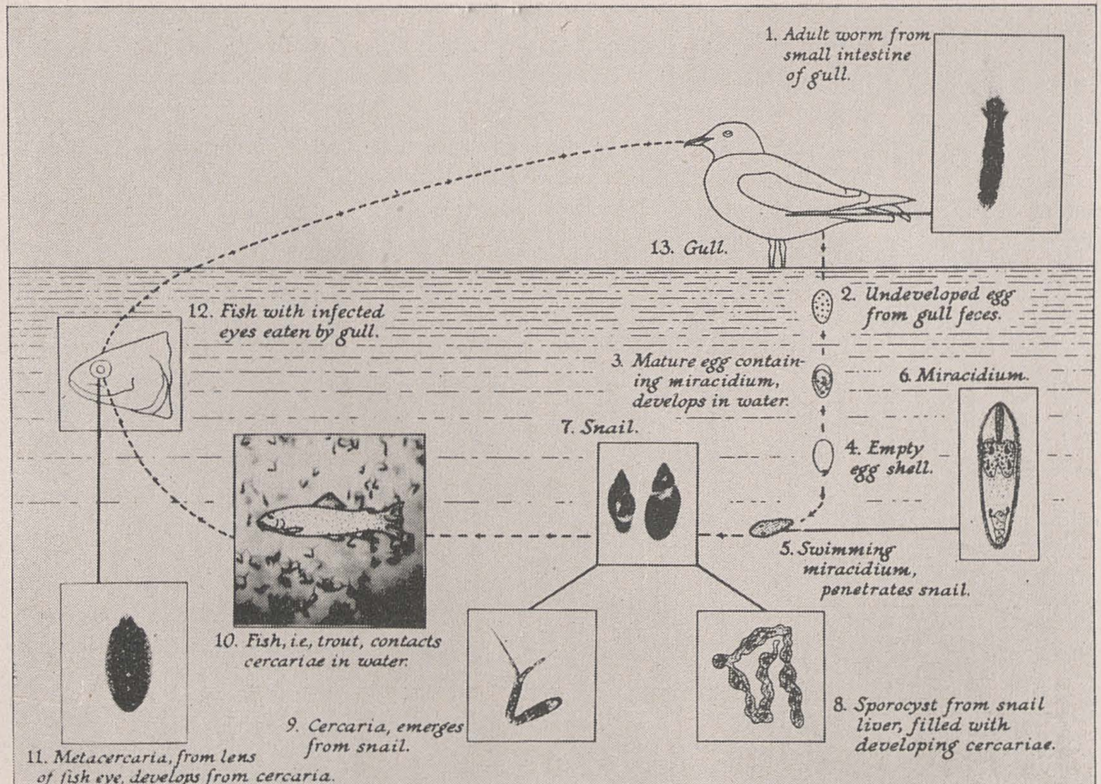

FIG. 16B. Diagram of the life cycle of the eye grub of trout (*Diplostomum sp.*) otherwise known as the Hackettstown eye fluke. (From Ferguson and Hayford, with permission of the U. S. Fish and Wildlife Service.)

mum, Uvulifer ambloplitis, Displostomum scheuringi, Clinostomum marginatum, Proteocephalus ambloplitis, and *Eustrongylides sp.* Because of this comparatively large array of important parasites, but few bodies of water will be found where the sunfish can be given a clean "bill of health". (See Table II.)

The Black Grubs

The 79 common sunfish that were examined in the state gave a state index of 23.9 black grubs per fish. Highland, Tyler, and Waumgumbaug lakes were quite free of fish carrying this noxious worm, for they had a parasite index of only 7.8, 2.2, and 0.6, respectively. Waramaug with 24.0 is about average and Taunton with 35.6 and Hall's Pond with 71.6 suggest comparatively heavy infestations.

The White Grub of the Liver

This parasite should be regarded as one that may do considerable damage when heavy infections occur year after year in the same locality. Fortunately, it was absent from the specimens that were examined from Highland, Taunton, and Tyler Lakes, while Waumgumbaug only carried 3.8 parasites per fish, which is considerably below the state average of 40.4. Hall's Pond appears to be among the worst in this respect, for the fish from it had an average of 97.5 parasites.

The Bass Tapeworm

Fortunately, this tapeworm is not universally present in common sunfish. The state average is only 6.0 and the specimens from Hall's Pond, Tyler, and Waumgumbaug did not shelter this parasite; Highland was below the state average with only 2.1, and Taunton was about average with 7.2. Waramaug, however, yielded 34.0, the highest figure yet encountered. Evidently here the sunfish is serving as a "reservoir of infection" for the bass tapeworm.

The Sunfish Tapeworm

In the summer of 1939 and again in 1940 a Pseudophyllidean tapeworm (Fig. 17) was found inhabiting the intestines of common sunfish. This tapeworm had never previously been recorded from the sunfish of Connecticut. In some lakes, young of the year were over 90 per cent infected. Whether or not this worm is ever present in sufficient numbers to harm the host is not known at this time.

TABLE II. SUMMARY OF THE DEGREE OF INFECTION IN 79 COMMON SUNFISH (*Lepomis gibbosus*) FROM SOME CONNECTICUT LAKES

PARASITES AND PARASITE INDEX BY LAKES

		Black Grub (*U. ambloplitis*)	Yellow Grub (*C. marginatum*)	White Liver Grub (*P. minimum*)	Eye Grub (*D. scheuringi*)	Bass Tapeworm (*P. ambloplitis*)
State Index		23.9	0.19	40.4	1.2	6.0
Lakes	No. Ex'd					
Hall's	12	71.6	1.3	97.5	4.2	—
Highland	7	7.8	—	—	—	2.1
Taunton	9	35.6	—	—	—	7.2
Tyler	9	2.2	—	—	2.2	—
Waumgumbaug	8	0.6	—	3.8	—	—
Waramaug	10	24.0	—	24.0	—	34.0

NOTE: In this and in all other tables a dash indicates no infection.

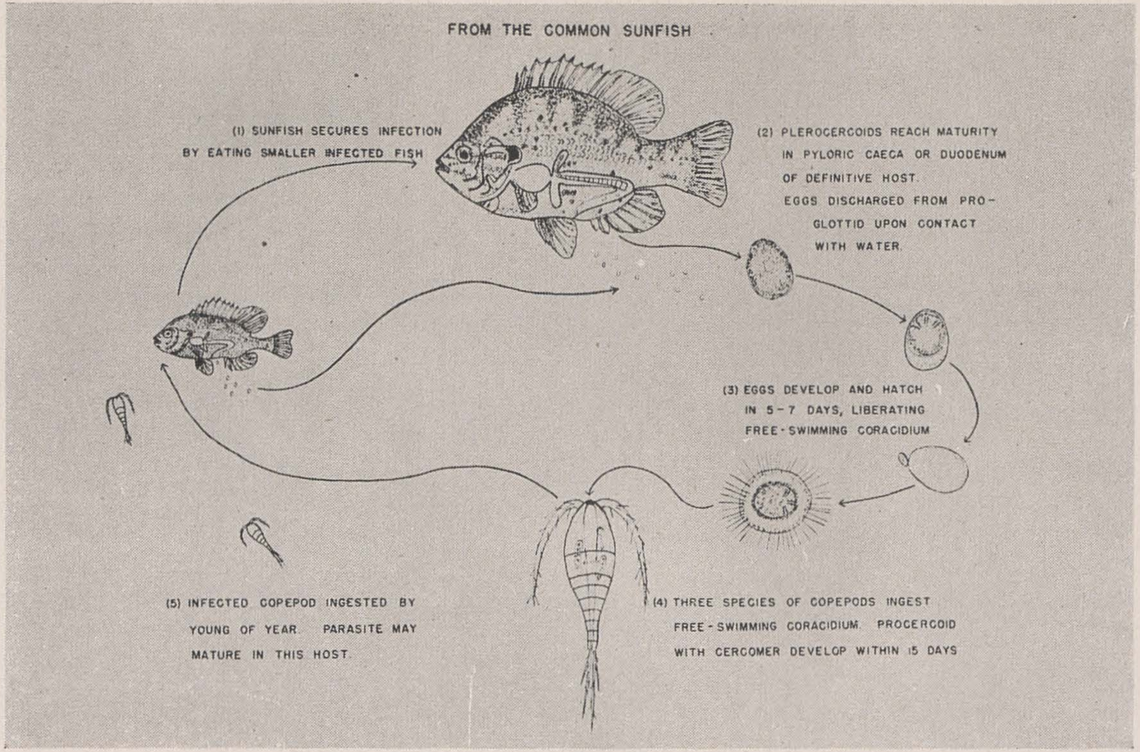

FIG. 17. Diagram of the life cycle of the Pseudophyllidean tapeworm of sunfish.

TABLE III. SUMMARY OF THE DEGREE OF INFECTION IN 20 CALICO BASS (*Pomoxis nigro-maculatus*) FROM SOME CONNECTICUT LAKES

PARASITES AND PARASITE INDEX BY LAKES

		Black Grub (*Neascus sp.*)	Eye Grub (*Diplostomulum sp.*)	Bass Tapeworm (*P. amblopliti*s)
State Index		1.0	0.25	0.5
Lakes	No. Ex'd			
Tyler	3	—	1.7	—
North Farms Reservoir	8	0.6	—	—

TABLE IV. SUMMARY OF THE DEGREE OF INFECTION IN 99 WHITE PERCH (*Morone americana*) FROM SOME CONNECTICUT LAKES

PARASITES AND PARASITE INDEX BY LAKES

Lakes	No. Ex'd	Eye Grub (*D. scheuringi*)	White Liver Grub (*P. minimum*)	Bass Tapeworm (*P. ambloplitis*)
State Index		0.99	0.05	0.34
Bantam	34	2.2	0.15	0.9
Candlewood	15	—	—	—
Lake Zoar	12	—	—	—
Twin Lakes	13	1.2	—	—
Waramaug	12	1.3	—	—

Other Parasites

The yellow grub of fish did not occur in great numbers in any of the sunfish examined from these lakes. Hall's Pond did provide fish that were slightly more heavily infected than the state average. The eye grub (*Diplostomulum scheuringi*) was also present in considerable numbers in the fish taken from Hall's Pond and Tyler Lake.

The Calico Bass (*Pomoxis nigro-maculatus*)

This excellent eating fish is quite widely scattered throughout Connecticut lakes, but it was not secured in sufficient numbers to furnish more than a glimpse of its parasitic acquisitions (Table III). About the only parasites of importance that it harbors is an occasional black grub, eye grub, or bass tapeworm, the state average for these three groups being 1.0, 0.25, and 0.5, respectively. At Tyler Lake there appeared to be a near epidemic of eye grubs as there were 1.7 per fish. Other infections were relatively unimportant. On the whole it should be regarded as one of the cleanest fish from the viewpoint of a parasitologist. This is supported by the findings of workers from other areas.[3, 4, 31]

The White Perch (*Morone americana*)

This fish occurs in a number of our Connecticut lakes. Like the calico bass it is apt to be quite lightly parasitized. This condition, however, seems to depend to a large extent upon the individual lake (Table IV). The author has never found a white perch infected with black grubs and it has only been rarely (at Bantam lake) that the white grub of the liver was found — and then only once — probably an accidental infection. The bass tapeworm likewise was only found in the white perch of two lakes, Bantam and Taunton. Thus from the parasitological point of view it may appear as a desirable addition to lakes and ponds, a view which may well be desired as other facts are considered.

The Smallmouth Bass (*Micropterus dolomieu*)

Data were secured on a total of 107 smallmouth bass. These 107 fish represented collections from 13 lakes. One hundred and one, or 95.3 per cent, of these were infected with 13 species of parasites.* However, this discussion will be limited to a few parasites that are recognized as economically important and that occurred quite frequently in the course of the survey: (1) the black grub (*Uvulifer ambloplitis*); (2) the red roundworm (*Eustrongylides sp.*); and (3) the bass tapeworm (*Proteocephalus ambloplitis*). All of these represent important parasites. Comparisons may be made of the bass from Columbia, Highland, Shenipsit, Taunton, Tyler, and Waumgumbaug lakes (Table V).

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*Of these 107 only 78 were examined completely; 77, or 98.7 per cent of the 78 examined completely were parasitized (Cf. Table X).

TABLE V. SUMMARY OF THE DEGREE OF INFECTION IN 107 SMALLMOUTH BASS (*Micropterus dolomieu*) FROM SOME CONNECTICUT LAKES

PARASITES AND PARASITE INDEX BY LAKES

Lake	No. Ex'd	Black Grub (*U. ambloplitis*)	Yellow Grub (*C. marginatum*)	White Liver Grub (*P. minimum*)	Eye Grub (*D. scheuringi*)	Bass Tapeworm (*P. ambloplitis*)	Red Roundworm (*Eustrongylides sp.*)
State Index		18.3	0.18	0.09	0.28	29.0	0.14
Columbia	32	18.8	—	—	—	7.2	0.16
Highland	8	32.5	0.6	—	—	78.7	0.6
Rogers	5	20.0	—	1.0	—	—	—
Shenipsit	17	5.9	0.3	—	—	94.4	—
Taunton	5	3.0	—	—	—	127.0	5.0
Tyler	16	48.4	—	—	0.6	—	—
Waumgumbaug	14	1.4	—	—	1.1	—	—

The Black Grub

This particular parasite has been shown to be capable of producing a significant loss of weight in young heavily infected fish.[21] Consequently it is a factor to reckon with if the production of fish is to be maintained. It will be seen from Table V, that the bass has 18.3 black grubs per fish throughout the state. Those from Columbia and Rogers are about average, while Highland with 32.5 and Tyler with 48.4 run considerably above the state average. Shenipsit, Taunton, and Waumgumbaug are considerably below the state average as they harbor only 5.9, 3.0, and 1.4, respectively.

The Red Roundworm

This was encountered in only three localities: Columbia, where it is about of average frequency; Highland and Taunton, where it is considerably higher.

The Bass Tapeworm

This parasite, more properly known as *Proteocephalus ambloplitis,* is quite common to the smallmouth bass of Connecticut as its index is 29.0. Columbia Lake yielded lightly infected bass averaging only 7.2, while Tyler and Waumgumbaug are two of the few bodies of water in which (on the basis of our specimens) the bass tapeworm does not seem to occur. *Great effort should be made to insure the planting only of bass free from the bass tapeworm,* especially in these bodies of water. Encouraging natural propagation may prove to be the best solution from the parasitological viewpoint.

It will be seen from Table V that the fishes from Highland, Shenipsit, and Taunton are all heavily infected by this parasite as they yield 78.7, 94.4, and 127.0 parasites per fish, respectively. The situation in Taunton Pond is one of the most serious encountered. While relatively few smallmouth bass were examined, both the small and largemouth bass gave evidence of a heavy infestation by this parasite. In some cases the gonads were so heavily infected that reproduction appeared out of the question. This was substantiated further by seining for young bass in 1939 and 1941. Few were recovered. With this heavy infection in these bass as well as in all other species of fish examined from this lake, it appears dubious that stocking bass should be continued. Incidentally it is interesting to note that these findings are supported by a study made by Hunninen[11] on some 22 lakes of the Delaware-Susquehanna Watershed in New York State, where the degree of infection of smallmouth bass showed a definite correlation with the presence of young bass as determined by seining.

The Largemouth Bass (*Huro salmoides*)

Many bodies of water in Connecticut afford good largemouth bass fishing, but few such areas were studied and only 27 specimens were secured for examination. Specimens were taken in some numbers from Highland, Peat Works, Taunton, and Waramaug (Table VI).

One interesting thing is that for some reason the largemouth bass harbors fewer species of parasites than the smallmouth. This is emphasized by the fact that they shelter 8 and 15 species respectively (see Table XI). This compares quite favorably with the data from Lake Erie bass where Bangham and Hunter[3] report 17 species of parasites from largemouth bass and 23 from smallmouth. However, Van Cleave and Mueller[31] report just the opposite from Oneida Lake, New York, where they found 17 and 14 species, respectively. However, other areas in New York[15-20] would tend to support the generalization that the largemouth bass normally harbors fewer parasites.

It is perhaps of some importance to call attention to the fact that only about three-quarters (74.1%) of the largemouth bass were parasitized compared with over 95 per cent for the smallmouth. It also appears that the burden of parasites is lighter in the former group since the state average is only 9.27 compared with 18.3 for the black grub. The white grub of the liver and the red roundworm were not found in the largemouth bass. Oddly enough the largemouth bass were more heavily infected by the bass tapeworm. Whether these ratios would be maintained after the examination of a larger sampling cannot be forecast with accuracy.

The Yellow Perch (*Perca flavescens*)

The yellow perch is probably the most widely distributed of our Connecticut fishes. It occurs in nearly every lake and pond in Connecticut where it was to be found originally, or appears now as the result of stocking. Because of wide distribution and availability the species is of considerable importance to Connecticut sportsmen.

The yellow perch carries more than its share of parasites; 85.7 per cent harbor some species of parasite. This species in Connecticut, as in other regions, also supports a wider *variety* of parasites than do either species of bass. Table XI lists a total of 22 different species compared with 18 for Lake Erie and 24 parasitic worms for Oneida Lake and a much smaller number for the bass (vide infra). The more important parasites which will be discussed here are the black grub (*Crassiphiala bulboglossa* or *Neascus sp.*), the sand grain grubs, which are probably *Tetra-*

TABLE VI. SUMMARY OF THE DEGREE OF INFECTION IN 31 LARGEMOUTH BASS (*Huro salmoides*) FROM SOME CONNECTICUT LAKES

PARASITES AND PARASITE INDEX BY LAKES

		Black Grub (*U. ambloplitis*)	Bass Tapeworm (*P. ambloplitis*)
State Index		9.3	36.1
Lake	No. Ex'd		
Highland	5	13.0	1.7
Peat Works Pond	5	—	—
Taunton	6	0.8	110.0
Waramaug	6	3.3	26.6

cotyle sp., the eye grub (*Diplostomulum scheuringi*),* the bass tapeworm (*Proteocephalus amboplitis*), and the red roundworm, which belongs to the group *Eustrongylides.*

The Black Grub

The black grub that infects the yellow perch is not the same species that appears in the smallmouth bass. As noted earlier, 41.7 per cent of the fish that were examined harbored this parasite. Nevertheless, it was a light infection as the weighted state index is only 4.2. Bantam, Candlewood, Columbia, Highland, Shenipsit, Stillwater, Twin, Tyler, Waumgumbaug, and Wononscopomuc yielded specimens which were either lightly infected, or else entirely free of this parasite. Several lakes, such as Zoar, Taunton, and Waramaug, with 7.3, 11.8, and 30.9, gave evidence of quite heavy infections.

The Sand Grain Grub

While these are not as prevalent in Connecticut yellow perch as in those from New York, nevertheless, they play an important role in this state. The state index of only 1.5 suggests that many bodies of water did not yield infected fish. Bantam, Taunton, and Zoar were the three most heavily infected areas encountered. Other regions gave promise of being practically free of this worm (Table VII).

The Eye Grub

Many yellow perch carry a few specimens of what appears to be *Diplostomulum scheuringi* in the humor of their eyes. The fish from Hall's Pond and Wononscopomuc were particularly heavily infected, other regions being average, or better than average.

The Bass Tapeworm

In many parts of the state the yellow perch does not harbor the bass tapeworm, as is indicated by a state index of only 1.6. Shenipsit (11.8), Stillwater (17.1), and Taunton (4.4) are significantly worse than the average. This is particularly important in the case of this species as it is now known that the yellow perch may carry not only the plerocercoid larvae, but also the adults.[17] The implications of this are too obvious to need further elucidation.

The Red Roundworm

This parasite occurs only sporadically in Connecticut yellow perch. Certain areas, however, as Lake Zoar, yield rather heavily

*Whether or not this proves to be the same species found by Ferguson and Hayford in trout remains to be determined experimentally.

TABLE VII. SUMMARY OF THE DEGREE OF INFECTION IN 256 YELLOW PERCH (*Perca flavescens*) FROM SOME CONNECTICUT LAKES

PARASITES AND PARASITE INDEX BY LAKES

Lake	No. Ex'd	Black Grub (*C. bulboglossa*)	Sand Grain Grub (*Tetracotyle sp.*)	Eye Grub (*D. scheuringi*)	Bass Tapeworm (*P. ambloplitis*)	Red Roundworm (*Eustrongylides sp.*)
State Index		4.2	1.5	2.0	1.6	0.4
Bantam	22	0.2	3.4	2.0	1.1	0.45
Candlewood	16	—	—	—	1.9	—
Columbia	32	1.6	—	0.6	0.2	0.2
Hall's	15	4.0	—	5.0	—	—
Highland	14	2.2	0.4	0.7	—	—
Lake Zoar	15	7.3	7.6	—	—	5.0
Rogers	23	5.9	—	2.8	—	—
Shenipsit	11	0.9	—	—	11.8	—
Stillwater	7	—	—	—	17.1	—
Taunton	17	11.8	4.1	—	4.4	0.3
Twin	8	—	—	1.3	—	—
Tyler	10	—	—	0.5	—	—
Waumgumbaug	19	1.6	—	2.1	—	0.3
Waramaug	11	30.9	0.5	—	—	—
Wononscopomuc	8	—	—	17.5	0.6	—

infected fish. Much work is needed on this parasite to determine its distribution, effect, and possible relation to man.

It should be borne in mind that most fish harbor more parasites than the species covered here. It was attempted, however, to limit the discussion throughout to species of importance to the sportsmen of the state.

The Chain Pickerel (*Esox niger*)

The chain pickerel is one of the more important game fishes occurring in the lakes and ponds of Connecticut. They are taken not only during the warm weather months, but also are much sought after by the ice fishermen. Consequently, information on their parasites is desirable. It should be remembered that pickerel are not readily netted and, hence, our data are limited to a few specimens from any given lake. Therefore, it is not possible to make as detailed a report on the pickerel as for the other important species of fish.

It is generally known that adult pickerel feed largely on fish, insects, and Crustacea (mostly crayfish). Various species in these groups serve as intermediate hosts for parasites. In spite of this, however, the pickerel that were examined harbored comparatively few species of parasites.

Data on 53 chain pickerel from nine lakes are available; however, 37 specimens were taken from a single lake (Pocotopaug) over a period of several years. A total of seven species of parasites occurred in specimens from the other eight lakes (Table XI). Of these the bass tapeworm and the eye grub should be regarded as undesirable. Both of these parasites occur in the larval stage, the former typically being found in the liver and the latter in the humors of the eye. It has been shown[28] that the tapeworm of pickerel (*Proteocephalus pinguis*) (Fig. 18) may cause the death of young fish. It is doubtful, however, if such heavy infections as are necessary to cause death occur in nature in Connecticut.

As noted above, 37 chain pickerel were examined from Lake Pocotopaug. Seven species of parasites were likewise found in these fish. Only two species were not encountered in those taken from the remaining lakes. The small protozoan *Trichodina renicola* may occur in the bladder and urinary system of the chain pickerel. This parasite was found in 13.5 per cent of those fish examined from Lake Pocotopaug. The same organism was found in the fish from two other lakes. While the pathogenicity of this one-celled animal has not been determined, it seems likely that large numbers may have a deleterious effect upon their host.

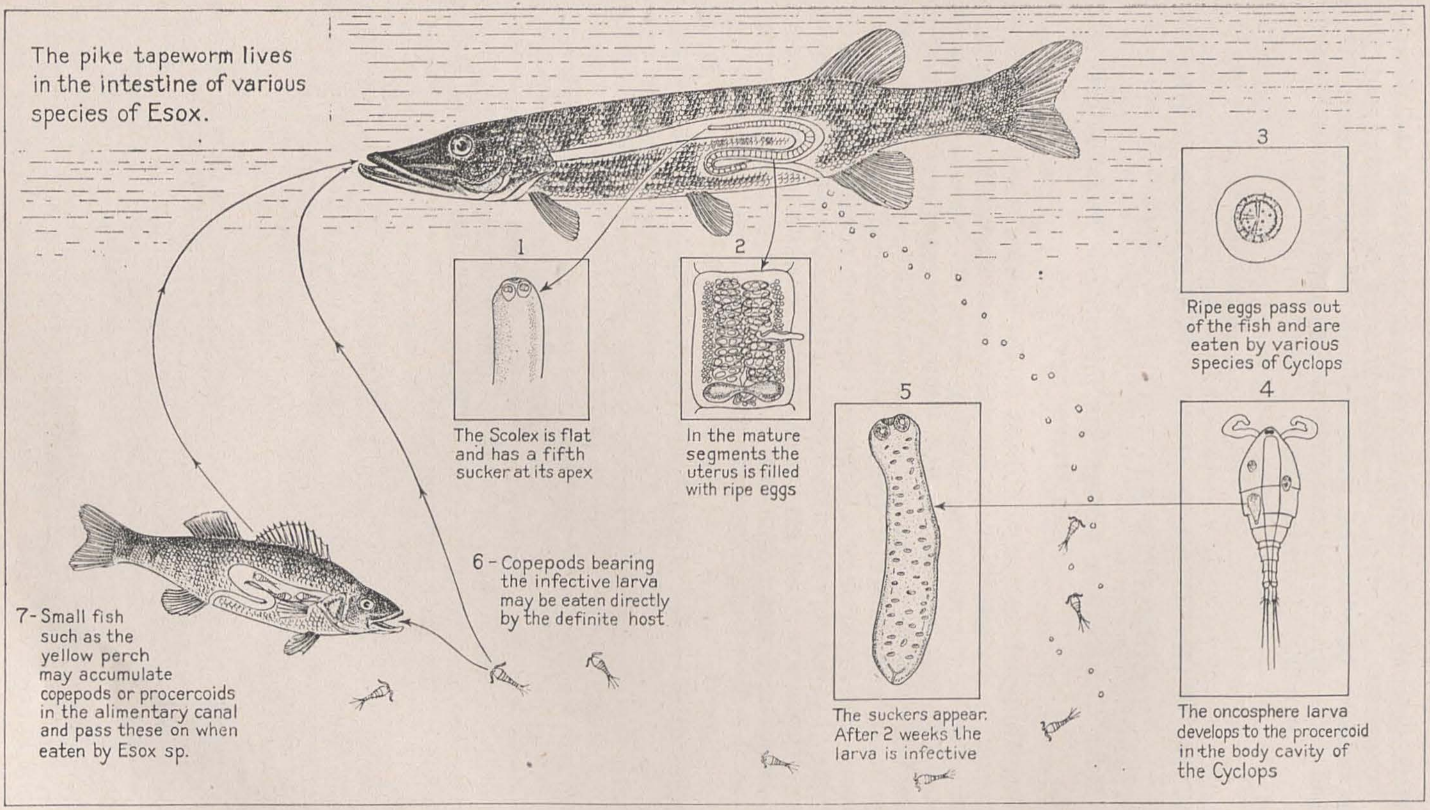

FIG. 18. Diagram of the life cycle of the pickerel tapeworm (*Proteocephalus pinguis*). (Courtesy of the New York State Conservation Dept.)

It is clear that the chain pickerel harbors three and possibly four important parasites. It scarcely need be pointed out that indiscriminate planting of these fish should be avoided. Only pickerel from uninfected stock should be used for restocking the lakes and ponds of Connecticut.

PART III. PARASITISM IN SOME CONNECTICUT FISHES AS COMPARED WITH OTHER STATES

More Connecticut Fishes Are Parasitized Than Those From Other States

One thing of primary interest to the fish culturist and to the sportsman is the situation in his state and especially in the particular area of the state in which he lives or fishes. During the summer of 1939 a total of 943 fishes representing twenty-four different species were examined for parasites from twenty-seven of the lakes and ponds of Connecticut. Naturally, all species of fish were not secured or examined in equal numbers. It is regrettable that more emphasis could not be placed on the forage fishes. However, attempts were made to examine the several more important game and pan species to furnish the necessary data on the distribution of parasites.

Ecological parasitological surveys have been made by several workers. In 1894, Ward[32, 33] gave one of the first reports when he listed the groups of parasites found in twenty species of fish from Lake St. Clair. Since then Marshall and Gilbert[24] contributed to our knowledge of the food and parasites of fish from lakes near Madison, Wisconsin. In 1912, Ward[34] again reported his findings on 991 fishes from sixty-two species and Essex and Hunter[4] published their data in 1926 on 652 fishes representing fourteen families and forty species of fishes from some of the rivers and lakes of the vast midwest area.

During the interval from 1929-1935, the Hunters,[15-20] Hunninen,[11] Hunter,[14] and Mueller[28] reported on the fish parasites of the various watersheds of New York. These covered between 300 and 1,500 fish a year.

No study as extensive as those just mentioned was undertaken again in this country until Van Cleave and Mueller[31] made a detailed report on the parasites occurring in 1,227 fish of thirty-four species taken from Oneida Lake, New York. Perhaps the largest body of water to be studied in this fashion was Lake Erie, which Bangham and Hunter reported on in 1939.[3] They examined 2,156 fish belonging to twenty-two families and seventy-nine different species.

Table VIII gives a summary of some of the distribution data on parasitized fish in various parts of the United States. It is unfortunate that the data of other workers (as Van Cleave and Mueller[31]) are not written so that comparisons may be made with other surveys. It is clear, however, that the lakes and ponds of Connecticut carry a somewhat greater number of infected fish than other lakes, since 434 of 598, or 72.5 per cent, of the fish examined were parasitized by one or more species of parasites.* Thus it is apparent that a greater proportion of fishes from Connecticut lakes and ponds studied in 1939 were parasitized than was the case of Lake Erie, Buckeye Lake, Ohio, or a group of five lakes from Minnesota and Wisconsin.

Connecticut Fishes Harbor Fewer Species of Parasites

The fresh-water fishes of Connecticut carry a number of parasites, ranging from bacteria to arthropods. It should be pointed out, however, that while a higher proportion of Connecticut fishes were parasitized, they *carried a smaller variety of parasites* than did the fishes collected from Lake Erie, Oneida Lake, and othe regions of New York State. For example, the 2,156 fish taken from Lake Erie harbored a total of 114 different parasites including 97 species of parasitic worms,[3] while Van Cleave and Mueller[31] report 68 different species of worms. The check list appearing as Table XII indicates that Connecticut fishes only carry a total of 47 species of worms. Clearly these data show that the fishes of Connecticut support fewer species of worm parasites than do the fishes of either Oneida Lake or Lake Erie. Even when the bacteria, fungi, leeches, and parasitic arthropods are added, Connecticut fishes carry a grand total of only 61 species. This is considerably less than the figure for Lake Erie where 114 were encountered. It is significant, however, that although there were *fewer* species of parasites reported, the percentage of parasitized fish was noticeably higher, being 72.5 per cent compared with 58.3 for the Lake Erie fishes. It is apparent that the fishes of Connecticut (and probably other New England states) harbor a smaller variety of parasites than is found west of a north and south line running through the Berkshires. This confirms similar observations recorded by Hunter and Rankin[23] in studying parasites of the pikes and pickerels (Esocidae).

*Actually, 345 more fish from Connecticut ponds and lakes were examined for economically important parasites during 1939. These are not included here in this discussion as the lumen of the alimentary canal was not examined and so some parasites were missed. Consequently, their inclusion would furnish an inaccurate picture of the situation. As intestinal parasites are common, yet sometimes of little known economic importance, some fishes from each area were examined for the parasites, omitting a study of the gut. This permitted an examination of a greater number of fish than would otherwise have been possible. The 345 fish that were examined in this fashion yielded 173 infections, representing a 50.7 per cent infection. If all data are lumped, 607 or 64.6 per cent of the grand total of 943 carried parasites. This figure however, cannot be used in making comparisons with other areas (as explained above), since the data of other workers are based upon supposedly complete examinations.

TABLE VIII. COMPARISON OF PARASITISM IN FRESH-WATER FISH

Body of Water	Authority	Number Examined	Number Parasitized	Percentage Infected
Five Minnesota and Wisconsin Lakes	Essex and Hunter, 1926	67	42	62.9
Buckeye Lake, Ohio	Bangham (unpublished)	514	338	65.7
Lake Erie, Ohio - N. Y.	Bangham and Hunter, 1939	2,156	1,257	58.3
Connecticut Lakes and Ponds	Hunter (present paper)	598*	434	72.5

*See footnote, p. 269.

The Parasitic Burden of Connecticut Fishes

It has been shown that *more* fresh-water fishes from Connecticut carry parasites than do the fishes from other states, but that there are *fewer species* of parasites recorded. The next point to be considered is the relation of these two facts to the parasitic burden of a given species of fish. It raises the interesting possibility that even though more fishes are parasitized in this State, nevertheless, they may harbor only one or two individuals of a given species compared with ten or twenty from fishes in other regions. Such a situation would warrant the interpretation that the fishes were in reality less heavily parasitized; in other words, their total parasite burden was less than in fishes from other regions.

While this is a significant point, if true, it is unfortunately a difficult one to prove, for few data are available for comparisons. It is possible, however, to make an analysis of the parasitic burden of two important Connecticut fishes, the yellow perch and the smallmouth bass, and to compare these with heretofore unpublished data on the same two species from some lakes and ponds in New York. For this purpose data on 314 yellow perch and 225 smallmouth bass from thirty-four and thirty-five lakes and ponds, respectively, in New York were selected haphazardly. These were compared with the findings for 126 yellow perch and 78 bass from twenty-two and fourteen Connecticut lakes and ponds, respectively. While the findings are summarized in Tables IX and X, several points need additional comment. In both cases more fish were infected in Connecticut; this was particularly noticeable in the case of the yellow perch. Another point that stands out is that in both instances more Connecticut perch and bass were lightly infected (carried between one and nine parasites) than those from New York, while more of the fish from New York State fell into the last category which represents a heavy infestation (fifty or more parasites). These figures explain the apparent contradiction that occurs when one tries to see how a fish that shelters *fewer* species of parasites than its New York relative can have a *larger proportion* of its population infected.

Turning to the yellow perch for a moment, one finds that over 85 per cent are infected in Connecticut compared with only about 77 per cent of the 314 New York perch examined. This difference is not apparent in the lightly infected fish, but those with moderately heavy infections represented approximately 41 and 26 per cent of those examined from Connecticut and New York, respectively. Among those that were heavily infected, the situation was reversed for more of those from New York supported heavy infections, 21.5 and 12.7 per cent, respectively. It is understandable then how the parasite index for Connecticut yellow perch should be 28.6 parasites per infected fish contrasted with 53.8 per fish for those from New York. The fact that Connecti-

TABLE IX. SUMMARY OF A COMPARISON OF DATA ON THE YELLOW PERCH FROM LAKES AND PONDS OF CONNECTICUT AND NEW YORK

General Comparisons

	Number of Lakes	Fish		Clean		Light		Medium		Heavy		Parasite Index per Inf. Fish
		Per cent inf.	Number ex'd	Per cent inf.	Number ex'd	Per cent inf.	Number ex'd	Per cent inf.	Number ex'd	Per cent inf.	Number ex'd	
Connecticut	22	85.7	126	14.3	18	31.7	40	41.2	52	12.7	16	38.6
New York	34	76.8	314	23.2	73	29.2	92	26.1	82	21.5	67	53.8

Percentage of Infected Fish Carrying One or More Species of Parasites

Number of Species of Parasites	Connecticut Percentage	New York Percentage
1 Species	31.5	38.2
2 Species	25.0	34.0
3 Species	30.0	20.3
4 Species	11.1	6.6
5 Species	2.5	—
6 Species	—	0.8
7 Species	—	—

Percentage of Fish Infected with Important Parasites

Parasite	Connecticut Percentage	New York Percentage
Black Grub (*Neascus sp.*)	41.7	16.6
Sand Grain Grub (*Tetracotyle sp.*)	18.5	20.7
Eye Grub (*D. scheuringi*)	17.6	17.4
Others	22.2	45.3

TABLE IX.—*Continued*

Data on Yellow Perch Parasitized by

Degree*	Black Grub (*Crassiphiala bulboglossa*)				Sand Grain Grub (*Tetracotyle sp.*)				Eye Grub (*Diplostomulum scheuringi*)			
	Connecticut		New York		Connecticut		New York		Connecticut		New York	
	Per cent inf.	Number ex'd	Per cent inf.	Number ex'd	Per cent inf.	Number ex'd	Per cent inf.	Number ex'd	Per cent inf.	Number ex'd	Per cent inf.	Number ex'd
L	71.1	32	70	28	85	20	18	9	78.9	15	64.2	27
M	26.6	12	20	8	15	3	18	9	21.1	4	11.9	5
H	2.2	1	10	4	—	—	64	32	—	—	23.8	10
Parasite Index	14.8		24.5		8.8		97.8		10.3		42.5	

*L = Light, M = Medium, H = Heavy.

cut yellow perch are more lightly infected than those from our neighboring state is still evident even when some of the economically important species of parasites are considered.

To be sure, there is not such a striking difference in the case of the black grub (which is the metacercaria of *Crassiphiala bulboglossa*) as more Connecticut fishes carry a medium infection, while the New York yellow perch are more heavily parasitized. Over 41 per cent of infected yellow perch carried this species contrasted with less than 17 per cent in the New York individuals. In the case of the sand grain grub, 64 per cent of the infected New York perch carried heavy infections compared with a complete absence of this category among the Connecticut yellow perch. A similar situation prevails in the case of the eye grub (*Diplostomulum scheuringi*).

Smallmouth bass are nearly always parasitized and they play host to a large number of parasites as nearly 99 and 96 per cent were infected in Connecticut and New York, respectively. The Connecticut bass were fairly evenly divided between light, medium, and heavy infections contrasted with 8, 38.7, and 49.3 per cent in the same groups in those from New York. Contrary to popular impression more Connecticut bass harbor black grubs (metacercariae of *Uvulifer ambloplitis*) than do those from New York, the figures being 76.6 and 65.1 per cent, respectively. When infections with this parasite do occur, however, a larger percentage, from New York carry medium and heavy infections, while 54.2 and 29.2 per cent of those from this State and New York, respectively, support light infections. This difference in the *degree* of infection is again reflected in the parasite index, for Connecticut bass carry only 28.9 per cent black grubs per infected fish, while those from New York support 58.7.

If these two species furnish representative samples of the conditions of parasitism in Connecticut and New York fishes, it becomes apparent how a larger percentage may be infected in Connecticut and yet the actual parasitic burden may be *less*. Perhaps one might logically interpret this phenomenon as an indication that the fishes from Connecticut are healthier than those from other states. This, of course, is debatable. However, it is probable that this condition is rather general for New England and in some way is associated with the absence of waterways communicating directly with the great Ohio-Mississippi watersheds, such as is found in New York. This factor together with the part played by the last glacial periods probably accounts, at least in part, for these differences.

The above discussion has centered about a comparison of parasitism in fishes from Connecticut and New York. It was not possible to make similar comparisons on all species at this time.

However, in the hope of furnishing a useful basis for future study in Connecticut, Table XI is appended. This table furnishes a summary of parasitism and at the same time provides some concept of the frequency of occurrence of various parasites in any particular species of fish.

One other rather striking and perhaps instructive point may be gleaned from Table XI. It is apparent that certain species of fishes harbor more parasites than do others. This is particularly noticeable in such species as the smallmouth bass, common sunfish, rock bass, and other related forms. A comparison of these, with a record of their stomach contents or known feeding habits, demonstrates quite clearly that those fish that feed on insects or insect larvae, crayfish, or other fishes carry the greatest *variety* of parasites. This is true because such carnivorous types engulf many of the smaller animals that serve as intermediate hosts in sufficient quantities to acquire a number of the different parasites carried by them. Conversely, it appears that the fishes that feed primarily on plants or vegetable debris harbor fewer parasites.

In a discussion of this sort it is essential not to lose sight of the fact that with many larval parasites, such as the black grubs, the white grub of the liver, or the yellow grub, infection does not depend upon the actual ingestion of the snail that carried the infective stage of the parasite. The only connection with the food habits of the fishes lies in the fact that certain species swim into the shallower waters to feed on snails or other organisms. Consequently, parasites that penetrate beneath the scales of the fish host may occur with equal frequency on herbivorous and carnivorous fishes.

Such a study would not be complete without a check list of the various parasites encountered. Such a list appears in Table XII.

PART IV. RECOMMENDATIONS AND CONCLUSIONS

This study was undertaken to survey the parasites occurring in the fresh-water fishes of Connecticut. Such a study stressed the distribution, relative abundance, and possible effect of these parasites on their hosts, and attempted to furnish data which may be interpreted in terms of a sound management program for the improvement of fishing. It was also hoped to discover any possible relationship which might exist between parasitism, limnology, growth rate of fishes, natural reproduction, and fishing success. As a result of this study certain conclusions or recommendations seem warranted:

(1) Proper steps should be taken to insure the selection of

TABLE X. SUMMARY OF A COMPARISON OF DATA ON THE SMALLMOUTH BASS FROM LAKES AND PONDS OF CONNECTICUT AND NEW YORK

General Comparisons

	Number of Lakes	Fish		Clean		Light		Medium		Heavy		Parasite Index
		Per cent inf.	Number ex'd	Per cent inf.	Number ex'd	Per cent inf.	Number ex'd	Per cent inf.	Number ex'd	Per cent inf.	Number ex'd	
Connecticut	14	98.8	78	1.3	1	26.9	21	34.6	27	35.8	28	66.4
New York	35	95.5	225	4.4	10	8.0	18	38.2	86	49.3	111	89.86

Percentage of Infected Fish Carrying One or More Species of Parasites

Number of Species of Parasites	Connecticut Percentage	New York Percentage
1 Species	18.2	16.7
2 Species	38.9	38.1
3 Species	19.5	25.1
4 Species	15.6	12.6
5 Species	6.5	4.2
6 Species	1.3	2.3
7 Species	—	0.9

Percentage of Fish Infected with Important Parasites

Parasite	Connecticut Percentage	New York Percentage
Black Grub	76.6	65.1
White Liver Grub	2.5	6.9
Yellow Grub	3.8	5.1
Bass Tapeworm	44.1	74.8
Red Roundworm	2.5	—

TABLE X.—*Continued*

Data on Infected Smallmouth Bass Parasitized With

	Black Grub (*Uvulifer ambloplitis*)				White Liver Grub (*Posthodiplostomum minimum*)				Yellow Grub (*Clinostomum marginatum*)				Bass Tapeworm (*Proteocephalus ambloplitis*)			
	Conn.		New York		Conn.		New York		Conn.		New York		Conn.		New York	
Degree*	Per cent inf.	Number ex'd	Per cent inf.	Number ex'd	Per cent inf.	Number ex'd	Per cent inf.	Number ex'd	Per cent inf.	Number ex'd	Per cent inf.	Number ex'd	Per cent inf.	Number ex'd	Per cent inf.	Number ex'd
L	54.2	32	29.2	41	100	2	26.6	4	100	3	63.6	7	29.4	10	27.1	44
M	34.0	20	40.7	57	—	—	33.3	5	—	—	36.3	4	32.3	11	41.3	67
H	11.4	7	30.0	42	—	—	40.0	6	—	—	—	—	38.2	13	31.4	51
Parasite Index	28.9		58.7		5.0		71.3		5.0		14.0		68.5		60.9	

*L = Light, M = Medium, H = Heavy.

parasite-free stock for stocking purposes in order to avoid further dissemination of important parasites.

(2) The bass tapeworm (*Proteocephalus ambloplitis*) occurs in a number of fishes of Connecticut, especially the small and largemouth bass and yellow perch. It follows that:

(a) Great care should be taken not to introduce this parasite into what now appears to be uninfected or lightly infected waters.

(b) The source of fish used for stocking all ponds and lakes should be carefully examined for the presence of these parasites to insure the introduction of parasite-free fish.

(c) Consideration should be given to the advisability of ceasing to stock certain badly infected lakes, and of draining or poisoning and restocking, or stocking with another species of fish.

(d) Care should also be exercised to avoid transplanting or introducing infected reservoir hosts, as the common sunfish, which might be a factor in further spreading the bass tapeworm.

(3) In view of the importance of such parasites as the sand grain grub and the red roundworm, it is recommended that attention be directed towards an elaboration of their life cycles. It will then be possible to determine whether or not control measures are feasible. In all events the introduction of fish infected with these two parasites into uninfected waters should be avoided.

(4) The following conclusions may be drawn regarding parasitism in general in Connecticut fishes:

(a) Greater numbers of fresh-water fishes of Connecticut are parasitized when comparisons are made with fishes from Oneida Lake, other New York lakes, or Lake Erie.

(b) Fewer species of parasites occur in Connecticut fishes than in the same fishes from New York State or Lake Erie.

(c) A comparison of yellow perch and smallmouth bass from New York and Connecticut shows that Connecticut fishes carry a lighter parasitic burden than do those from New York.

TABLE XI. FREQUENCY OF OCCURRENCE OF VARIOUS PARASITES IN THE FISHES OF CONNECTICUT‡

KEY—*Abundant* means occurring in 70 - 100% of the fish; *Common* means occurring in 30 - 69% of the fish; *Occasional* means occurring in 10 - 29% of the fish; *Rare* means occurring in 0.1 - 9.9% of the fish.

Bold face type indicates parasites of economic importance.

*Immature or larval stage; [1]Also definitive host; [2]Adult; [3]Since identifications have not been completed, these are grouped together; [4]Based on single specimen; [5]Based on two specimens; [6]Based on four specimens; [7]Based on five specimens; [8]For other data see Hunter and Rankin, 1940. Tr. Am. Fish Soc., 69: 268-272.

CHUB SUCKER (*Erimyzon oblongus oblongus*)

RARE

**Diplostomulum sp.*
**Neascus sp.*
Neoechinorhynchus sp.
Octospinifer macilentus

ROCK BASS (*Ambloplitis rupestris*)

ABUNDANT

Uvulifer ambloplitis *

COMMON

Diplostomulum scheuringi *

OCCASIONAL

Posthodiplostomum minimum *

RARE

Proteocephalus sp.
*[1]***Proteocephalus ambloplitis***
Dichylene cotylophora
Capillaria catenata
Spinitectus carolini
Pomphorhynchus bulbocolli

‡It will be noted that throughout the text as well as this table a number of scientific names for the metacercariae of the Strigeidae have been used instead of the names for the adults as indicated by Dubois, 1938. This may be explained by the fact that the writer feels there is still considerable doubt as to the validity of a number of these species and hence used the terms describing the metacercariae until such time as it is possible for experimental studies to reveal the proper relationships of these forms.

CALICO BASS (*Pomoxis nigro-maculatus*)

OCCASIONAL

**Neascus sp.*
**Proteocephalus amboplitis*

RARE

**Diplostomulum sp.*

LARGEMOUTH BASS (*Huro salmoides*)

COMMON

**Uvulifer ambloplitis*
**Proteocephalus ambloplitis*

OCCASIONAL

Leptorhynchoides thecatus

RARE

**Diplostomulum sp.*
[1]*Proteocephalus ambloplitis*
Dichylene cotylophora
Neoechinorhynchus cylindratus
Ergasilus centrarchidarum

COMMON SUCKER (*Catostomus commersonnii*)

OCCASIONAL

[3]Cestodaria
**Tetracotyle communis*
Ergasilus sp.

RARE

**Diplostomulum flexicaudum*
**Diplostomulum sp.*
**Neascus sp.*
**Ligula intestinalis*
Pomphorhynchus bulbocolli
Leptorhynchoides sp.
"Bleeding Scales"

SMALLMOUTH BASS (*Micropterus dolomieu*)

COMMON

**Uvulifer ambloplitis*
*[1]*Proteocephalus ambloplitis*
Proteocephalus sp.
Leptorhynchoides thecatus

OCCASIONAL

Dichylene cotylophora

RARE

Clinostomum marginatum
Posthodiplostomum minimum
Diplostomulum scheuringi
Crepidostomum cornutum
Eustrongylides sp.
Spinitectus carolini
Spinitectus gracilis
Neoechinorhynchus cylindratus
Ergasilus centrarchidarum
Myxobolus sp.
Ichthyophthirius multifiliis

CHAIN PICKEREL (*Esox niger*)

COMMON

Proteocephalus ambloplitis
Proteocephalus pinguis

OCCASIONAL

Trichodina renicola

RARE

Macroderoides flavus
Azygia angusticauda
Diplostomulum sp.
Argulus versicolor
Leptorhynchoides thecatus

COMMON BULLHEAD (*Ameiurus nebulosus*)

OCCASIONAL

Corallobothrium n. sp.
Alloglossidium geminus
Leptorhynchoides thecatus

RARE

Phyllidostomum staffordi
Crepidostomum cornutum
Proteocephalus ambloplitis
Dichylene cotylophora
Agamonema sp.

RED-BELLIED SUNFISH (*Lepomis auritus*)

COMMON

Posthodiplostomum minimum
Uvulifer ambloplitis
Spinitectus gracilis

OCCASIONAL

Diplostomulum scheuringi
Eustrongylides sp.

RARE

Crepidostomum sp.
**Proteocephalus amboplitis*
Proteocephalus sp.
Spinitectus sp.
Ascaroidea
Illinobdella moorei

COMMON SUNFISH (*Lepomis gibbosus*)

COMMON

**Posthodiplostomum minimum*
**Uvulifer ambloplitis*

OCCASIONAL

**Diplostomulum scheuringi*
**Proteocephalus ambloplitis*
[2]Leptorhynchoides thecatus

RARE

Crepidostomum sp.
Crepidostomum cooperi
**Tetracotyle sp.*
**Clinostomum marginatum*
Proteocephalus sp.
Camallanus oxycephalus
**Eustrongylides sp.*
Spinitectus carolini
Spinitectus gracilis
Spinitectus n. sp.
Dichylene cotylophora
Myobolus sp. — liver
Myxobolus sp. — flesh
Bothriocephalus n. sp.

GOLDEN SHINER (*Notemigonus crysoleucas*)

COMMON

**Crassiphiala bulboglossa*

RARE

**Posthodiplostomum minimum*
Plagiocirrus primus
Glaridacris sp.
**Tetracotyle sp.*
**Diplostomulum sp.*
Illinobdella moorei

YELLOW PERCH (*Perca flavescens*)

COMMON

**Neascus sp.*

OCCASIONAL

Crepidostomum cooperi
Bunodera sacculata
**Tetracotyle sp.*
**Diplostomulum scheuringi*
**[2]Proteocephalus ambloplitis*
Dichylene cotylophora

RARE

Proteocephalus pinguis
Proteocephalus sp.
**Posthodiplostomum minimum*
**Clinostomum marginatum*
**Tetracotyle diminuta*
Azygia angusticauda
**Eustrongylides sp.*
Spinitectus carolini
Agamonema sp.
Leptorhynchoides thecatus
Neoechinorhynchus sp.
Furunculosis
Piscicola punctata
Myxobolus sp.
Illinobdella alba

WHITE PERCH (*Morone americana*)

OCCASIONAL

**Diplostomulum scheuringi*
Dichylene cotylophora
*Unidentified degenerating
nematode and cestode cysts.

RARE

Bunodera lucioperca
Crepidostomum cooperi
**Posthodiplostomum minimum*
**Proteocephalus ambloplitis*
Spinitectus carolini
Dichylene robusta
Leptorhynchoides thecatus

BARRED KILLIFISH (*Fundulus diaphanus*)

COMMON

**Crassiphiala bulboglossa*

OCCASIONAL

**Posthodiplostomum minimum*
**Proteocephalus ambloplitis*

RARE

Crepidostomum sp.
**Diplostomulum sp.*
Proteocephalus sp.
**Hymenolepidae*
**Eustrongylides sp.*

BRIDLED MINNOW (*Notropis bifrenatus*)

OCCASIONAL

**N. ptychocheilus*
**Ligula intestinalis*

RECORDS OF DOUBTFUL VALUE

[4]BROWN TROUT (*Salmo fario*)

No Parasites

[7]RAINBOW TROUT (*Salmo gairdnerii*)

COMMON

Crepidostomum farionis
Leptorhynchoides thecatus

[4]EUROPEAN TENCH (*Tinca tinca*)

ABUNDANT

**Strigeidae — Neascus sp.*

[5]FALLFISH (*Leucosomus corporalis*)

COMMON

Neoechinorhynchus cylindratus

[4, 8]GRASS PICKEREL (*Esox americanus*)

ABUNDANT

**Proteocephalus ambloplitis*
Capillaria catenata

[7]ROUND WHITEFISH (*Prosopium cylindraceum quadrilaterale*)

OCCASIONAL

Leptorhynchoides sp.

[6]SOCKEYE SALMON (*Oncorhynchus nerka*)

No parasites

[4]LAKE TROUT (*Cristivomer namaycush*)

No parasites

TABLE XII.

CHECK LIST OF PARASITES FOUND IN FRESH-WATER FISHES OF CONNECTICUT

KEY

*Represents a larval form.

†Also adult.

‡Probably represents several species. Found on scales of yellow perch, golden shiner, sucker, calico bass, and *Fundulus*.

§Are in hard white cysts.

£Species of uncertain identification. Found on golden shiner, barred killifish, and European tench.

PLATYHELMINTHES OR FLATWORMS

TREMATODA OR FLUKES

1. *Crepidostomum cornutum*
2. *Crepidostomum cooperi*
3. *Bunodera lucioperca*
4. *Bunodera sacculata*
5. *Azygia angusticauda*
6. *Plagiocirrus primus*
7. *Alloglossidium geminus*
8. *Macroderoides flavus*
9. **Clinostomum marginatum* — yellow grub
10. *Phyllidostomum staffordi*
11. **Diplostomulum scheuringi* — eye grub
12. **Posthodiplostomum minimum* — white liver grub
13. *‡*Neascus sp.* — black grub
14. **Neascus ptychocheilus*
15. **Crassiphiala bulboglossa* — black grub of perch
16. *§*Tetracotyle sp.* — sand grain grub
17. **Tetracotyle diminuta*
18. *£*Tetracotyle sp.*
19. **Tetracotyle communis*
20. **Uvulifer amblopitis* — black grub of bass
21. **Diplostomum flexicaudum*

CESTODA OR TAPEWORMS

22. *†*Proteocephalus ambloplitis* — bass tapeworm
23. *Proteocephalus pinguis* — pickerel tapeworm
24. *Proteocephalus sp.*
25. *Proteocephalus pearsei*
26. *†*Corallobothrium n. sp.*
27. **Ligula intestinalis*
28. **Hymenolepidae sp.*
29. *Hypocaryophyllaeus paratarius*
30. *Glaridacris confusus*
31. *Glaridacris catostomi*
32. *Bothriocephalus n. sp.*

NEMATHELMINTHES OR ROUNDWORMS

NEMATODA OR THREADWORMS

33. *Camallanus oxycephalus*
34. *Dichylene cotylophora*
35. *Dichylene robusta*
36. *Spinitectus carolini*
37. *Spinitectus n. sp.*
38. *Spinitectus gracilis*
39. **Eustrongylides sp.* — red roundworm
40. *Capillaria catenata*
41. **Agamonema*
42. *Ascaroidea*

ACANTHOCEPHALA OR SPINY-HEADED WORMS

43. *†*Leptorhynchoides thecatus*
44. *Neoechinorhynchus cylindratus*
45. *Neoechinorhynchus sp.*
46. *Pomphorhynchus bulbocolli*
47. *Octospinifer macilentus*

PROTOZOA OR ONE-CELLED ANIMALS

48. *Ichthyophthirius multifiliis*
49. *Microsporidia*
50. *Myxobolus sp.* — small liver cyst
51. *Myxobolus sp.* — small kidney cyst
52. *Myxobolus sp.* — flesh cyst
53. *Trichodina renicola* — bladder

BACTERIA OR PARASITIC PLANTS

54. *Bacterium salmonicida* — furunculosis
55. "Bleeding scales"

ANNELIDA OR SEGMENTED WORMS

HIRUDINEA OR LEECHES

56. *Piscicola punctata*
57. *Illinobdella moorei*
58. *Illinobdella alba*

ARTHROPODA

PARASITIC CRUSTACEA OR FISH LICE

59. *Ergasilus centrarchidarum*
60. *Ergasilus sp.*
61. *Argulus versicolor*

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APPENDIX I.

PONDFISH STOCKING

Following is a list of the waters which have been covered by the survey, together with a list of the species which have been stocked in each body of water during the years covered by departmental records. This list is followed by those game species which are suitable to the water and which should receive attention in the interests of better fishing.

Water	*Past Stocking History*	*Species Recommended for Attention*
Alexander Lake Killingly	Lake trout, white perch, pike perch, yellow perch, rainbow trout, roach, smallmouth black bass, largemouth black bass, pickerel, bullheads, shiners, smelt, calico bass.	Smallmouth black bass.
Ball Pond New Fairfield	Landlocked salmon, lake trout, yellow perch, pike perch, white perch, pickerel, bullheads, smallmouth bass, largemouth bass, calico bass, shiners.	Present fish production satisfactory — no special attention needed.
Bantam Lake Litchfield and Morris	Landlocked salmon, lake trout, smallmouth bass, largemouth bass, yellow perch, pickerel, bullheads, calico bass, white perch, shiners, roach.	Smallmouth bass, yellow perch, chain pickerel.
Basham Lake East Haddam	Pickerel, yellow perch, smallmouth bass, largemouth bass, calico bass, bullheads, shiners, roach, landlocked salmon, rainbow trout.	Smallmouth bass, chain pickerel.
Beardsley Park Pond Bridgeport	Pickerel, yellow perch, calico bass, bullheads, shiners, roach, white perch.	Chain pickerel, yellow perch, common bullhead.

Water	*Past Stocking History*	*Species Recommended for Attention*
Black Rock Pond Watertown	Yellow perch, calico bass, bullheads, shiners, roach, rainbow trout.	Yellow perch, chain pickerel, common bullhead.
Candlewood Lake Danbury, Sherman, Brookfield, New Fairfield and New Milford.	Pickerel, yellow perch, smallmouth bass, largemouth bass, calico bass, bullheads, shiners, roach, pike perch, smelt, white perch, rainbow trout.	Largemouth bass, chain pickerel, yellow perch, white perch.
Cedar Swamp Lake Bristol and Wolcott	Pickerel, yellow perch, smallmouth bass, calico bass, bullheads, shiners, roach, catfish.	Smallmouth bass, yellow perch, chain pickerel.
Columbia Reservoir Columbia	Pickerel, yellow perch, smallmouth bass, calico bass, bullheads, shiners, roach.	Smallmouth bass, yellow perch, chain pickerel.
Crystal Lake Ellington and Stafford	Pickerel, yellow perch, smallmouth bass, largemouth bass, calico bass, bullheads, shiners, roach, landlocked salmon, lake trout, catfish, smelt.	Brook or rainbow trout. Alternative — smallmouth bass, yellow perch, smelt.
Gardner Lake Salem, Montville and Bozrah	Pickerel, yellow perch, smallmouth bass, calico bass, bullheads, shiners, landlocked salmon, lake trout.	Smallmouth bass, yellow perch, chain pickerel.
Green Falls Reservoir Voluntown	Bullheads, calico bass, yellow perch, smallmouth bass, shiners, rainbow trout.	Smallmouth bass.
Hall's Pond Eastford	Pickerel, yellow perch, smallmouth bass, bullheads, shiners, roach, largemouth bass.	Largemouth bass.

APPENDIX I.—*Continued*

Water	*Past Stocking History*	*Species Recommended for Attention*
Highland Lake Winchester	Pickerel, yellow perch, smallmouth bass, calico bass, bullheads, shiners, roach, lake trout, landlocked salmon, smelt, rock bass.	Smallmouth bass, chain pickerel.
Hodge Pond Voluntown	Yellow perch, rainbow trout.	Common bullhead.
Housatonic Lake Derby and Shelton	Pickerel, yellow perch, calico bass, bullheads, shiners, roach, salmon, largemouth bass, white perch.	Black bass, chain pickerel.
Long Pond Ledyard and North Stonington	Pickerel, yellow perch, smallmouth bass, largemouth bass, calico bass, bullheads, shiners, roach, lake trout, landlocked salmon, white perch.	Brook or rainbow trout. Alternative — smallmouth bass.
Mashapaug Lake Union	Pickerel, yellow perch, smallmouth bass, calico bass, bullheads, shiners, roach, landlocked salmon.	Smallmouth bass, chain pickerel.
Moodus Reservoir East Haddam	Pickerel, yellow perch, largemouth bass, calico bass, bullheads, sunfish, rock bass.	Largemouth bass, chain pickerel.
Moriarty's Pond Wilton	Yellow perch, bullheads, calico bass, brook trout, rainbow trout, smallmouth bass.	Brook or rainbow trout.
Mt. Tom Pond Litchfield, Morris and Washington	Lake trout, smallmouth bass, yellow perch, pickerel, calico bass, bullheads, roach, rainbow trout, white perch.	Smallmouth bass, chain pickerel.
North Farms Reservoir Wallingford	Pickerel, yellow perch, calico bass, bullheads, shiners, roach, largemouth bass.	Chain pickerel.

APPENDIX I.—*Continued*

Water	*Past Stocking History*	*Species Recommended for Attention*
Pataganset Lake East Lyme	Pickerel, yellow perch, smallmouth bass, largemouth bass, calico bass, bullheads, shiners, roach, rainbow trout, white perch, rock bass.	Smallmouth bass, chain pickerel.
Peat Works Pond Berlin and Meriden	Pickerel, yellow perch, calico bass, bullheads, shiners, roach, salmon, largemouth bass.	Largemouth bass, chain pickerel.
Pickerel Lake Colchester and East Haddam	Yellow perch, largemouth bass, common bullhead, calico bass.	Largemouth bass.
Lake Pocotopaug East Hampton	Pickerel, yellow perch, smallmouth bass, largemouth bass, calico bass, bullheads, shiners, roach, lake trout, landlocked salmon, white perch.	Black bass.
Powers Lake East Lyme	Lake trout, rainbow trout, yellow perch, bullheads, smallmouth bass, golden shiner, sunfish.	Chain pickerel.
Lake Quassapaug Middlebury and Woodbury	Pickerel, yellow perch, smallmouth bass, largemouth bass, calico bass, bullheads, shiners, roach, lake trout, landlocked salmon, carp, rainbow trout, steelhead trout.	Smallmouth bass, yellow perch, chain pickerel.
Rogers lake Lyme and Old Lyme	Pickerel, yellow perch, smallmouth bass, largemouth bass, calico bass, bullheads, shiners, roach, striped bass, landlocked salmon, rock bass, lake trout.	Smallmouth bass, yellow perch, chain pickerel.

APPENDIX I.—*Continued*

Water	*Past Stocking History*	*Species Recommended for Attention*
Roseland Lake Woodstock	Pickerel, yellow perch, smallmouth bass, largemouth bass, calico bass, bullheads, shiners, roach.	Black bass, yellow perch, chain pickerel.
Samp Mortar Reservoir Fairfield	Pickerel, yellow perch, smallmouth bass, largemouth bass, calico bass, bullheads, shiners, roach, white perch, rock bass.	Largemouth bass, chain pickerel.
Shaw Lake (Hayward) East Haddam	Pickerel, yellow perch, smallmouth bass, largemouth bass, calico bass, bullheads, shiners, roach, lake trout.	Black bass, yellow perch, chain pickerel.
Shenipsit Lake Tolland, Ellington and Vernon	Pickerel, yellow perch, smallmouth bass, largemouth bass, calico bass, bullheads, shiners, roach, landlocked salmon, rainbow trout, lake trout, catfish, smelt.	Largemouth and smallmouth bass, yellow perch, chain pickerel.
Stillwater Pond Torrington	Pickerel, yellow perch, smallmouth bass, calico bass, bullheads, shiners, roach, rainbow trout, largemouth bass.	Black bass, yellow perch.
Taunton Lake Fairfield	Pickerel, yellow perch, smallmouth bass, largemouth bass, calico bass, bullheads, shiners, landlocked salmon, white perch, lake trout, chinook salmon.	Smallmouth bass, white perch.
Lake Terramuggus Marlborough	Pickerel, yellow perch, smallmouth bass, calico bass, bullheads, shiners, roach, largemouth bass.	Chain pickerel, yellow perch black bass.
Trumbull Reservoir Trumbull	Pickerel, smallmouth bass, bullheads, yellow perch, rainbow trout, shiners, white perch.	Yellow perch, chain pickerel.

APPENDIX I.—*Continued*

Water	*Past Stocking History*	*Species Recommended for Attention*
Twin Lake (East) Salisbury	Pickerel, yellow perch, smallmouth bass, largemouth bass, calico bass, bullheads, shiners, roach, landlocked salmon, lake trout, rainbow trout, white perch, smelt, rock bass, sockeye salmon.	Lake trout.
Tyler Pond Goshen	Pickerel, yellow perch, smallmouth bass, calico bass, bullheads, shiners, roach, landlocked salmon, rainbow trout, pike perch, suckers.	Smallmouth bass, chain pickerel.
Lake Waramaug Warren, Washington and Kent	Pickerel, yellow perch, smallmouth bass, calico bass, bullheads, landlocked salmon, lake trout, rainbow trout, smelt, largemouth bass, white perch.	Black bass, chain pickerel.
Waumgumbaug Lake Coventry	Pickerel, yellow perch, smallmouth bass, calico bass, bullheads, shiners, roach, landlocked salmon, lake trout, pike perch, rainbow trout, smelt, white perch, rock bass.	Smallmouth bass, chain pickerel, yellow perch.
West Hill Pond New Hartford	Pickerel, yellow perch, smallmouth bass, calico bass, bullheads, shiners, roach, landlocked salmon, lake trout, brook trout, smelt, rainbow trout.	Rainbow or brook trout.
Willimantic Reservoir Bolton, Coventry and Vernon	Pickerel, yellow perch, smallmouth bass, calico bass, bullheads, shiners, roach, landlocked salmon, crawfish.	Smallmouth bass, chain pickerel, yellow perch.

APPENDIX I.—*Continued*

Water	*Past Stocking History*	*Species Recommended for Attention*
Wattles Pond (Winnemaug Lake) Watertown	Pickerel, yellow perch, smallmouth bass, largemouth bass, calico bass, bullheads, roach, shiners, tench.	Largemouth bass, chain pickerel.
Winchester Lake Winchester	Yellow perch, bullheads, calico bass, roach.	Chain pickerel, yellow perch, bullheads.
Lake Wononscopomuc Salisbury	Pickerel, yellow perch, smallmouth bass, largemouth bass, calico bass, bullheads, shiners, roach, landlocked salmon, lake trout, rainbow trout, smelt, golden trout, menominee whitefish.	Lake trout and rainbow trout.
Zoar Lake Oxford, Newtown and Southbury	Pickerel, yellow perch, smallmouth bass, calico bass, bullheads, shiners, roach, pike prech, white perch, largemouth bass.	Pike perch.

APPENDIX II.

TECHNICAL AND ANALYTICAL METHODS

Morphometric Data

Contours were plotted on maps at intervals of one or two meters; areas were measured directly with the planimeter, and volumes between contours calculated from the formula for the frustum of a cone:

$$V = \frac{A_1 + A_2 + \sqrt{A_1 A_2}}{3} \times D$$

where $V =$ the volume between two contours whose areas are A_1 and A_2, and $D =$ the contour interval; all in metric units. The volumes were summated to give total volume of the lake; mean depth is volume divided by area. Shore lines were traced with a rotameter, and the development of the shore line calculated; this value is the ratio of lake perimeter to the circumference of a circle equal in area to the lake. Drainage basins were measured on U. S. G. S. topographic maps, and the ratio (drainage area: the lake area) calculated.

Temperatures

Temperatures were taken with a Richter-Wiese reversing thermometer, provided with an auxiliary thermometer for correction to within 0.01° C.

Water samples; Transparency; Color

Methods outlined in Section II, Part III.

Plankton

Qualitative samples were taken with 20 cm. plankton net, equipped with No. 20 bolting silk mesh. *Total seston* determined by filtration of 1 liter of surface water through a Pfaltz & Bauer 35-second membrane filter under suction; residue dried for 36 hours at 60° C., weighed, ignited in the Bunsen flame in a silica crucible, and weighed again. Sedgwick-Rafter counts were made on two 1 cc. residues from 200 cc. surface water after filtration through a 1-second membrane filter under suction. Chlorophyll and carotinoid analyses were made colorimetrically, following Riley's[33] modification of the Harvey method.

Bottom Fauna

Methods outlined in Section II, Part III. Weights are "formalin weights".[21]

Chemical Analyses

Oxygen was determined by the Alsterberg modification of the Winkler method, as described by Maucha (1932). This method is clearly the only reliable method in the presence of reducing substances such as organic matter and ferrous iron. Percentage saturation was calculated from the table given by Standard Methods of Water Analysis (8th edition, 1936), correction for barometric pressure being calculated from the elevation using Smithsonian Institution Tables. *Alkalinity* is methyl-orange alkalinity, reported as p.p.m. bicarbonate ion; the use of distilled water saturated with CO_2 as a standard was practiced as recommended by Saunders.[39] pH was determined colorimetrically or potentiometrically, using the glass electrode. *Color* of water (apparent color) was determined according to Standard Methods of Water Analysis, using Hellige discs for standards. *Nitrate* was estimated by the phenol-disulfonic acid method, as recommended by Standard Methods of Water Analysis. *Total Phosphorus* has been determined by the ceruleo-molybdate method of Denigés, using the oxidation technique of Robinson and Kemmerer.[36] *Soluble phosphorus* has been determined by the same method, without preliminary oxidation.[17] *Total iron* was estimated by the potassium thiocyanate method described in Standard Methods of Water Analysis; the dipyridyl method of Hill, as outlined by Cooper[4] has been used in the analysis of *ferrous iron*. *Calcium* was determined by the method of Meloche and Setterquist[24]; *magnesium* by Barnes's[1] variation of the Kolthoff colorimetric method; the Winkler method, as described by Maucha[23] was followed in the determination of *total manganese*. *Silica* was estimated as recommended by Robinson and Kemmerer[37], using picric acid for colorimetric comparison. Analysis of *organic nitrogen* in mud samples was made by the Kjeldahl method, using copper sulphate as catalyst. The mud samples were unwashed Ekman samples from near the maximum depth of the lake.

Oxidation-reduction potentials were determined, using a Leeds & Northrup potentiometer with platinum electrode, the values obtained being referred to the standard hydrogen electrode.[14]

NOTE: All reference numbers refer to literature cited in Section II.

APPENDIX III.

LIMNOLOGICAL MASTER SHEET

	Area (Acres)	Max. Depth (Ft.)	Mean Depth (Ft.)	Ratio Drainage Area: Lake Area	Mean Summer Chlorophyll*	Seston Organic Matter **	Mean Total Phosphorous*	Winter Nitrate*	Bicarbonate**	Mean Transparency (Ft.)	Humus Color**	Bottom Fauna (No. per Sq. Yd.)	Bottom Fauna (Lbs. per Acre)	Oxygen Deficit per Unit Area
Limestone Region														
Queechy Lake, N.Y.	150.1	44	22.6	6.6	5.33	1.79	11.7	49	123.1	18.7	9	1,960	33.1	.0317
East Twin Lake	549.8	75	32.4	2.9	3.01	1.6	11	14	129.6	20.6	10	6,570	147	.0354
Wononscopomuc Lake	352.6	102	36.3	5.09	2.69	0.7	8.4	12	134.0	28.8	10	14,020	108	.0307
Sylvan Lake, N.Y.	125.0	124	70.9		3.96				134.8	27.2				
Western Highland Region														
Highland Lake	434.7	62	19.7	10.59	2.39	1.1	9	48	16.6	18.0	10	9,680	62.5	.0150
West Hill Pond	235.9	59	31.8	2.45	1.10		11	40	12.3	26.5	10	5,330	76.0	
Stillwater Pond	94.4	26.2	11.7	60.7	2.39		9	27	28.7	9.2	25			
Lake Waramaug	698.1	40	22.1	12.11	10.07		9	100	19.5	14.8		19,800	208	
Mt. Tom Pond	59.8	45.5	21.2	6.42	3.74	3.6	12	125	24.1	18.0	15	11,200	194	.0194
Bantam Lake	1001	25	14.3	19.3	14.70		18	96	34.9	7.6	33	10,000	84.7	
Glenida Lake, N.Y.	172	108	49.6	2.52	2.86	1.5	10		61.8	22.9	5			.0188
Ball Pond	89.6	49.2	19.0	2.60	5.54	4.2	14	80	34.6	8.9	15	12,300	168	.0182
Candlewood Lake	5600	85			4.52		10	80	38.6	10.2	13	6,600	36.2	
Lake Quassapaug	289.5	65	28.5	3.16	5.62	1.2	7	10	11.4	24.2	5	15,800	79.5	.0296
Taunton Pond	126.1	29.5	21.5	6.11	2.78		13		22.7	23.0	5	5,350	56.0	
Lake Zoar	984	78.7	24.6		6.21		31		122.7	13.8	15			
Lake Housatonic	320	21.3	8.7		5.32		13		148.2	7.2	20			
Trumbull Reservoir	50.6	26.2	13.0	171	5.90				26.6	6.6	30	3,500	11.6	
Moriarty's Pond	19.0	26.2	16.1	40.19	8.23		9		22.8	18.0	15	12,400	34.5	
Samp Mortar Reservoir	47.6	26.2	10.1	380	11.50		10		20.6	10.2	25	12,200	30.6	
Beardsley Park Pond	46.0	21.3	11.2	335	6.20		20		21.7	7.2	30	15,800	85.1	
Lowland Region														
Silver Lake	138	12.8	4.6	10.69	14.80		30		66.5	3.6	35			
Job's Pond	33.4	44.3	21.6	4.6	7.65	1.9	17	57	11.7	12.5	15			.0247
Black Pond					7.55		21	17	41.4	13.8				
Beseck Lake	117.2	26	12.5	11.36	13.56		31	41	33.2	4.9	27	5,180	30.2	
Dooley's Pond					58.40		109	160	37.2		40			
North Farms Reserv.	63.1	9.2	3.5	6.86	23.80		10		42.4	3.3	40	12,200	67.0	
Lake Quonnipaug	115.0	48.5	16.7	16.0	6.11	1.1	10	33	33.1	12.5	13			.0273
Linsley Pond	23.3	48.5	22	20.3	15.25	2.9	21	122	62.5	8.5	27	24,600	312	.0418
Eastern Highland Region														
Lake Mashapaug	302	36	14.8	1.73	1.91	1.7	5		9.6	11.5	10	4,330	43.7	.0169
Shenipsit Lake	[illegible]	65	27.6	20.0	1.10	1.6	5		16.0	18.0	15	4,250	28.4	.0276
Crystal Lake	201.0	47.6	21.9	6.7	3.53	1.2	11	60	12.3	13.1	15	1,920	9.7	.0252
Roseland Pond	89.1	19.7	10.1		4.80		13		29.6	8.2	30			
Alexander Lake	191.2	50.8	21.4	3.28	3.35		11	20	11.5	26.2	5	6,210	40.6	
Hall Pond	82.3	13	7.6	9.36	3.49		11		19.3	9.2	25			
Lake Waumgumbaug	376	39	29	4.56	3.16	1.2	11		5.5	20.0	15	19,700	210.	.0256
Columbia Lake	281.7	25.6	16.7	7.33	5.64		21	41	13.8	16.4	30	4,730	58.5	
Terramuggus Lake	81.2	37.4	17.7	4.16	0.96	1.0	12	24	13.4	19.6	10	19,300	80.1	
Lake Pocotopaug	510.5	36.1	12.5	4.4	6.37	4.5	14	33	13.3	18.7	10	6,050	70.0	.0119
Pickerel Lake	87	7.9		11.21	2.87		8		12.9	6.6	55	3,130	7.2	
Moodus Reservoir	451	9.5		9.42	5.45	3.2	12	38	14.6	6.2	55	3,790	18.6	
Bashan Lake	274	45.9	16.2	3.97	2.08	1.3	17		9.4	26.9	5	9,000	72.6	.0128
Hayward Lake	193	37.4	10.0	5.4	2.54	3.2	11	40	13.0	17.7	23	11,300	97.9	
Gardner Lake	484.1	45.6	14.7	6.74	3.45	1.0	10	40	13.4	13.1	25	1,440	21.2	
Green Falls Reserv.	46.9	29.6	13.4	16.06	3.06		4	120	9.8	13.1	25	2,770	13.7	
Rogers Lake	265.5	65	19.5	16.07	2.87	1.5	8		15.3	17.0	15	14,700	67.6	.0310
Powers Lake	151.7	13	8.3	6.6	5.07		9	30	14.4	13.1	30	6,880	23.1	
Pataganset Lake	120.0	36.8	12.6	23.48	4.07	1.6	14	54	13.4	13.1	25	4,080	25.9	.0202
Long Pond	98.5	68.5	13.9	20.68	3.54	2.1	8	40	16.5	13.1	30	10,100	53.8	.0184

* Parts Per Billion
** Parts Per Million

APPENDIX IV.

Master sheet showing occurrence of species in Connecticut lakes covered by the 1937, 1938 and 1939 surveys. An "X" indicates species collected or observed by survey; numeral "1" indicates species reliably reported.

	Bowfin	Round Whitefish	Sockeye Salmon	Brown Trout	Rainbow Trout	Lake Trout	Brook Trout	Smelt	Common Eel	Common Sucker	Chub Sucker	Carp	Tench	Golden Shiner	Fallfish	Horned Dace	Black-nosed Dace	Bridled Minnow	Spot-tail Minnow	Common Shiner	Cut-lips Minnow	Common Bullhead	Grass Pickerel	Chain Pickerel	Barred Killifish	Largemouth Black Bass	Smallmouth Black Bass	Calico Bass	Blue-gill Sunfish	Red-bellied Sunfish	Common Sunfish	Rock Bass	Banded Sunfish	Pike Perch	Yellow Perch	Johnny Darter	Fusiform Darter	White Perch
Alexander Lake										1				x				x				x		x	x		x			x	x				x			x
Ball Pond											x			x								x		x		x		x		x	x				x	x		x
Bantam Lake										x				x				x				x		x	x	x	x	x		x	x				x	x		x
Basham Lake														x					x	x		1		x	x	x	x				x				x			
Beardsley Park Pond									x	x				x					x			1		x	x			x			x				x			
Black Rock Pond							x			x	x			x	x	x	x					x		1							x				1			
Candlewood Lake					x							x		x	x				x			x		x	x	x	x	x		x	x	x		x	x			x
Cedar Swamp Lake											x			x								x		x	x	x	x				x				x			
Columbia Lake										x				x	x							x		x	x		x	x	x	x	x				x			
Crystal Lake								x						x								x		x	x		x				x				x			
Gardner Lake														x				x				x		x	x		x	x		x	x				x			
Green Falls Reservoir					x				x	x				x								x		x			x	x			x		x		x			
Halls Pond														x								x		x		x	x				x				x			
Highland Lake										x				x								x		x		x	x				x	x			x			
Hodge Pond											x											x													x			
Housatonic Lake										x		x		x	x		x		x	x		1		1		x	x		x	x		x			x	x		x
Long Pond											x			x				x				1		x			x				x				x			
Mashapaug Lake										x				x				x				x		x			x				x				x			
Moodus Reservoir																		x				x		x		x					x				x			
Moriarty's Pond					x		x							x										x			x				x				x			
Mount Tom Pond														x								x		x	x		x				x				x			1
North Farms Reservoir											x			x				x				x		x		x		x			x				x			
Pataganset Lake														x				x				x		x	x		x	x			x	x			1		x	x
Peat Works Pond											x			x				x				x		x	x	x		x			x				x			
Pickerel Lake														x										x			x	x			x				x			
Pocotopaug Lake														x								x	x	x	x	x	x	x			x		x		x	x		
Powers Lake														x								1		x							x				x			
Quassapaug Lake					x									x				x		x		x		x			x				x				x	x		
Rogers Lake									x		x			x				x				x		x	x		x	x			x		x		x	x		
Roseland Lake														x								x		x		x	x	x			x				x			
Samp Mortar Reservoir										x	x			x				x				x		x		x					x				x			x
Shaw Lake														x				x				1		x	x	x	x	x			1				x			
Shenipsit Lake								x		x				x	x					x		x	x	x	x	x	x	x			x				x			
Stillwater Pond					x					x				x				x				x		x	x		x	x		x	x				x			
Taunton Pond										x				x								1		x	x	x	x			x	x				x	x		x
Terramuggus Lake											x			x								1		x	x	x	x				x				x			
Trumbull Reservoir				x	x					x				x				x				1		x	x					x	x				x			x
Twin Lake (East)		x	x			x				x				x				x				1		x	x	x	x				x				x			x
Tyler Pond										x	x			x				x				1			x		x			x	x				x	x		
Waramaug Lake										x				x	x							x			x	x				x	x				x	x		x
Waumgumbaug Lake														x	x			x				x		x	x		x			x	x				x			
West Hill Pond					x		x							x								1		1			x				1				x			
Willimantic Reservoir										x	x			x				x				x		x	x		x				x				x			
Wattles Pond											x		x	x								1		x		x	x				x				x			
Winchester Lake														x				x				x		x							x				x			
Wononscopomuc Lake					x	x				x				x								x		x	x	x	x			x	x	x			x	x		
Zoar Lake	x				x		x			x		x		x	x				x	x	x	x			x	x	x	x		x	x	x			x	x		x

APPENDIX V.

SUMMARY OF INFORMATION AND RECOMMENDATIONS FOR THE IMPROVEMENT OF FISHING*

Within the following pages is presented a brief résumé of the data which has been gathered on each important lake studied, together with recommendations for the improvement of fishing. The numerous technical complexities which exist in each body of water are not discussed because these things have no general interest and are merely a means to an understanding of the fundamental problems so that fishing may be improved. The fishery biologist must necessarily deal with a mass of detailed technical data in order to fully appreciate the problems in any body of water. However, when such investigational work is sponsored by a public conservation agency, the biologist should feel an obligation to report the pertinent facts and make recommendations in terms which require no specialized training to understand.

It will be noted that the recommendations are simple and are entirely possible to put into operation under Connecticut conditions. They are based on a systematic interpretation of known facts with the exception of certain recommendations to *stock specific numbers* of fish. These recommendations are an estimate of the extent of stocking necessary to accomplish the purpose in mind, for as has been pointed out in Section I, it is impossible to derive such figures from an interpretation of Survey data. Some readers may be surprised that an extensive stocking program has not been proposed. An honest interpretation of the data gathered by the Survey fails to show *the need or the desirability* for extensive stocking of pond fishes and indicates where considerable money can be diverted to other phases of fish restoration where it is badly needed.

It is hoped that the recommendations which are presented will stimulate sportsmen and riparian property owners to cooperate in improving fishing in their localities. It is quite obvious that many of the improvement measures can best be carried on by local groups working with the State Board of Fisheries and Game. The ideal arrangement consists of a local group accepting responsibility for carrying out part of the Survey recommendations on the lakes in which they are particularly interested. Such groups should correlate their activities such as shore improvement, removing weed species and reporting observations on fishing conditions with the activities of the State Board, the latter to act as a fact finding and advisory agency, to supply all posters and fish which are needed for stocking.

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*Recommendations for the improvement of fishing should not be regarded as being in effect until so announced by the Board.

In the discussion of each lake, a list of the various species which have been stocked in that body of water in the past is given. This is no indication that all of the species stocked were successful and became established. In most cases quite the contrary was true, and only those species best suited to the waters survived. It is apparent that many species which are not highly regarded by anglers were introduced and became established at the expense of more valuable game fish.

ALEXANDER LAKE, Killingly

Description

Area, 191.2 acres. Maximum depth, 50.8 feet. Average depth, 21.4 feet. Natural in origin; formed by two basins nearly separated by a sand bar. Source, ground water and springs. Shoreline largely composed of small round stones and almost completely barren of aquatic vegetation; extensive areas of submerged vegetation below the zone of wave action. Plankton and bottom food values low.

Development

Privately owned, formerly a water supply for village of Goodyear. Cottages numerous on north shore. Boat livery present. Shore largely wooded.

Notes on Fish Life

Species stocked: yellow perch, chain pickerel, common bullhead, smallmouth and largemouth bass, calico bass, sunfish, white perch, pike perch, golden shiners, rainbow trout, lake trout and smelt.

Yellow perch numerous and badly stunted. Smallmouth bass grow rapidly but are not abundant. Common sucker reportedly very abundant. Forage species scarce. Marked absence of young smallmouth bass along the shore, possibly due to the lack of suitable cover.

Recommendations for the Improvement of Fishing

Adapted for smallmouth bass, but decided need of shore cover for young bass; this could be supplied by submerged brush or piles of large rocks. Suitable bass spawning areas should be protected prior to July 1st. Increase legal length of bass to 12 inches.

Legal length and daily catch limit on yellow perch should be suspended temporarily; more drastic methods of removal advisable.

Marginal trout water, but not recommended for trout management.

BALL POND, New Fairfield

Description

Area, 89.9 acres. Maximum depth, 49.2 feet. Average depth, 19 feet. Natural in origin, but level raised about three feet. Fed by ground water. Shoreline rocky with sparse emergent vegetation; dense beds of submerged and floating leafed vegetation at south end. Thermally stratified; bottom waters deficient in oxygen. Average amount of plankton and bottom fauna.

Development

Privately owned with numerous cottages. Boat livery present. Shores partially wooded.

Notes on Fish Life

Species stocked: yellow perch, chain pickerel, common bullheads, smallmouth and largemouth bass, calico bass, white perch, pike perch, lake trout and landlocked salmon.

White perch abundant and attain a good size. Fish production appears good despite heavy fishing.

Black grubs and bass tapeworm are the important fish parasites present.

Recommendations for the Improvement of Fishing

No changes recommended at present. Not suitable for development as trout waters. No stocking.

BANTAM LAKE, Litchfield and Morris

Description

Area, 1,001 acres. Maximum depth, 45 feet. Average depth, 14.3 feet. Largest natural body of water in Connecticut; level has been raised so that maximum possible fluctuation is 7½ feet. Inlet and outlet in close approximation at north end. Shoreline rocky on east and west sides; south and north ends relatively flat with considerable submerged and emergent vegetation. Extensive shoals in North Cove. Basic fertilizers and plankton values high but bottom food poor. Copper sulphate treatments carried out for at least 16 years.

Development

Privately owned; flowage rights owned by utilities company. Numerous cottages. Boat livery present. White Memorial Foundation property borders on north and east shores.

Notes on Fish Life

Species stocked: yellow perch, chain pickerel, common bullheads, largemouth and smallmouth bass, calico bass, sunfish, white perch, golden shiners, lake trout, landlocked salmon.

White and yellow perch abundant and badly stunted.

Fished heavily both summer and winter with relatively poor results.

Bass heavily parasitized with bass tapeworm.

Recommendations for the Improvement of Fishing

Manage for smallmouth bass, chain pickerel, and yellow perch. Drastic reduction of the white perch, yellow perch and calico bass populations recommended; temporarily suspend all catch regulations on these three species.

Protect spawning areas for bass prior to July 1st; increase legal length on bass to 12 inches and reduce catch limit to 6 fish per day. Increase legal length of chain pickerel to 16 inches and reduce daily catch limit to 6 fish.

Discontinue further copper sulphate treatment.

BASHAM LAKE, East Haddam

Description

Area, 274 acres. Maximum depth, 47.5 feet. Average depth, 16.2 feet. Artificial in origin; fed by small tributary and ground water. Shoreline largely rocky with scant marginal vegetation; submerged weed beds extensive due to exceptional transparency of the water. Plankton low and bottom fauna average. Thermally stratified. Water level fluctuates.

Development

Privately owned. Few cottages; boat liveries present. Shores entirely wooded.

Notes on Fish Life

Species stocked: yellow perch, chain pickerel, common bullheads, largemouth and smallmouth bass, calico bass, sunfish, golden shiners, rainbow trout and landlocked salmon.

Smallmouth black bass stunted; younger age groups abundant. Parasitized with tapeworm and black grubs.

Forage fish scarce.

Recommendations for the Improvement of Fishing

Manage for smallmouth bass. Fluctuation in water level may have adverse effect on fish life. Increase legal length of chain pickerel to 16 inches. No stocking recommended.

BEARDSLEY PARK POND, Bridgeport

Description

Area, 46 acres. Maximum depth, 21.3 feet. Average depth, 11.2 feet. Artificial in origin; created by damming Pequonnock River. Shoreline largely with dense growth of submerged and marginal vegetation. Bottom water deficient in oxygen. Plankton and bottom fauna production good.

Development

Publicly owned by City of Bridgeport. No cottages. Boat livery present. Shores largely open. Under special regulation by the State Board of Fisheries and Game through cooperative agreement with the Park Commission of the City of Bridgeport.

Notes on Fish Life

Species stocked: yellow perch, chain pickerel, common bullheads, calico bass, sunfish, white perch and golden shiners.

Trout are occasionally taken but these are probably temporary residents from the inlet. Chemical data indicate that this water is not suitable for trout management.

Large common suckers and golden shiners abundant.

No important fish parasites except black grubs.

Recommendations for the Improvement of Fishing

Manage for chain pickerel, yellow perch and common bullheads.

Encourage increase of pickerel to utilize apparent abundance of forage fishes; increase legal length to 16 inches and reduce daily catch limits to 6 fish per day. Temporarily suspend all ice fishing.

The heavy fishing burden and small size of this water warrants stocking with adults of the species recommended. No stocking with fingerlings or fry.

BLACK ROCK POND, Watertown

Description

Area, 9.3 acres. Maximum depth, 16 feet. Artificial in origin; fed by cold spring tributary.

Development

Publicly owned (State Park). Boats not allowed. No cottages.

Notes on Fish Life

Young golden shiners and common sunfish abundant. Brook trout in inlet. Species stocked: yellow perch, common bullheads, calico bass, sunfish, golden shiners and rainbow trout.

Recommendations for the Improvement of Fishing

Manage for chain pickerel, yellow perch and common bullheads.

Small size and heavy concentration of anglers warrant stocking with adults of species to be favored. No fingerling stocking recommended.

CANDLEWOOD LAKE, New Fairfield, Danbury, Sherman, New Milford, and Brookfield

Description

Area, 5,600 acres. Maximum depth, 85 feet, but the depth of most of the coves is less than 50 feet. Artificial in origin, including in its basin Neversink, Squantz and Barses Ponds. (Impounded in 1923.) Fed by tributaries and water pumped from the Housatonic River. Water used to generate electricity and this results in considerable fluctuation of water level. The long shoreline provides a variety of fish habitats ranging from rocky cliffs to dense growths of aquatic vegetation. Water is deficient in nutrient substances and low in plankton and bottom fauna. Oxygen deficiency at all depths below 30 feet in summer.

Development

Privately owned with extensive localized shore development. Several boat liveries. Shoreline largely wooded.

Notes on Fish Life

Species stocked: yellow perch, chain pickerel, common bullheads, largemouth and smallmouth bass, calico bass, sunfish, white perch, pike perch, golden shiners, rainbow trout and smelt.

White perch are extremely abundant, attain fair size and are caught in almost commercial quantities. Fishing for black bass is moderately good, although the younger age groups of largemouth bass are abundant in the weedy covers. Smallmouth bass are not well suited for this water. Heavy plants of pike perch for four years have produced only limited winter fishing and scarcely any summer fishing; there is no evidence of the natural reproduction of this species. The large number of two-year old rainbow trout stocked provided relatively poor fishing, although an occasional rainbow trout is still taken. Physical and chemical data show that this water is not suitable for trout management. Smelt have been stocked for a number of years, but have never become established.

Recommendations for the Improvement of Fishing

Manage for largemouth bass, white perch, yellow perch and chain pickerel.

Increase legal length on black bass to 12 inches, and on chain pickerel to 16 inches. Establish protected spawning areas for bass. Temporarily restrict the catch limit on chain pickerel to 6 fish and give complete protection during the ice fishing season.

White perch have apparently not suffered adversely despite prodigious numbers removed during the past several years. Checks on anglers' catches and growth rate studies indicate that under the original regulations cropping was efficient. The law has recently been revised to reduce the catch limit to 15 fish; however, it is thought advisable to restore the original limit of 30 fish as there is possible danger of stunting if the fish become over-abundant.

Further plants of pike perch and rainbow trout not recommended. Natural reproduction of suitable species appears adequate.

COLUMBIA LAKE, Columbia

Description

Area, 281.7 acres. Maximum depth, 25.6 feet. Average depth, 16.7 feet. Artificial in origin. Fed by small tributary. Shoreline entirely rocky, but extensive beds of submerged vegetation below the zone of wave action. No thermal stratification. Plankton and bottom fauna production average.

Development

Publicly owned by the town of Columbia. Numerous cottages. Boat liveries present. Shoreline largely wooded. Under special regulation by State Board of Fisheries and Game through cooperative agreement with the Town of Columbia.

Notes on Fish Life

Species stocked: yellow perch, chain pickerel, common bullheads, smallmouth bass, calico bass, sunfish and golden shiners.

Smallmouth bass and yellow perch are abundant and furnish good fishing. Calico bass were recently introduced and are apparently becoming established; this species is regarded as an unwise addition and every effort should be made to discourage its increase.

Reproduction of bass and yellow perch is very successful and has been adequate to supply good fishing in the past.

Golden shiners are scarce and the principle forage for all large fish, including pickerel, is crayfish.

Important fish parasites: black grubs numerous in smallmouth bass; light infestation of bass tapeworm.

This lake has been under special regulation since 1937; these regulations include reduction of the daily creel limit, increase in legal length, protecting bass spawning areas and limiting the ice fishing season. Fishing has definitely improved since these regulations have been in effect. Smallmouth bass, in particular, have responded to this treatment.

Recommendations for the Improvement of Fishing

Manage primarily for smallmouth bass and yellow perch. Continue the following special regulations: smallmouth bass, 12 inches (6 per day) and chain pickerel, 6 fish per day; ice fishing prohibited after December 31st. These changes are recommended: increase legal length on chain pickerel to 16 inches; remove all catch restrictions on calico bass.

Protect bass spawning areas.

No stocking recommended.

CRYSTAL LAKE, Ellington and Stafford

Description

Area, 201 acres. Maximum depth, 47.6 feet. Average depth, 21.9 feet. Natural in origin with level raised. Fed by small tributaries and bottom springs. Shoreline partly rocky with stretches of sand, mud and marginal vegetation. Low in plankton and bottom fauna. Thermally stratified and bottom waters not deficient in oxygen.

Development

Privately owned, but water used for industrial purposes. Boat livery present. Shores largely wooded.

Notes on Fish Life

Species stocked: yellow perch, chain pickerel, common bullheads, smallmouth and largemouth bass, calico bass, sunfish, golden shiners, lake trout, landlocked salmon, smelt and catfish.

Fishing for smallmouth bass and yellow perch fair. Ice fishing permitted and some smelt are taken by this method.

Recommendations for the Improvement of Fishing

Under proper management would be suitable for brook or rainbow trout. This, however, would entail removal of present warm-water fish population, probably by poisoning. Such a procedure may be warranted since at present there are no lakes being managed for trout in the eastern part of the state and this is one of the few waters in this region suitable for trout management.

If management for trout is found to be impracticable, manage for smallmouth bass, yellow perch and smelt. Bass and smelt spawning areas should be protected, the legal length of bass increased to 12 inches and the daily creel limit reduced to 6 fish.

GARDNER LAKE, Salem, Montville and Bozrah

Description

Area, 485.1 acres. Maximum depth, 45.6 feet. Average depth, 14.7 feet. Natural in origin with level raised. Fed by small tributaries; considerable fluctuation in water level each year. Extensive gravel shoals, mud flats and areas with marginal vegetation when high water level is maintained. Because of the extensive shoal areas, slight decreases in water level result in the exposure of considerable food-producing areas. Plankton and bottom fauna production average. Thermally stratified and bottom waters deficient in oxygen.

Development

Privately owned, but water rights controlled and used for industrial purposes. Boat livery present. Numerous cottages. Shoreline largely wooded. Under special regulation by the State Board of Fisheries and Game through cooperative agreement with property owners.

Notes on Fish Life

Species stocked: yellow perch, chain pickerel, common bullheads, smallmouth bass, calico bass, golden shiners, lake trout and landlocked salmon.

Smallmouth bass grow well and furnish fair fishing. Yellow perch are stunted.

The excessively low water levels suffered during the summer season probably have a marked effect upon fishing. Observations on two successive years, one in which the water level was low and another during which it was high, showed marked differences in fish life. High water resulted in an abundant growth of vegetation and large numbers of young game fish and minnows were present. These were conspicuously absent during the low water year.

Recommendations for the Improvement of Fishing

Manage primarily for smallmouth bass, yellow perch and secondarily for chain pickerel.

Water level fluctuation should be held at minimum, particularly in spring and early summer. Protect bass spawning areas. Special legal lengths and creel limits now in effect, which should be continued, are: black bass, 12 inches (6 per day) and chain pickerel, 16 inches (6 per day). The legal length of yellow perch should be returned to 7 inches. Close to ice fishing.

GREEN FALLS RESERVOIR, Voluntown

Description

Area, 46.9 acres. Maximum depth, 29.6 feet. Mean depth, 13.4 feet. Artificial in origin. Fed by two small tributaries and springs. Shoreline largely marginal aquatic vegetation; some ledges and boulders. Plankton and bottom fauna low. Thermally stratified and oxygen deficiency in bottom water.

Development

Publicly owned (in State Forest). No cottages. No boat livery, but privately owned boats permitted. Picnic facilities available.

Notes on Fish Life

Species stocked: yellow perch, common bullheads, smallmouth bass, calico bass, golden shiners, and rainbow trout.

This pond was formerly stocked with large numbers of legal size rainbow trout. Catch records indicated only a small return was made from these plants. The Survey showed that this is definitely not trout water.

Smallmouth and calico bass are established and provide fair fishing.

Recommendations for the Improvement of Fishing

Due to low food production and small size, this pond will probably never support a heavy concentration of anglers. Since smallmouth seem well established, it appears wise to favor them in this water. Spawning areas should be established and a 12 inch legal length imposed. Natural reproduction might be supplemented by stocking with bass fry.

HALL'S POND, Eastford

Description

Area, 82.3 acres. Maximum depth, 13 feet. Mean depth, 7.6 feet. Artificial in origin. Shoreline with weedy areas, stumps, gravel and sand. Numerous small islands with gravel and rocky shores.

Development

Privately owned. Several cottages. Boat livery. Shores entirely wooded. Under special regulation by the State Board of Fisheries and Game through cooperation with property owners.

Notes on Fish Life

Species stocked: yellow perch, chain pickerel, common bullheads, largemouth and smallmouth bass, sunfish, and golden shiners.

Largemouth bass provide good fishing. Golden shiners are abundant.

All species of fish heavily parasitized; black, yellow, eye and white grub of liver present.

Recommendations for the Improvement of Fishing

Manage for largemouth bass. Increase legal length of largemouth to 14 inches. Regulations on other species as prescribed by State law. Protect bass spawning areas.

HIGHLAND LAKE, Winchester

Description

Area, 434.7 acres. Maximum depth, 62 feet. Mean depth, 19.7 feet. Natural in origin with level raised and composed of three basins, of which the middle one is the deepest. Thermal stratification with oxygen deficiency in deep waters. Shoreline composed largely of boulders and rocks; extensive flats on upper basin. Fed by tributaries. Plankton and bottom fauna low.

Development

Privately owned and water rights used for industrial purposes. Considerable fluctuation of water level. Numerous cottages. Boat liveries present. Shoreline largely wooded.

Notes on Fish Life

Species stocked: yellow perch, chain pickerel, common bullheads, largemouth and smallmouth bass, calico bass, rock bass, sunfish, golden shiners, lake trout, landlocked salmon and smelt.

Yellow perch stunted.

Lowering water level exposes only shoal areas of lake and may be a serious limiting factor in fish production.

Bass tapeworm, black and yellow grubs and red roundworm are present in several species of game fish.

Recommendations for the Improvement of Fishing

Fluctuations in water level should be reduced to a minimum and, if possible, eliminated during spring and early summer.

Manage for smallmouth bass. Increase legal length to 12 inches and reduce creel limit to 6 fish. Establish bass spawning areas. Increase the legal length of chain pickerel to 16 inches and reduce catch limit to 6 per day. Increase creel limit of yellow perch to 30 and restrict ice fishing to this species.

If water level is lowered during late spring, stocking with smallmouth bass is considered advisable.

HODGE POND, Voluntown

Description

Area, 5 acres (estimated). Maximum depth, 6 feet. Artificial in origin; fed by springs. A mud hole with extensive weed areas along the shores and covering the bottom. Food production high.

Development

Owned by State of Connecticut (State Forest). No cottages. No boat livery. Shore entirely wooded.

Notes on Fish Life

Species stocked: yellow perch and rainbow trout.

This water was formerly stocked with two-year old rainbow trout, but is entirely unsuited for this species.

Recommendations for the Improvement of Fishing

Manage for bullheads.

Discontinue all stocking of rainbow trout and other species. In a small pond of this type it is easy to create an over-populated condition by excessive stocking.

HOUSATONIC LAKE, Shelton and Derby

Description

Area, 320 acres. Maximum depth, 21.3 feet. Mean depth, 8.7 feet. Artificial in origin. A long, narrow lake formed by damming the Housatonic River at Shelton. Shoreline of sand and rocks. Luxuriant growth of marginal and submerged vegetation. Plankton and bottom fauna production average. Considerable fluctuation in water level.

Development

Privately owned and water used for water power. Few cottages and State Park. Boat livery. Shores largely wooded.

Notes on Fish Life

Species stocked: yellow perch, chain pickerel, common bullheads, largemouth and smallmouth bass, calico bass, sunfish, white perch, golden shiners and salmon.

Recommendations for the Improvement of Fishing

Management recommendations difficult to make because of constantly changing conditions. Increase legal length of black bass to 12 inches and of chain pickerel to 16 inches.

LONG POND, Ledyard and North Stonington

Description

Area, 98.8 acres. Maximum depth, 68.5 feet. Mean depth, 13.9 feet. Natural in origin with level raised and maintained by two dams, one about 20 feet and another about three. Shoreline of rocks and boulders; extensive shallow, weedy cove on east shore. Thermally stratified.

Development

Privately owned. Several cottages. No boat livery. Shore entirely wooded.

Notes on Fish Life

Species stocked: yellow perch, chain pickerel, common bullheads, smallmouth and largemouth bass, calico bass, sunfish, white perch, golden shiners, lake trout and landlocked salmon.

Fair fishing for smallmouth bass.

Deep basin of lake is well suited for brook or rainbow trout.

Recommendations for the Improvement of Fishing

Manage for brook or rainbow trout. Removal of all warm-water species, probably by poison, necessary before stocking with trout.

If this is impracticable, manage for smallmouth bass.

MASHAPAUG LAKE, Union

Description

Area, 302 acres. Maximum depth, 65 feet. Average depth, 27.6 feet. Natural in origin with level raised; fluctuations in water level; fed by tributaries. Several islands. Shoreline almost entirely rocky; beds of submerged vegetation below the zone of wave action. Thermally stratified, but bottom water deficient in oxygen. Plankton and bottom fauna production low.

Development

Privately owned and water used for industrial purposes. Few cottages. No boat livery. Shore entirely wooded.

Notes on Fish Life

Species stocked: yellow perch, chain pickerel, common bullheads, smallmouth bass, calico bass, sunfish, golden shiners and landlocked salmon.

This lake is well suited for smallmouth bass, but continual lowering of the water level during the spring and summer prevent it from furnishing the best possible fishing. The shores provide excellent spawning grounds for smallmouth if the water level is maintained. Young smallmouth bass and golden shiners are scarce.

Red roundworms and black grubs are important parasites present.

Recommendations for the Improvement of Fishing

Manage for smallmouth bass. Fluctuations in water level should be held to a minimum, particularly during the spring and early summer. Increase legal length of bass to 12 inches and reduce the creel limit to 6 fish per day. Protect bass spawning areas.

Increase legal limit of chain pickerel to 16 inches and reduce creel limit to 6 per day.

Stock with smallmouth bass as long as present fluctuation of water level continues.

MOODUS RESERVOIR, East Haddam

Description

Area, 451 acres. Maximum depth, 9½ feet. Artificial in origin; fed by tributaries. Shoreline almost entirely weedy with dense beds of submerged vegetation. Water brown in color from peat extractives.

Development

Privately owned. Few cottages. Boat liveries present.

Notes on Fish Life

Species stocked: yellow perch, chain pickerel, common bullheads, largemouth bass, calico bass, rock bass and sunfish.

Good largemouth bass fishing.

Recommendations for the Improvement of Fishing

Manage for largemouth bass and chain pickerel. Increase legal length of bass to 12 inches and of chain pickerel to 16 inches. Protect bass spawning areas.

No stocking recommended.

MORIARTY'S POND, Wilton

Description

Area, 19.2 acres. Maximum depth, 26 feet. Average depth, 16.1 feet. Artificial in origin; fed by a small tributary. Shoreline largely ledges dropping off into deep water. Thermally stratified.

Development

Privately owned; reserve water supply. No cottages. No boats allowed. Shores partly wooded.

Notes on Fish Life

Species stocked: yellow perch, common bullheads, smallmouth bass, calico bass, rainbow trout and brook trout.

Spawning grounds for warmwater fish largely absent. Fish life not abundant.

Recommendations for the Improvement of Fishing

This is not ideal trout water, but it can be made to support a limited amount of brook or rainbow trout fishing. If managed for trout, it is important that no warmwater species be stocked.

MT. TOM POND, Litchfield, Morris and Washington

Description

Area, 59.8 acres. Maximum depth, 45.5 feet. Average depth, 21.2 feet. Natural in origin; fed by springs. Shoreline with considerable marginal vegetation, gravel, rocks and mud. Thermal stratification with a considerable amount of the bottom waters deficient in oxygen. Plankton production fair and bottom food abundant.

Development

Few cottages. Boats usually available. Shores largely wooded. Part of shoreline owned by State Park and provides picnic facilities.

Notes on Fish Life

Species stocked: yellow perch, chain pickerel, common bullheads, smallmouth bass, calico bass, sunfish, white perch, rainbow trout and lake trout.

Oxygen deficiency in the bottom waters and large numbers of warmwater fishes make it impossible to secure a satisfactory return of stocked trout.

Recommendations for the Improvement of Fishing

Manage for smallmouth bass and chain pickerel. Reduce present legal length on smallmouth bass to 12 inches and increase legal length on pickerel to 16 inches. Protect bass spawning areas.

No stocking recommended.

NORTH FARMS RESERVOIR, Wallingford

Description

Area, 63.1 acres. Maximum depth, 9.2 feet. Average depth, 3.5 feet. Artificial in origin. Entire bottom with a dense growth of submerged vegetation. Plankton and bottom fauna production high.

Development

Privately owned. Boats available. One cottage. Shores partly wooded.

Notes on Fish Life

Species stocked: yellow perch, chain pickerel, common bullheads, largemouth bass, calico bass, sunfish and golden shiners.

During the summer of 1935 nearly the entire fish population was lost through a peculiar combination of "working" and weather conditions resulting in a nearly complete temporary exhaustion of the oxygen supply. The fish population was restored as quickly as possible by intensive stocking of adult fish. Fish life at present time is extremely abundant, but there appears to be a lack of a large carnivorous fish to utilize the available forage. Golden shiners, common bullheads and calico bass are abundant.

Recommendations for the Improvement of Fishing

Manage for chain pickerel. Increase legal length to 16 inches and reduce creel limit to 6 pickerel per day; temporarily prohibit all ice fishing for this species.

Stocking with fingerling or adult pickerel recommended.

PATAGANSET LAKE, East Lyme

Description

Area, 120 acres. Maximum depth, 36.8 feet. Average depth, 12.6 feet. Natural in origin with level raised; fed by springs and small tributary. Shoreline somewhat rocky wth considerable marginal vegetation in the coves. Plankton and bottom fauna low. Some fluctuation in water level.

Development

Owned by State of Connecticut. Few cottages. No boat livery. Shores largely wooded. Under special regulation by the State Board of Fisheries and Game. No motor boats permitted.

Notes on Fish Life

Species stocked: yellow perch, chain pickerel, common bullheads, smallmouth and largemouth bass, calico bass, rock bass, sunfish, white perch and rainbow trout.

Lake not heavily fished and provides fair fishing.

Spawning areas for smallmouth bass apparently localized on east shore. Young bass and yellow perch scarce.

Numerous marine fish-eating birds visit the lake; these may be partially responsible for the apparent scarcity of young fish.

Recommendations for the Improvement of Fishing

Manage for smallmouth bass and chain pickerel. Increase legal length of bass to 12 inches and of chain pickerel to 16 inches. Protect bass spawning areas.

Stocking of smallmouth bass and pickerel recommended.

PEAT WORKS POND (Silver Lake), Meriden and Berlin

Description

Area, 138 acres. Maximum depth, 11.5 feet. Average depth, 4.5 feet. Artificial in origin; fed by tributaries. Shoreline with considerable marginal vegetation and dense beds of submerged vegetation over the entire bottom. Basic fertilizers, plankton and bottom fauna values high.

Development

Owned by State of Connecticut. Few cottages. Boats permitted. Shores largely open fields. Under special regulation by State Board of Fisheries and Game.

Notes on Fish Life

Species stocked: yellow perch, chain pickerel, common bullheads, largemouth bass, calico bass, sunfish, golden shiners, and salmon.

The extensive weed beds provide a favorable habitat for most of the species present. Young game fish and golden shiners are abundant.

Fishing for largemouth bass, chain pickerel and yellow perch is good, although angling is somewhat difficult because of the luxuriant growth of aquatic vegetation. Yellow perch are abundant and grow very slowly. Important parasites are black grub, white grub of the liver and red roundworm.

Recommendations for the Improvement of Fishing

Conditions for reproduction and survival of the young of the species present are so favorable that it appears essential to foster the abundance of large carnivorous fish in order to maintain a proper state of balance. Manage for largemouth bass and chain pickerel; increase legal length of bass to 12 inches and of pickerel to 16 inches. Reduce catch limit of pickerel to 6 fish per day. Permit ice fishing for yellow perch only.

No stocking recommended.

PICKEREL LAKE, East Haddam and Colchester

Description

Area, 87 acres. Maximum depth, 7.9 feet. Artificial in origin; fed by tributaries. Shoreline with considerable marginal vegetation, but submerged vegetation scant because of low transparency of water. Excessive litter from trees (leaves and brush) submerged about the shore. Low in plankton and bottom fauna production. Considerable fluctuation in water level.

Development

Privately owned, with State-owned right-of-way on north end. Few cottages. Boat livery. Shores entirely wooded.

Notes on Fish Life

Species stocked: yellow perch, chain pickerel, common bullhead, largemouth bass and calico bass.

Fishing for largemouth bass and pickerel good, but varies from year to year; this may be due to the fluctuations in water level, which also varies considerably in different years.

Recommendations for the Improvement of Fishing

Manage for largemouth bass. Increase legal length of bass to 12 inches. Protect bass spawning areas. Largemouth bass may be stocked, but stocking needs are primarily dependent on water level.

Hold fluctuations in water level to a minimum, particularly in spring and early summer.

LAKE POCOTOPAUG, East Hampton

Description

Area, 510.5 acres. Maximum depth, 36.1 feet. Average depth, 12.5 feet. Natural in origin with level raised slightly. Shoreline largely rocky with some sand; extensive submerged weed beds below the zone of wave action. Plankton and bottom fauna production low.

Development

Privately owned. Numerous cottages. Boat liveries. Shores partly wooded.

Notes on Fish Life

Species stocked: yellow perch, chain pickerel, common bullheads, smallmouth and largemouth bass, calico bass, sunfish, white perch, golden shiners, lake trout and landlocked salmon.

One of the most heavily fished lakes in Connecticut. It formerly had the reputation of being one of the best smallmouth bass waters, but since the introduction of largemouth the catch has gradually shifted to the latter species. Calico bass have become established and appear frequently in the catch; their success may also have been made at the expense of smallmouth bass. Large numbers of yellow perch are taken both in summer and winter fishing. Pickerel fishing is generally poor.

Recommendations for the Improvement of Fishing

This lake illustrates the unfortunate consequences of careless or ill-advised stocking, for it is best suited for smallmouth bass. Under present conditions, however, it must necessarily be managed as largemouth bass water as there is no practicable way by which the balance may be shifted to favor only the smallmouth. If all anglers were able to positively distinguish these two species, a management program could be established by which the smallmouth could be protected at the expense of the largemouth. Under the present burden of fishing, there is good reason to believe that such a program would be successful.

Increase the legal length on black bass to 12 inches and protect bass spawning areas.

Close to all ice fishing.

POWER'S LAKE, East Lyme

Description

Area, 151.7 acres. Maximum depth, 13 feet. Average depth, 8.3 feet. Artificial in origin. Fed by tributaries. Shore line rocky with sparse marginal vegetation, stumps and forest litter. Low in plankton and bottom fauna production.

Development

Owned by the State of Connecticut. No cottages. Yale University Engineering School owns property bordering lake. No boat livery, but no restrictions on private boats. Shores entirely wooded. Under special regulation by the Connecticut State Board of Fisheries and Game.

Notes on Fish Life

Species stocked: yellow perch, chain pickerel, common bullheads, smallmouth bass, sunfish, golden shiners, rainbow trout and lake trout.

Young chain pickerel and golden shiners abundant.

Recommendations for the Improvement of Fishing

Manage for chain pickerel. Increase legal length on chain pickerel to 16 inches.

Ice fishing should be permitted on this lake because of the lack of boating facilities.

No stocking recommended.

QUASSAPAUG LAKE, Middlebury and Woodbury

Description

Area, 289.5 acres. Maximum depth, 65 feet. Average depth, 28.5 feet. Natural in origin, but level raised. Shore line of main body—rocks, sand or gravel; the long narrow coves on the north end have a luxuriant growth of marginal and submerged vegetation. Thermally stratified. Water very transparent. Bottom fauna production average.

Development

Privately owned. Numerous cottages. Boat liveries. Shores largely wooded. Under special regulation by the State Board of Fisheries and Game.

Notes on Fish Life

Species stocked: yellow perch, chain pickerel, common bullheads, smallmouth bass, sunfish, golden shiners, rainbow trout, lake trout, landlocked salmon and carp.

This is marginal trout water. Only legal size rainbow trout have been stocked in recent years and these plantings have given fair returns. Competition from many warm-water species is undoubtedly a factor that adversely affects trout fishing and good trout fishing will probably result only when this competition has been eliminated, but considerable interest in fishing for smallmouth and other warm-water fishes make this undesirable.

For these reasons it appears better to favor warm-water species in this lake. The weedy coves produce large quantities of forage fish and provide suitable habitats for yellow perch and pickerel. The main body of the lake is well suited to smallmouth bass. The growth rate of smallmouth and yellow perch are satisfactory.

Black grubs and red roundworms are the only important parasites present.

Recommendations for the Improvement of Fishing

Manage for smallmouth bass, yellow perch and chain pickerel. Increase legal length on bass to 12 inches and reduce the catch limit to six bass per day. Increase legal length of chain pickerel to 16 inches and reduce the daily limit to 6 fish.

Protect bass spawning areas.

Prohibit all ice fishing.

No stocking recommended.

ROGERS LAKE, Lyme and Old Lyme

Description

Area, 265.5 acres. Maximum depth, 65 feet. Average depth, 19.5 feet. Natural in origin with level raised. Fed by tributaries. Shoreline rocky with considerable marginal vegetation. Several islands. Thermally stratified. Plankton production is low and bottom food is average.

Development

Privately owned. Numerous cottages. Boat livery. Shores largely wooded.

Notes on Fish Life

Species stocked: yellow perch, chain pickerel, common bullheads, smallmouth and largemouth bass, calico bass, rock bass, sunfish, golden shiners, lake trout, landlocked salmon and striped bass.

Reproduction of all game species appears adequate.

The lake furnishes fair fishing for smallmouth bass, calico bass, yellow perch and chain pickerel.

Recommendations for the Improvement of Fishing

Manage for smallmouth bass, yellow perch and chain pickerel. Increase legal length on bass to 12 inches. Increase legal length on pickerel to 16 inches. Protect bass spawning areas.

ROSELAND LAKE, Woodstock

Description

Area, 89 acres. Maximum depth, 19.6 feet. Average depth, 10 feet. Natural in origin with level raised; fed by tributaries. Shoreline rocky with marginal vegetation.

Development

Privately owned. Few cottages. Boats available. Under special regulation by State Board of Fisheries and Game.

Notes on Fish Life

Species stocked: yellow perch, chain pickerel, common bullheads, largemouth and smallmouth bass, calico bass, sunfish and golden shiners.

Fishing for largemouth bass and yellow perch is fair. Reproduction and growth rate of these species appears satisfactory.

The water is more typical of largemouth bass habitat than it is of smallmouth. For this reason the largemouth will probably continue to dominate the smallmouth.

Recommendations for the Improvement of Fishing

Manage for black bass, yellow perch and chain pickerel. Increase legal length of bass to 12 inches and reduce catch limit to 6 bass per day. Increase legal length of chain pickerel to 16 inches and reduce the daily creel to limit of 6 fish.

Protect bass spawning areas.

Prohibit all ice fishing.

SAMP MORTAR RESERVOIR, Fairfield

Description

Area, 47.5 acres. Maximum depth, 26.2 feet. Average depth, 10.1 feet. Artificial in origin. Shoreline—gravel and rocks with considerable marginal vegetation.

Development

Privately owned; leased by State Board of Fisheries and Game. No cottages. Boats not permitted. Shores partly wooded.

Notes on Fish Life

Species stocked: yellow perch, chain pickerel, common bullheads, largemouth and smallmouth bass, rock bass, sunfish, white perch and golden shiners.

Reproduction of largemouth bass and chain pickerel apparently adequate. Forage fish abundant. Habitat best suited for largemouth bass, chain pickerel and yellow perch.

Fished rather heavily.

Recommendations for the Improvement of Fishing

Manage for largemouth bass and chain pickerel. Increase legal length on black bass to 12 inches and on chain pickerel to 16 inches.

SHAW LAKE (Hayward), East Haddam

Description

Area, 193 acres. Maximum depth, 37.4 feet. Average depth, 10 feet. Deep water confined to a small area. Bottom food is higher than other nearby lakes. Natural in origin, with level slightly raised. Fed by tributaries. Shoreline—rocks and gravel with considerable marginal vegetation.

Development

Privately owned. Numerous cottages. No boat livery. Shores largely wooded. Under special regulation by State Board of Fisheries and Game through cooperative agreement with owners.

Notes on Fish Life

Species stocked: yellow perch, chain pickerel, common bullheads, smallmouth and largemouth bass, calico bass, sunfish, golden shiners and lake trout.

Fishing good, particularly for calico bass and yellow perch.

An epidemic destroyed a large part of the yellow perch population during the early summer of 1938. The return of perch fishing was hastened by the stocking of adult fish from the Connecticut River.

Reproduction of game species appears adequate.

Recommendations for the Improvement of Fishing

Manage for black bass, yellow perch and chain pickerel. Increase legal length on black bass to 12 inches and on chain pickerel to 16 inches. With these special regulations there appears no need for the shortened open season now in effect. Open seasons as prescribed by law recommended.

Close to ice fishing after December 31st.

SHENIPSIT LAKE, Tolland, Ellington and Vernon

Description

Area, 531 acres. Maximum depth, 65 feet. Average depth, 27.6 feet. Natural in origin, with level raised. Fed by tributaries and springs. Shoreline—rocks, gravel and sand with localized weedy areas. Plankton and bottom fauna production low. Thermally stratified and bottom waters not deficient in oxygen. Considerable fluctuation in water level.

Development

Privately owned; water used for power and as a water supply. Few cottages. No boat livery, but private boats permitted. Shores largely wooded.

Notes on Fish Life

Species stocked: yellow perch, chain pickerel, common bullheads, smallmouth and largemouth bass, calico bass, sunfish, golden shiners, rainbow trout, lake trout, landlocked salmon, smelt and catfish.

Fishing for small and largemouth bass good. Young of both of these species abundant. Some smelt caught during the ice fishing season.

Reports of occasional catches of trout or salmon are believed to be authentic. This is marginal trout water.

Reproduction of bass appears adequate, although there is a heavy infestation of bass tapeworm which may interfere with reproduction at some future time. Black and yellow grubs and white grub of the liver also present.

Recommendations for the Improvement of Fishing

Manage for large and smallmouth bass, yellow perch and chain pickerel. Increase legal length on black bass to 12 inches and on chain pickerel to 16 inches.

Protect bass spawning areas and smelt spawning tributaries.

STILLWATER POND, Torrington

Description

Area, 94.4 acres. Maximum depth, 26 feet. Average depth, 11.7 feet. Artificial in origin, formed by damming Naugatuck River. Shoreline—gravel and rocks with considerable marginal vegetation; coves with dense beds of submerged and floating vegetation. Large portion of shoreline drops off abruptly and does not appear very productive. Low in nutrient fertilizers.

Development

Privately owned and formerly closed to public fishing. No cottages. Boats available, but fishing by permit only. Under special regulation by State Board of Fisheries and Game through cooperative agreement with the owners and the Torrington Fish and Game Club. Shores largely wooded.

Notes on Fish Life

Species stocked: yellow perch, chain pickerel, common bullheads, smallmouth and largemouth bass, calico bass, sunfish, golden shiners and rainbow trout.

Prior to 1933 this pond was closed to public fishing. When first opened it furnished good fishing but in recent years there has been a marked decline in angling success (complete catch records are available). This is believed to have been caused by the excessively heavy burden of fishing for the size of the pond.

Legal size rainbow trout were stocked in 1938, but only a small percentage were recovered by anglers.

Large suckers and forage species abundant.

Reproduction of black bass apparently inadequate. Heavy infestation of bass tapeworm in both large and smallmouth. Heavy stocking of bass has been carried out in an effort to compensate for this.

Growth of all game species is good.

Recommendations for the Improvement of Fishing

Survey data indicates no reason for the decline in angling success other than over-fishing.

Increase legal length of chain pickerel to 16 inches and reduce daily catch limit to 6. Increase legal length of black bass to 12 inches and reduce daily catch limit to 6. Protect bass spawning areas. Reduce fluctuation in water level to a minimum, particularly in spring and early summer.

Remove all catch restrictions on calico bass.

Stock only black bass and chain pickerel and these only if water level has been lowered sharply during the spawning season.

TAUNTON POND, Newtown

Description

Area, 126 acres. Maximum depth, 29.5 feet. Average depth, 21.5 feet. Natural in origin with level raised. Fed by springs. Shoreline—boulders, rocks and gravel with some marginal vegetation. Water very transparent and thermally stratified. Plankton and bottom fauna low.

Development

Privately owned; municipal water supply. Few cottages. Boats available. Shores largely wooded. Under special regulation by State Board of Fisheries and Game.

Notes on Fish Life

Species stocked: yellow perch, chain pickerel, common bullheads, smallmouth and largemouth bass, calico bass, white perch, golden shiners, lake trout, landlocked salmon and chinook salmon.

This lake is well suited for smallmouth bass but this species is heavily infested with bass tapeworm. It is possible that this parasite has seriously impaired natural reproduction since no young smallmouth were secured by seining about the shore. Largemouth are established and are becoming more abundant.

White perch are common and grow to a relatively large size.

Growth rate of smallmouth and yellow perch good and of white perch exceptional.

Occasional trout have been reported from this lake. However, physical and chemical data show that this water is, at best, marginal trout water and unsuitable for trout management.

Recommendations for the Improvement of Fishing

Manage for smallmouth bass and white perch. Increase legal length of bass to 12 inches. Protect bass spawning areas. Increase legal length on white perch to 10 inches.

Stock smallmouth black bass fry.

Rechecked summer of 1941 at the request of interested fishermen. Conditions esssentially the same as in initial examination. Young of smallmouth bass rare, with largemouth somewhat more common. White perch apparently becoming more abundant, but the growth still good (attain a length of 8 - 9 inches during their third growing season). Infestation of tapeworm in bass still heavy, all specimens examined infected. No change in previous recommendations.

TERRAMUGGUS LAKE, Marlborough

Description

Area, 81.2 acres. Maximum depth, 37.4 feet. Average depth, 17.7 feet. Natural in origin. Fed by springs. Shoreline—rocks, gravel and sand with sparse marginal vegetation. Plankton production low and bottom fauna average. Thermally stratified with the bottom waters somewhat deficient in oxygen.

Development

Privately owned. Numerous cottages. Boat livery. Shores partly wooded.

Notes on Fish Life

Species stocked: yellow perch, chain pickerel, common bullheads, largemouth and smallmouth bass, calico bass, sunfish and golden shiners.

Fishing fair for black bass, yellow perch and pickerel. Reproduction of bass appears adequate.

Recommendations for the Improvement of Fishing

Manage for black bass, yellow perch and chain pickerel. Increase legal length on bass to 12 inches and reduce the creel limit to 6 fish per day. Increase the legal length on chain pickerel to 16 inches and reduce the creel limit to 6 fish per day.

Protect bass spawning areas.

This is marginal trout water; chemical and physical conditions appear adequate for brook or rainbow trout; if the warm-water species were removed, would be suitable for trout management.

TRUMBULL RESERVOIR, Trumbull

Description

Area, 50.6 acres. Maximum depth, 26.2 feet. Average depth, 12.9 feet. Fed by Pequonnock River. Shoreline—rocks and gravel with marginal vegetation. Plankton and bottom fauna production low. Oxygen deficiency in bottom waters.

Development

Privately owned. No cottages. No boat livery. Shores entirely wooded. Leased and under special regulation by the State Board of Fisheries and Game.

Notes on Fish Life

Species stocked: yellow perch, chain pickerel, common bullheads, smallmouth bass, white perch, golden shiners and rainbow trout.

Legal size rainbows have been planted in the spring just prior to the fishing season. Though it is impossible to determine the returns secured from these plants, it seems likely that they were low. This is definitely not trout water. Many of the trout are known to have left the Reservoir and were captured in the inlet or outlet.

This pond is suitable for warm-water species. Forage fish abundant.

Angling burden light.

Recommendations for the Improvement of Fishing

Manage for yellow perch and chain pickerel. Increase the legal length on chain pickerel to 16 inches and reduce the daily catch limit to 6 fish.

No stocking recommended.

TWIN LAKE (EAST), Salisbury

Description

Area, 549.8 acres. Maximum depth, 75 feet. Average depth, 32.4 feet. Natural in origin; fed by tributaries and springs.

Shoreline rocky with dense beds of submerged weed beds below the zone of wave action; north end shallow with considerable marginal and submerged vegetation.

This is one of the largest and deepest lakes studied in Connecticut. The water is hard and molluscs are abundant. Phosphorus and nitrogen are low. Although phytoplankton production is not high, the great depth and unusual transparency allow plankton and rooted vegetation to grow at unusually great depths. This, in part, compensates for the plankton deficiency per unit volume at the surface.

The lake is well stratified in summer and usually has a plentiful oxygen supply in the deep water.

The bottom is very productive of fish food organisms at all depths.

Development

Privately owned. Numerous cottages. Boat liveries. Shores largely wooded.

Notes on Fish Life

Species stocked: yellow perch, chain pickerel, common bullheads, smallmouth and largemouth bass, calico bass, rock bass, sunfish, white perch, golden shiners, lake trout, landlocked salmon, smelt and sockeye salmon.

The lake is an excellent example of ideal trout habitat. Lake trout were formerly caught here and at present sockeye salmon and round whitefish are abundant.

Unfortunately the trout fishing potentialities of this lake have never been realized because of the indiscriminate and unjustified stocking of undesirable warm-water fish. White and yellow perch and the black basses occur in considerable numbers and furnish good fishing. Reproduction of warm-water species appears to be adequate. Black bass are badly infested with tapeworm which at some future time may seriously interfere with reproduction. However, it would seem that this lake would be a more valuable asset if it were made to provide good lake trout fishing. Round whitefish and sockeye salmon would serve as forage.

Recommendations for the Improvement of Fishing

Manage for lake trout. The complete removal of warm-water fish is impracticable, but they should be suppressed by angling. Remove catch restrictions on all warm-water species, and discontinue all stocking of these species.

Stock yearling lake trout according to the following schedule: first year, 10,000 fish; second year, 5,000 fish; third year, 3,000 fish; fourth year, 2,000 fish. This planting schedule must be regarded as tentative and is subject to revision after the second year on the basis of subsequent examinations.

TYLER POND, Goshen

Description

Area, 182 acres. Maximum depth, 27.9 feet. Shoreline rocky with considerable marginal vegetation; floating bog at north end. Dense growth of pond weeds over entire bottom. Fed by tributaries. Bottom food production good.

Development

Privately owned. Numerous cottages. Boat livery.

Notes on Fish Life

Species stocked: yellow perch, chain pickerel, common bullheads, smallmouth bass, calico bass, golden shiners, rainbow trout, landlocked salmon, pike perch and suckers.

Yellow perch abundant and stunted. Smallmouth bass, calico bass and chain pickerel grow rapidly. Golden shiners are extremely abundant. Chub suckers abundant.

The extensive weed beds afford excellent protection for forage species and young game fish. Under these conditions a prolific game species may become excessively abundant and this may result in poor growth. This has apparently happened with the yellow perch. However, species which feed primarily on other fish are extremely successful.

Fish lightly infested with important parasites.

Recommendations for the Improvement of Fishing

Manage for smallmouth bass and chain pickerel. Temporarily give complete protection to chain pickerel. Increase legal length of smallmouth bass to 12 inches. Temporarily suspend all catch restrictions on yellow perch and calico bass.

Protect bass spawning areas.

WARAMAUG LAKE, Warren, Washington and Kent

Description

Area, 698.1 acres. Maximum depth, 40 feet. Average depth, 22.1 feet. Natural in origin with level raised. Shoreline largely rocky with local weedy areas. Fed by tributaries. Plankton and bottom fauna production high. Thermally stratified with oxygen deficiency in the bottom waters.

Development

Privately owned. Numerous cottages. Boat liveries. Shore largely wooded.

Notes on Fish Life

Species stocked: yellow perch, chain pickerel, common bullheads, smallmouth and largemouth bass, calico bass, white perch, rainbow trout, lake trout, landlocked salmon and smelt.

White perch very abundant, but the maximum size peculiar to this lake is rather small (8 - 9 inches). Yellow perch abundant and grow slowly. Reproduction of small and largemouth bass appears adequate.

Black and eye grub and white grub of liver present. Bass tapeworm occurs in considerable quantities. Sunfish apparently act as reservoir host.

Recommendations for the Improvement of Fishing

Manage for black bass and chain pickerel. Increase legal length of black bass to 12 inches and limit catch to 6 fish per day. Temporarily close season on pickerel. Temporarily remove all catch restrictions on white and yellow perch and calico bass.

Protect bass spawning areas.

The removal of sunfish is urged.

No stocking recommended.

WATTLES POND (Winnemaug Lake), Watertown

Description

Area, 120 acres. Artificial in origin. Fed by small tributaries and springs. Shoreline with dense growth of marginal and submerged vegetation; rocks, sand and stumps in localized areas. Two small islands.

Water level fluctuates.

Development

Privately owned. Few cottages. Boats available. Under special regulation by Connecticut State Board of Fisheries and Game. Shores partly wooded.

Notes on Fish Life

Species stocked: yellow perch, chain pickerel, common bullheads, smallmouth and largemouth bass, calico bass, sunfish, golden shiners and tench.

This lake provides ideal habitat for largemouth, chain pickerel and yellow perch.

Heavily fished. Wardens' reports indicate good fishing, considering size of pond.

Recommendations for the Improvement of Fishing

Manage for largemouth bass and chain pickerel.

The following special regulations are recommended: legal length on largemouth bass, 12 inches, 6 fish per day; legal length on chain pickerel, 16 inches, 6 fish per day; ice fishing prohibited.

Remove all restrictions on calico bass. Protect bass spawning areas.

Keep fluctuations in water level to a minimum, particularly in the spring and early summer.

WAUMGUMBAUG LAKE, Coventry

Description

Area, 376 acres. Maximum depth, 40 feet. Average depth, 28.9 feet. Natural in origin with level raised about 4 feet. Shoreline—rocks, sand and gravel with localized marginal weedy areas. Submerged weed beds below the zone of wave action. Water very transparent. Thermally stratified with an oxygen deficieny in the bottom water.

Water level fluctuates considerably.

Development

Privately owned and water utilized for industrial purposes. Numerous cottages. Boat liveries. Shores largely wooded. Under special regulation by State Board of Fisheries and Game through cooperative agreement with owners.

Notes on Fish Life

Species stocked: yellow perch, chain pickerel, common bullheads, smallmouth bass, calico bass, rock bass, sunfish, white perch, golden shiners, rainbow trout, lake trout, landlocked salmon, smelt and pike perch.

This lake produces good smallmouth and yellow perch fishing. The growth rate of game species is satisfactory and reproduction appears adequate. Golden shiners abundant.

This lake is subject to an excessively heavy fishing burden, both in summer and in winter.

Black and yellow grubs, white grub of liver and red roundworms are the important parasites present.

Bass are apparently free of tapeworm.

Recommendations for the Improvement of Fishing

The following regulations are now in effect and should be continued. Smallmouth bass, 12 inches, 6 per day. Chain pickerel, 16 inches, 6 per day. Ice fishing is restricted to 3 days per week.

Remove all catch restrictions on calico bass.

Protect bass spawning areas.

Hold fluctuations in water level to a minimum, particularly in the early spring and summer.

WEST HILL POND, New Hartford

Description

Area, 235.9 acres. Maximum depth, 59 feet. Average depth, 31.8 feet. Natural in origin with level raised; fed by small tributaries and springs. Shoreline—rocks, sand and gravel with small localized areas with marginal aquatic vegetation. Transparency of water high (26.6 feet), and submerged weeds are extensive below the zone of wave action. Plankton production is low but bottom fauna is average. Thermally stratified with abundant oxygen in deep waters.

Water level fluctuates considerably.

Development

Privately owned and water used for industrial purposes. Cottages numerous. Boats available. Under special regulation by State Board of Fisheries and Game through cooperative agreement with the owners.

Notes on Fish Life

Species stocked: yellow perch, chain pickerel, common bullheads, smallmouth bass, calico bass, sunfish, golden shiners, rainbow trout, lake trout, landlocked salmon, smelt and brook trout.

Physical and chemical conditions are very favorable for trout management. Yearling and two-year old rainbow trout that have been planted since 1934 have produced fair fishing. There is a spawning run in a small tributary but this is of questionable value for natural reproduction. Not enough fish are produced naturally to support fishing. It is believed possible to provide much better trout fishing if competition from warm-water species can be eliminated.

Smallmouth bass are abundant but badly stunted.

Recommendations for the Improvement of Fishing

Manage for brook or rainbow trout. For best fishing results it is considered essential to remove all warm-water fish. If this is impracticable, these should be suppressed as much as is possible by angling. Remove all catch regulations on warm-water species.

Under present conditions a stocking of 3,000 yearly rainbow trout or their equivalent is believed to be the maximum number that can be supported. This number may be increased if the numbers of competitive species are reduced.

WILLIMANTIC RESERVOIR, Bolton, Vernon and Coventry

Survey data invalidated as a result of destruction of dam. Will be resurveyed when reservoir is again filled and biological conditions have had time to become stabilized.

WINCHESTER LAKE, Winchester

Description

Area, 229 acres. Maximum depth, 16.4 feet. Average depth, 13 feet. Artificial in origin, earthen and stone dam 20 feet high. Considerable brush and many stumps and dead trees in water. Luxuriant growth of submerged vegetation. Water level fluctuates.

Development

Privately owned. Boat livery present. Under special regulation by State Board of Fisheries and Game through cooperative agreement with owners and Torrington Fish and Game Club. Fishing by permit only. Shores wooded.

Notes on Fish Life

Species stocked: yellow perch, calico bass, sunfish, chain pickerel, and bullheads.

Angling for pickerel, perch and bullheads good, but perch are somewhat stunted at present. Golden shiners are abundant.

Recommendations for the Improvement of Fishing

Manage primarily for chain pickerel. Increase legal length to 16 inches. Regulations on other species as prescribed by State law. No restrictions on the taking of calico bass.

WONONSCOPOMUC LAKE, Salisbury

Description

Area, 352.6 acres. Maximum depth, 102 feet. Average depth, 36.3 feet. Natural in origin with level raised. Fed by tributaries and springs. Shoreline—rocks, gravel, sand, with localized area of marginal vegetation. This is the deepest lake yet found in Connecticut. It resembles East Twin Lake in many of its characteristics, but is more transparent (Secchi reading, 29.5 feet) and vegetation may be found growing in 40 feet of water. The water is thermally stratified and the deep waters are well supplied with oxygen.

Development

Privately owned. Some cottages. Boats available. Shores partly wooded. Under special regulation by State Board of Fisheries and Game through cooperative agreement with owners.

Notes on Fish Life

Species stocked: yellow perch, chain pickerel, common bullheads, largemouth and smallmouth bass, calico bass, sunfish, golden shiners, rainbow trout, lake trout, landlocked salmon, round whitefish, smelt and golden trout.

This lake resembles East Twin Lake in its suitability for trout and the same criticisms with regard to stocking of warm-water species apply in this case. Lake trout have been established for some years and provide fair fishing. No systematic stocking program has been in effect and the success of natural reproduction is not known, but it is believed that the latter is responsible for at least some of the present fishing. During fall of 1939, 5,000 fingerling lake trout were planted; these fish were marked, having the left pectoral fin removed, and returns from this plant will be used as a guide for future management.

Yearling and two-year old rainbow trout have been stocked for the past several years. No measurements of the returns are available but it is believed to be fairly high.

Black and eye grub and white grub of the liver are the important parasites of warm-water fishes.

Recommendations for the Improvement of Fishing

Manage for lake trout and rainbow trout.

Too little knowledge available regarding growth rate and reproduction of lake trout in this lake. Records on returns from the plant of marked trout mentioned above will greatly assist future lake trout management. It is quite possible that a systematic annual stocking program is necessary and that the present special legal length of 15 inches is inadequate.

It appears that the present rainbow stocking is near the limit which can safely be made with the present warm-water fish population. It is recommended that all catch restrictions on warm-water species be removed for the purpose of creating more room for rainbows. The present special regulations (10 inches — 5 per day) should be continued.

ZOAR LAKE, Monroe, Newtown, Oxford and Southbury

Description

Area, 975 acres. Maximum depth, 75.5 feet. Mean depth, 24.6 feet. Artificial in origin, formed by damming the Housatonic River. Shoreline—rocks, sand, gravel and mud, with luxuriant growth of marginal and submerged vegetation in protected and shallow areas. Considerable and rapid fluctuation in water level.

Development

Privately owned and water used for power. Some cottages. Boat liveries. Shores largely wooded.

Notes on Fish Life

Species stocked: yellow perch, chain pickerel, common bullheads, largemouth and smallmouth bass, calico bass, sunfish, white perch, golden shiners and pike perch.

Young fish, particularly common suckers, abundant. Yellow and white perch abundant but grow slowly. An occasional rainbow trout is taken but it is probably a stocked fish which has dropped down into the lake from the stream above. However, this water is not suitable for trout management. Pike perch plants have been made but this species never became established. This is surprising, since the water appears suited for this species; the Housatonic River above the lake would provide spawning grounds and there appears to be abundant forage in the lake itself.

Commercial fishing is carried out for carp and suckers.

Recommendations for the Improvement of Fishing

It appears desirable to make another attempt to establish pike perch and to manage for this species. The stocking of at least 10 million fry per year is recommended for 4 consecutive years. The plants should be made in quiet pools of the Housatonic River, a short distance above the lake.

If pike perch become established, it would probably be wise to discontinue commercial fishing for common suckers.

List of Bulletins
of the
State Geological and Natural History Survey

Any of the following bulletins that are not out of print will be sent postpaid on receipt of the price.

1. First Biennial Report of the Commissioners of the State Geological and Natural History Survey, 1903-1904; 18 pp. 23 cm., 1904 (Out of print).

2. A Preliminary Report on the Protozoa of the Fresh Waters of Connecticut: by Herbert William Conn, Ph.D.; 69 pp., 34 pls., 23 cm., 1905. (Out of print).

3. A Preliminary Report on the Hymeniales of Connecticut: by Edward Albert White, B.S.; 81 pp., 40 pls., 23 cm., 1905. (Out of print).

4. The Clays and Clay Industries of Connecticut: by Gerald Francis Loughlin, S.B.; 121 pp., 13 pls., 23 cm., 1905. .35

5. The Ustilagineae, or Smuts, of Connecticut: by George Perkins Clinton, S.D.; 45 pp., 55 figs., 23 cm., 1905. .20

6. Manual of the Geology of Connecticut: by William North Rice, Ph.D., LL.D., and Herbert Ernest Gregory, Ph.D.; 273 pp., 31 pls., 22 figs., (10 maps), 23 cm., 1906. (Out of print)

7. Preliminary Geological Map of Connecticut: by Herbert Ernest Gregory, Ph.D. and Henry Hollister Robinson, Ph.D.; 39 pp., 2 maps (1 in pocket), 23 cm., 1907. (Out of print).

8. Bibliography of Connecticut Geology: by Herbert Ernest Gregory, Ph.D., 123 pp., 23 cm., 1907. .20

9. Second Biennial Report of the Commissioners of the State Geological and Natural History Survey, 1905-1906; 23 pp., 23 cm., 1906. .10

10. A Preliminary Report on the Algae of the Fresh Waters of Connecticut: by Herbert William Conn, Ph.D., and Lucia Washburn (Hazen) Webster, M.S.; 78 pp., 44 pls., 23 cm., 1908. .40

11. The Bryophites of Connecticut: by Alexander William Evans, Ph.D., and George Elwood Nichols, B.A.; 203 pp. 23 cm., 1908. (Out of print).

12. Third Biennial Report of the Commissioners of the State Geological and Natural History Survey, 1907-1908; 30 pp., 23 cm., 1908. (Out of print).

13. The Lithology of Connecticut: by Joseph Barrell, Ph.D., and Gerald Francis Loughlin, Ph.D.; 207 pp., 6 tables, 23 cm., 1910. (Out of print).

14. Catalogue of the Flowering Plants and Ferns of Connecticut Growing Without Cultivation: by a Committee of the Connecticut Botanical Society consisting of Charles Burr Graves, A.B., M.D., Edwin Hubert Eames, M.D., Charles Humphrey Bissell, Luman Andrews, Edgar Burton Harger, Ph.B., and Charles Alfred Weatherby, A.M.; 569 pp., 23 cm., 1910. .90

15. Second Report on the Hymeniales of Connecticut: by Edward Albert White, B.S.; 70 pp., 28 pls., 23 cm., 1910. .40

16. Guide to the Insects of Connecticut, prepared under the direction of Wilton Everett Britton, Ph.D. Part I. General Introduction: by Wilton Everett Britton, Ph.D. Part II. The Euplexoptera and Orthoptera of Connecticut: by Benjamin Hovey Walden, B.Agr.; 169 pp., 11 pls., 16 figs. (1 map), 23 cm., 1911. (Out of print).

17. Fourth Biennial report of the Commissioners of the State Geological and Natural History Survey, 1909-1910; 31 pp., 23 cm., 1910. .10

18. Triassic Fishes of Connecticut: by Charles Rochester Eastman, Ph.D.; 78 pp., 11 pls., 8 figs., 23 cm., 1911. .30

19. Echinoderms of Connecticut: by Wesley Roswell Coe., Ph.D.; 152 pp., 32 pls., 29 figs., 23 cm., 1912. .50

20. The Birds of Connecticut: by John Hall Sage, M.S., and Louis Bennett Bishop, M.D., assisted by Walter Parks Bliss, M.A.; 370 pp., 23 cm., 1913. .60

21. Fifth Biennial Report of the Commissioners of the State Geological and Natural History Survey, 1911-1912; 27 pp., 23 cm., 1912. .10

22. Guide to the Insects of Connecticut, prepared under the direction of Wilton Everett Britton, Ph.D. Part III. The Hymenoptera, or Wasp-like Insects, of Connecticut: by Henry Lorenz Viereck, with the collaboration of Alexander Dyer MacGillivray, Ph.D., Charles Thomas Brues, M.S., William Morton Wheeler, Ph.D., and Sievert Allen Rohwer; 824 pp., 10 pls., 15 figs., 23 cm., 1916. 2.15

23. Central Connecticut in the Geologic Past: by Joseph Barrell, Ph.D.; 44 pp., 5 pls., 23 cm., 1915. .20

24. Triassic Life of the Connecticut Valley: by Richard Swann Lull, Ph.D., 285 pp., 3 maps, 12 pls., 126 figs., 23 cm., 1915. .70

25. Sixth Biennial Report of the Commissioners of the State Geological and Natural History Survey, 1913-1914; 24 pp., 23 cm., 1915. .10

26. The Arthrostraca of Connecticut: by Beverly Waugh Kunkel, Ph.D.; 261 pp., 84 figs., 23 cm. 1918. .85

27. Seventh Biennial Report of the Commissioners of the State Geological and Natural History Survey, 1915-1916; 17 pp., 23 cm., 1917. .10

28. Eighth Biennial Report of the Commissioners of the State Geological and Natural History Survey, 1917-1918; 21 pp., 23 cm., 1919. (Out of print)

29. The Quarternary Geology of the New Haven Region, Connecticut: by Freeman Ward, Ph.D., 80 pp., 9 pls., 17 figs., 23 cm., 1920. .60

30. Drainage Modifications, and Glaciation in the Danbury Region, Connecticut: by Ruth Sawyer Harvey, Ph.D.; 59 pp., 5 pls., 10 figs., 23 cm., 1920. .55

31. Check List of the Insects of Connecticut: by Wilton Everett Britton, Ph.D.; 397 pp., 23 cm., 1920. 1.60

32. Ninth Biennial Report of the Commissioners of the State Geological and Natural History Survey, 1919-1920; 18 pp., 23 cm., 1920. .10

33. Geology of the Stonington Region, Connecticut: by Laura Hatch Martin, Ph.D.; 70 pp., 1 map, 8 figs., 23 cm., 1925. .60

34. Guide to the Insects of Connecticut, prepared under the direction of Wilton Everett Britton, Ph.D. Part IV. The Hemiptera or Sucking Insects of Connecticut: by Wilton Everett Britton, Ph.D., with collaboration of James Francis Abbott, Ph.D., Arthur Challen Baker, Ph.D., Harry Gardner Barber, A.M., William Thompson Davis, Dwight Moore DeLong, Ph.D., William Delbert Funkhouser, Ph.D., Harry Hazelton Knight, Ph.D., Asa Chandler Maxson, Herbert Osborn, D.Sc., Howard Madison Parshley, Sc.D., Edith Marion Patch, Ph.D., Louis Agassiz Stearns, M.Sc., José Rollin de la Torre-Bueno, F.E.S., Edward Payson Van Duzee, Harley Frost Wilson, M.S.; 807 pp., 20 pls., 169 figs., 23 cm., 1923. 2.15

35. Tenth and Eleventh Biennial Reports of the Commissioners of the State Geological and Natural History Survey, 1921-1924; 17 pp., 23 cm., 1924. .10

36. The Uredinales or Rusts of Connecticut and Other New England States: by Willis Roberts Hunt, Ph.D.; 198 pp., 2 figs., 23 cm., 1926. 1.00

37. Catalogue of the Lichens of Connecticut: by Alexander William Evans, Ph.D., and Rose Meyrowitz, M.S.; 56 pp., 23 cm., 1926. .60

38. Twelfth Biennial Report of the Commissioners of the State Geological and Natural History Survey, 1925-1926; 23 pp., 1 pl., 23 cm., 1927. .10

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