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Biological Study of the Fishes
of the Lake Okoboji Region

A. P. Larrabee

Iowa

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AN ECOLOGICAL STUDY OF THE FISHES OF THE LAKE OKOBOJI REGION

by

AUSTIN P. LARRABEE

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AUSTIN P. LARRABEE

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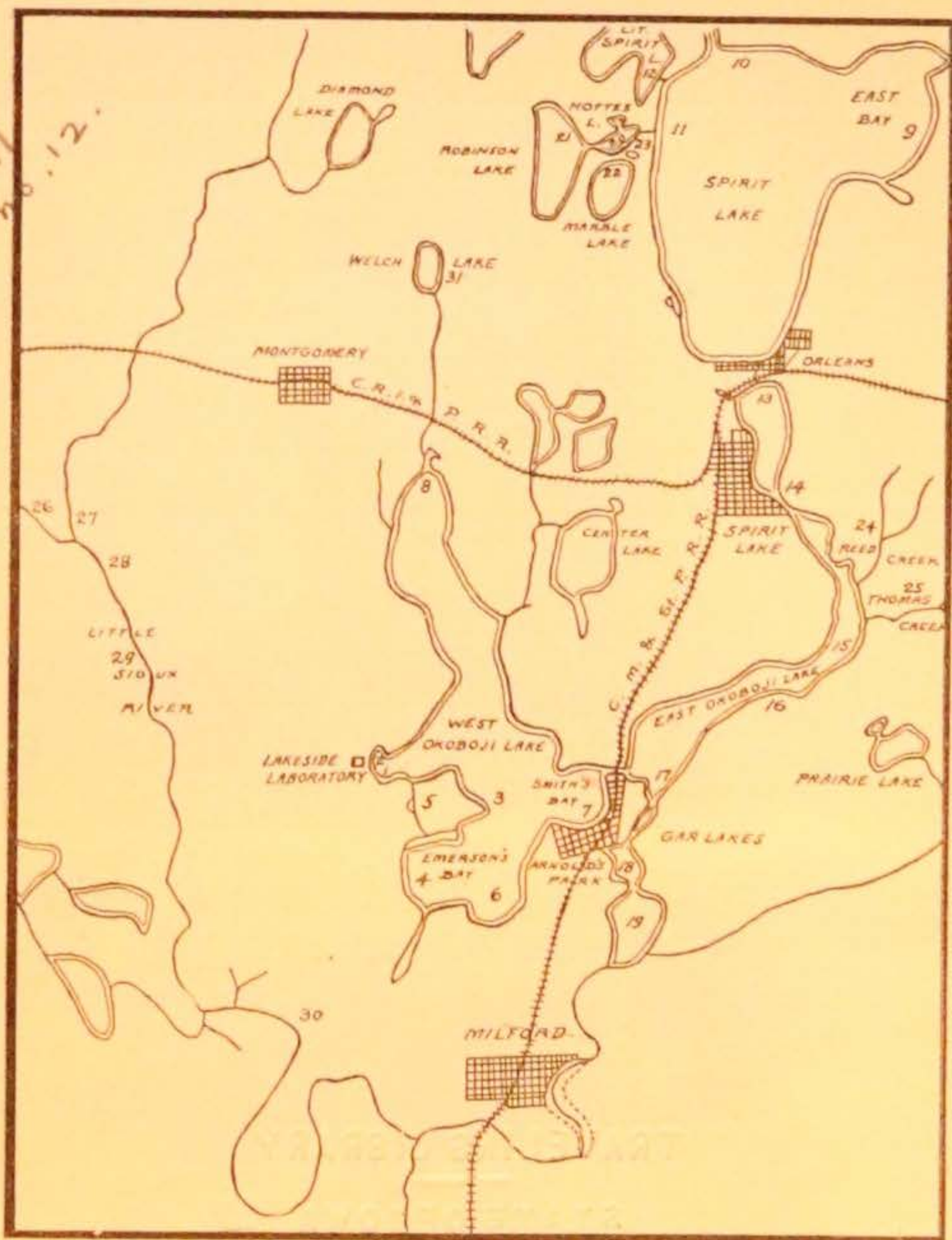


Fig. 1. Map of the Lake Okoboji Region, showing collecting stations

- | | | | |
|--------|------------------------|--------|-----------------------------|
| 1-8. | West Okoboji Lake | 18. | Middle Gar Lake |
| 1. | Miller's Bay | 19. | Lower Gar Lake |
| 2. | Sand-bar | 20. | Hottes Lake |
| 3. | Gull Point | 21. | Robinson Lake |
| 4. | Emerson's Bay | 22. | Marble Lake |
| 5. | Drainage Canal | 23. | Sunken Lake |
| 6. | Deep Hole, Emerson Bay | 24. | Reed Creek |
| 7. | Smith's Bay | 25. | Thomas Creek |
| 8. | North End | 26-30. | Little Sioux River |
| 9-11. | Spirit Lake | 26. | West Branch |
| 9. | East Bay | 27. | East Branch |
| 10. | Crandall's Lodge | 28. | Below junction of 26 and 27 |
| 11. | Opposite Hottes Lake | 29. | Near Hanging Bog |
| 12. | Little Spirit Lake | 30. | Big Bend |
| 13-17. | East Okoboji Lake | 31. | Welch Lake |
| 13. | Outlet of Spirit Lake | | |
| 14. | Drawbridge | | |
| 15. | Kline's Bay | | |
| 16. | Rocky Point | | |
| 17. | Outlet | | |

AN ECOLOGICAL STUDY OF THE FISHES OF THE LAKE OKOBOJI REGION

INTRODUCTION

This paper contains the results of studies of the fishes of the Lake Okoboji region, made by the writer during the summers of 1921, 1922, 1924, and 1925. The writer spent in all thirty-five weeks at the Lakeside Laboratory while carrying on this work. At first the intention was to investigate the distribution of certain fishes in the lakes with the factors involved, but this was enlarged later to include the listing of all the fishes found there together with their ecological habitats. The paper includes the studies not only of lake fishes but also of certain creek fishes and those of the Little Sioux River.

Through the courtesy of the Iowa State Fish and Game Department, the writer was allowed to collect the fishes necessary for this study. For this purpose seines were commonly used, and at times the hook and line. This was supplemented, when there was opportunity, by the examination of fishes in live bait boxes and in the catches of the local fishermen, together with such information as could be obtained regarding fishes. The location of the various collecting stations is shown in Figure 1, a map of the region. At the time of collecting, notebook records were made of the time of day, temperature, and weather conditions, as well as data regarding the different species and the numbers of each taken. The fish for identification were kept alive if possible. Others were preserved in 10% formalin. In case the food of the fish was to be determined, the body cavity was opened so as to allow the preservative free access to the digestive tract. This examination was made at the laboratory as soon as possible after collecting. The fish was first measured and the length, which did not include the caudal fin, recorded. Then the stomach and intestines were removed, slit open, and the contents carefully scraped out on a glass slide. The materials were examined mainly under a dissecting microscope, using the compound microscope when necessary. The different constituents were then teased apart and segregated with needles and the percentage of the volume of each estimated.

But little work has been done with the fishes of this region. Meek collected here in 1890 and records eighteen species from Spirit, East, and West Okoboji Lakes.¹ Everman also visited Spirit Lake in 1892. The statements made in his itinerary are brief and concise.

“Nov. 1. Went to Spirit Lake, Iowa.

“Nov. 2. Cold weather having set in, we decided to close the work here and return to Washington.”²

Although his stay was brief, he found one of the eighteen species recorded by Meek. More recently, in October, 1920, Mr. Carfield, Superintendent of Fish Culture of the U. S. Biological Station at Fairport, Iowa, visited the lakes, making an investigation of the conditions affecting the supply of fishes, especially of the game fishes.

In a letter to Mr. W. A. Albert, State Fish and Game Warden, he casually mentions fourteen species occurring in the lakes. These are referred to by their common names, making exact identification often difficult or impossible. However, three new species are added to Meek's list. One of them, the common carp, *Cyprinus carpio*, was introduced into the lakes after Meek and Evermann were there. The other two, the channel cat, *Ictalurus punctatus*, and the white bass, *Roccus chrysops*, are probably native but have had their original numbers increased through stocking by the State Department.

The writer wishes to express his indebtedness to Dr. F. A. Stromsten for the advice given and suggestions made during the progress of this study and in the preparation of the manuscript. His friendly interest has been an invaluable aid throughout. The writer is indebted also to Mr. W. A. Albert, State Fish and Game Warden, for permission to collect fishes and for information given, and to the U. S. Fish Commission for literature supplied. He owes much to Mr. Will Shear, Warden in charge of the Fish Hatchery at Orleans, and to Mr. Frank P. Hopkins of Spirit Lake for assistance freely and willingly given. Their knowledge of the fishes and of their haunts has been of great value in making this study. He is indebted, also, to Mr. Harry Tennant for his courtesy in allowing the writer free access to his mounted specimens of fishes and for information given. And for aid in collecting and in other ways, the

¹ Meek, S. E. Notes on the Fishes of Western Iowa and Eastern Nebraska. Bull. U. S. F. C., Vol. 14, p. 133-138, 1894.

² Evermann, B. W. and Cox, U. O. Report on the Fishes of the Missouri River Basin. Rep. U. S. Comm. of Fish and Fisheries, p. 352-429, 1894.

writer expresses his appreciation to Professors H. M. Kelly and Albert Kuntz, and to Messrs. E. M. Fitch, J. W. Breukelman, G. E. Potter, and D. T. Jones. To all these as well as to others unnamed, the writer wishes to record his thanks.

LIST AND CLASSIFICATION OF THE FISHES OF THE LAKE OKOBOJI REGION

The following is a systematic outline of the fishes recorded from this region. But one sub-class, the Teleostomi, of the class Pisces, the true fishes, is concerned. Seven orders of this sub-class are represented here. The classification employed is based on that of Jordan and Evermann with the adoption of certain changes made by Jordan in his recent work on fishes.³ The species recorded by Meek are indicated by a letter M after them. If a species has not been observed by the author, it is bracketed.

Series Ganoidea.

Order Selachostomi. The Paddlefishes.

Family Polyodontidæ. The Paddlefishes.

Polyodon spathula (Walbaum). Spoonbill.

Order Rhomboganoidea. The Garpikes.

Family Lepidosteidæ. The Garpikes.

Lepidosteus osseus (Linnaeus). Long-nosed Gar. M.

Lepidosteus platystomus (Rafinesque). Short-nosed Gar.

Series Teleostei.

Order Isospondyli.

Family Hiodontidæ. The Mooneyes.

Hiodon alosoides (Rafinesque). Northern Mooneye.

Family Salmonidæ. The Salmon Family.

Cristivomer namaycush (Walbaum). Great Lake Trout.

Order Eventognathi.

Family Catostomidæ. The Suckers.

Ictiobus cyprinella (Cuvier & Valenciennes). Big-mouth Buffalo.

Ictiobus bubalus (Rafinesque). Small-mouth Buffalo.

Carpionides carpio (Rafinesque). Common River Carp.

Catostomus commersonii (Lacepede). Common Sucker.⁴

Moostoma aureolum (Le Sueur). Common Red-horse.

³Jordan, D. S. Fishes. D. Appleton & Co., N. Y., 1925.

⁴Another sucker, *C. nigricans* probably, has been reported to the author who has not been able to verify the report.

Family Cyprinidæ. The Minnow Family.

- Cyprinus carpio* Linnæus. Common Carp.
Hybognathus nuchalis Agassiz. Silvery Minnow.
Pimephales notatus (Rafinesque). Blunt-nosed Minnow.
Semotilus atromaculatus (Mitchill). Horned Dace.
Abramis crysoleucas. (Mitchill). Golden Shiner. M.
Cliola vigilax (Baird & Girard). Bullhead Minnow.
Notropis cayuga Meek. Cayuga Minnow.
Notropis heterodon (Cope). Variable-toothed Minnow.
Notropis blennius (Girard). Straw-colored Minnow.
Notropis hudsonius (De Witt Clinton). Shiner. M.
Notropis lutrensis (Baird & Girard). Red-finned Minnow.
Notropis jejunus (Forbes). Shiner.
Rhinichthys atronasus (Mitchill). Black-nosed Dace.
Hybopsis storerianus (Kirtland). Storer's Chub.

Order Nematognathi. The Catfishes.

Family Siluridæ. The Catfishes and Bullheads.

- Ictalurus punctatus* (Rafinesque). Channel Cat.
Ameiurus natalis (Le Sueur). Yellow Bullhead.
Ameiurus nebulosus (Le Sueur). Speckled or Brown Bullhead.
Ameiurus melas (Rafinesque). Black Bullhead.
 (*Leptops olivaris* Rafinesque. Flat-head Cat.)

Order Haplomi.

Family Esocidæ. The Pikes and Pickerels.

- Esox lucius* Linnæus. Common Pike. M.

Family Pœciliidæ. The Killifishes.

- Fundulus diaphanus menona* (Jordan & Copeland). Menona Top-minnow.
 (*Fundulus zebrinus* Jordan & Gilbert. M.)^o

Order Acanthopteri. The Spiny-rayed Fishes.

Family Gasterosteidæ. The Sticklebacks.

- Eucalia inconstans* (Kirkland). Brook Stickleback.

Family Percopsidæ. The Trout-perches.

- Percopsis guttatus* Agassiz. Trout-perch. M.

Family Centrarchidæ. The Sunfishes.

- Pomoxis annularis* Rafinesque. White Crappie.
Pomoxis sparoides (Lacepede). Black Crappie. M.
Ambloplites rupestris (Rafinesque). Rock Bass.

^o For discussion of this record, see page 15.

- Apomotis cyanellus* (Rafinesque). Green Sunfish.
Lepomis megalotis (Rafinesque). Long-eared Sunfish.
Lepomis humilis (Girard). Orange-spotted Sunfish.
Lepomis pallidus (Mitchill). Bluegill. M.
Eupomotis gibbosus (Linnæus). Common Sunfish. M.
(*Micropterus dolomieu* Lacepede. Small-mouthed Black Bass. M.)
Micropterus salmoides (Lacepede). Large-mouthed Black Bass. M.

Family Percidæ. The Perch Family.

- Stizostedion vitreum* (Mitchill). Wall-eyed Pike. M.
Stizostedion canadense griseum (De Kay). Sauger. M.
Perca flavescens (Mitchill). Perch. M.
Percina caprodes (Rafinesque). Log-perch.
Boleosoma nigrum (Rafinesque). Johnny Darter. M.
Etheostoma iowæ Jordan & Meek. Iowa Darter. M.

Family Serranidæ. The Sea Bass.

- Roccus chrysops* (Rafinesque). White Bass.

Family Sciaenidæ. The Drums or Croakers.

- Aplodinotus grunniens* Rafinesque. Sheepshead.

HABITAT AND DISTRIBUTION

Polyodon spathula (Walbaum). Spoonbill; Paddlefish

No specimens of the spoonbill have been taken by the writer. Several large-sized ones, however, have been taken during the past twelve or fifteen years in East and West Okoboji Lakes. These have been taken mainly during the fall and winter months. An extremely large one, and the largest one yet recorded, as given in the Okoboji Protective Association Bulletin, No. 12, 1916, measured six feet and nine inches in length,⁶ and weighed 185 pounds. This individual, a male, was speared by a fisherman, R. Vandergeek, through the ice near the north end of West Okoboji Lake in the winter of 1915-1916. The same article relates the capture of another one, also speared through the ice, off Pillsbury's Point in the same lake. This one, which was a female, is reported to have weighed 210 pounds and to have measured six feet and seven inches from tip to tip. The author has found on investigation that the weight of the latter paddlefish was exaggerated. Mr. Hopkins, in a letter to

⁶ Measurements are from tip to tip.

the author writes, "——it weighed, when Mr. Tennant received it, 168 pounds and had been out of the water a week. Mr. Tennant estimated its weight not over 175 pounds when speared." This specimen and a third one were mounted by, and are in the possession of Mr. Tennant who has given the writer the opportunity of examining them. The third paddlefish, which was caught in a gill net in Miller's Bay in January, 1918, measured six feet and four inches over all and weighed 146 pounds. At least five other large-sized ones, although considerably smaller than those discussed, have been taken in East or West Okoboji Lakes. But none have been taken since 1918 although certain fishermen have reported that they have seen others.

It seems probable that very few if any spoonbills still exist in the lakes, and that the number has been limited in the past. The species is one of rivers and larger streams rather than of lakes, occurring in waters with muddy bottoms. Yet it is in the lakes that the largest individuals have been found. Evermann and Clark record two from Lake Manitou, Indiana, weighing 173 and 163 pounds respectively.⁷ Forbes and Richardson mention another large specimen from Lake Tippecanoe, Indiana, which weighed 150 pounds.⁸ Similar examples from other lakes are on record. The large size attained in the lakes may be due in large measure to the favorable food conditions found there. For the lakes furnish for this species an especially abundant supply of food which consists largely of entomostraca and insect larvæ.

Lepidosteus osseus (Linnæus). Long-nosed Gar

This species is reported by Messrs. Hopkins and Shear to be commonly distributed in the three major lakes of this region. But few have been taken with seine during the summer. These were seined over both muddy and sandy bottoms. Apparently this species prefers deeper water in the summer than the Short-nosed Gar. Otherwise the two resemble each other closely in their habits and distribution.

Lepidosteus platystomus (Rafinesque). Short-nosed Gar

This fish occurs commonly in waters of shallow to moderate depths, mainly among aquatic vegetation and over both muddy and sandy bottom. Both this and the preceding species have the habit of

⁷ Evermann and Clark, Lake Maxinkuckee, p. 310.

⁸ Forbes and Richardson, Fishes of Illinois, p. 17.

floating on the surface for some time, resembling a stick in the water. This may be of some value in catching their prey, although none have been observed to feed at such times. The jaws armed with sharp teeth are well fitted for seizing and holding their prey. Mr. G. E. Potter found the food of the adults here to consist of about 60% fish and 40% crayfish.⁹

Hiodon alosoides (Rafinesque). Northern Mooneye

This species is of rare occurrence in the lakes. The writer has taken none and has learned of but two specimens being taken. One of these was caught in East Okoboji Lake in August, 1922. This specimen was not seen by the writer but a plaster mold of it made by a storekeeper in Orleans was examined. The diagnostic character of the species, the dorsal fin with nine rays and placed slightly posterior to the ventral one, was clearly evident in the imprint.

The other specimen was caught several years ago in Minnewashta Lake, the Middle Gar Lake. It was mounted and kept as a curiosity by a storekeeper in Arnold's Park. Here, in the summer of 1925, the writer had the opportunity of examining and identifying it.

Cristivomer namaycush (Walbaum). Great Lake Trout

This trout is not a native here, and although several attempts to introduce it have been made during the past twenty-five years, it probably exists now in limited numbers if at all. It has been introduced into both Spirit and West Okoboji Lakes, mainly in the latter. In 1922, the latest attempt, 40,000 adult trout were planted in West Okoboji Lake. On the whole, these different attempts have not been successful. About fifteen years ago four or five trout were caught. One of these taken in Spirit Lake was mounted and in the summer of 1925, still hung on the wall of a pool room in the town of Spirit Lake. No others have been taken so far as the writer could learn.

The Great Lake trout in general requires deep cold water, apparently able to exist under such conditions with a relatively small amount of oxygen.¹⁰ Spirit Lake, which has a maximum depth of 7.6 m. and only a slight change in temperature from the surface to the bottom, evidently furnished unfavorable conditions for this fish. Successful planting could not be expected here. West Okoboji Lake

⁹ Potter, G. E., The Food of the Short-nosed Garpike (*Lepidosteus platystomus*). Ia. Acad. Sci., Vol. XXX, p. 167-170, 1923.

¹⁰ Kemmerer, George, Bouvard, J. F., and Boorman, W. R. Northwestern Lakes of the U. S. Biological and chemical studies with reference to the possibilities in production of fish. Bull. Bur. of Fisheries, Vol. 39, p. 51-140, 1923-24.

with a maximum dept of 40.2 m. has both the depth and the low temperature required. After the summer stratification has taken place, the lowest stratum, the hypolimnion, remains practically uniform in temperature, but not so in its oxygen content. The sources of oxygen are cut off, for the hypolimnion is cut off from the air by the upper two layers and there is little or no photosynthesis. On the other hand, through decomposition and respiration the amount of oxygen is decreased. Birge and Juday, on July 31, 1919, found a decrease from 2.23 cc. per liter at 15 m., with a slight increase at 18 m., to 0.86 cc. at 33 m. From their results, they state, "— it is safe to predict that this gas all disappeared, from the lower portions of the hypolimnion at least, before the time of the autumnal overturn."¹¹ Students of Stromsten have found such to be the case, and the amount of oxygen decreased in the upper hypolimnion so as to make conditions unfavorable for the trout. Again the food supply, largely of fish, may be limited in the depths which the trout would occupy in summer. The author has no evidence, however, to support this.

Ictiobus cyprinella (Cuvier & Valenciennes). Big-mouth Buffalo

This is the common buffalo fish of the lakes, occurring in the three major lakes and in the smaller ones adjoining Spirit. During the summer it prefers weedy waters six to eight meters deep over a mud bottom, although the writer has taken three specimens in East Okoboji at the depth of two to three meters. During the spawning season in the spring, buffalos are said to be tolerably common in the shallow water along the shores where the eggs are deposited.

Ictiobus bubalus (Rafinesque). Small-mouth Buffalo

Meek records this species, reporting two or three specimens taken in East Okoboji. The author has taken none. It is reported from all three major lakes, occurring in much less numbers than the preceding species.

Carpiodes carpio (Rafinesque). Common River Carp

This species has not been taken in any of the lakes, but occurs tolerably commonly in the Little Sioux River where it was seined by the author. It was taken most commonly in the swifter waters of the West Branch, and in limited numbers only below the junction of the two branches where the flow was less rapid.

¹¹ Birge, E. A. and Juday, C. A Limnological Reconnaissance of West Okoboji. Stud. in Nat. Hist., Univ. of Ia., IX, No. 1, p. 42, 1920.

Catostomus commersonii (Lacepede). Common Sucker

The common sucker occurs commonly in the major lakes and in the Gar Lakes. In the summertime, it is found in the deeper waters mainly on a rocky bottom, and has not been taken with the seine along shore. It is also tolerably common in the Little Sioux River, showing a preference for the swifter flowing portions.

Moxostoma aureolum (Le Sueur). Red-horse

The writer has not taken any of this species in the lakes. Two specimens, one a mounted specimen taken by Mr. Tennant in East Okoboji and the other taken in West Okoboji by Mr. Hopkins, have been examined. It is said by Mr. Tennant to occur in the Gar Lakes also. One was seined by the writer in the West branch of the Little Sioux River. Judging from the statement made to the writer, it is evidently an uncommon fish in this region.

Cyprinus carpio Linnæus. Carp

The carp first appeared in the lakes fifteen or sixteen years ago, and in a few years it was common in East and West Okoboji and in the Gar Lakes. High water, five or six years later, enabled it to extend its range into Spirit Lake where it occurs in lesser numbers than in the other lakes mentioned. It prefers weedy muddy bottomed portions of the lakes in shallow to moderate depths.

In the Little Sioux River two specimens of the variety known as the mirror carp were taken in July, 1922. In this variety the scales are few and much enlarged occurring in two or three irregular rows of scales, with the rest of the body naked. None of these have been taken in the lakes.

Hybognathus nuchalis Agassiz. Silvery Minnow; River Shiner

This minnow, as the second name infers, is a river form, occurring abundantly in the Little Sioux mainly over a muddy bottom. None have been recorded from any of the lakes. It is used to some extent for commercial bait, but the distance to the river makes it too inconvenient to be commonly used.

Pimephales notatus (Rafinesque). Blunt-nosed Minnow; Chub

The blunt-nosed minnow prefers weedy shallow waters with muddy bottom. The writer found it common in North Hottes Lake but did not take any elsewhere except in the Little Sioux River, although it was reported by Mr. Shear to be common in both Spirit and East Okoboji Lakes.

This and the bullhead minnow, *Cliola vigilax*, are the ones most commonly used for bait by the fishermen at the lakes. These two resemble each other so closely that they are not commonly distinguished as separate species. Besides the generic differences of the two, *notatus* has a blunter nose and the scales on the upper half of the body are dark-edged due to the concentration of the minute dots there. *Vigilax*, on the other hand, has a more rounded nose, and the specks are scattered over the scales rather than restricted to the edges.

Semotilus atromaculatus (Mitchill). Horned Dace; Creek Chub

This is a typical creek fish, occurring commonly in both Reed and Thomas Creeks. This is one of the pioneer fishes to take possession of young brooks or creeks. It is found especially in the deeper pools under shelving banks or tree roots where the current is strong enough to keep the water clean and well oxygenated.

Abramis crysoleucas (Mitchill). Golden Shiner

The golden shiner was taken from the three major lakes and from Marble, Hottes, and Robinson Lakes. It was found most common in the three last lakes, showing a preference for weedy and comparatively shallow water with muddy bottom. In East Okoboji and Spirit Lakes, a limited number was taken over a sandy bottom.

Cliola vigilax (Baird & Girard). Bullhead Minnow

But two specimens of this minnow were taken by the writer in the major lakes. One of these was seined in Miller's Bay, West Okoboji Lake, the other near Crandall's Lodge at the north end of Spirit Lake. Both were taken near patches of weeds, over a sandy or gravelly bottom. Such isolated occurrences suggest the possibility that these had escaped from the bait boxes of local fishermen. The writer has seined it in large numbers in Welch Lake, and it is reported by Mr. Hopkins to be as common in Center Lake. In Welch Lake it was taken in shallow water over a muddy bottom comparatively free of water plants.

Notropis cayuga Meek. Cayuga Minnow

This is an uncommon minnow in this region, and was taken in three localities only, Miller's Bay, (West Okoboji Lake), Hottes Lake, and Sunken Lake. In the first two it was taken in shallow water between the water weeds and the shore and over sandy bottom. But in Sunken Lake where it occurred rather commonly, it

was found among a dense growth of aquatic vegetation, mainly *Elodea*, and over a muddy bottom.

Notropis heterodon (Cope). Variable-tooth Minnow

This minnow is, in general, rare in the lakes. In a kettle hole near Stony Point, East Okoboji, it was found tolerably common. Here it was taken among weeds over a bottom of sandy silt. Otherwise it was not taken except in Miller's Bay where a half dozen in all were seined. The conditions were the same as those given for *cayuga*.

These two minnows, *heterodon* and *cayuga*, resemble each other closely. The latter has a very small mouth and a pale chin, while the former has a moderate sized mouth and a black chin.

Notropis blennioides (Girard). Straw-colored Minnow

This species is common in the Little Sioux River, and occurs in limited numbers in West Okoboji Lake and in Reed and Thomas Creeks. It has not been seined in any other of the lakes, but probably occurs in East Okoboji at least. Apparently it prefers the cool running waters of streams. In West Okoboji it was taken in shallow water along shore over a sandy bottom.

Notropis hudsonius (De Witt Clinton). Shiner; Spot-tailed Minnow

This is the most common minnow of the major lakes. None were taken in any of the minor ones. It frequents shallow water along shore generally over a sandy or gravelly bottom. Although still common, the numbers have been reduced by its use for live bait. Meek, in 1892, found it the principal minnow used for this purpose by the local fishermen.¹² That it is not the principal one now is due to its lessened numbers, and because other species of minnows can be more easily obtained in some of the nearby smaller lakes.

Notropis lutrensis (Baird & Girard). Red-finned Minnow

This minnow is a river dweller occurring rather commonly in the Little Sioux River. It shows a preference for the swift water of the riffles of the river. Two specimens only have been taken in the lakes. One of these was taken by Mr. Hopkins from the East Lake in July, 1922. The second one was seined by Messrs. Jones and Breukelman in Miller's Bay in July, 1924. It seems probable that

¹² Meek, Seth E. Fishes of Western Iowa and Eastern Nebraska, p. 136.

these two had escaped from minnow boxes, rather than occurring naturally in the lakes.

Notropis jejunus (Forbes). Shiner; Gull Point Chub

This shiner is apparently a localized form occurring mainly around Gull Point, West Okoboji Lake, thereby giving it the name of Gull Point Chub. But one specimen was taken by the writer. This was seined August 4, 1922, in clear shallow water over a sandy bottom.

Rhinichthys atronasus (Mitchill). Black-nosed Dace

The black-nosed dace, like the horned dace, is a typical creek fish and is found tolerably common under similar conditions in Reed and Thomas Creeks. It has not been found elsewhere in this region.

Hybopsis storerianus (Kirtland). Storer's Chub; River Chub

The writer has seen but one specimen of this species, this one caught by Mr. Hopkins in East Okoboji Lake. Mr. Shear states that it is common in the Little Sioux River and is taken occasionally in the lakes during the spring seining.

Ictalurus punctatus (Rafinesque). Channel Cat

The channel cat is undoubtedly a native of this region as specimens have been taken in the Little Sioux River. Mr. Shear informed the writer that this species was introduced into the lakes about 1913 or 1914. In the winter of 1917-18, eighteen of these and the flathead cats, averaging sixteen pounds in weight, were taken in gill nets. Small fry of this and the other large cat-fish were first seen in the summer of 1921. In 1922, the State Fish and Game Department introduced 30,000 adults into West Okoboji and 18,000 in Spirit Lake. A few are caught each season. The writer had the opportunity to examine one caught in East Okoboji Lake in August, 1925.

Ameiurus natalis (Le Sueur). Yellow Bullhead; Yellow Cat

This bullhead prefers water of moderate depth with muddy bottom in or near the water plants. Its range extends into deeper waters than that of the other bullheads. It is common in both East and West Okoboji Lakes, and occurs in lesser numbers in Spirit Lake.

Ameiurus nebulosus (Le Sueur). Common Bullhead

The common bullhead shows a preference for the same conditions as *natalis* but is found more commonly in shallow water. It is toler-

ably common in all the major lakes, but was found especially common in the shallow weedy Robinson and Hottes Lakes. Here, in 1922, the local fishermen came for their market supply of bullheads.

Ameiurus melas (Rafinesque). Black Bullhead

Like the other bullheads, this one prefers muddy bottom ranging in depth somewhat between the other two, although seined from as shallow water as the common bullhead. It is the commonest of the bullheads in Spirit Lake and occurs rather commonly in the other major lakes.

Leptops olivaris (Rafinesque). Flathead Cat

The writer has not collected any of this species. Apparently it was introduced accidentally with shipments of the channel cat, *I. punctatus*. As noted in the discussion of the latter, individuals of the flatheads were also taken in the gill nets in the winter of 1917-18. Mr. Hopkins reported one caught in East Okoboji Lake in the winter of 1925-26.

Esox lucius Linnæus. Common Pike; Northern Pickerel

This fish occurs commonly in the lakes, preferring the weedy portions which constitute its typical habitat. It is a swift predaceous fish which lies in wait for its prey, mainly fish, capturing it with a quick dash. The subcylindrical shape of the body fits it for moving in between the stems of the water plants without hindrance. This shape may be of further aid to the fish because of its resemblance to a submerged stick, which would be increased by its habit of remaining nearly motionless in the water. Thus its unsuspecting victim might approach within capturing distance.

Fundulus diaphanus menona (Jordan & Copeland). Menona Top-minnow

The top-minnow is found most commonly in the shallow water with a sandy bottom, either in the weeds or between them and the shore. It occurs commonly along the sand-bar in Miller's Bay, West Okoboji Lake during August, and less commonly earlier in the season. It was seined also in East Bay, Spirit Lake, and in Hottes Lake.

Meek recorded *F. zebrinus* from East Okoboji Lake.¹³ None of the specimens taken by the writer could be referred to that species.

¹³ Meek, S. E. Notes on the Fishes of Western Iowa and Eastern Nebraska, p. 137.

Zebrinus has sixty scales in the lateral series and twenty-one transversely. There are fourteen or fifteen rays in the dorsal fin, and thirteen or fourteen in the anal.¹⁴ The specimens collected by the writer had from forty-two to fifty scales in the lateral and twelve to fourteen in the transverse series. The dorsal had twelve to thirteen rays and the anal ten to eleven. If Meek was correct in his identification, apparently *menona* has supplanted *zebrinus* completely or nearly so. The occurrence of the latter seems doubtful enough to warrant its omission.

Eucalia inconstans (Kirtland). Brook Stickleback

This stickleback was seined commonly in shallow water over a mud bottom in Swan Lake, Dickinson County, in August, 1924. This lake is in the drainage system of the Des Moines River. However, the species is included here because Mr. Hopkins had taken it in Reed Creek before the sloughs, once characteristic of it, were drained.

Percopsis guttatus Agassiz. Trout Perch

One specimen of this species has been taken in the lakes by the writer. This was seined in East Bay, Spirit Lake, July 21, 1921, in water between one and two meters deep, over a sandy bottom and near water weeds. Twelve other individuals were taken in the Little Sioux River, July 28, 1922. Meek in his list includes the statement of Evermann regarding this fish. On November 2, 1892, the latter found four specimens in the minnow box of a hotel. He states further that Mr. H. E. Owen, then proprietor of the Lake Park House of Spirit Lake, reported the species as "abundant in the lakes."¹⁵ While this statement may have applied at that time, it certainly does not now for the trout perch is evidently uncommon at present.

Pomoxis annularis Rafinesque. White Crappie; Crappie

The crappie is common in all the major lakes. It shows a preference for water four to six meters deep with a muddy bottom, in or near water weeds. It comes into shallower water for feeding in the evening.

¹⁴ Jordan, D. S. and Everman, B. W. Fishes of North-Middle America, Vol. I, p. 646.

¹⁵ Meek, S. E. Notes on the Fishes of Western Iowa and Eastern Nebraska, p. 137.

Pomoxis sparoides (Lacepede). Black Crappie; Calico Bass

This species has not appeared as frequently as the preceding one in seining. Its habitat is similar to that of the white crappie with which it is frequently confused. Besides its darker markings, this species has the anal fin reticulated with dark greenish markings, while the anal fin of *annularis* is nearly plain. *Sparoides* has seven or eight spines in the dorsal fin, *annularis* six.

Ambloplites rupestris (Rafinesque). Rock Bass

Only three individuals of this species have been taken, all from Miller's Bay, West Okoboji Lake. It is said by Mr. Shear, to occur in limited numbers in all the major lakes. It prefers moderate depths with rocky bottom.

Apomotis cyanellus (Rafinesque). Green Sunfish

This sunfish is generally found in or near water weeds, ranging from near the shore line to a depth of three to four meters. It shows a preference for a sandy silt bottom. It is a common fish in the weedy bays of West Okoboji and occurs less commonly in East Okoboji and Spirit Lakes.

Lepomis megalotis (Rafinesque). Long-eared Sunfish

This fish shows a preference for shallow weedy waters, with a bottom of mud or sandy silt. In 1922, it was taken in considerable numbers in Robinson Lake, fifty-five at one drag of the seine. Several were also seined in North Hottes and two in East Okoboji. It was not recorded elsewhere.

Lepomis humilis (Girard). Red-spotted Sunfish

The red-spotted sunfish has been recorded only from the Little Sioux River. In 1924, seven adults were seined in the west branch of the river, in water from one to one half meters deep. In August of the next year, six young of that season were taken from a pool in the otherwise dry bed of the river.

Lepomis pallidus (Mitchill). Bluegill

With the exception of the perch, the bluegill is the most abundant fish in the three major lakes. It has not been recorded from any of the smaller ones. It is found under a variety of conditions of depth and bottom. It is frequently taken in the shallow water around docks, but its more characteristic habitat is in or near the growths of water weeds.

Eupomotis gibbosus (Linnæus). Common Sunfish; Pumpkin-seed

This is a characteristic fish of the weedy portions of the major lakes, in water of shallow to moderate depth, and in the shallow weedy lakes, Robinson and Hottes. Like the bluegill, it is found over different types of bottom ranging from mud to sand.

Micropterus dolomieu Lacepede. Small-mouthed Bass

Meek records this species as follows, "Among the waters covered by this report, the small-mouthed bass was found only in Spirit Lake."¹⁶ It has not been recorded by the writer, but is reported by Mr. Shear as occurring rarely, through accidental introduction with the large-mouthed bass. Every few years, according to his statement, one of this species is caught here.

Micropterus salmoides (Lacepede). Large-mouthed Bass

This is one of the best and most important game fishes of this region. It is tolerably common in the three major lakes. It prefers the weedy portions of the lake, but is not limited to them, and may be found over different types of bottom.

Stizostedion vitreum (Mitchill). Wall-eyed Pike; Pike

This is the most important game fish of the lakes, and occurs in considerable numbers in the three major lakes. The State Fish Hatchery at Orleans is maintained wholly for the propagation of this fish. In 1922, 9,000,000 fry were liberated in West Okoboji, 5,000,000 in Spirit Lake, and 3,000,000 in East Okoboji.¹⁷ The spawning season begins soon after the ice is out of the lakes, the fishes coming into shallow water near the shore for this purpose. During the summer, they migrate to deeper water where the bottom is rocky.

Stizostedion canadense griseum (De Kay). Sauger

The sauger has not been taken by the writer in this region, and but one specimen, a mounted one owned by its captor, Mr. Harry Tennant, of Arnold's Park, has been examined. It is mentioned by Meek as occurring in Spirit Lake,¹⁸ and by Carfield in his letter to the State Game Warden. It is reported by Mr. Shear as tolerably

¹⁶ Meek, S. E. Notes on the Fishes of Western Iowa and Eastern Nebraska, p. 138.

¹⁷ Figures supplied by Dr. John H. Malony, State Fish and Game Dept.

¹⁸ Meek, S. E. Notes on the Fishes of Western Iowa and Eastern Nebraska, p. 138.

common in the lakes. Very likely it is not commonly distinguished from the other species.

Perca flavescens (Mitchill). Yellow Perch; Perch

This is the commonest and most widely distributed of all the fishes in the lakes. It is found under a variety of conditions of bottom, from mud as in North Hottes to sandy as in Spirit Lake, and from shallow water one and one half meters to nearly twenty-seven meters (eighty-seven feet) in Emerson Bay of West Okoboji. It may also be found in or near the growth of water weeds or away from them. It attains its largest size in Spirit Lake. A young individual, 40 mm. long, was taken in Thomas Creek, July 20, 1922.

Percina caprodes (Rafinesque). Sand Darter; Log Perch

This species is found on sandy or gravelly bottom in shallow water. It is abundant in Spirit Lake, where it was seined most commonly in water from one to one and one half meters deep. It was not taken in East Lake, although it probably occurs there. Only one specimen was taken in the West Lake. This was seined along the Sand-bar by Messrs. D. T. Jones and G. E. Potter, August 12, 1924.

Boleosoma nigrum (Rafinesque). Johnny Darter

Meek records this species from both East Okoboji and Spirit Lakes. "A specimen was found in a minnow basket at Spirit Lake where it seems to be used as live bait to some extent."¹⁹ It was not taken by the writer in the lakes but was seined in the Little Sioux River in the summers of 1924 and 1925.

Etheostoma iowæ Jordan and Meek. Iowa Darter

Meek collected this species in Spirit Lake, but gives no data concerning it.²⁰ The writer has not collected it personally but has in his possession six specimens collected by Mr. Hopkins in Spirit Lake, May 12, 1926. He states that he has seen this species in late spring or early summer in East Okoboji Lake, in shallow water over sand between the weeds and the shore.

Roccus chrysops (Rafinesque). Silver Bass; White Bass

This is a common species in both East and West Lakes, less so in Spirit Lake. On June 26, 1922, 200 were taken in the seine in East

¹⁹ Meek, S. E. Notes on the Fishes of Western Iowa and Eastern Nebraska, p. 138.

²⁰ *Loc. cit.*

TABLE I
Summary of Distribution

Species	West Okoboji	East Okoboji	Spirit	Hottes	Reed Creek	Thomas Creek	Little Sioux River
<i>P. spathula</i>	x?	x?					
<i>L. osseus</i>	x	x	x				
<i>L. platystomus</i>	x	x	x				
<i>H. alsoides</i>		x					
<i>C. namaycush</i>	x?	?	x?				
<i>I. cyprinella</i>	x	x	x	x			
<i>I. bubalus</i>	x	x	x				
<i>Carpiodes carpio</i>							x
<i>C. commersonii</i>	x	x	x				x
<i>M. aureolum</i>	x	x					x
<i>Cyprinus carpio</i>	x	x	x				x
<i>H. nuchalis</i>							x
<i>P. notatus</i>		x	x	x			x
<i>S. atromaculatus</i>					x	x	x
<i>A. crysoleucas</i>	x	x	x	x			
<i>C. vigilax</i>	x	x	x				
<i>N. cayuga</i>	x			x			
<i>N. heterodon</i>	x	x					
<i>N. blennius</i>	x				x	x	x
<i>N. hudsonius</i>	x	x	x				
<i>N. lutrensis</i>	x	x					x
<i>N. jejunus</i>	x						
<i>R. atronasus</i>					x	x	
<i>H. storerianus</i>		x					x
<i>I. punctatus</i>	x	x	?				x
<i>A. natalis</i>	x	x	x				
<i>A. nebulosus</i>	x	x	x	x			
<i>A. melas</i>	x	x	x				x
<i>L. olivaris</i>	x	x					
<i>E. lucius</i>	x	x	x	x			
<i>F. diaphanus</i>	x	x	x	x			
<i>E. inconstans</i>					x?		
<i>P. guttatus</i>		x	x				
<i>P. annularis</i>	x	x	x				
<i>P. sparoides</i>	x	x	x				
<i>A. rupestris</i>	x	x	x				
<i>A. cyanellus</i>	x	x	x				
<i>L. megalotis</i>		x		x			
<i>L. humilis</i>							x
<i>L. pallidus</i>	x	x	x				
<i>E. gibbosus</i>	x	x	x	x			
<i>M. dolomieu</i>			x				
<i>M. salmoides</i>	x	x	x				
<i>S. vitreum</i>	x	x	x				
<i>S. canadense</i>		x	x				
<i>P. flavescens</i>	x	x	x	x	x	?	
<i>P. caprodes</i>	x	x	x				
<i>B. nigrum</i>		x	x				x
<i>E. iowæ</i>		x	x				
<i>R. chrysops</i>	x	x	x				
<i>A. grunniens</i>	x	x	x				
Totals	36	40	33	10	5	3	14

TABLE II
Summary of Habitat of Lake Fishes

Species	Mud	Sand	Rock	Open	Weedy
<i>P. spathula</i>	x				
<i>L. osseus</i>	x	x			x
<i>L. platystomus</i>	x	x			x
<i>C. namaycush</i>				x	
<i>I. cyprinella</i>	x				x
<i>C. commersonii</i>			x	x	
<i>Cyprinus carpio</i>	x				x
<i>P. notatus</i>	x				x
<i>A. crysoleucas</i>	x				x
<i>C. vigilax</i>	x	x		x	x
<i>N. cayuga</i>	x	x		x	x
<i>N. heterodon</i>	x	x		x	x
<i>N. blennius</i>		x		x	
<i>N. hudsonius</i>		x		x	x
<i>N. lutrensis</i>		x		x	
<i>I. punctatus</i>	x			x	
<i>A. natalis</i>	x			x	x
<i>A. nebulosus</i>	x			x	x
<i>A. melas</i>	x			x	x
<i>L. olivaris</i>	x			x	
<i>E. lucius</i>	x	x		x	x
<i>F. diaphanus</i>		x		x	x
<i>E. inconstans</i>	x				x
<i>P. guttatus</i>		x		x	
<i>P. annularis</i>	x		x	x	x
<i>P. sparoides</i>	x		x	x	x
<i>A. rupestris</i>		x	x	x	x
<i>A. cyanellus</i>		x		x	x
<i>L. megalotis</i>	x				x
<i>L. pallidus</i>	x	x		x	x
<i>E. gibbosus</i>	x	x			x
<i>M. salmoides</i>	x	x		x	x
<i>S. vitreum</i>			x	x	
<i>P. flavescens</i>	x	x	x	x	x
<i>P. caprodes</i>		x		x	
<i>B. nigrum</i>		x		x	
<i>E. iowæ</i>		x		x	
<i>R. chrysops</i>	x		x	x	x
<i>A. grunniens</i>	x		x	x	
Totals	26	20	8	29	26

Okoboji near the outlet of Spirit Lake in water from one to two meters deep over sandy bottom. Later in the season they prefer somewhat deeper water, under different conditions of bottom. On July 20, 1922, they were caught in abundance in water three to four meters deep, over a muddy bottom. They were also being caught near a rocky point at the outlet of East Okoboji into the Upper Gar Lake, where the water was six or seven meters deep.

Aplodinotus grunniens Rafinesque. Sheepshead; Fresh-water Drum

The sheepshead is common in East and West Okoboji Lakes, but is rather rare in Spirit Lake. It was not recorded elsewhere. It is found more commonly in moderate depths over both muddy and rocky bottom.

The observations regarding the distribution and habitat of the fishes of this region are summarized in Tables I and II. The occurrence of the species is indicated by the letter "x". Species marked "x?" have occurred here but are doubtfully present now. Those marked "?" may occur but have not been found or reported and are not included in the totals. Table II includes only those lake fishes for which definite data were obtained. These observations apply to the summer season only.

THE FISHES OF REED AND THOMAS CREEKS

On the east side of East Okoboji Lake are two small creeks which flow into the lake within a half mile of each other. These will be designated as Thomas and Reed Creeks respectively, the names given to them in the past from owners of the adjoining land. These creeks resemble each other in their physical features, so that a common description, in the main, will serve for the two. Both are small creeks with bottoms mainly of silt with some intermixture of sand. They are narrow and shallow with occasional deeper pools and with slightly developed riffles in places where the flow, otherwise rather sluggish, becomes moderately fast. Near the lake, the creeks flow through a wooded tract in which the dominant type of tree is the bur oak, *Quercus macrocarpa*. Of the two, Thomas Creek is the larger, with larger, deeper, and more numerous pools, and with a more rapid current. Just before entering the woods, this creek is fed by four springs.

This latter creek was first visited by the writer in the summer of 1921. During the seasons of 1922 and 1924, both creeks were visited and collections made, temperature taken, and samples of the water taken. In 1922, the samples were tested by the Winkler method for their oxygen content by Mr. Wesley Damerow. In 1924, others were tested by Miss Josephine Bockwoldt for the hydrogen ion concentration. These tests indicate a high hydrogen ion concentration. It seems probable that this may be accounted for by the boggy ground through which, for a part of their course, the creeks flow. The results of these tests as well as the temperature reading and the weather conditions are given in Table III.

TABLE III
A. Reed Creek

Date	Time	Weather	Wind	Air temp.	Water temp.	O cont.	H. ion conc.
7/20/22	1:15 P.M.	Fair	Light, S.	*	*	6.70	
8/2/22	9:30 A.M.	Clear	Calm	29°C.	17°C.		
8/12/22	11:10 A.M.	Clear	Light, S.	29°C.	21°C.	9.38*	
						8.98	
7/28/24	11:15 A.M.	Clear	Light, S. E.	31°C.	18°C.		5.32
8/4/24	9:45 A.M.	Clear	Light, S.	29°C.	16°C.		4.78.
8/12/24	2:00 P.M.	Clear	Light, N. E.	26°C.	19°C.		
8/14/24	3:20 P.M.	Hazy	Strong, S.	28.5°C.	20.5°C.		

B. Thomas Creek

Date	Time	Weather	Wind	Air temp.	Water temp.	O cont.	H. ion conc.
7/20/22	2:30 P.M.	Fair	Light, S.	*	**	7.63	
8/4/24	10:00 A.M.	Clear	Light, S.	28°C.	22°C.		4.76
8/12/24	2:30 P.M.	Clear	Light, N. E.	25°C.	23°C.		
8/14/24	3:55 P.M.	Hazy	Strong, S.	27°C.	22°C.		

* Thermometer broken

** Two samples taken

The fish found in the two creeks were nearly identical. Four species were recorded from both and a fifth one from Reed Creek. In both the main species were the creek chub, *Semotilus atromaculatus*, the black-nosed dace, *Rhinichthys atronasmus*, and the straw-colored minnow, *Notropis blennioides*. An immature perch, *Perca flavescens*, 40 mm. long, was taken in Thomas Creek about three fourths of a mile from the mouth. Mr. Hopkins has taken adult perch in Reed Creek near the mouth, in the spring when the water was high, and it probably comes into the other creek under similar conditions. Mr. Hopkins also has taken the brook stickleback, *Eucalia inconstans*, in past years from Reed Creek. The writer has no evidence whether or not it still occurs here. The distribution of the fishes in the two creeks was similar. The great majority of the creek chub and the black-nosed dace was found in the deeper pools where they could find shelter under the overhanging shelves formed by the grasses and other herbaceous plants, or by the roots of adjoining trees. The straw-colored minnows showed a preference for the swifter waters of the creek, and were frequently observed in or near the riffles, although a few were taken in the pools with the other two species. Of the three, the creek chub was the most numerous, the black-nosed dace next in abundance, with the straw-colored minnow the least common.

The food of seventeen fishes from Reed Creek was studied. Of these, thirteen were creek chubs, three were straw-colored minnows, and the remaining one a black-nosed dace. The results are summarized in Table IV.

TABLE IV
Food of Seventeen Fishes from Reed Creek

Species	Total length in mm.				Water Algae	Clado- Weed	Cope- cera	Cray- poda	Cray- fish	Insects		Hydra- carina
	No.	Mn.	Mx.	Av.						Larva	Adult	
<i>S. atromaculatus</i>	13	25	91	46.1	0.66	1.3			5	35.4	57.5	*
<i>E. atronasus</i>	1			73.0						12.0	88.0	
<i>N. blennius</i>	3**	24	45	36.6	Traces		1.5	0.5		95.0	3.0	

* One individual was found in the thirteen fishes examined

** One with stomach and intestines nearly empty; remaining contents unidentifiable; percentages based on two specimens

The food of the creek chub, as indicated in the table, consisted largely of insects, 92.8% in all. Of the thirteen studied, three had eaten only adult insects, and in two others, these formed 96% and 98% respectively. The insects eaten were almost wholly either aquatic coleoptera, mainly *Gyrinida*, or water-boatmen, *Corixa* sp. One individual, not of the five mentioned, had eaten a grasshopper. Insect larvæ constituted all the food in one specimen, and 90% and 97% respectively in two others. Fully 90% of these were chironomid larvæ, the remainder consisting of other dipterous larvæ and the nymphs of water-boatmen. Another individual had eaten crayfish and also some filamentous algæ, *Vaucheria*.

Forbes and Richardson speak of this fish as having "an unusually varied diet for a minnow, including considerable quantities of vegetable food on the one hand and small fish on the other. A fourth of the food of twenty-two specimens consisted of algæ and of miscellaneous vegetable debris. Four of the specimens had eaten little else than filamentous algæ, and three had captured small fishes. Grasshoppers, caterpillars, ants, chrysomelid and scarabæid beetles, and various other terrestrial insects together with *Corixa*, dipterous larvæ, and other aquatic forms, were the insects represented, and three of the twenty-two specimens had eaten only crayfishes."²¹ Everman and Clark state "the principal food of the chub consists of insect larvæ, aquatic insects, worms, and small crustaceans."²²

The numbers of the other two species are in themselves too small

²¹ Forbes, S. A. and Richardson, R. E. Fishes of Illinois, p. 123.

²² Evermann, B. W. and Clark, H. W. Lake Maxinkuckee, a Physical and Biological Survey, vol. 1, p. 346.

for definite conclusions. In the case of one of these, *Notropis blennioides*, other data are available, which tend to confirm the result obtained by the writer. Forbes and Richardson state, "from the little that is known of its feeding habits, its food is no more peculiar than its general appearance, consisting of a mixture of aquatic insects, and chance vegetation."²³ In an earlier paper Forbes gives the results of a study of five of these minnows. Seventy-five per cent of the food was animal matter, the remaining plant, mainly grass seeds.²⁴ Of the former, insect larvæ constituted 58% and copepods, almost wholly *Cyclops*, 10%.

These three fishes are typical pioneer fishes characteristic of young streams such as the two creeks studied. Shelford, some years ago, pointed out that the creek chub, *Semotilus atromaculatus*, is the species "most commonly found in the smallest streams and nearest the headwaters of the larger streams."²⁵ In most cases the red-bellied dace, *Chrosomus erythrogaster*, which is not found here, was the next one to be found as one went downstream from the source, but in some he found the black-nosed dace, *Rhinichthys atronasus*, to be the second species. In one stream, too, the straw-colored minnow, *Notropis blennioides*, was one of six species to be found in the first mile from the source. In Reed and Thomas Creeks, the range of these three species coincided, although the relative numbers of the creek chub were somewhat greater in the uppermost pools. During the two seasons the conditions under which they lived were nearly similar. The temperature of the water was low especially in the pools of Reed Creek. The oxygen content of the water was high with apparently a high hydrogen ion concentration also. Stretches of gravel or sand, which occur occasionally, furnish favorable spawning beds, and during the summer there is an abundant supply of insect food which appears to be the chief food item at this season.

THE OKOBOJI LAKES

The Okoboji Lakes, products of the Wisconsin ice sheet, include three major lakes, Spirit, East and West Okoboji, and several minor ones. The West and East Lakes are connected by a narrow channel between the towns of Arnold's Park and Okoboji. There is a creek

²³ Forbes, S. A. and Richardson, R. E. Fishes of Illinois, p. 138.

²⁴ Forbes, S. A. The Food of smaller Fresh-water Fishes. Bull. III, Ill. State Lab. Nat. Hist., Vol. I, p. 65-94, 1883.

²⁵ Shelford, V. E. Ecological Succession. I, Stream Fishes. Biol. Bull., Vol. 21, p. 9-25, 1911.

between Spirit Lake and East Lake through which a small stream of water flows, when the level of the former lake is high enough. During the summer seasons of 1924 and 1925, there was little or no water in this runaway. These lakes drain through the Gar Lake with which East Lake is connected, into the Little Sioux River. The amount of water which goes into this river is said to be slight in comparison with the amount lost from the lakes through evaporation. Welch Lake to the north of, and Center Lake to the east of West Okoboji Lake, have poorly developed streams through which a small amount of water flows into the latter. To the west and northwest of Spirit Lake are five of the minor lakes, Little Spirit, Hottes, Robinson,²⁶ Marble, and Sunken. These drain into Spirit Lake, the last four through Hottes Lake. During the seasons referred to before, the level of these four lakes was lowered so that they are entirely cut off from each other, and Hottes Lake itself from Spirit Lake. The total drainage area of the lakes is not great, 84,500 acres²⁷ or 132 square miles. In Table V the size and depths of the lakes are given. With the exception of West Okoboji, the areas were taken from the Iowa Lake Bed Report, 1917 and the other figures are based on studies made of the maps of the State Highway Commission.

TABLE V
Size and Depth of the Lakes

Name of Lake	Area in acres	Length of shoreline in miles	Volume in cubic meters	Maximum depth in meters	Mean depth in meters
Spirit	5660	18.3	225,548,000	7.6	5.5
West Okoboji ²⁸	3788	18.2	188,340,000	40.2	12.3
East Okoboji	1875	16.7	22,687,000	7.9	3.0
Center	264	2.6	3,567,000	4.5	3.2
Welch	57	1.4	344,000	1.9	1.5
Little Spirit	724*	10.4	5,132,000	3.7	2.1
Hottes	312	7.0	1,758,000	2.4	1.4
Marble	175	2.7	1,058,000	2.1	1.5

* 214 acres only in Iowa, the remainder in Minnesota.

Some years ago Shelford traced the ecological succession in several sand-bottomed ponds located in Indiana near the south end of

²⁶ The west portion of Hottes Lake as shown on maps 23-24, State Highway Commission, 1915.

²⁷ Iowa Lake Bed Survey Report, 1917, p. 54.

²⁸ Birge, E. A. and Juday, Chancey. A Limnological Reconnaissance of West Okoboji. Stud. in Nat. Hist., Univ. of Ia., Vol. IX, No. 1, p. 5, 1920.

Lake Michigan.²⁹ In the earliest stage the bottom was free of plant growth. This was followed by a stage in which the bottom was overgrown with *Chara*, frequently associated with a growth of bulrushes near the edge of the pond. This, as Shelford states, "prepares a way for the vegetation which reaches to and above the surface. This, in turn, fills the pond still further and the strictly marsh vegetation takes possession. The history of the true pond is then at an end and the story of the marsh begins."³⁰

Some of these ecological stages may be found in the lakes of the Okoboji region. The early bare-bottom stage is nearly realized in the case of Welch Lake. The bottom is mainly of silt with a slight intermixture of sand along the shore. On the west shore and to a lesser extent on the east side the bottom is rocky. The slope is gradual, and the greatest depth is not quite two meters. Filamentous algæ were noted on the rocks and other objects in the water but no *Chara* was found, and the aquatic seed plants were scarcely represented. Phytoplankton in which *Microcystis* predominated was very abundant, giving a greenish color to the water. The fish fauna is very limited. The bullhead minnow, *Cliola vigilax*, was seined by the writer in great numbers, and several young black bullheads, *Ameiurus melas*, were also taken. Mr. Shear, who for twenty years has seined this lake for minnows, states that with the exception of an occasional pike, *Esox lucius*, he has never taken other than these two species.

Another ecological stage much in advance of Welch Lake is represented by Spirit Lake. This lake, the largest in the state, is shallow in comparison with its size, reaching a depth of only 7.6 meters. With the exception of East Bay the outline is very regular. The shores are comparatively low so that it is exposed to winds from all directions. The bottom of the shallower waters is chiefly sandy although gravel, both coarse and fine, and clay occur. The slope of the bottom is very gradual. There are several rock reefs in the lake, mainly in deeper water although a few of them reach the shore.

While the amount of vegetation other than the phytoplankton and attached filamentous algæ is relatively moderate, well developed growths of water weeds and of rushes are found in different portions

²⁹ Shelford, V. E. Ecological Succession. II, Pond Fishes. Biol. Bull., 21, p. 127-151, 1911.

³⁰ Shelford, V. E. Animal Communities in Temperate America, p. 151, 1913.

of the lake. The phytoplankton in the summer time becomes so abundant as to form a green scum on the surface of the calm water. Shimek accounts for the moderate growth of the higher plants by the lack of sheltered bays, "coupled with the prevailing sandy or gravelly shores and bottom, and the greater exposure of the surface to storms."³¹

While earlier ecological stages may be found, the lake as a whole has reached the stage of early maturity. The conditions are evidently favorable for fish life, for thirty-three species representing twelve families have been recorded from this lake. It is extremely doubtful, however, that one of these, the Great Lake Trout, *Cristivomer namaycush*, is found here at the present time.

West Okoboji Lake presents conditions markedly different from the two lakes already discussed, and in the matter of depth differs from all of the lakes of this region. Its mean depth, 12.3 meters, is greater than the maximum of any other of these lakes, and it reaches a maximum depth of 40.2 meters. West Okoboji is nearly six miles long, and while it is three miles across in its widest portion, its average width is approximately a mile. It is not so exposed as Spirit Lake, its bank for the most part high, abrupt, and wooded, although in several places the land slopes down to the water's edge. The outline of this lake is irregular. Three well developed bays cut off to a greater or less extent by points of land and outstretching reefs are found on the southeast and west shores. Smaller bays and coves also occur on either side of the lake. "The main slope of the bottom of the lake is fairly uniform to the depth of eighty feet, but below that depth the slopes are decidedly steeper."³²

West Okoboji has attained the stage of maturity, although in different localities other stages from the bare-bottom to that of the marsh may be found. More favorable conditions for aquatic vegetation are afforded in this lake than in Spirit Lake. The bottom is not so uniformly sandy here, and there is better protection from wave action, especially in the three bays referred to. Wylie concluded from a survey made of the lake that about 1100 acres, about 30% of the lake, was occupied by the larger plants. In most places, he states, these are submerged and do not come to the surface.³³

³¹ Shimek, Bohumil. The Plant Geography of the Lake Okoboji Region. Bull. from Lab. Nat. Hist., Univ. Ia., Vol. VII, No. 5, 1915.

³² Birge, E. A. and Juday, Chancey. A Limnological Reconnaissance of West Okoboji. p. 5.

³³ Wylie, R. B. The Major Vegetation of Lake Okoboji. Proc. Ia. Acad. Sci., Vol. 27, p. 91-97, 1920.

The growth of phytoplankton becomes conspicuous from midsummer on, but not so marked, however, as that found in Spirit Lake.

A slightly larger number of fishes, thirty-six, has been recorded from this lake. This number includes again the Great Lake trout which has been planted in the lake with doubtful success. The great majority of fishes, both of species and individuals, are found in the bays in the vicinity of the water weeds.

East Okoboji is a long narrow lake, nearly seven miles in length, and averaging about one half a mile in width. It is irregular in outline and generally has high banks, many of them wooded. The lake is shallow with a maximum depth of 7.9 meters, and an average of 3.0 meters. This lake with its abundant growth of aquatic vegetation represents a stage of maturity in advance of the West Lake. Forty species of fish have been recorded from this lake.

The most advanced ecological stage which is represented here is found in the small shallow lakes, Marble, Hottes, and Robinson. The last named with which the author is most familiar will be used to illustrate this stage. When first visited, in 1922, Robinson Lake was about one and one half miles long and half a mile wide. It was very shallow, the greatest depth then less than two meters. The bottom, soft and mostly clay, with some sandy silt, was largely covered with a rich growth of water weeds. In some parts of the lake patches of rushes occurred. Six species of fish were taken in this lake. During the next three years the rainfall was so greatly reduced that the level of all the lakes was greatly lowered. Robinson and the adjoining shallow lakes were in danger of drying up completely and the fish life nearly, if not completely, exterminated. About twenty years ago under similar conditions, so the writer was informed, these lakes became dry. They are in the stage of old age, and are so shallow that they do not have sufficient volume of water to withstand a series of dry seasons.

GENERAL DISCUSSION

The results obtained from these studies indicate that a large number of species prefer a habitat in or near the growths of water weeds.³⁴ Of the forty-five species listed from the lakes here, twenty-six are found there all or part of the time, while twelve show a preference for open water. The writer has no data for the remaining seven species. Wylie, in his survey of the vegetation of Lake

³⁴ Potamogetons, *Myriophyllum*, and *Ceratophyllum* are the dominant types.

Okoboji, made the following observation: "During the entire month given to this survey, and during which time hundreds of people were observed fishing in various parts of Lake Okoboji, no fish were being caught except in or along the edge of these masses of major vegetation."³⁵ There are two evident advantages derived from a habitat among the aquatic plants. In the first place, it affords a wide range of food possibilities, and secondly, it provides excellent shelter. Predaceous species as the Pike, *Esox lucius*, concealed by vegetation, lie in wait for their prey. Other species as the carp, *Cyprinus carpio*, lay their eggs in such places, and the nests of the sunfishes may be found in shallow water near the shore among the water plants. While the differences in the numbers of species recorded from the three major lakes are not large enough to be significant, yet it is interesting to note that their order coincides with the relative amount of vegetation found. Thus Spirit Lake with a moderate amount of vegetation has thirty-three species of fishes, West Okoboji with a large amount, thirty-six species, and East Okoboji with relatively the greatest amount, has forty.

Robinson Lake with a proportionately greater growth of vegetation than East Okoboji, might be expected to have a greater number of species than the latter, but only six species were taken there.³⁶ The most conspicuous difference between the two is that of depth, Robinson having a maximum depth of 1.6 meters while that of East Okoboji was 7.9 meters. While the difference in depth may be a factor in accounting for the greater number of species in the one than in the other, it seems probable that other factors are more concerned. The oxygen content of the water is probably favorable, for two samples taken from different parts of the lake on August 12, 1922, gave 5.07 and 5.22 cc. per liter. Another sample taken July 28, 1924, and tested for the hydrogen ion concentration, gave a pH of 5.71. This degree of acidity is probably an important factor in limiting the number of species. Possibly the high temperature of the lake at times during the summer is another factor. On July 27, 1922, at 2:15 P. M., the surface temperature near the shore was thirty-one degrees, C., one degree cooler than the air, and on August 24, 1924, at 2:20 P. M., the same temperature was noted with an air temperature of twenty-seven degrees, C. Three of the species

³⁵ Wylie, R. B. The Major Vegetation of Lake Okoboji. Proc. Ia. Acad. Sci., Vol. 27, p. 97, 1920.

³⁶ These and the following statements apply to conditions in 1922.

found in this lake occurred in great numbers, namely, the black bullhead, *Ameiurus melas*, the long-eared sunfish, *Lepomis megalotis*, and the common sunfish, *Eupomotis gibbosus*. Two others, the perch, *Perca flavescens*, and the golden shiner, *Abramis crysoleucas*, were tolerably common, and the pike, *Esox lucius*, was found in lesser numbers. Evidently the conditions were favorable for these fishes, but were not the kind preferred by other species, for opportunity in the past has been given them to enter this lake at the time of high water when Robinson, Hottes, and Marble Lakes were connected with each other and with Spirit Lake.

Under certain conditions of weather the oxygen content of Spirit Lake apparently becomes so reduced as to make conditions for the fishes most unfavorable. Under ordinary conditions the oxygen supply is kept up in part by photosynthesis in the water plants and in part by wave action. Exposed as it is on all sides, the surface for the most part is kept in motion and the oxygen distributed. The lake is too shallow for stratification during the summer and from the meager data available, the temperature and oxygen content appear to vary but little from the surface to the bottom under ordinary conditions.

For three or four days ending August 6, 1922, calm weather prevailed with high temperature. On the 6th, Dr. J. H. Malony reported that the wall-eyed pike, *Stizostedion vitreum*, were dying in great numbers in Spirit Lake and the perch, *Perca flavescens*, and the shiner, *Notropis hudsonius*, had suffered but not to such a marked extent. Specimens of the first two species were examined but nothing abnormal was discovered. On the 7th, when the writer visited the lake, a strong northwest wind was blowing and the lake was too rough to venture out on it. Larger fishes than those examined on the preceding day were washed in together with great numbers of smaller ones. Among them, black bullheads, *Ameiurus melas*, eight or ten inches long were noted. The number of dead fishes washed in decreased during the day until in the afternoon it was apparent that no more fish were dying.

Dr. G. M. Smith, who visited the lake on the morning of the 7th, came to the conclusion that decomposition of algæ was responsible for the death of the fishes. Exposure to the sun during the calm days had killed the phytoplankton so extensively that its decay in the water had consumed much of the oxygen present. At the same time the high temperature of the water during this period would

also tend to diminish the oxygen. It seems probable that the oxygen was so reduced during the period of calm ending the 6th, as to suffocate the fish.

On the 8th, the writer accompanied Professor F. A. Stromsten and Mr. Wesley Damerow to this lake where temperatures at different depths were taken with an electric resistance thermometer and samples of water taken for determination of the oxygen content. The results are given in the following table.

TABLE VI
Temperature Readings and Oxygen Content, Spirit Lake

Depth	Midway between Templar's Park and Red Nose Point 9:30 A.M.		East of Templar's Park 2:30 P.M.	
	Temp.	O cc. per liter	Temp.	O cc. per liter
0 m.	21.88°C.	5.61	23.50°C.	7.92
1 m.	21.80°C.	5.84	22.00°C.	
2 m.	21.85°C.	5.47	21.55°C.	
3 m.	21.80°C.	5.28	21.39°C.	4.99
4 m.	21.75°C.	5.62	21.30°C.	
5 m.	21.60°C.	5.85	21.20°C.	
6 m.			21.00°C.	3.67

It will be noted that the temperature varied but little from the surface to the bottom, and that the oxygen supply was evidently ample. It seems probable that the oxygen supply, which had been diminished in the ways mentioned, was restored to normal by the gale on the 7th. This stirred up the lake so that the oxygen was mixed with the water, and viable conditions once more established for the fishes. A similar occurrence under like conditions took place in early July 1921, but with less fatality to the fishes.

The number of species found in the Little Sioux River was much less than the number in the major lakes. Only twelve species were found in the river as compared with forty-five in the three lakes together. This is quite in accord with the observations of Pearse who states, "rivers, at least in summer, contain fewer fishes per unit of area than lakes. For fishes a river is a highway and a refuge. It gives access to the stores of food in swamps and lakes, and in winter furnishes an environment which is fairly stable. However, a river is not capable of producing much fish food within itself. The food resources available to lake fishes in the bottom mud cannot occur in quantity in rivers because the bottom is continually changing."⁵⁷

⁵⁷ Pearse, A. S. The Distribution and Food of the Fishes of Three Wisconsin Lakes in Summer. Univ. Wis. Stud. in Sci., No. 3, p. 53, Madison, 1921.

It will be noted, however, that Robinson Lake had but half the number of species found in the Little Sioux River, again indicating that the conditions in that lake were not favorable for a large number of species.

SUMMARY

Fifty-one species, possibly fifty-two, distributed among seven orders, fifteen families, and thirty-seven genera were recorded from the Lake Okoboji region. Of these, forty-five species were listed from the lakes, fourteen from the Little Sioux River, and five from Reed and Thomas Creeks. Two species, the small-mouth buffalo, *Ictiobus bubalus*, and the small-mouthed bass, *Micropterus dolomieu*, which were recorded by Meek, have not been taken by the writer. In the case of two other species, the spoonbill, *Polyodon spathula*, and the Great Lake trout, *Cristivomer namaycush*, the writer has no conclusive evidence to indicate whether or not they still occur in the lakes.

Observations were made regarding the summer habitat of thirty-eight species. Twelve were found to have a preference for muddy bottom, nine for sandy, and two for rocky. Nine species were found on both muddy and sandy bottoms, four on both muddy and rocky, one on both sandy and rocky, and another one was found on all three. Twenty-six species were found among aquatic vegetation, nine practically all the time and the remaining seventeen part of the time. Twelve showed a decided preference for open water. The preference for vegetation is presumably due to the abundance and variety of the food supply found there and to the shelter afforded by it.

During the summer season Reed and Thomas Creeks are narrow and shallow with occasional deeper pools and slightly developed riffles. Five species were listed from these creeks. Three of these, named in the order of the numbers found, the creek chub, *Semotilus atromaculatus*, the black-nosed dace, *Rhinichthys atronasus*, and the straw-colored minnow, *Notropis blennioides*, constituted the main fish life of both creeks. An immature perch, *Perca flavescens*, was taken in Thomas Creek. Adults of this species occur in the spring during high water in Reed Creek and very likely would be found in Thomas Creek under similar conditions. The brook stickleback, *Eucalia inconstans*, has been taken in years past in Reed Creek. Whether or not it occurs there now is uncertain. The brook chub

and the black-nosed dace were found mainly in the deeper pools with overhanging shelves of vegetation while the straw-colored minnow showed a preference for the swifter waters of the creeks. During the two seasons when the studies were made the conditions under which these three species lived were very similar. The temperature of the water was low, especially in the pools of Reed Creek. The water was well oxygenated and a high hydrogen ion concentration was indicated. The food, as judged by the stomach contents of seventeen of these fishes, consists mainly of insects during the summer.

Several ecological stages are represented by the different lakes of the Okoboji region. The earliest one, approximating the bare-bottom condition, is represented by Welch Lake. Three species of fishes were listed from this lake. Successive stages of maturity with increasing amounts of vegetation are found in Spirit, West Okoboji, and East Okoboji Lakes. The number of species of fishes recorded, while not markedly different, increased slightly with the greater amount of vegetation, thirty-three, thirty-six, and forty species respectively in the three lakes. The most advanced stage is found in the shallow lakes, Hottes, Robinson, and Marble. Robinson Lake, taken as a typical example, had but six species although the aquatic vegetation was relatively greater than that of East Okoboji. The acidity of the lake as indicated by a pH of 5.71 has probably been a factor in limiting the number of species here. The high temperature of the water at times during the summer, at least 31° C., associated with the extreme shallowness of the lake may be another factor.

Spirit Lake at times presents unfavorable conditions for fish life. A period of clear calm days with high temperature appears to kill the minute plants of phytoplankton. By the decay of these the oxygen supply of the lake is apparently reduced to such an extent that great numbers of fish are killed. The amount of oxygen supplied to the water through photosynthesis is not so great in this lake because of the rather moderate amount of vegetation. However, the lake is so exposed that under ordinary conditions there is a sufficient supply of oxygen through wave action.

The number of species of fishes found in the Little Sioux River was much less than that of the three major lakes. From Robinson Lake, however, less than half as many species were recorded as from the river.

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