A STUDY OF THE FISH PRODUCTION OF A NATURAL FARM POND

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Raymond J. Buller

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by

Raymond J. Buller

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"A STUDY OF THE FISH PRODUCTION OF A NATURAL FARM POND."

INTRODUCTION

This paper presents the results of a fisheries investigation of Tihart Lake conducted by the writer, and includes data gathered over a period of eight months (July 1, 1943 to March 1, 1944). The greater part of the field work was carried on during the first three months. The types of field work carried on during this period were: the collection of fish samples; taking of scale samples, as well as measurements from the captured fish; mapping the pond; and portions of the chemical and biological surveys.

It should not be necessary to remark on the purpose of a fisheries investigation, but one has to talk with but a few sportsmen to realize a clear statement of purpose is justified. A greater interest in scientific investigations is being shown by anglers 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. However, these reports are scattered and it is almost impossible for the average reader to secure a knowledge of presentations which give a clear understanding to the biology of a fisheries survey.

The principal objective of the work here reported was a study of the actual fish production of Tihart Lake with "an eye towards" increasing this yield in future years through a proposed management plan. A secondary objective was concern of reports that a large carp population inhabited the pond. These reports were of interest as the Zoology and Home

Economics Departments of Michigan State College were experimenting with the edible qualities of this species. Permission was obtained to remove these fishes from the pond for such experimental purposes. The results of the findings concerning carp of Tihart Lake may be found under that branch of the biological survey of the pond dealing with fishes.

THE INVESTIGATIONS AND PERSONNEL

The actual field operations were conducted by the writer with the assistance of Mr. Leo Klever. The field work was done largely from July 1 to October 30, 1943. Mr. George Wallace and Mr. Hommer Sessions aided in the work from time to time during the entire period.

The mapping of the pond was superintended by the writer with assistance of the three above-mentioned men and the prepared base map was redrawn by the writer. The outline of this map, which is to be found on the inside of the back cover of this volume, is based entirely on triangulation points at thirty shore stations from a common base line. Bottom contours, distribution of vegetation beds, and bottom types are from readings at additional stations.

PHYSICAL SURVEY OF TIHART LAKE

Location.

Tihart Lake, in Ingham County, is situated in Meridian Township (T. 4 N., R. 1 W., Sec. 14) about five miles northeast of East Lansing on a farm owned by Mr. Harold Church, and managed by Mr. Tomlinson. The pond is elongate in a north and south direction and is flanked on the west and north by rolling farm land. The pond is accessible only through the farm yard and lane of the farm on which it occurs.

Area.

The area of Tihart Lake, 8.38 acres, was obtained from the prepared base map by the use of a planimeter. The marshy nature of the shoreline made mapping very difficult and because of this the actual area may be slightly greater than the figure given above. The given area is that of the open water only, irrespective of flooded marshy portions which occur at several points about the border of the pond.

Classification.

There has been a great deal of controversy as to the definition of a pond as differing from a lake. Forel (1892) defines a lake as a standing body of water occupying a basin and lacking continuity with the sea and defines a pond as a lake of slight depth. Welch (1935) defines a pond as a small, shallow standing body of water in which quiet water and extensive occupancy by higher aquatic plants are common

characteristics. He refers to all larger standing bodies of water as lakes. By applying the definitions of both Forel and Welch to Tihart Lake plus the data which follows, it can be readily understood why the writer has chosen to classify it as a natural pond. A natural pond being one that is formed in a normal catch basin as compared to an artificially impounded pond.

By applying a classification developed by Forel and later modified by Whipple pertaining to temperature, Tihart Lake may best be classified as a temperate pond of the third order. It is of the temperate type because the surface temperatures vary above and below 4° C, and it is a third order pond because the temperature of the bottom water is very similar to that of the surface water and circulation is continuous except when covered with ice.

Using still another classification, on the basis of productivity, Tihart Lake falls in the dystrophic type. This classification is based on plankton communities, bottom fauna, dissolved oxygen supply, bottom deposits, and biological productivity.

Tihart Lake lies in a shallow basin almost surrounded by a marshy area. This general form is also characteristic of the dystrophic type.

Drainage.

Drainage waters entering Tihart Lake are limited to those coming from a marshy area extending several miles east and north of the pond, served by the inlet which empties into the pond near the center of the south-east shore. Throughout

the normal seasons the flow remains regular and carries very little sediment into the pond. During the rainy seasons however, this normal flow and carrying capacity is greatly increased resulting in a delta of sand found at the mouth of the inlet.

Very little run-off water from the surrounding higher ground finds its way into the pond. The surrounding soil is a mixture of sand, silt, clay and muck, much of which holds water rather well and retards run-off where it might occur.

In the presence of a permanent outlet, fluctuations in water level are not noticeable. Approximately two miles below the pond the outlet joins the outlet of Lake Lansing which is tributary to the Red Cedar River. This arrangement places Tihart Lake in the Grand River drainage system.

Depth.

The maximum depth of the pond is thirteen feet. The depth measurements were secured in the following manner: ten boat trips were taken across the pond at right angles to its long axis, and one trip was made along the long axis. A depth measurement was secured every five oar strokes on all these trips, using a cone-shaped sounding weight. It is entirely possible, however, to have missed any deep holes that might occur in the pond using this method, but the characteristics of the bottom make this improbable.

The bottom contours and slopes from the shore to the deepest parts of Tihart Lake are irregular. The five-foot

contour was found in several instances in close proximity to the shoreline. It is only in the north-east end of the pond that the bottom slope is gradual. The ten-foot contour was found to have approximately the same relationship to the five-foot contour as the five-foot contour has to the shoreline. The slope from the ten-foot depth to the deepest parts of the pond is very slight. This arrangement gives Tihart Lake a saucer-shaped basin with the greatest bottom area covered by ten or more feet of water.

Bottom Types.

Three distinct bottom types were found, namely: fibrous peat, marl, and sand. Sand covers only a very small area, at the point where the inlet enters the pond. Here a delta of alluvial sand has been deposited after heavy rains, have swollen the inlet and increased its carrying capacity. The sand extends some 20 to 30 feet into the pond and is hard enough to bear the weight of a person, unlike the rest of the shoreline which is fibrous peat and will not support a human.

Fibrous peat comprises the bottom of all the shoreline, save that area described above. Along the south-east and north-west shores it extends, in some instances, 50 to 75 feet before merging into the marl which is the characteristic bottom type for the pond. Along the north-west shore the fibrous peat extends but a short distance, 15 to 25 feet, into the pond before giving away to the marl bottom. Only a narrow fringe of fibrous peat was found along the north shore. Here the marl extends to within 5 to 10 feet of the shoreline.

Along stretches of the east and west shore continuous with the south end of the pond, fibrous peat supports continuous beds of emergent spatterdock. Three more or less distinct habitats are thus presented, each determined by the underlying bottom.

Turbidity.

The color of the water in Tihart Lake is brown, characteristic of its bog and marshy surroundings. Turbidity runs high: a Secchi disc reading on July 10, 1943, was 2 feet 4 inches. Readings taken at ten-day intervals, July 20 and August 1, 1943, were 3 feet 3 inches and 4 feet 2 inches, respectively. The high turbidity on July 10 is thought to have been caused by the great numbers of plankters and algae present on that date. As the summer progressed these plants and animals began to die and the water became less turbid.

There were times during this period of high turbidity that the pond was covered with a thin bluish-green bloom, the plankton and algae being so numerous. The effect of the bloom upon fishes was not noticeable.

CHEMICAL SURVEY OF TIHART LAKE

Table 1 lists the chemical analyses of water samples taken from Tihart Lake during the winter of 1944. The methods used were those outlined in Standard Methods for the Examination of Water and Sewage (1938). The Winkler method was used for the determination of the parts per million of dissolved oxygen.

TABLE 1

CHEMICAL CHARACTERISTICS OF TIHART LAKE

STATION	DATE	DEPTH OF SAMPLE	TEMPERATURE IN DEGREES CENTIGRADE	pH	DISSOLVED OXYGEN WINKLER METHOD	FREE CARBON DIOXIDE	METHYL ORANGE ALKALINITY
1	1/25/44	0-S*	4	---	9.9	11	210
		13-B**	4.5	---	4.0	22	280
2	2/17/44	0-S	3	7.4	12	8	290
		10-B	5	7.2	5.8	14	336
3	2/17/44	0-S	3.5	7.67	15	12	250
		7-B	5	7.0	7.2	20	325

* Surface readings
** Bottom readings

It may be noted from reviewing the data in Table 1 that there is a considerable oxygen depletion at the bottom. This is to be expected, owing to the organic nature

of the bottom deposits. This is not a limiting factor, however, since the pond is relatively shallow. A shallow pond such as Tihart Lake is subject to winter anaerobiosis and an accompanying fish-kill should the ice cover and heavy snows persist. The last few winters have been moderate and there are no reports of a winter kill for Tihart Lake.

The free carbon dioxide in Tihart Lake is high. This is natural during the winter months since the ice cover prohibits the escape of the gas. An area of open water occurred at the point where the inlet empties into the pond throughout the winter. This may account for the difference in values of free carbon dioxide at station 2 and stations 1 and 3 as the open water would permit escape of some of the gas. Station 2, it may be noted from the map, was near and almost in line with the inlet. The high results for the bottom readings are attributed to the accumulation and decomposition of organic matter.

The waters of Tihart Lake are only slightly alkaline, having an average pH value near 7.3. The methyl orange alkalinity or bound carbon dioxide is high as is the case of most of the waters of this region.

The chemical characteristics of Tihart Lake are similar to those of Burke, Park and Rose Lakes and Lake Lansing (Roelofs 1941).

Vegetation.

The higher aquatic flora are represented by both emergent and submergent plants. The yellow water lily, spatterdock, or cow lily (Nuphar advena Ait.) is by far the most common and prominent species present. Only one other species of emergent or surface vegetation was found. This plant was the lesser duckweed (Lemna minor L.) which was not discovered in the pond until late in the season (Oct. 1943).

The distribution and extent to which the yellow water lily inhabits the pond is demonstrated on the map. The beds of emergent vegetation shown in this map are entirely composed of spatterdock. Swingle and Smith (1942) consider pond weeds to be noxious because they grow so rapidly that they soon fill the pond. They are also objectionable because they protect the smaller fish from larger ones so well that the pond may soon become overcrowded and the fish stunted. Smith and Swingle (1940 and 1941) have developed methods of controlling pond weeds by mechanical means and by the use of fertilizers.

Lagler and Ricker (1942) consider the yellow water lily to be of positive value in providing shade to cool the water, in harboring insects important as fish food, and in providing fish shelter. The spatterdock beds in Tihart Lake have not reached the extent at which they have deleterious effects upon the pond and are believed to be of positive value to it. In support of this belief, bluegills and

largemouth bass were observed lying in the shade made by the leaves of this plant during the hot, clear summer days. Numerous schools of young fishes were observed among the beds of yellow water lily, and many bluegill and largemouth bass fingerlings were taken with a scap net from such beds.

The submergent vegetation consists of one green algae (Spirogyra sp.), water weed (Anacharis canadensis Michx.), water buttercup (Ranunuculus aquatilis L.), and coontail (Ceratophyllum demersum L.). Of these four submergents, the algae and coontail are by far the most common. Coontail was found almost as extensively in the pond as spatterdock. It grows along the shore in water to a depth of five feet. None of the submergent vegetation penetrates beyond the five foot depth since the water is too turbid for such growth to exist.

An important semi-aquatic plant of the shoreline is the water willow (Decodon verticillatus (L.) Ell). This normally terrestrial species forms a fringe up to ten feet in width for three-quarters of the shoreline. The water willow is supported by the fibrous peat and is accompanying the encroaching bog mat. This places the roots and stems of this plant in water up to a foot in depth. Just as the extensive beds of spatterdock afford fish shelter so does the water willow. Many of the younger fishes (bluegill) and smaller fishes (stickle back and mudminnow) were found using this feature of the pond as a shelter and haven from the larger predacious fishes.

It is also possible that these submerged areas of water willow may be utilized for spawning during the spawning seasons of such species as the carp, pike, and even bass and bluegill.

Food of Fishes.

Bottom samples taken with an Ekman-Birge (size: 6" x 6") dredge were analyzed in order to determine the kinds and amount of available fish food organisms. These, six in all, include collections taken from all of the bottom types of the pond (sand, fibrous peat and marl) at varying depths. The stations at which the samples were taken are indicated on the map.

The samples collected by the use of the dredge were transferred to large glass jars and brought into the laboratory. Here the animal life was picked out of each and preserved in 10% formalin solution and later identified. The following discussion lists the organisms found in the samples by station, the bottom type, and the depth at which it was taken.

Station #1. Bottom type--sand; depth--about 10 inches. The organisms found in this sample were Ostracoda; Copepoda; genera Cathocamptus and Cyclops; the scud (Hyalella), order Amphipoda; and larvae of the genus Chironomus, order Diptera. The Ostracoda, Amphipoda, and Chironomids were quite common. Single specimens of the two genera of Copepods were identified from the sample.

Station #2. Bottom type--marl; depth--10 feet. Organisms identified in this sample were Ostracoda and larvae of the order Diptera, genera Corethra and Chironomus. All of these animals were abundant in the collection. The Chironomids were the large red so-called "blood worms."

Station #3. Bottom type--fibrous peat; depth--about 2 feet. Ostracoda; the two genera of Copepoda, Canthocamptus and Cyclops, and the Amphipod, Hyalella, were common in this sample. A single specimen of the water mite, Hydracarina, as well as a nymph of the damsel fly, genus Anomalagrion were identified. Chironomid larvae were very abundant. Nymphs of the order Ephemeroptera, genus Caenis, were common and one leech, class Hirudinea, was found in the sample.

Station #4. Bottom type--fibrous peat; depth--12 inches. This collection taken from the same type of habitat as No. 3 was found to exhibit the greatest variety of insect life. Ostracoda and the Amphipod, Hyalella, were relatively common. Leeches, class Hirudinea, were found as in the preceding sample. Chironomid larvae and the May fly nymph, Caenis, were sparsely represented. Nymphs of the damsel fly, genus Anomalagrion and the two genera Tetragoneuria and Somatochlora of dragon flies were also identified from the sample.

Station #5. Bottom type--marl; depth--13 feet. But three forms of animal life were identified from this collection. Ostracoda and the phantom midge larvae, Corethra, were abundant. Chironomid larvae, the "blood worm", were common.

Station #6. Bottom type--fibrous peat; depth--18 inches. This sample yielded but three forms of animal life as did the preceding collection. The "blood worm" larvae, Chironomus, was very abundant. Ostracods were common and a single nymph of the May fly, Caenis, was identified.

The following list of aquatic insects, adults, nymphs, and larvae was secured through the identification of insects collected at odd times throughout the physical and chemical surveys. Some were collected with the scap net while others were taken at the time the aquatic vegetation was collected. The list is as follows:

Order Odonata---nymphs
  Suborder Zygoptera---damsel flies
    Family Coenagrionidae
      Genus Argia
  Suborder Anisoptera---dragon flies
    Family Libellulidae
      Genus Tetragoneuria
        " Sympetrum
        " Mesothemis
        " Somatochlora
        " Plathemis
Order Hemiptera---adults
    Family Corixidae---Water-Boatman
      " Nepidae---Water Scorpion
      " Belostomatidae---Giant Water Bug
Order Coleoptera---adults and larvae
    Family Dytiscidae---Predacious Diving-Beetle

Table 11 lists the animal life phylogenetically and the numbers of each taken at the six stations in the pond as well as the aquatic insects collected at odd times.

Microscopic plants (phytoplankton) occurred in quantity in samples taken on July 15, 1943. Cyanophyceae, blue-green algae, genus Nostoc was the dominant form. Another blue-green form was the genus Aphanocapsa. The most abundant

TABLE 11

Phylogenetic List and Numbers of Animal Life Collected from Tihart Lake.

Phylogenetic List	Station Number 1	2	3	4	5	6	Misc.
Phylum Annelida							
Class Hirudinea			1	4			
Phylum Arthropoda							
Class Crustacea							
Subclass Ostracoda	x*	xx**	x	x	xx	x	
Subclass Copepoda							
Genus Canthocamptus	1		1				
Genus Cyclops	2		1				
Subclass Malacostraca							
Order Amphipoda							
Genus Hyalella	3		8	11			
Class Insecta							
Order Ephemeroptera							
Genus Caenis			10	1		1	
Order Odonata							
Suborder Zygoptera							
Family Coenagrionidae							
Genus Anomalagrion			1	3			
Genus Agria							1
Suborder Anisoptera							
Family Libellulidae							
Genus Tetragoneuria				1			9
" Somatochlora				1			3
" Sympetrum							1
" Mesothemis							1
" Plathemis							1
Order Hemiptera							
Family Corixidae							xx
Family Nepidae							1
Family Belostomatidae							1
Order Coleoptera							
Family Dytiscidae							5
Order Diptera							
Family Chironomidae							
Genus Chironomus	8	20	28	3	6	13	
Family Culicidae							
Genus Corethra		27			16		
Class Arachnoidea							
Order Hydracarina			1				

* Common
** Abundant

green algae, Chlorophyceae, was the genus Oedogonium. Other green algae forms common to the pond are desmids and diatoms. Microscopic animals (zooplankton) identified from the pond were the Ostracods and Copepods named above which were taken at the time of bottom sampling.

Figure 1 shows the food chain leading to the production of legal-sized game fish in the pond. The key industry animals are consumed by young bluegills and crappies. These young centrarchids, plus minnows, provide the principal food for largemouth bass, the larger bluegills and black crappies and the northern pike. Another common group of fish typically feeds directly upon bottom foods. Its members are the white sucker and golden redhorse.

Fishes.

The fishes of Tihart Lake were captured with nets and by hook and line fishing. Three types of nets were used, namely: fyke, gill, and scap nets. Two 2½-inch stretched (1¼-inch square) mesh fyke nets were placed in the pond July 7, 1943. These were set parallel with the shoreline to take fishes in their shoreward movements. The fyke net sets were changed each week as the catch tended to become less after the nets had remained in the same area for a period of four or five days. Occasionally one of the nets was placed in deep water, but this practice was abandoned as the catch was not large enough to warrant it.

A fifty-foot leader of 4-inch stretched (2-inch bar) mesh was added to one of the fyke nets in hopes of increasing

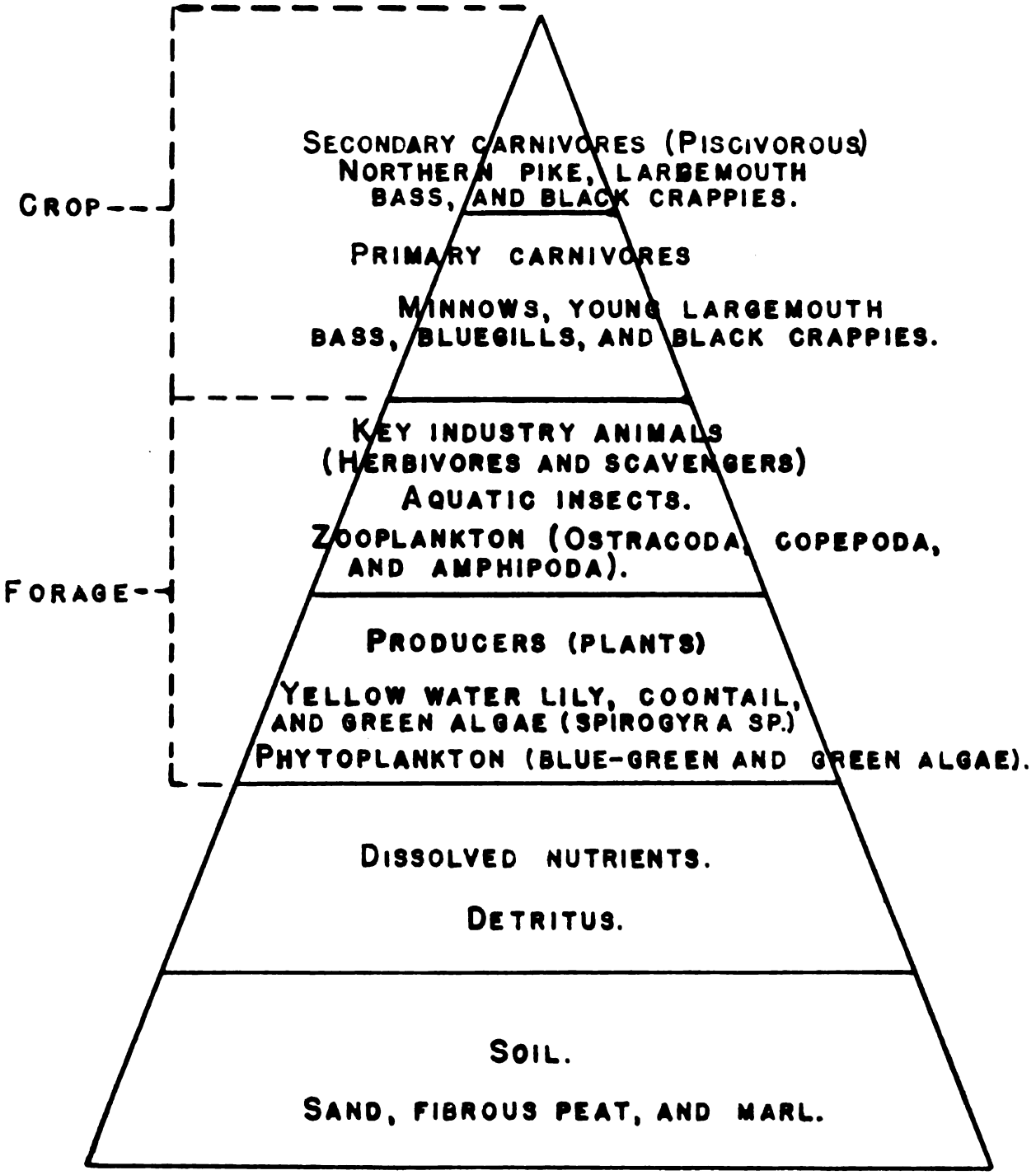


FIG. 1. FOOD CHAIN RELATIONSHIP FOUND IN TIHART LAKE.

the catch. The net was set with the leader running out from shore with the fyke net at the outer end. This arrangement increased the catch of turtles in the net but had very little effect on increasing the fish catch.

Gill nets varying from 3½-5-inch stretched (1 3/4-2½-inch square) mesh were placed in the pond for several days in August, 1943 and again for a two-week period in October, 1943. These nets were set both parallel with the shore and running out into the pond from shore. Very little difference was noted in the numbers of fish captured in relation to the net set. During the two-week period of October that gill nets were run in the pond, two 100 feet gill nets were tied end to end making a net 200-feet in length. This net when set stretched approximately halfway the distance across the pond. Even this arrangement failed to increase the fish catch any appreciable amount. It was useful, however, in obtaining some of the larger suckers inhabiting the pond.

The catch taken by hook and line fishing proved to be very small. One species, however, was taken by this method that was not taken in the nets. There are no creel census reports available for the pond. It is the author's belief that such reports would show a very low catch as compared to the time fished.

A scap net, a shallow dip net with a long handle, was used from the boat and shore to take small fish along the shoreline. Many bluegill and bass fingerlings were taken in this manner as well as several other shore and mud-dwelling species.

The standard and total lengths in millimeters were recorded for all the fishes captured in the nets and by hook and line fishing except the bullheads. Only a record of the numbers of this species captured was recorded. Scale samples were taken from all the game fishes captured. These were removed from the left side of the fish mid-way between the dorsal fin and lateral line. The scales were placed in specially prepared envelopes bearing the measurements of the respective fish. Those fish taken alive in the nets were returned to the pond after the anal fin had been clipped. The clipping of the anal fin was done to serve as a check for fishes recaptured in the nets. The bullhead was the only species recaptured in the nets. The right pelvic fin was clipped on those that were taken a second time.

The netting of fish was discontinued after a species list had been compiled for the pond and scale samples and measurements had been taken and recorded for a total of one hundred and sixty-six specimens. Table III presents the species, manner of capture and total numbers of each taken during the three and one-half months of netting operation in Tihart Lake.

TABLE 111

Species	Method of Capture				Total
	Fyke net	Gill net	Scap net	Hook and line	
Bowfin, dogfish	x				1
Golden redhorse	x				2
Common sucker	x	x			30
Carp*					
Yellow bullhead	x			x	54
Tadpole madtom**			x		
Mud minnow**			x		
Northern pike	x	x			10
Yellow perch				x	5
Johnny darter**			x		
Largemouth bass	x		x	x	13
Warmouth bass		x	x		3
Sunfish	x				4
Bluegill	x		x	x	54
Black crappie	x				45
Brook stickleback**			x		

* This species is reported for the pond, none were captured during the netting operations.

** Numbers of these fishes were not recorded but included here in the species list for the pond.

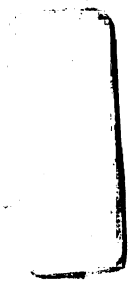
An annotated list of fishes that occur in Tihart Lake with a brief discussion of each species follows.

Amiidae--Bowfins

1. Amia calva Linnaeus. Bowfin, dogfish. But one specimen was captured in a fyke net. A predatory species which is considered rare to the pond.

Catostomidae--Suckers

2. Catostomus commersonnii commersonnii (Lacepede). Common sucker. Figures from the netting results show this species to be a common one of the pond. The species is of major importance in ecological relations with other species both as a food supply and as a competitor.



3. Moxostoma erythrurum (Rafinesque). Golden redhorse. Two specimens were taken in July in the fyke nets. It is not as abundant as the common sucker, but of importance in ecological relations with other species.

Cyprinidae--Minnows

4. Cyprinus carpio Linnaeus. Carp, German carp. Reports are that this species was observed spawning along the shores of the pond early in the summer. However, not a single specimen, young or adult, was taken throughout the netting operations. It cannot be concluded from this fact however, that carp do not inhabit the pond.

Several schools of small minnows were observed in the pond at various times throughout the summer. Attempts were made to capture them for identification purposes. None were captured, however. These fishes are important, serving as forage fishes for the larger fishes of the pond.

Ameiuridae--Catfishes

5. Ameiurus natalis (Le Sueur). Northern yellow bullhead. This species is common in the pond. A survey of fishermen showed that this species is not sought for in angling. A total of fifty-four specimens were captured in the fyke nets, the anal fins of which were clipped, and returned to the pond. This is the only species to have been recaptured in the nets.

6. Schilbeodes gyrinus (Mitchell). Tadpole madtom. A relatively common species of the pond which inhabits the shallow, weedy areas. Of little value as a forage species.

Umbridae--Mudminnows

7. Umbra limi (Kirtland). Mudminnow. A common forage species of the pond. Found to share the shallow, weedy areas with the tadpole madtom.

Esocidae--Pickerels

8. Esox lucius (Linnaeus). Northern pike. A thinly scattered member of the pond. It is an important game fish and furnishes some fishing in winter as well as summer. Also important as a predatory species in keeping the numbers of smaller fishes in check.

Percidae--Perches

9. Perca flavescens (Mitchell). Yellow perch. Rare, but five were taken by hook and line early in the summer. Of very little value for angling.

10. Boleosoma nigrum nigrum (Rafinesque). Johnny darter. A species sparsely distributed in the pond inhabiting the shallow, weedy areas.

Centrarchidae--Sunfishes

11. Huro salmoides (Lacepede). Largemouth bass. One of the three most important species inhabiting the pond. Figures from the netting operations tend to show that this species is not abundant in the pond. It is felt however, that a very small percentage of the adult bass in the pond were captured. Many fry and fingerlings of the species were observed in the shallows of the pond. The species is important as a game fish and furnishes a great deal of angling.

12. Chaneobryttus gulosus (Cuvier). Warmouth bass.

Rare to the pond. But four specimens were taken in the gill nets in October, 1943. This fish is of little angling importance, the young serving as forage for the larger fishes.

13. Lepomis gibbosus (Linnaeus). Common sunfish. Another rare member of the pond. Not abundant enough to be of any angling importance.

14. Lepomis macrochirus macrochirus (Rafinesque). Common bluegill. The most common and abundant species inhabiting the pond. This fish is the one most sought for by anglers in both winter and summer fishing.

15. Pomoxis nigro-maculatus (Le Sueur). Black crappie. This fish ranks with the bluegill in abundance. It, as well as the bluegill, furnishes a great deal of fishing in both winter and summer.

Gasterosteidae--Sticklebacks

16. Eucalia inconstans (Kirtland). Brook stickleback. A common species dwelling in the shallow, weedy areas of the pond.

Growth rate studies.

This study on the age and growth of the fishes from Tihart Lake is based on 166 specimens taken throughout the summer, fall and winter of 1943. The 166 fish were taken with fyke nets, gill nets, seap nets and hook and line. All measurements were obtained from fresh fish in the field by means of a specially constructed measuring board. Standard and total length measurements were recorded in millimeters on the scale envelopes containing scale samples of the respective fish.

The scales were cleaned, mounted in a glycerine-gelatine solution, and studied in the customary manner by means of a microprojection apparatus at magnifications of 28 and 46 diameters. The microprojection machine employed in determining the age of scales of fishes from Tihart Lake is constructed similarly to the one described by Van Oosten, Deason and Jobes (1934). All growth computations were based on measurements made along the anterior radius of the projected images of the scales. The calculations were made on the assumption that the bodyscale ratio remained constant at all times after the completion of the first annulus. The age of each fish, expressed by Roman numerals, indicates the number of annuli found on the scales. Thus, a III-year fish represents one taken in its fourth year of life. I am greatly indebted to Dr. Peter Tack for valuable assistance rendered in determining the ages of some of the more difficult scales.

The order in which the age and growth analysis of fishes from Tihart Lake occurs is based on the angling importance and relative abundance of the species inhabiting the pond. Fish will be given only their vernacular names in what follows; a list of corresponding scientific names is given earlier in the paper under that section dealing with the fishes of the pond.

BLUEGILLS

This species and following fish, black crappie, are about equal in abundance. The bluegill however, is of greater importance and is therefore considered first.

In Table 1V the fish in the sample have been divided into age groups and according to the year class to which they belong, with individuals of each group arranged by their standard length. The number of individuals in each age group and the percentage of that number in the entire collection are shown at the bottom of the table. The column at the right gives the number of fish of each size group. The table reveals that no fish taken were younger than 3 years or older than 9 and that age groups 11, 111, V11, and V111 were poorly represented. Age group V predominated in the sample, comprising 39 percent of the catch. The bulk (79.6 percent) of the sample was composed of individuals that belonged to age groups 1V, V, and V1.

TABLE 1V

Frequency distribution of Tihart Lake bluegills according to standard length in millimeters, age group (Roman numerals), and year class (calendar years), with sexes combined.

Standard length in mm.	Age group and year class							Total number
	11 1941	111 1940	1V 1939	V 1938	V1 1937	V11 1936	V111 1935	
94.5-104.5	1	..	..	..	..	..	..	1
104.5-114.5	..	..	..	..	..	..	..	
114.5-124.5	2	..	1	..	..	..	..	3
124.5-134.5	..	3	2	..	..	..	..	5
134.5-144.5	..	1	4	4	..	..	..	9
144.5-154.5	..	1	3	6	2	..	..	12
154.5-164.5	..	..	3	8	4	2	..	17
164.5-174.5	..	..	..	3	3	..	..	6
174.5-184.5	..	..	..	..	..	..	1	1
Number	3	5	13	21	9	2	1	54
Percentage	5.5	9.3	24.0	39.0	16.7	3.7	1.8	

Table V shows the mean standard length and mean increment in standard length of bluegills of each age group for sexes combined. Figure 2 shows the growth curve of Tihart Lake bluegills. The curves of this figure are based on the mean standard lengths and the mean annual increment taken from Table V. The growth illustrated by the curve is normal until it reaches age group VII where it suddenly turns upward to the age group VIII mark. The explanation for this feature of the growth curve is an insufficient number of specimens of age group VIII.

In length the bulk (70.3 percent) of the sample ranged between 136 millimeters, standard length (total length 6.8 inches) and 164 millimeters, standard length (total length 8.26 inches). Figure 3 presents this data graphically. It may be noted, by reviewing Table IV, that length is a poor index of age, since fish of the same length may belong to as many as three or four different age groups.

TABLE V

Mean standard length and increment in length for each year class and age group of Tihart Lake bluegills, sexes combined.

Year class	Age group	No. of specimens	Mean standard length in mm.	Mean total length in inches.	Increment in S. L.*
1941	II	3	110	5.5	..
1940	III	5	137	6.8	27
1939	IV	13	143	7.2	6
1938	V	21	154	7.7	11
1937	VI	9	159	7.9	5
1936	VII	2	162	8.1	3
1935	VIII	1	178	8.9	16

*Standard length

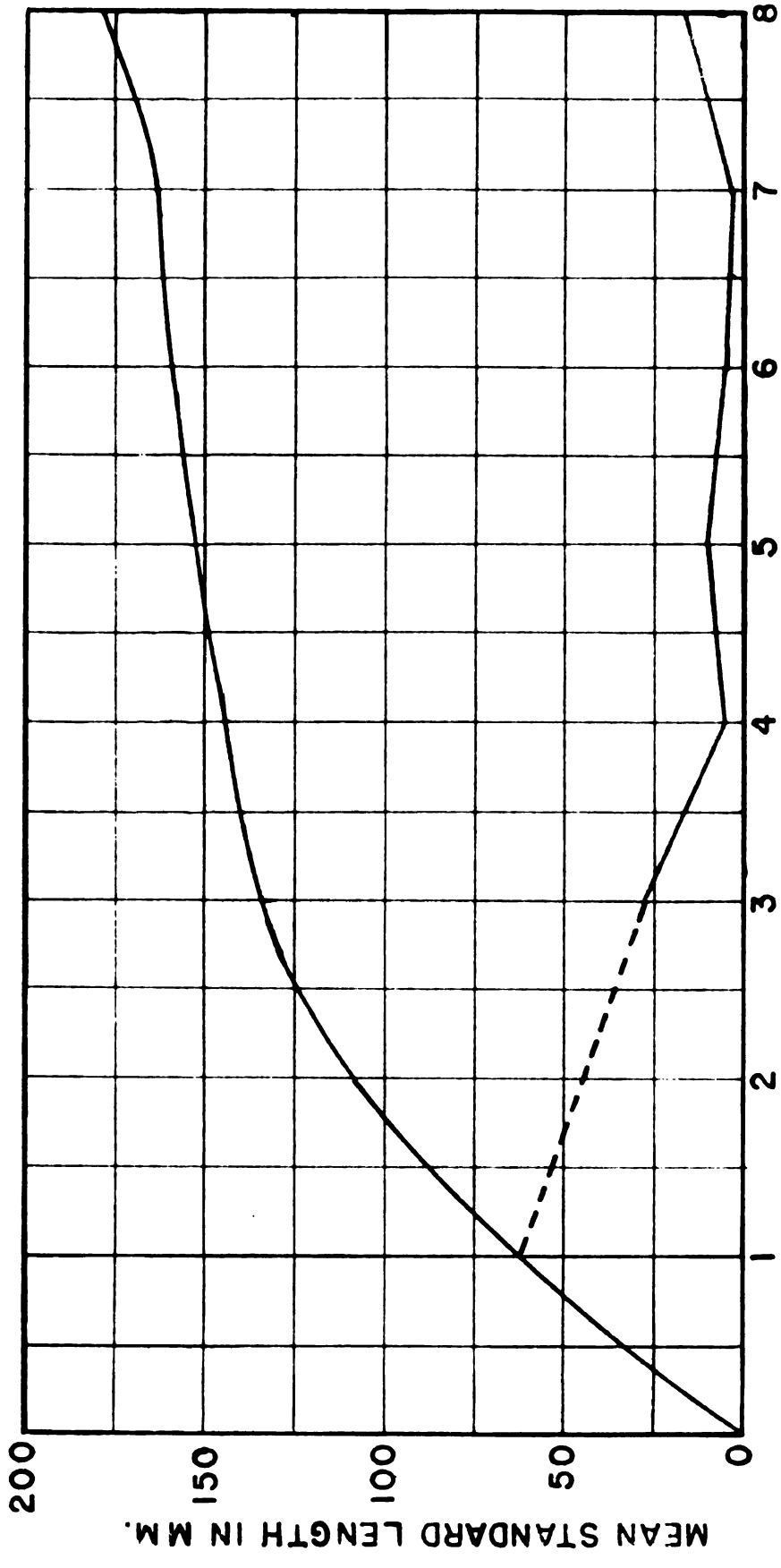


FIG. 2. GROWTH CURVES OF TIHART LAKE BLUEGILLS
UPPER CURVE—MEAN STANDARD LENGTH OF EACH AGE GROUP. LOWER CURVE—MEAN INCREMENT IN STANDARD LENGTH FOR EACH AGE GROUP. CURVES BASED ON FIGURES OF TABLE V.

FIG. 3. STANDARD LENGTH FREQUENCY DISTRIBUTION OF TIHART LAKE BLUEGILLS.

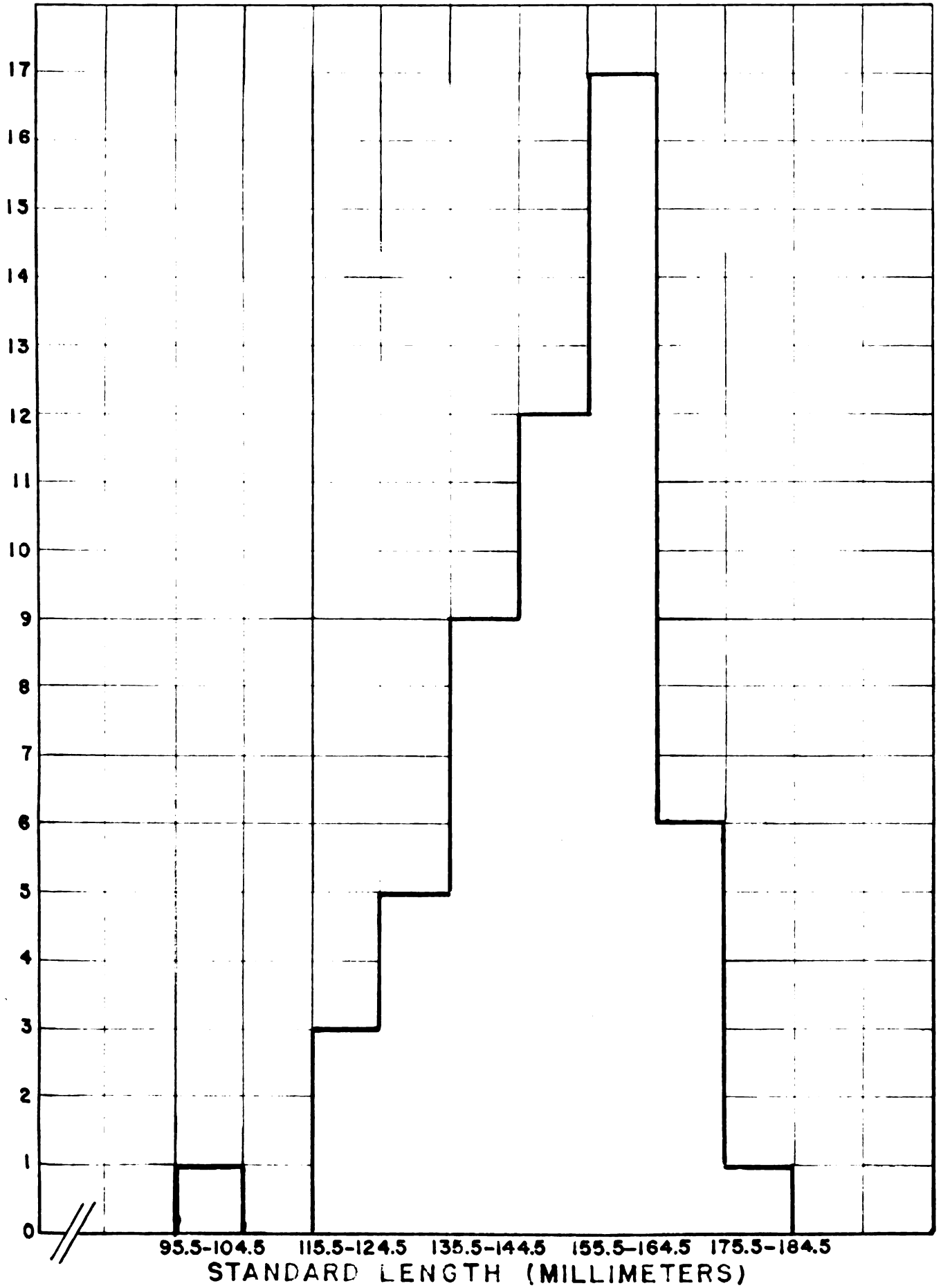


Table VI shows for sexes combined the mean computed standard length at each annulus of the bluegills. The method of calculation used was the formula developed by Fraser (1920). The standard length at any annulus is equal to

$$L_n = C + \frac{S_n}{S}(L-C)$$

where C is the length at the time of scale formation (20 millimeters was assumed for bluegills, black crappies and largemouth bass), S_n is the scale diameter (or radius) at any annulus, S is the scale diameter (or radius) at time of capture, and L is the length at time of capture. The number of specimens used in calculating the standard length at any annulus is indicated in the table. The calculated lengths are to be regarded as close approximations rather than actual lengths.

TABLE VI

Mean calculated standard lengths for each annulus of each year class and age group of Tihart Lake bluegills, with sexes combined.

Year class	Age group	No. of specimens	Calculated standard length, in mm., at annulus							
			1	2	3	4	5	6	7	8
1941	II	3	50	92	...	...	...	...	...	...
1940	III	4	52	86	118	...	...	...	...	...
1939	IV	3	51	86	118	143	...	...	...	...
1938	V	3	40	67	96	128	138	...	...	...
1937	VI	3	36	63	93	119	137	153	...	...
1936	VII	2	38	59	87	109	128	144	156	...
1935	VIII	1	36	66	102	118	142	157	166	173
Grand averages calculated length			43	74	102	123	136	151	161	173

The calculated lengths indicate considerable variation

in the growth of the different age groups. For example, age groups VI and VIII reached a length of only 36 millimeters at the first annulus mark, whereas age group III attained a length of 52 millimeters. Differences in rates of growth occurred also in the other age groups.

An analysis of the growth data for Tihart lake bluegills shows that the growth of this species is about normal for this section of the state. The fish reach the Michigan legal limit during their fourth year of life, and when growth for that year is completed are about 6.8 inches long. The growth of this species in Tihart Lake is comparable to the growth exhibited by Foots Pond bluegills where they achieve a length of 6.7 inches in their fourth year of life (Ricker and Lagler, 1942).

BLACK CRAPPIE

In Table VII the fish in the sample have been divided into age groups and according to the year class to which they belong, with the individuals of each group arranged by their standard length. The number of individuals in each age group and the percentage of that number in the entire collection are shown at the bottom of the table. The column at the right gives the number of fish of each size group. The table reveals that no fish taken were younger than 3 years or older than 8 and that age groups II, VI and VII were poorly represented. Age groups IV predominated in the sample, comprising 35.5 percent of the catch. The bulk (73.2 percent) of the sample was composed of individuals

that belonged to age groups III, IV and V.

TABIE VII

Frequency distribution of Tihart Lake black crappies according to standard length in millimeters, age group (Roman numerals), and year class (calendar years), with sexes combined.

Standard length, in mm.	Age group and year class II 1941	III 1940	IV 1939	V 1938	VI 1937	VII 1936	Total number
109.5-119.5	3	3	..	..	..	..	6
119.5-129.5	..	1	..	..	..	..	1
129.5-139.5	..	1	..	..	..	..	1
139.5-149.5	..	..	..	..	..	..	..
149.5-159.5	..	1	4	1	..	..	6
159.5-169.5	..	1	2	1	..	..	4
169.5-179.5	..	..	6	1	..	..	7
179.5-189.5	..	1	2	2	3	1	9
189.5-199.5	..	..	2	4	1	1	8
199.5-209.5	..	..	..	..	2	..	2
209.5-219.5	..	..	..	..	..	..	..
219.5-229.5	..	..	..	..	..	..	..
229.5-239.5	..	..	..	..	..	1	1
Numbers	3	8	16	9	6	3	45
Percentage	6.7	17.7	35.5	20.0	13.4	6.7	

Table VIII shows for sexes combined the mean standard length and mean increment in standard length of black crappies of each age group. Figure 4 shows the growth curve of Tihart Lake black crappies. The curves of this figure are based on the mean standard lengths and the mean annual increment taken from Table VIII. The curve indicates the growth for this species is relatively rapid.

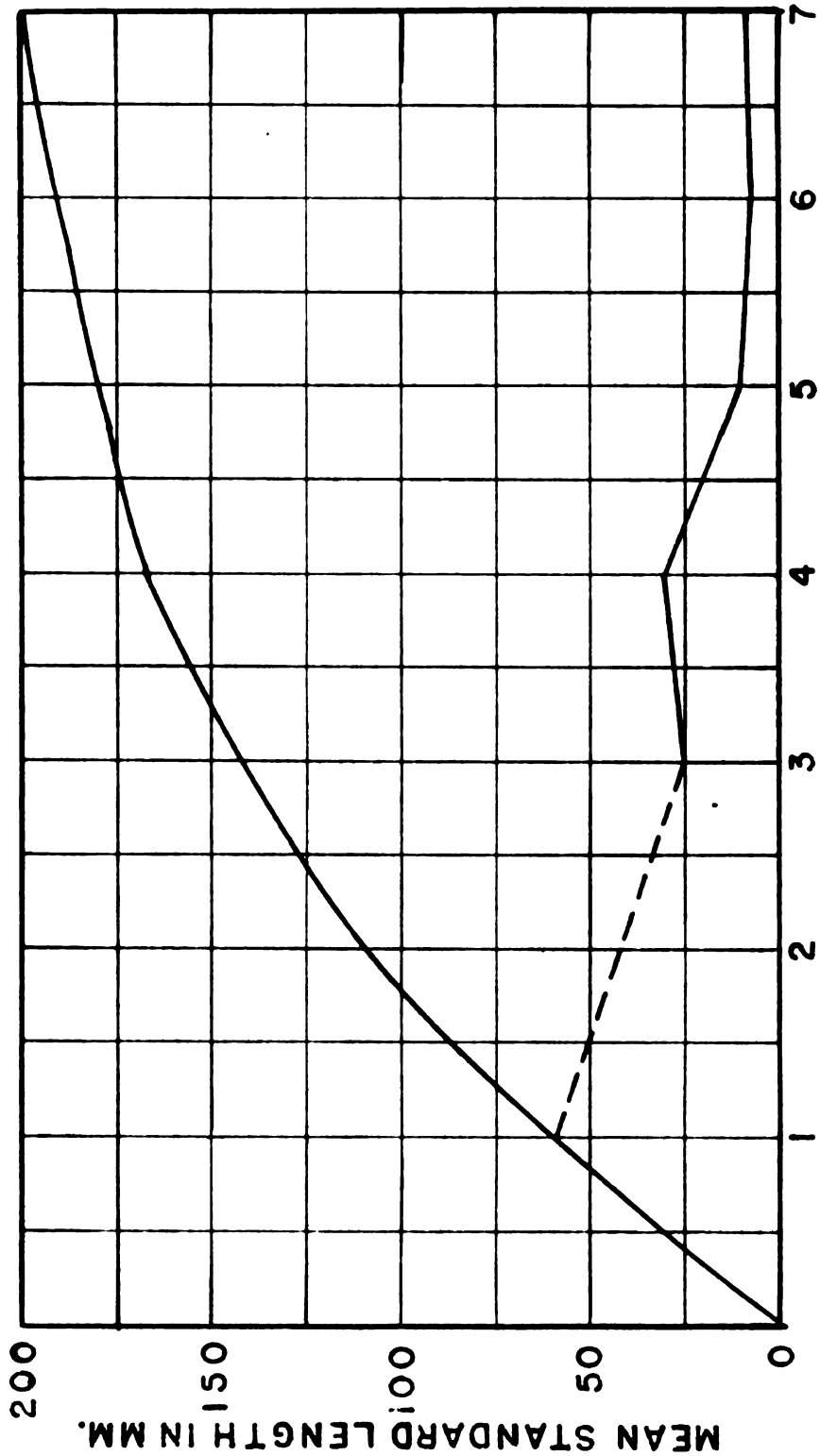


FIG. 4. GROWTH CURVES OF TIHART LAKE BLACK CRAPPIES
UPPER CURVE — MEAN STANDARD LENGTH OF EACH AGE GROUP. LOWER CURVE — MEAN INCREMENT IN STANDARD LENGTH FOR EACH AGE GROUP. CURVES BASED ON FIGURES OF TABLE VIII.

TABLE VIII

Mean standard length and increment in length for each year class and age group of Tihart Lake black crappies, sexes combined.

Year class	Age group	No. of specimens	Mean Standard length in mm.	Mean total length in inches	Increment in S.L.*
1941	II	3	113	5.6	..
1940	III	8	138	6.9	25
1939	IV	16	178	8.6	40
1938	V	9	182	9.1	4
1937	VI	6	192	9.6	10
1936	VII	3	204	10.3	12

*Standard length.

In length the bulk (75.5 percent) of the sample ranged between 151 millimeters, standard length (total length 7.5 inches) and 197 millimeters, standard length (total length 9.9 inches). Figure 5 shows the standard length frequency distribution of Tihart Lake black crappies.

The calculated standard length at each anulus of the black crappies was computed in the same manner as that for the bluegills. Table IX shows for sexes combined the mean computed standard length at each annulus of the black crappies.

The calculated lengths indicate considerable variation in the growth of the different age groups. For example, age VII reached a length of only 38 millimeters at the first annulus mark, whereas age groups II and III attained lengths of 49 and 50 millimeters respectively. Differences in rates of growth occurred also in the other age groups.

FIG. 5. STANDARD LENGTH FREQUENCY DISTRIBUTION OF TIHART LAKE BLACK CRAPPIES.

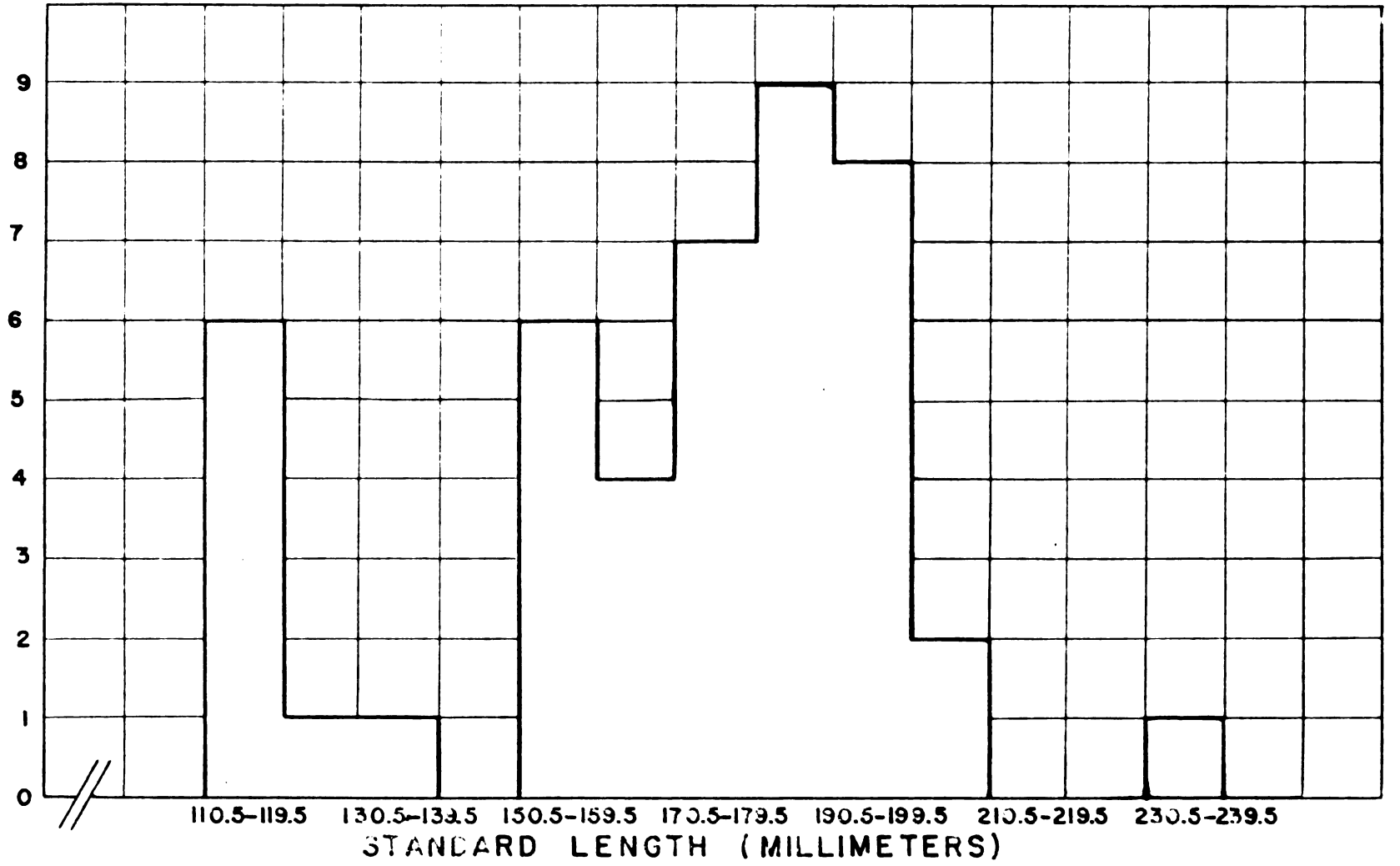


TABLE IX

Mean calculated standard lengths for each annulus of each year class and age group of Tihart Lake black crappies, sexes combined.

Year class	Age group	No. of specimens	Calculated standard length, in mm., at annulus						
			1	2	3	4	5	6	7
1941	II	3	49	81	...	...	...	...	...
1940	III	3	50	78	105	...	...	...	...
1939	IV	3	47	84	135	155	...	...	...
1938	V	3	45	74	120	155	179	...	...
1937	VI	3	47	78	104	134	166	185	...
1936	VII	1	38	65	88	124	153	189	222
Grand averages calculated length			49	77	110	142	166	187	222

An analysis of the growth data for Tihart Lake black crappies indicates that the growth of this species is relatively rapid. The fish reach the Michigan legal limit early in their fourth year of life, and when growth for that year is completed are about 6.9 inches long. The species attains greater length and exhibits more rapid growth than the bluegill which is considered the major species of the pond.

LARGEMOUTH BASS

The material for this species is less extensive than that of the bluegills and black crappies as only 13 specimens were captured. Age determinations were, in general, quite difficult. Accessory growth cessation marks were common and were a serious problem in age determinations. Table X presents the growth data of 13 largemouth bass from Tihart Lake.

TABLE X

Mean calculated standard lengths for each annulus of each age group of Tihart Lake largemouth bass, with sexes combined.

Age group	No. of specimens	Mean lengths when caught S.L.* in mm.	Mean lengths when caught T.L.** in in.	Calculated S.L.*, in mm., at annulus 1	2	3	4	5
II	7	213	10.1	59	157	...	...	...
III	3	267	12.7	61	141	233	...	...
IV	1	315	14.9	48	115	212	289	...
V	2	400	18.8	111	185	255	319	370
Grand averages calculated length				70	150	233	304	370

*Standard length
**Total length

In general, the rate of growth of these fish is not particularly rapid. Total length averages for the age groups shows that the species reaches legal size (10 inches total length) during their third year of life, so the population is by no means stunted. Difficulty in catching food during the summer months, when turbidity is high, may be a factor that retards growth.

NORTHERN PIKE

The growth data for this species is scanty as only 10 scale samples were taken. These were aged in the same manner as those of other fishes from the pond. The distribution by age groups was as follows: age group II-2, age group III-4, age group V-3, and age group IX-1. The smallest specimen captured measured 15 inches (total length) and the largest measured 32 inches (total length). The available growth data for this species indicates that they reach legal size (14 inches total length) late in their third year of life or early in the fourth year, and when growth for the

fourth year is completed are about 20.7 inches long (total length).

SUCKERS

Thirty white suckers were captured during the netting operations. All the scale samples but one, the scales of which were regenerated and therefore discarded, were aged. The age group distribution of the sample was as follows: age group IV-12, mean total length 414 millimeters; age group V-12, mean total length 430 millimeters; and age group VI-5, mean total length 492 millimeters.

Two golden red horse were captured belonging to age groups IV and VII measuring 234 and 371 millimeters (total length) respectively.

MISCELLANEOUS FISHES

Five yellow perch were taken by hook and line from the pond, 3 in age group III and 2 in age group IV. All were over the legal size (6 inches total length).

Three warmouth bass of the age group IV were captured in gill nets. The average total length of these fishes was 8.4 inches.

Of the 4 common sunfish captured one was in its fourth year of life, one in its fifth year and two in their sixth year of life. Their total lengths were 5.5, 6.3, and 6.7 inches respectively.

Turtles.

It is apparent from the numbers captured in the fyke nets during the fishing operations that Tihart Lake harbors a large population of turtles. It was not uncommon for a day's catch in either one of the fyke nets to contain more turtles than fish. On one occasion a total of 31 turtles were taken in one catch. Five species were identified from the pond. The following list gives the species and the number of each captured during the netting operations in the pond:

Sternotherus odoratus (Latreille)--Musk turtle--------4
Chelydra serpentina (Linne)--Snapping turtle---------31
Emys blandingii (Holbrook)--Blanding's turtle--------30
Chrysemys picta (Agassiz)--Western Painted turtle---169
Amyda spinifera (LeSueur)--Soft-shell turtle----------4

Lagler (1941) in a study of predatory animals and game fish found, after examining 186 snapping turtle stomachs, that the food of this species consists of 36.2% water plants, 34.2% game fish, and 19.6% carrion. He also found, after examining 394 western painted turtle stomachs, that the chief items of its food are 61.5% water plants and 19.5% aquatic insects. It may be noted by reviewing the numbers captured that these two species are the most abundant species of turtles found in the pond. Assuming that the food of these turtles in Tihart Lake is comparable to the findings of Lagler, predation by these animals is a problem to be considered. The turtle population was depleted to some extent during the netting operations since many of them drowned in the nets. The removal of some of these animals during the summer of 1943 may help to increase the fish production for

the next year or so. A more detailed study is needed, however, to determine the exact nature of this relationship between the turtles and game fish in the pond.

MANAGEMENT SUGGESTIONS

Balance of natural factors.

It is apparent that a delicate balance exists between the fishes and food organisms in Tihart Lake. This is evidenced by the fact that there are no stunted fish populations or an overabundance of any single species. The balance between the legal size game fishes and the forage fishes is also precarious. There seems to be only enough forage fish to maintain the population of legal size game fish. This is undesirable as very few game fish are added to the crop each year. There also seems to be an abundance of coarse fish (suckers), of large size, which do not enter into the crop.

Stocking policy.

Under circumstances such as those found during the summer of 1947, no stocking of Tihart Lake would be necessary, with the possible exception of an additional forage species. Not only does the pond support a population of game fish of the kind suited to its present condition, but natural propagation is successful, and survival is favored by the extensive beds of aquatic vegetation and turbidity.

Predators.

The only fish predators occurring in great enough numbers

and regarding which there is sufficient evidence to warrant concern in Tihart Lake are the turtles. The true significance of these animals in relation to the game fish population is not clearly understood. An attempt should be made, at least every other year, to remove some of these animals, especially the snapping turtle. About one-third of the diet of this species consists of game fish (Lagler, 1941). Not only would it relieve some of the predation in the pond, but it would also provide a palatable food. The numbers of the western painted turtle should be reduced at the same time, as about one-fifth of their diet consists of aquatic insects (Lagler, 1941). This would make additional food organisms available for the insectivorous fishes (bluegills).

The bowfin population is small, only one individual was captured in three and one-half months of netting.

Competitor species.

Some effort could be made to eliminate the yellow perch and warmouth bass. They feed upon other fishes and fish food organisms and are of no angling value. These fishes should not be returned to the pond when caught on hook and line.

Fishing pressure.

The abundance of legal size game fishes in the pond indicates that the crop is not being harvested in large enough numbers. The failure to do so creates competition between the species and but a limited number of each are added to the crop each year. The pond is capable of producing a good

number of game fishes. If the maximum returns are to be obtained from a pond, a high percentage of the large fish must be caught (Smith and Swingle, 1940). Therefore, a greater fishing pressure is suggested.

Addition of fertilizers.

Since there is a direct relation between the plankton content of pond water and its fish productivity, an increase in plankton will lead to an increase in fish. The application of commercial fertilizer to pond water increases the amount of plankton and when sufficient fertilizer is applied to double the plankton content the amount of fish supported by the pond is about doubled (Swingle and Smith, 1938).

Tihart Lake, in bog surroundings, is rich in organic minerals. Because of this it would not be necessary to apply organic fertilizers to the pond.

Swingle and Smith (1938) found, from experiments conducted with distilled water innoculated with a plankton culture, that the most efficient production of plankton is obtained when the water contains 4 parts per million of nitrogen (N), 1 part per million of phosphorus (P) and 1 part per million of potassium (K).

Mixed fertilizers are more convenient to use for fertilizing small ponds. Swingle and Smith (1941) recommend the following quantities of commercial mixed fertilizer required for one application per surface acre for ponds of neutral or acid water:

100 pounds 6-8-4 mixture
10 pounds nitrate of soda

to be applied separately or mixed. The desired ratio of the elements is very nearly supplied by an 8-8-3 fertilizer. A commercial fertilizer near this ratio is 6-8-4 except that it is short on nitrogen. By adding 10 pounds of sodium nitrate for every 100 pounds of 6-8-4 mixture, the ratio is brought to approximately 8-8-4, which supplies the elements N, P, and K in about the right proportion. The procedure usually followed is to make three applications at weekly intervals in the spring and subsequent applications only as needed, usually every four weeks thereafter. Fertilizers need only be applied during the growing season, June to September. The pond should be fertilized only if the increased fish production will be utilized.

Parasites.

The fishes of Tibart Lake are free of heavy infestations of parasites. Several large parasitic copepods, Argulus sp., were found on largemouth bass and suckers. The tapeworm, Ligula catostomus, was found in several of the suckers.

Little concern need be had over the parasites since the infestation is low and the parasites are removed in cleaning or destroyed when cooked and are not parasites of man.

SUMMARY

Tibart Lake is a shallow 8.58-acre pond of the Grand River drainage system. It received drainage waters from the low marshy area which extends east and north of the pond. There are no great fluctuations of the water level in the presence of a permanent outlet. Plankton turbidity is high

during the summer months. The most important and abundant aquatic vegetation is the yellow water lily or spatterdock.

The waters of the pond are only a slightly alkaline, having an average pH value near 7.3. The free carbon dioxide and dissolved oxygen content is normal. The bound carbon dioxide is high as is the case of most of the waters of this region.

The key industry animals in the food chain leading to production of game fish in the pond are the zooplankton and aquatic insect nymphs and larvae. These animals consume the phytoplankton and plant materials present in the pond and in turn are consumed by the primary carnivores (young bluegills, black crappies, and minnows). The young centrarchids, plus some minnows, provide the principal food for largemouth bass, black crappies, and the northern pike. The other common group of fishes, suckers and golden redhorse, typically feeds directly upon bottom foods.

An analysis of the growth rate data for the three most important species (bluegill, black crappie, and largemouth bass) found in the pond indicates growth to be normal for this section of the state. The three above mentioned species reach legal size in their fourth, late third or early fourth, and third year of life respectively. An insufficient number of northern pike scale samples makes the growth analysis of this species difficult. From the scanty data, it is believed that they attain legal size during their late third or early fourth year of life. Growth data of the other species of game fish found in the pond are

negligible as they are minor members of the fish population.

The pond harbors a large population of turtles (five species), 238 of which were captured during the netting operations. A more detailed study is needed to determine the exact nature of their relationship to the fish population.

Management suggestions for utilization of the pond's fishes include: removal of some of the snapping and western painted turtles at least every other year; a greater fishing pressure; and applications of inorganic fertilizers, if the added fish production is fully utilized.

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