DISTRIBUTION AND FOOD OF THE FISHES OF GREEN LAKE, WIS., IN SUMMER

By A. S. Pearse

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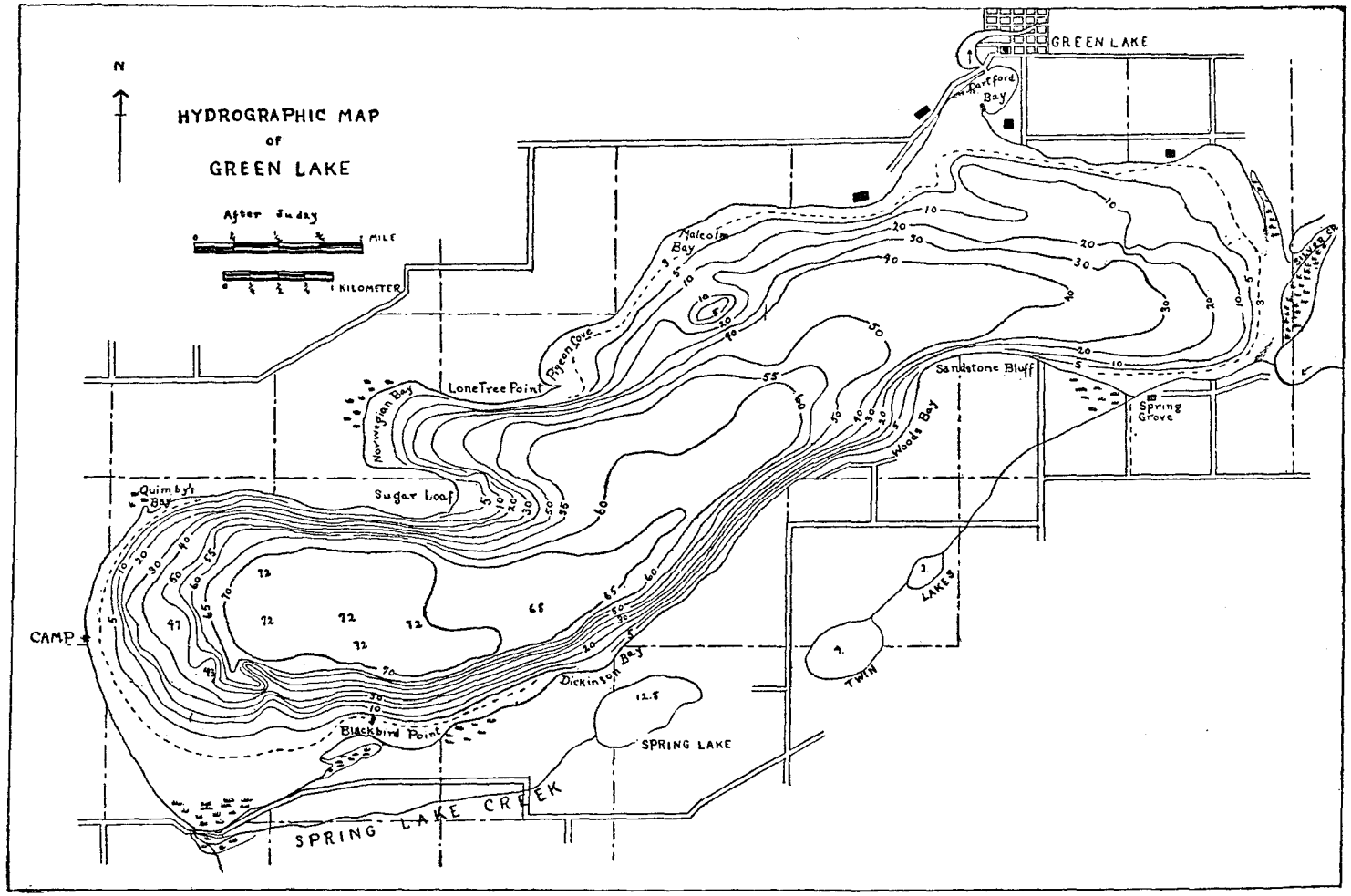

FRONTISPIECE.

DISTRIBUTION AND FOOD OF THE FISHES OF GREEN LAKE, WIS., IN SUMMER.

By A. S. PEARSE, *University of Wisconsin.*

CONTENTS.

INTRODUCTION.

Green Lake is of particular interest on account of its depth (237 feet). It measures 11.9 km. in length, 3.22 km. in width, has a maximum depth of 72.2 m., and a mean depth of 33.1 m. Its area at a depth of 70 m. is 2.1 km.[2] The water is very clear and the plankton content rather poor. The shores are for the most part sandy or stony, and the slope of the beaches is usually deep.

During the summer of 1919 the writer camped at the western end of the lake from August 11 to September 5. In front of the camp was a considerable stretch of sandy beach (frontispiece); the deepest parts of the lake and Spring Lake Creek (at the southwest corner of the lake) were readily accessible by rowboat. Temperatures were taken once each week and are recorded in Table 1.

TABLE 1.—TEMPERATURES OF GREEN LAKE IN DEGREES CENTIGRADE, 1919.[1]

Date.	Depth, in meters.									
	1	5	10	12.5	15	25	35	45	55	65
Aug. 14	22.2	22.2	16.4	9.5	8.1	6.4	5.7	5.2	5.0	4.9
Aug. 20	21.6	21.7	19.8	13.2	9.5	6.6	5.8	5.5	5.0	4.9
Aug. 28	21.2	20.7	20.6	12.6	9.1	6.0	6.0	5.8	5.0	4.9
Sept. 4	20.2	19.7	19.5	16.6	9.9	7.1	6.15	5.1	5.0	4.8

[1] The deep-sea thermometer used in taking the temperatures was loaned by C. Juday, of the Wisconsin Geological and Natural History Survey.

Fishing was carried on at various depths in the open lake and in Spring Lake Creek with gill nets measuring 75 by 4 feet. A 30 by 4 foot minnow seine was used in shallow water along the shores. Trot-lines baited with earthworms were set a few times, particularly to catch bullheads. Two hundred and three fishes, belonging to 17 species, were examined, special attention being given to the ciscoes, which were plentiful in deep water.

In making examinations the skin, fins, mouth, and gills first received attention. The fish was then slit open from vent to chin, and a careful inspection of the visceral organs was made. The contents of the intestine was stripped out on a glass plate and teased apart with needles under a binocular microscope, this being supplemented with a compound microscope when necessary. The intestine was then slit open and examined for food and parasites.

The data relating to parasites are reserved for a general publication dealing with several Wisconsin lakes; those concerning distribution and food are presented in this paper.

FISHES CAUGHT IN GREEN LAKE.

Ambloplites rupestris (Rafinesque): Rock bass.
Ameiurus natalis (Le Sueur): Yellow bullhead.
Ameiurus nebulosus (Le Sueur): Speckled bullhead.
Amia calva Linnaeus: Dogfish.
Boleosoma nigrum (Rafinesque): Johnny darter.
Catostomus commersonii (Lacépède): Common sucker.
Cyprinus carpio Linnaeus: German carp.
Esox lucius Linnaeus: Northern pike, pickerel.
Eupomotis gibbosus (Linnaeus): Pumpkinseed.
Fundulus diaphanus menona (Jordan and Copeland): Top-minnow.
Lepomis incisor (Cuvier and Valenciennes): Bluegill.
Leucichthys birgei Wagner: Cisco.
Micropterus dolomieu Lacépède: Smallmouth black bass.
Micropterus salmoides (Lacépède): Largemouth black bass.
Notropis atherinoides Rafinesque: Shiner.
Perca flavescens (Mitchill): Yellow perch.
Pimephales notatus (Rafinesque): Blunt-nosed minnow.

Other species doubtless occur in the lake. Joe Norton, an experienced fisherman living on the shore of the lake, says that gars are often seen. A sheepshead was caught in the lake several years ago.

DISTRIBUTION OF THE FISHES.

In order to determine the distribution of the fishes in Green Lake four methods were used. Gill nets were set at various depths; a minnow seine was used alongshore; trot-lines were set; and some trolling was done with a spoon hook.

The five gill nets used were always set tied together in a "string," all being of the same size (4 by 75 feet), but differing in the mesh (bar measure: ¾, 1, 1½, 2, 3 inches). Nets were set in the morning and pulled the following day. Table 2 gives a complete list of the catches in the string of gill nets.

TABLE 2.—GILL-NET CATCHES IN GREEN LAKE, 1919.[1]

Date.	Size of mesh.	Depth set.	Time set.	Catch.	Date.	Size of mesh.	Depth set.	Time set.	Catch.
	Inches.	*Meters.*	*Hours.*			*Inches.*	*Meters.*	*Hours.*	
Aug. 13...	¾	41.5	22.5	3 ciscoes.	Aug. 26...	¾	6	23.5	1 perch.
	1	41.5	22.5	14 ciscoes.		1	6	23.5	1 centharcid.
	1½	41.5	22.5	6 ciscoes.		1½	6	23.5	1 pickerel, 1 rock bass.
	2	41.5	22.5	Nothing.		2	6	23.5	1 bluegill, 2 pickerel.
	3	41.5	22.5	2 ciscoes.		3	6	23.5	Nothing.
Aug. 14...	([2])	71.5	23.6	Nothing.	Aug. 27...	([2])	3	23.7	Nothing.
	1	71.5	23.6	8 ciscoes.		1	3	23.7	1 pickerel.
Aug. 15...	([2])	20	23.3	Nothing.		1½	3	23.7	3 bluegills, 1 perch.
Aug. 16[4]..	¾	[5] 7.5	23.7	Nothing.		1½	3	23.7	1 rock bass.
	1	[5] 8	23.5	1 rock bass.		2	3	23.7	1 pickerel.
	1	8	23.5	1 crayfish.	Aug. 28...	¾	1.8	23.5	5 perch.
	1½	[6] 9.3	23.5	1 crayfish.		1	1.8	23.5	2 pickerel.
	2	[6] 12	23.5	2 pickerel.		1½	1.8	23.5	4 pickerel.
	3	[6] 15	23	2 suckers.		2	1.8	23.5	1 rock bass.
	3	15	23	1 smallmouth black bass.		3	1.8	23.5	Nothing.
Aug. 18...	([2])	5	22	Nothing.	Sept. 1[7]...	¾	1	7.6	1 pickerel, 1 pumpkinseed.
	1½	5	22	1 pickerel.		1	1	7.7	4 perch, 9 pickerel.
	1½	5	22	2 rock bass.		1	1	7.7	1 pumpkinseed.
Aug. 19...	¾	70.3	24.2	2 ciscoes.		1½	1	7.2	1 bluegill, 3 perch.
	1	70.3	24.2	68 ciscoes.		1½	1	7.2	12 pickerel.
	1½	70.3	24.2	27 ciscoes.		2	1	7.2	3 bluegills, 1 largemouth black bass.
	2	70.3	24.2	3 small ciscoes.		2	1	7.2	6 pumpkinseeds.
	3	70.3	24.2	1 small cisco.		3	1	6.8	Nothing.
Aug. 20...	([2])	50	23.5	Nothing.	Sept. 2....	¾	4	23.5	3 perch, 1 pickerel.
	1	50	23.5	1 cisco.		1	4	23.5	1 pickerel.
	2	50	23.5	1 cisco.		1½	4	23.5	1 pickerel, 1 carp.
Aug. 21...	([3])	37–44	23.3	Nothing.		2	4	23.5	Nothing.
Aug. 22...	([2])	21	22.7	Nothing.		3	4	23.5	Nothing.
Aug. 23...	([2])	8–10.5	23.5	Nothing.	Sept. 4....	¾	1.5–3	24.5	1 pickerel, 1 rock bass.
	2	8–10.5	23.5	1 pickerel.		1	1.5–3	24.5	1 rock bass.
	3	8–10.5	23.5	1 smallmouth black bass.		1½	1.5–3	24.5	1 pickerel, 1 rock bass.
Aug. 25...	([2])	2– 3.6	22.5	Nothing.		1½	1.5–3	24.5	1 clam (Lampsilis luteola).
	¾	2– 3.6	22.5	5 perch.		2	1.5–3	24.5	Nothing.
	1½	2– 3.6	22.5	1 bluegill.		3	1.5–3	24.5	Nothing.
	1½	2– 3.6	22.5	1 pickerel.					
	1½	2– 3.6	22.5	1 rock bass.					
	2	2– 3.6	22.5	3 bluegills.					
	2	2– 3.6	22.5	1 sucker.					

[1] All nets were 4 by 75 feet.
[2] Indicates that nets of the other meshes than those listed for catches on this date were set at the depth given, but nothing was caught.
[3] Indicates that five nets having ¾, 1, 1½, 2, and 3 inch meshes were set, but nothing was caught.
[4] Set string of nets on steep slope.
[5] Bare bottom.
[6] Among plants.
[7] Spring Lake Creek, half mile above mouth; set nets alternately from either bank, away from mouth, in following order: 3, 1½, ¾, 1, and 2 inch mesh.

Table 3 gives a summary of all the gill-net catches (except that of Sept. 1 in Spring Lake Creek) arranged according to depth.

This summary shows that ciscoes are confined to depths below 40 m. and the "catch per hour" figures indicate that ciscoes are the most abundant larger fishes in the lake. Young ciscoes probably spend a year or more in shallow water, for schools of from 100 to 200 fingerlings were observed three times, swimming in the middle of the lake at the surface in bright sunlight. The pickerel ranges deeper than other shallow-water species.

There is a zone above the ciscoes (20 to 40 m.) where there are few or no fishes. Footing up the "catch per hour" for all species at all depths we have the following figures: Total hours all nets were set—419.4; catch per hour—bluegills, 0.094; carp, 0.01; cisco, 1.447; largemouth black bass, 0; rock bass, 0.1; perch, 0.13; pickerel, 0.207; pumpkinseed, 0; smallmouth black bass, 0.03; sucker, 0.053.

If the abundance of fishes large enough to be caught in gill nets is judged by the "catch per hour," the species occur in the following ratios in Green Lake during the summer: Cisco, 48; pickerel, 7; perch, 4; rock bass, 3; bluegill, 3; sucker, 2; small-

mouth black bass, 1; carp, +; large mouth black bass,[1] +; pumpkinseed,[1] +. These figures probably are almost correct with two exceptions: There are doubtless schools of carp too large to be caught in the nets used; and the pickerel, because it is fairly abundant and probably moves about more in search of food, is captured more often than the other fishes considered. There seems to be no question that the cisco is far more abundant than any other species.

TABLE 3.—SUMMARY OF GILL-NET CATCHES IN GREEN LAKE, 1919, GIVING DEPTH AND CATCH PER HOUR.

Depth in meters.	Size mesh in inches.	Time set in hours.	Blue-gill.	Rock bass.	Perch.	Pick-erel.	Carp.	Sucker.	Small-mouth black bass.	Cisco.
1 to 5	¾	117.5	.....	0.01	0.11	0.01	.....	.....	.....	.....
	1	117.5	.....	.01	.....	.04	.....	.....	.....	.....
	1½	117.5	0.03	.02	.01	.06	0.01	.....	.....	.....
	2	117.5	.05	.01	.....	.01	.....	0.01	.....	.....
	3	117.5	.....	.....	.....	.....	.....	.....	.....	.....
Total	.....	.....	.08	.05	.12	.12	.01	.01	.....	.....
5 to 10	¾	97.2	.....	.....	.01	.....	.....	.....	.....	.....
	1	97.2	.....	.02	.....	.....	.....	.....	0.01	.....
	1½	97.2	.....	.03	.....	.02	.....	.....	.....	.....
	2	69	.014	.....	.....	.044	.....	.....	.....	.....
	3	69	.....	.....	.....	.....	.....	.....	.....	.....
Total	.....	.....	.014	.05	.01	.064	.....	.....	.01	.....
10 to 20	¾	22.7	.....	.....	.....	.....	.....	.....	.....	.....
	1	22.7	.....	.....	.....	.....	.....	.....	.....	.....
	1½	22.7	.....	.....	.....	.....	.....	.....	.....	.....
	2	46.2	.....	.....	.....	.043	.....	.....	.....	.....
	3	46.2	.....	.....	.....	.....	.....	.043	.02	.....
20 to 40	¾	46.6	.....	.....	.....	.....	.....	.....	.....	.....
	1	46.6	.....	.....	.....	.....	.....	.....	.....	.....
	1½	46.6	.....	.....	.....	.....	.....	.....	.....	.....
	2	46.6	.....	.....	.....	.....	.....	.....	.....	.....
	3	46.6	.....	.....	.....	.....	.....	.....	.....	.....
40 to 72	¾	93.8	.....	.....	.....	.....	.....	.....	.....	0.053
	1	93.8	.....	.....	.....	.....	.....	.....	.....	.98
	1½	93.8	.....	.....	.....	.....	.....	.....	.....	.35
	2	93.8	.....	.....	.....	.....	.....	.....	.....	.032
	3	93.8	.....	.....	.....	.....	.....	.....	.....	.032
Total	.....	.....	.....	.....	.....	.....	.....	.....	.....	1.447

It is interesting in this connection to compare the results for Lake Mendota during the summer of 1919. Lake Mendota has a maximum depth of 25.6 m. It differs from Green Lake ecologically in that its lower water stagnates (Birge and Juday, 1911). This means that the deeper parts (below 8 to 15 m.) are without oxygen during August, September, and October. The important ecological feature in this lake as a habitat for fishes is the fact that the water above the thermocline is well aerated and warm, while that below is without oxygen and comparatively cool. The temperatures of the water in Lake Mendota during the period work was being done in Green Lake are available through the courtesy of President E. A. Birge, of the University of Wisconsin.

While the writer was working in Green Lake, Leslie Tasche was setting a string of five nets (precisely like those used in Green Lake) in Lake Mendota. The summary of some of his catches will serve as a basis for comparison between the two lakes. The nets were set in Lake Mendota on the steep slope off the end of Picnic Point, where general conditions are much like those in Green Lake.

[1] This species is included because young or adults were caught in the lake by other methods of fishing than gill nets; + indicates an amount less than 0.1 per cent. throughout this paper.

TABLE 4.—TEMPERATURES OF LAKE MENDOTA IN DEGREES CENTIGRADE, 1919.

Date.	Depth in meters.											
	0	5	8	9	10	11	12	13	15	17	20	23
Aug. 1	24.1	24.1	24.0	18.1	14.0	12.5	11.5	11.3	10.4	10.1	9.8	9.4
Aug. 19	23.3	22.6	22.4	22.3	16.3	12.7	11.6	10.9	10.4	10.1	9.8	9.7
Aug. 29	21.3	21.3	21.3	21.2	16.9	13.1	12.2	11.6	11.5	10.4	9.5	9.7
Sept. 4	20.3	20.3	20.2	20.2	18.5	15.7	12.8	12.2	10.8	10.2	10.0	10.0

FISHES CAUGHT IN GILL NETS IN LAKE MENDOTA.

Ambloplites rupestris (Rafinesque): Rock bass.
Catostomus commersonii (Lacépède): Common sucker.
Cyprinus carpio Linnæus: German carp.
Esox lucius Linnæus: Northern pike, pickerel.
Lepisosteus osseus (Linnæus): Gar.
Lepomis incisor (Cuvier and Valenciennes): Bluegill.
Leucichthys sp.?: Cisco.
Micropterus salmoides (Lacépède): Largemouth black bass.
Perca flavescens (Mitchill): Yellow perch.
Pomoxis sparoides (Lacépède): Crappie.
Roccus chrysops (Rafinesque): White bass.
Stizostedion vitreum (Mitchill): Wall-eyed pike.

TABLE 5.—GILL-NET CATCHES IN LAKE MENDOTA, 1919.[1]

Date.	Size mesh.	Depth set.	Time set.	Catch.	Date.	Size mesh.	Depth set.	Time set.	Catch.
	Inches.	*Meters.*	*Hours.*			*Inches.*	*Meters.*	*Hours.*	
June 24	¾	23	25	6 perch.	Aug. 22	¾	3	22.5	5 perch.
	1	23	25	55 perch.		1	3	22.5	2 perch, 1 rock bass.
	1½	23	25	1 cisco.		1½	3	22.5	1 bluegill, 1 sucker.
	2	23	25	Nothing.		2	3	22.5	1 white bass.
June 25	(2)	21	23	Nothing.		3	3	22.5	1 carp.
June 26	(3)	22	27.5	Nothing.	Aug. 23	¾	11	24.5	18 perch.
	1	22	27.5	1 perch.		1	7	24.5	111 perch.
July 28	(2)	23	22.5	Nothing.		1½	5	24.5	Nothing.
July 30	(2)	22	22	Nothing.		2	4	24.5	1 wall-eyed pike.
Aug. 1	¾	19	24	Nothing.		3	3	24.5	Nothing.
	1	18	24	10 perch.	Aug. 26	(2)	22	24	Nothing.
	1½	16	24	1 cisco.	Aug. 27	¾	8	24.5	3 perch.
	2	15	24	Nothing.		1	6	24.5	1 largemouth black bass, 16 perch.
	3	14	24	Nothing.		1½	5	24.5	Nothing.
Aug. 2	¾	3	24	2 perch.		2	5	24.5	1 carp.
	1	4	24	1 gar, 14 perch, 1 rock bass.		3	4	24.5	3 carp.
	1½	6	24	1 rock bass.	Aug. 28	¾	16	22.5	Nothing.
	2	9	24	Nothing.		1	10	22.5	75 perch.
	3	14	24	Nothing.		1½	6	22.5	1 rock bass, 1 white bass.
Aug. 7	(3)	22	24	Nothing.		2	4	22.5	Nothing.
	1	22	24	1 perch.		3	4	22.5	1 carp.
Aug. 8	¾	13	23.5	9 perch.	Aug. 29	¾	14	23.5	Nothing.
	1	8	23.5	98 perch.		1	13	23.5	8 perch.
	1½	7	23.5	3 rock bass.		1½	14	23.5	Nothing.
	2	5	23.5	Nothing.		2	12	23.5	Nothing.
	3	4	23.5	Nothing.		3	10	23.5	2 carp, 1 largemouth black bass.
Aug. 9	¾	13	25	19 perch.	Sept. 2	(2)	22	23.5	Nothing.
	1	11	25	254 perch.	Sept. 3	¾	7	23	9 perch.
	1½	9	25	3 rock bass.		1	8	23	52 perch, 1 crayfish.
	2	7	25	1 largemouth black bass.		1½	10	23	1 cisco, 1 sucker.
	3	5	25	1 carp.		2	11	23	1 cisco.
Aug. 12	(2)	23	24	Nothing.		3	14	23	Nothing.
Aug. 13	(2)	19–10	24	Nothing.	Sept. 4	¾	19	24	Nothing.
Aug. 14	¾	3	23.5	Nothing.		1	18	24	1 perch.
	1	4	23.5	22 perch.		1½	15	24	Nothing.
	1½	6	23.5	1 pickerel.		2	12	24	1 carp.
	2	8	23.5	1 carp.		3	9	24	Nothing.
	3	11	23.5	1 carp.	Sept. 5	¾	6	23.5	6 perch.
Aug. 19	(2)	22	24	Nothing.		1	7	23.5	1 crappie, 28 perch.
Aug. 20	¾	17	24	Nothing.		1½	7	23.5	1 crappie.
	1	14	24	12 perch.		2	8	23.5	Nothing.
	1½	12	24	1 cisco.		3	8	23.5	1 carp, 1 largemouth black bass.
	2	12	24	1 cisco.					
	3	12	24	Nothing.					
Aug. 21	(3)	2–4	24	Nothing.					
	1	2–4	24	1 crappie.					

[1] All nets were 4 by 75 feet.
[2] Indicates that five nets, having ¾, 1, 1½, 2, and 3 inch meshes, were set, but nothing was caught.
[3] Indicates that nets of the other meshes than those listed for catches on this date were set at the depth given, but nothing was caught.

The data summarized in Table 5 cover a somewhat longer period of time than that including the catches in Green Lake. It might have been longer, for fishing in Lake Mendota was carried on from March 29 to September 29, 1919; but the general results do not differ markedly from those already published for this lake (Pearse and Achtenberg, 1920), and therefore only the period necessary to make adequate comparisons with Green Lake is listed. The summary shows clearly that perch were abundant in deep water in June and that they gradually migrated to higher levels as that region of the lake lost its oxygen. This migration offers a striking contrast to the conditions in Green Lake, where there is oxygen at all depths during the summer and where the common deep-water fishes (ciscoes) remain in the depths of the lake.

Table 6 gives a summary of catches in Lake Mendota from August 13 to September 4, grouped to show the total catches at different depths.

TABLE 6.—SUMMARY OF GILL-NET CATCHES IN LAKE MENDOTA, 1919, GIVING DEPTH AND CATCH PER HOUR.

Depth, in meters.	Size mesh, in inches.	Time set, in hours.	Perch.	Crappie.	Rock bass.	Bluegill.	Sucker.	Wall-eyed pike.	White bass.	Carp.	Large-mouth black bass.	Cisco.	Pickerel.	Crayfish.
0 to 5.....	¾	70	0.07	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	1	70	.34	0.01	0.01	.....	.....	.....	.....	.....	.....	.....	.....	.....
	1½	95.5	.....	.....	.....	0.01	0.01	.....	.....	.....	.....	.....	.....	.....
	2	118	.....	.....	.....	.....	.....	0.01	0.01	0.01	.....	.....	.....	.....
	3	142.5	.....	.....	.....	.....	.....	.....	.....	.03	.....	.....	.....	.....
Total.	.....	.....	.41	.01	.01	.01	.01	.01	.01	.04	.....	.....	.....	.....
5 to 10.....	¾	47.5	.03	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	1	71	2.52	.....	.....	.....	.....	.....	.....	.....	0.01	.....	.....	0.01
	1½	69	.....	.....	.01	.....	.01	.....	.04	.....	.....	0.01	0.01	.....
	2	23.5	.....	.....	.....	.....	.....	.....	.....	.04	.....	.....	.....	.....
	3	47.5	.....	.....	.....	.....	.....	.....	.....	.04	.02	.....	.....	.....
Total.	.....	.....	2.55	.....	.01	.....	.01	.....	.04	.08	.03	.01	.01	.01
10 to 15.....	¾	48	.38	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	1	48	1.36	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	1½	95.5	.....	.....	.....	.....	.....	.....	.....	.....	.....	.01	.....	.....
	2	116.5	.....	.....	.....	.....	.....	.....	.....	.01	.....	.02	.....	.....
	3	94.5	.....	.....	.....	.....	.....	.....	.....	.01	.....	.....	.....	.....
Total.	.....	.....	1.74	.....	.....	.....	.....	.....	.....	.02	.....	.03	.....	.....
15 to 23.....	¾	166	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	1	119.5	.01	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	1½	71.5	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	2	71.5	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	3	71.5	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Total.	.....	.....	.01	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....

Footing the total catch per hour for all species caught in Lake Mendota the results are: Perch, 4.71; carp, 0.14; white bass, 0.05; cisco, 0.04; largemouth black bass, 0.03; rock bass, 0.02; sucker, 0.02; bluegill, 0.01; crappie, 0.01; pickerel, 0.01; wall-eyed pike, 0.01; gar, +; crayfish, 0.05. Most of the fishes were not caught below 10 m., the only exceptions being the carp, cisco, and perch.

The perch is by far the most abundant fish large enough to be caught in gill nets at all depths in Lake Mendota. The comparative number of fishes for the two lakes judged by catches per hour in gill nets, is shown in Table 7.

TABLE 7.—COMPARISON SHOWING RELATIVE NUMBERS OF FISHES IN GREEN LAKE AND LAKE MENDOTA, AS JUDGED BY CATCHES IN GILL NETS.

	Green Lake.	Lake Mendota.		Green Lake.	Lake Mendota.		Green Lake.	Lake Mendota.
Bluegill	9	1	Perch	12	471	Sucker	6	2
Carp	3	15	Pickerel	21	1	Wall-eyed pike	.....	1
Cisco	144	4	Pumpkinseed	+	+	White bass	.....	5
Crappie	.....	1	Rock bass	9	2			
Gar	+	+	Smallmouth black bass	3	+	Total	186	506
Largemouth black bass	+	3						

This table shows that Green Lake does not have as many fishes large enough to be caught in gill nets as Lake Mendota. This is certainly true of the smaller fishes also, as judged by catches with minnow seines alongshore. The bearing of this fact will be discussed later. Table 7 also shows that there is an interesting compensatory relation between the fishes of the two lakes. The deep-water, bottom-feeding fishes—the perch in Mendota and the cisco in Green Lake—are much more abundant in both lakes than all the shallow water species together. The perch is absent from the deeper waters of Green Lake but in Mendota largely replaces the ciscoes in deep water and is more abundant than the pickerel, which exceeds it in Green Lake. The carp, crappie, largemouth black bass, wall-eyed pike, and white bass are more abundant in Lake Mendota. The bluegill, cisco, pickerel, rock bass, smallmouth black bass, and sucker are more abundant in Green Lake. It is interesting to note that the two fishes which probably are most similar in habits (the smallmouth and largemouth black bass) together have the same ratio of abundance in the two lakes. However, the smallmouth was the only one caught in gill nets in Green Lake and the largemouth the only one caught in Lake Mendota. These facts indicate that the two basses compete with each other and that peculiarities in the two lakes make each best fitted to one of them. In other words, there is room for a certain number of bass, and in Green Lake conditions are best suited for the smallmouth, in Lake Mendota for the largemouth.

The hauls for four days with the minnow seine are given in detail. These were made on a sandy beach bearing a scanty growth of aquatic plants at the west end of Green Lake from the shore line to a depth of 1½ m.

August 16.—Eighteen blunt-nosed minnows, 2 perch, 6 smallmouth black bass.

August 18.—Two largemouth black bass, 3 perch, 4 smallmouth black bass, 2 top minnows.

August 20.—Three Johnny darters, 2 largemouth black bass, 3 perch, 4 pickerel, 10 shiners, 10 smallmouth black bass, 3 top minnows.

August 29.—Four bluegills, 25 Johnny darters, 19 largemouth black bass, 17 perch, 1 pickerel, 1 shiner, 51 smallmouth black bass, 10 top minnows.

Summary.—Four bluegills, 18 blunt-nosed minnows, 28 Johnny darters, 23 largemouth black bass, 25 perch, 5 pickerel, 11 shiners, 71 smallmouth black bass, 15 top minnows.

Arranged in the order of their abundance, as judged by the catches in minnow seines, the small shore fishes rank as follows: Smallmouth black bass, 18; Johnny darter, 7; perch, 6.2; largemouth black bass, 5.8; blunt-nosed minnow, 4.5; top minnow, 3.7; shiner, 3; pickerel, 1.2; bluegill, 1.

These results again show the dominance of the smallmouth over the largemouth black bass in Green Lake, and (although the writer has not kept statistical records of

hundreds of hauls) there is no doubt that the opposite is true in Lake Mendota. The Johnny darters are characteristic shallow-water fishes on sandy shores everywhere in Wisconsin. Some lakes, however, have other species of darters more abundant alongshore. For example, the Iowa darter (*Etheostoma iowæ*, Jordan and Meek) is the abundant one in Oconomowoc Lake. The minnows are characteristic more or less of all shallow-water habitats. The perch ranges through all bottom habitats and is probably the most versatile of our lake fishes. The pickerel, bass, and bluegill belong with the shore vegetation, and, as vegetation is not very plentiful in Green Lake, these fishes are not numerous.

On the evening (6.30 p. m.) of September 2, a trot-line 20 feet in length, bearing 49 No. 1 Limerick hooks baited with earthworms, was set outside a rush-grown bar extending from the bay behind Blackbird Point (front.) westward; depth, 1.2 to 2 m. Next morning (6.30 a. m.) the catch was 1 bluegill, 5 perch, 1 dogfish. At 6.50 p. m. on September 3, 50 hooks were set inside the same bar (1 to 1.5 m.) on 200 feet of line. The catch at 6.50 a. m. on September 4 was 7 bluegills, 4 perch, 1 rock bass, 1 mussel, *Lampsilis luteola* (Lamarck).

If these trot-line catches mean anything, they indicate that there are more bluegills inside the bar and that perch occur in equal numbers on either side. Perch, as has been suggested heretofore, are versatile fishes which invade practically all available habitats. Bluegills, though fitted to live among aquatic vegetation, are remarkably quick to take advantage of any new sources of abundant food. An instance of this was observed in Green Lake on the evening of August 22. The lake was very calm and on its surface were numerous ants, of some species that had been making its nuptial flight during that day. The whole surface of the west end of the lake was at intervals marked by little ripples caused by fishes feeding on the ants. All fishes observed from a rowboat before darkness fell were bluegills, though other species were doubtless taking advantage of this unusual supply of food.

FOOD OF THE FISHES.

The foods eaten by the fishes of Green Lake in 1919 are given in the following lists. The figures used in connection with foods all mean per cent by volume as estimated by the writer at the time of examination; + indicates an amount less than 0.1 per cent. Lengths of fishes are given in millimeters and do not include the caudal fin. Fishes are arranged in alphabetical order according to scientific names. Summaries for all species are given in Table 8. Unless otherwise mentioned all catches are off the sandy shore at the east end of the lake (frontispiece).

Ambloplites rupestris (Rafinesque). Rock bass.

August 16.—Depth, 8 m.; number examined, 1; length, 108. Food: Chironomid pupæ, 2; crayfish, 98.

August 22.—Number examined, 1; length, 30. Food: Chironomus larvæ, 25; mayfly larvæ, 50; Hyalella, 20; Eurycercus, 5.

August 23.—Number examined, 1; length, 47. Food: Chironomus larvæ, 5; large blue water mite, 30; ostracods, 2; cyclops, 12; Eurycercus, 3; Ceriodaphnia, 18; sand, 30.

August 26.—Number examined, 2; lengths, 192, 57. Food: Chironomus larvæ, 2.5; C. pupæ, 2.5; crayfish, 50; Ceriodaphnia, 45.5.

August 27, 28.—Number examined, 2; lengths, 190, 208. Food: Crayfish, 100.

September 4.—Number examined, 3; lengths, 213, 171, 111, average, 165. Food: Crayfish, 66.7; *Cambarus virilis*, 33.3.

Summary.—Number examined, 12 (2 empty); lengths, 30 to 213, average, 134. Food: Insect larvæ, 11.8; insect pupæ, 0.6; crayfishes, 64; mites, 4.2; ostracods, 0.2; amphipods, 2.9; entomostracans, 12; sand, 4.2.

Two-thirds of the food of this species consisted of crayfish.

Ameiurus natalis (Le Sueur). Yellow bullhead.

August 29.—Mouth of Spring Lake Creek; number examined, 2; lengths, 290, 270. Food: Fish, 32.5; mayfly nymphs, 10; insects, 17.5; Gelastocoris, 6.5; crayfish, 10; Hyalella, 12.5; Ceriodaphnia, 1; plants, 10.

Summary of food.—Fish, 32.5; insects and nymphs, 34; crayfishes, 10; amphipods, 12.5; entomostracans, 0.1; plants, 10.

A third of the food of this species was fish and a third insects.

Ameiurus nebulosus (Le Sueur). Speckled bullhead.

August 29, 1919.—Mouth of Spring Lake Creek; number examined, 9; lengths, 265 to 320, average, 302. Food: Mayfly nymphs, 2.8; dragonfly nymphs, 1; crayfish, 25.6; cladoceran, 0.1; amphipods, 0.8; Hyalella, 2.1; Sphæriidæ, 0.6; Planorbis, +; *Physa heterostropha*, 31.4; oligochætes, 3; *Herbobdella punctulata*, 4.2; seeds, 8.9; plants, 10.1; Myriophyllum, 3; filamentous algæ, 0.8; unknown débris, 5.6.

Summary of food.—Insect nymphs, 3.8; mites, 0.5; crayfishes, 25.6; amphipods, 2.6; cladoceran, 0.1; Sphæriidæ, 0.6; snails, 31.4; annelids, 7.2; plants, 22; algæ, 0.8; unknown, 5.6.

The favorite foods of this bullhead were snails, plants, and crayfishes.

Boleosoma nigrum (Rafinesque). Johnny darter.

August 20.—Number examined, 5; lengths, 32 to 46, average, 40.2. Food: Chironomus larvæ, 66; Hyalella, 10; ostracods, 0.2; sand, 23.8.

August 22.—Number examined, 1; length, 34. Food: Chironomus larvæ, 95; sand, 5.

August 24.—Number examined, 1; length, 38. Food: Chironomus larvæ, 75; sand, 25.

August 26.—Number examined, 4; lengths, 37 to 47, average, 41. Food: Chironomus larvæ, 92.5; sand, 7.5.

Summary.—Number examined, 11; average length, 38.3. Food: Chironomus larvæ, 82.1; amphipods, 2.5; ostracods, 0.1; sand, 15.3.

Catostomus commersonii (Lacépède). Common sucker.

August 16.—Depth, 14.5 m.; number examined, 2; lengths, 542, 510. Food: Chironomid larvæ, 23.5; Sialis nymph, 2.5; insects, 0.5; ostracods, 1; amphipods, 60; Eurycercus, +; oligochætes, 0.5; Sphæriidæ, 6.5; mud, 1; sedimentary débris, 4.5.

August 25.—Depth, 4 m.; number examined, 1; length, 364. Food: Chironomid larvæ, 4; Leptocella larva, 1; Hyalella, 2; Sphæriidæ, 76.8; Amnicola, 1; *Valvata tricarinata*, 0.2; sand, 15.

Summary.—Number examined, 3; lengths, 364 to 542, average, 445. Food: Insect and larvæ, 19.3; amphipods, 40.7; entomostracans, 0.7; clams, 29.9; snails, 0.4; oligochætes, 0.3; sedimentary débris, 3; mud and sand, 5.7.

The sucker partakes of a considerable variety of foods, the most important being amphipods, little clams, and insects.

Cyprinus carpio Linnaeus. German carp.

September 2.—Number examined, 1; length, 133. Food: Chironomid larvæ, 2; Hyalella, 25; ostracods, 33; Eurycercus, 1; Ceriodaphnia, 10; Sphæriidæ, 15; plant remains, 3; fine débris, 10; sand, 2.

Esox lucius Linnaeus. Pickerel.

August 16.—Depth, 11.5 m.; number examined, 2; lengths, 553, 576. Food: Shiners, 100.

August 18.—Depth, 5 m.; number examined, 2; lengths, 466, 410. Food: Minnows, 50; fish remains, 50.

August 20.—Number examined, 1; length, 402. Food: Fish remains, 70; ostracods, 10; Chara, 20.

August 22.—Number examined, 1; length 100. Food: Shiners, 100.

August 23.—Depths, 4.6, 11.5 m.; number examined, 2; lengths, 550, 495. Food: Perch, 25; shiners, 15; fish remains, 60.

August 26.—Number examined, 3; lengths, 570, 635, 665. Food: Fish remains, 100 (2 empty).

August 27.—Number examined, 2; lengths, 307, 565. Food: Fish remains, 100 (1 empty).

August 28.—Number examined, 5; lengths, 300 to 475, average, 393. Food: Minnows, 100 (3 empty).

September 2.—Number examined, 2; lengths, 485, 600. Food: Fish remains, 100 (1 empty).

September 3.—Number examined, 3; lengths, 211, 490, 540, average, 414. Food, Fish remains, 100 (1 empty).

Summary.—Number examined, 24; lengths, 100 to 665, average, 445. Food: Perch, 2.5; shiner, 21.5; minnow, 15; fish remains, 58; ostracods, 1; plants, 2.

Eupomotis gibbosus (Linnaeus). Pumpkinseed.

September 1.—Mouth of Spring Lake Creek; number examined, 4; lengths, 163 to 168, average, 165. Food: Chironomid larvæ, 2; dragonfly nymphs, 25; Planorbis, 33.3; Physa, 17.7; Valvata, 2; Sphæriidæ, 5; *Herbobdella punctulata*, 15.

September 2.—Near mouth of Spring Lake Creek; number examined, 1; length, 73. Food: Chironomid larvæ, 92; Sphæriidæ, 8.

Summary.—Number examined, 5; average length, 146. Food: Insect larvæ and nymphs, 59.5; snails, 26.5; small clams, 6.5; leeches, 7.5.

Fundulus diaphanus menona (Jordan and Copeland). Top minnow.

August 15.—Number examined, 1; length, 52. Food: Hyalella, 100.

August 18.—Number examined, 1; length, 52. Food: Chironomid larvæ, 60; chironomid pupæ, 19; gordiacean in chironomid pupæ, 1; sand, 20.

August 20.—Number examined, 2; lengths, 46, 59. Food, Chironomid larvæ, 10; chironomid pupæ, 15; Hyalella, 25; Ceriodaphnia, 25; Pleuroxus, 1.5; Bosmina, 10; Acroperus, 15; ostracods, 2.5; sand, 10.

August 21.—Number examined, 4; lengths, 50 to 53. Food: Chironomid larvæ, 11.3; chironomid pupæ, 23.8; Hyalella, 44.3; Ceriodaphnia, 14.3; Bosmina, 0.5; Chydorus, 1.5; ostracods, 0.5; sand, 4.

August 22.—Number examined, 1; length, 55; Food: Caddisfly larvæ, 45; Hyalella, 50; ostracods, 5.

August 23.—Number examined, 3; lengths, 18 to 53, average, 38. Food: Chironomid larvæ, 30; chironomid pupæ, 6.7; Hyalella, 20.2; Ceriodaphnia, 8.3; Chydorus, 6.7; ostracods, 23.3; sand, 5.

Summary.—Number examined, 12; lengths, 18 to 55, average, 44. Food: Chironomid larvæ, 17.9; caddisfly larvæ, 3.8; chironomid pupæ, 13.7; Hyalella, 31.8; cladocerans, 16.6; ostracods, 6.4; gordiacean, 0.1; sand, 5.9.

Lepomis incisor (Cuvier and Valenciennes). Bluegill.

August 25.—Number examined, 4; lengths, 164 to 186; average, 177. Food: Chironomid larvæ, 1.3; dragonfly nymphs, 0.3; *Leptocerus dilutus* larvæ and cases, 13.3; collembolan, +; ants, 8.8; mite, +; Hyalella, 66.7; Eurycercus, +; Amnicola, 0.3; Ancylus, +; plants, 1.5; algæ, 0.3; sand, 7.8.

August 26.—Number examined, 1; length, 176. Food: Chironomid pupæ, 0.2; Chara, 99.6; plants, 0.2.

August 27.—Number examined, 3; lengths, 143 to 170, average, 160. Food: *Leptocerus dilutus* larvæ and cases, 58.3; crayfish, 33.3; plants, 6.6; sand, 1.7.

August 29.—Spring Lake Creek; number examined, 1; length, 173. Food: Dragonfly nymphs, 15; insects, 40; seeds, 5; plants, 20; fine débris, 20.

August 30.—Number examined, 2; lengths, 43, 157. Food: Chironomid larvæ, 25; chironomid pupæ, 15; collembolan, 50; fine débris, 10.

September 1.—Spring Lake Creek; number examined, 1; length, 175. Food: Sponge, 10; Myriophyllum, 80; wild rice seeds, 10.

September 3.—Number examined, 1; length, 172. Food: *Melanoplus femur-rubrum*, 35; crayfish, 65.

September 4.—Number examined, 5; lengths, 164 to 188, average, 176. Food: *Leptocerus dilutus* larvæ and cases, 64.8; Physa, 1; Planorbis, 0.2; Potamogeton, 7; plants, 17.6; algæ, 6.

Summary.—Number examined, 18; lengths, 43 to 188, average, 165. Food: Insect larvæ, 33; insect pupæ, 1.7; adult insects, 12.9; mite, +; crayfishes, 9.2; amphiods, 14.8; cladocerans, +; snails, 0.5; sponge, 0.5; plants, 21.3; algæ, 1.7; fine débris, 2.2; sand, 2.2.

Leucichthys birgei Wagner. Cisco.

August 13.—Depth, 41.5 m.; number examined, 10; lengths, 148 to 288, average, 199. Food: Chironomid larvæ, 0.3; Mysis, 5; Pontoporeia, 76.6; copepods, 1.6; ostracods, 5; Sphæridæ, 11.1; Amnicola, 0.6; Planorbis, 0.2; brown, spindle-shaped seeds, 0.8; plants, 0.5; bottom ooze, 1.6; calcium carbonate crystals, 0.1; unknown, 1.1.

August 14.—Depth, 71.5 m.; number examined, 8; lengths, 207 to 246, average, 225. Food: Chironomid larvæ, 3.3; Mysis, 13.3; Pontoporeia, 24.2; Canthocamptus, 3.3; ostracods, 12.5; oligochætes, 21.7; Sphæriidæ, 0.8; brown seeds, 0.2; dandelion seed, 0.2; bottom ooze, 12.6.

August 19.—Depth, 70.5 m.; number examined, 12; lengths, 154 to 296, average, 228. Food: Chironomid larvæ, 0.2; Silais nymph, 0.4; Pontoporeia, 73; oligochætes, +; Sphæriidæ, 14.8; Valvata, 0.1; Linnæa, 0.2; Amnicola, 0.3; Planorbis, 0.6; brown seeds, 0.1; plants, 0.4; bottom ooze, 9.8.

Summary.—Number examined, 30; lengths, 148 to 296, average, 218. Food: Insect larvæ, 1.1; Mysis, 4.7; amphipodis, 61.2; copepods, 1.3; ostracods, 3; Sphæriidæ, 9.9; snails, 0.8; seeds, 0.4; plants, 0.3; bottom ooze, 8.2; calcium carbonate crystals, +; unknown, 0.3.

The cisco feeds largely on crustaceans and molluscs in summer. Eighty-eight per cent of its food is made of bottom ooze and the organisms associated with the bottom. Perhaps the ciscoes turn more to plankton at other seasons. If so, their feeding habits differ markedly from the perch, which is the deep-water fish in Lake Mendota, for it feeds largely from the bottom at all seasons (Pearse & Achtenberg, 1920).

Micropterus dolomieu Lacépède. Smallmouth black bass.

August 15.—Number examined, 6; lengths, 46 to 57, average, 51.5. Food: Chironomid larvæ, 6; Orthocladius, 30.1; mayfly nymphs, 0.6; chironomid pupæ, 4; insects, 0.8; Acroperus, +; Eurycercus, 0.1; Ceriodaphnia, 57.8; plant remains, 0.3; filamentous algæ, +; sand, 0.3.

August 16.—Depth, 14.5 m.; number examined, 1; length, 392. Food: Perch, 50; grasshopper, 50.

August 18.—Number examined, 2; lengths, 52, 56. Food: Chironomid larvaæ, 35; mayfly nymphs, 7.5; beetle larvæ, 5; chironomid pupæ, 30; Hyalella, 225.

August 21.—Number examined, 1; length, 55. Food: Chironomid larvæ, 35; Eurycercus, 1; Ceriodaphnia, 64.

August 23.—Depth, 10 m.; number examined, 1; length, 395. Food: Fish remains, 100.

Summary.—Number examined, 11; lengths, 46 to 395, average, 114. Food: Fish, 13.6; insect larvæ, 31.8; insect pupæ, 7.6; insect adults, 5; amphipods, 4.1; cladocerans, 37.6; plants, 0.2; sand, 2.

Micropterus salmoides (Lacépède). Largemouth black bass.

August 18.—Number examined, 3; lengths, 49, 58, 61. Food: Fish, 5; chironomid larvæ, 3.3; damselfly nymphs, 13.3; mayfly nymphs, 6.7; chironomid pupæ, 15.7; Corixa, 8.4; Chydorus, 0.3; amphipod, 2.7; Hyalella, 4; ostracods, 0.3; Eurycercus, 0.3; Ceriodaphnia, 39; sand, 1.

August 19.—Number examined, 1; length, 52. Food: Chironomid larvæ, 15; chironomid pupæ, 40; Eurycercus, 10; Ceriodaphnia, 30; sand, 5.

August 20.—Number examined, 1; length, 63. Food: Chironomid larvæ, 25; chironomid pupæ, 75.

August 21.—Number examined, 3; lengths, 63, 63, 64. Food: Chironomid larvæ, 6.7; mayfly nymphs, 5; chironomid pupæ, 9.3; fly, 3.3; Hyalella, 13.3; Ceriodaphnia, 61.3; sand, 1.

August 22.—Number examined, 8; lengths, 55 to 283, average, 97. Food: Chironomid larvæ, 9; mayfly nymphs, 6.3; chironomid pupæ, 13.5; midges, 14; fly, 0.3; crayfish, 8.1; Hyalella, 28.5; ostracods, 0.1; Chydorus, 0.1; Eurycercus, 0.8; Ceriodaphnia, 7.2; plants, 10.6; sand, 1.5.

Summary.—Number examined, 16; lengths, 49 to 283, average, 78. Food: Fish, 1; insect larvæ, 16.1; insect pupæ, 18.6; adult insects, 8; crayfish, 4; amphipods, 18; cladocerans, 24.8; ostracods, 0.1; plants, 5.2; sand, 1.4.

Only one of the fishes examined was over 88 mm. in length. This one had eaten chironomid pupæ, 15, and plants, 85. The most important foods for all bass examined are insects and their immature stages (42.7), cladocerans, and amphipods.

Notropis atherinoides Rafinesque. Shiner.

Only one shiner was examined for food and it was empty. It was supposed that shiners would be easy to catch alongshore and they were therefore neglected until the period for study was nearly completed—then none was to be found.

Perca flavescens (Mitchill). Yellow Perch.

August 15.—Number examined, 2; lengths, 68, 73. Food: Chironomus larvæ, 10; Orthocaldius larvæ, 15; mayfly nymphs, 2.5; caddisfly larvæ, 5; Hyalella, 15; ostracods, 0.5; Ceriodaphnia, 52.

August 18.—Number examined, 5; lengths, 70 to 113, average, 81. Food: Chironomid larvæ, 25; mayfly nymphs, 3; chironomid pupæ, 34; Hyalella, 12.4; Chydorus sphæricus, 0.2; Eurycercus, 1.2; Ceriodaphnia, 23.2; sand, 1.

August 22.—Number examined, 2; lengths, 93, 97. Food: Chironomid pupæ, 37.5; Hyalella, 59.5; Ceriodaphnia, 0.5; plants, 2.5.

August 23.—Number examined, 1; length, 74. Food: Chironomid larvæ, 22; caddisfly larvæ, 2; chironomid pupæ, 15; Hyalella, 32.8; Eurycercus, 23; Ceriodaphnia, 5; sand, 0.2.

August 25.—Number examined, 5; lengths, 115 to 127, average, 122. Food: Chironomid larvæ, 5; mayfly nymphs, 4; chironomid pupæ, 1; mite, 4; crayfish, 16.2; Hyalella, 19; ostracods, +; Physa, 39.6; Amnicola, 5; plants, 2.6; Arcellalike seeds, 1.4; algæ, 0.2; unknown, 2.

August 26.—Number examined, 1; length, 121. Food: Sialis nymphs, 85; sand, 5; unknown, 10.

August 28.—Number examined, 4; lengths, 118 to 132, average, 126. Food: Chironomid larvæ, 19.3; mayfly nymphs, 12.5; caddisfly larvæ, 2; chironomid pupæ, 2.5; Hyalella, 53.5; Physa, 6.2; plants, 1.2; sand, 0.5; bottom débris, 2; unknown, 0.3.

August 30.—Number examined, 8; lengths, 72 to 83, average, 77. Food: Chironomid larvæ, 9; mayfly nymphs, 14.3; chironomid pupæ, 4.4; Hyalella, 49.8; Chydorus, +; Eurycercus, 2.1; Ceriodaphnia, 18.1; plants, 0.6; Arcellalike seeds, 0.6; sand, 1.1.

September 1.—Spring Lake Creek; number examined, 7; lengths, 183 to 268, average, 216. Food: Fish, 2.9; chironomid larvæ, 0.1; caddisfly larvæ, 3.6; dragonfly nymphs, 85.5; Hyalella, 1; Physa, 3.3; Sphæriidæ, 1.4; Herbobdella, 1.1; plants, 2.

September 2.—Number examined, 1; length, 130. Food: Leptocerus larvæ, 5; plants, 95.

September 3.—Trot-line near bar; number examined, 6; lengths, 122 to 143, average, 134. Food: Sialis nymphs, 8; dragonfly nymphs, 10; chironomid pupæ, 4; crayfish, 10; Hyalella, 44; Ceriodaphnia, 4; oligochætes, 10; plants, 4; sand, 4; bottom débris, 2.

Summary.—Number examined, 43; lengths, 73 to 268, average, 112. Food: Fish, 0.5; insect larvæ, 34.1, insect pupæ, 8; mite, 0.5; crayfishes, 3.2; amphipods, 28.2; ostracods, +; cladocerans, 10.7; snails, 6.6; clams, 0.2; leeches, 0.2; oligochætes, 1.2; plants, 3.8; sand, 1; bottom débris, 0.4; unknown, 0.5.

The chief foods of the perch are insect larvæ, amphipods, and other crustaceans. It is worthy of note that the large perch caught on September 1 in Spring Lake Creek had eaten 85.5 per cent dragonfly nymphs. The perch's food in all habitats is largely from the bottom and from the aquatic vegetation.

Pimephales notatus (Rafinesque). Blunt-nosed minnow.

Three of these little minnows were examined, but only one contained food. This one was caught August 30, measured 52 mm. in length, and had eaten chironomid larvæ, 50, and chironomid pupæ, 50.

GENERAL REMARKS ON FOODS.

Arranged according to their use by all of the 15 species studied in Green Lake, the foods come in the following order: Insect larvæ (21.7), amphiphods (16.5), fish (9.6), crayfishes (7.8), cladocerans (7.6), insect pupæ (6.7), plants (4.5), snails (4.4), clams (4.1), insects (3.3), ostracods (3.3), sand (2.5), mud (2), oligochætes (0.6), leeches (0.5), unknown (0.4), mites (0.4), Mysis (0.3), algæ (0.2), copepods (0.1).

Sixty-seven and seven-tenths per cent of the food of the fishes of Green Lake is arthropods; 31.7 per cent, insects in all stages; and 35.6 per cent, crustaceans. About

85 per cent of the food comes from the bottom (65) and the water plants (20), leaving only one large item—the cladocerans—unassigned, and probably a portion of this item should be placed with the bottom and water plants. It is of course impossible to give exact figures in assigning animals used as food to particular habitats, but there is no doubt that the fishes get the greater part of their food from the bottom and from the shore vegetation. The open-water plankton (which to be sure is poor in this lake) is of little importance, except perhaps as food for the young of ciscoes and other fishes.

According to the ratios of particular foods consumed (during the period when observations were made), the fishes of Green Lake may be arranged as follows:

Fish.—Pickerel (97), yellow bullhead (32.5), smallmouth black bass (13.6), largemouth black bass (0.9), perch (0.5).

Insect larvæ.—Johnny darter (82.1), pumpkinseed (59.5), blunt-nosed minnow (50), perch (34), bluegill (33), smallmouth black bass (31.9), top-minnow (21.7), sucker (19), largemouth black bass (16.7), rock bass (11.8), yellow bullhead (10), speckled bullhead (3.8), carp (2), cisco (1.1).

Insect pupæ.—Blunt-nosed minnow (50), largemouth black bass (18.6), top-minnow (13.7), perch (8), smallmouth black bass (7.8), bluegill (1.7), rock bass (0.6).

Adult insects.—Yellow bullhead (24), bluegill (12.9), largemouth black bass (9.3), smallmouth black bass (5), sucker (0.3).

Mites.—Rock bass (4.2), speckled bullhead (0.5), blunt-nosed minnow (0.5), bluegill, +.

Crayfishes.—Rock bass (64), speckled bullhead (25.6), yellow bullhead (10), bluegill (9.2), largemouth black bass (4.1), perch (3.2).

Mysis.—Cisco (4.7).

Amphipods.—Cisco (61.2), sucker (40.7), top-minnow (35.2), perch (28.6), carp (25), largemouth black bass (18), bluegill (14.8), yellow bullhead (12.5), smallmouth black bass (4.1), rock bass (2.9), speckled bullhead (2.6), Johnny darter (2.5).

Cladocerans.—Smallmouth black bass (37.6), largemouth black bass (25.4), top-minnows (16.6), rock bass (12), carp (11), perch (10.7), yellow bullhead (1), speckled bullhead (0.1), bluegill (+).

Copepods.—Cisco (1.3).

Ostracods.—Carp (33), top-minnow (6.4), cisco (3), pickerel (1), sucker (0.7), rock bass (0.2), Johnny darter (0.1), largemouth black bass (0.1), perch (+).

Clams (all Sphæriidæ).—Sucker (29.9), carp (15), cisco (9.9), pumpkinseed (6.5), speckled bullhead (0.6), perch (0.2).

Snails.—Speckled bullhead (31.4), pumpkinseed (26.5), perch (6.6), cisco (0.8), bluegill (0.5), sucker (0.4).

Lecches.—Pumpkinseed (7.5), perch (0.2).

Oligochætes.—Speckled bullhead (7.2), perch (1.2).

Nematodes (*Gordiacean*).—Top-minnow (0.1).

Sponges.—Bluegill (0.5), sucker (0.3).

Plants.—Speckled bullhead (22), bluegill (21.3), yellow bullhead (10), largemouth black bass (5.2), perch (3.8), carp (3), pickerel (2), cisco (0.7), smallmouth black bass (0.2).

Algæ.—Bluegill (1.7), speckled bullhead (0.8).

Bottom ooze.—Carp (10), cisco (8.2), sucker (3), bluegill (2.2), perch (0.5).

Sand.—Johnny darter (15.3), top-minnow (5.9), sucker (5.7), rock bass (4.2), bluegill (2.2), carp (2), perch (1), smallmouth black bass (0.2), largemouth black bass (0.1).

Unknown.—Speckled bullhead (5.6), perch (0.4).

TABLE 8.—FOOD OF FISHES OF GREEN LAKE, AUG. 12 TO SEPT. 4, 1919.

Common and scientific name.	Number examined.	Average length in millimeters.	Fish.	Insect larvæ.	Insect pupæ.	Insects, adult.	Mites.	Crayfishes.	Mysis.	Amphipods.	Cladocerans.	Copepods.	Ostracods.
Bluegill, Lepomis incisor	18	165	.....	33	1.7	12.9	+	9.2	.....	14.8	+	.....	.....
Bullhead, speckled, Ameiurus nebulosus	9	302	.....	3.8	.....	.....	0.5	25.6	.....	2.6	0.1	.....	.....
Bullhead, yellow, Ameiurus natalis	2	280	32.5	10	.....	24	.....	10	.....	12.5	1	.....	.....
Carp, Cyprinus carpio	1	133	.....	2	.....	.....	.....	.....	.....	25	11	.....	33
Cisco, Leucichthys birgei	30	218	.....	1.1	.....	.....	.....	.....	4.7	61.2	.....	1.3	3
Johnny darter, Boleosoma nigrum	11	38	.....	82.1	.....	.....	.....	.....	.....	2.5	.....	.....	.1
Largemouth black bass, Micropterus salmoides	16	78	.9	16.7	18.6	9.3	.....	4.1	.....	18	25.4	.....	.1
Minnow, blunt-nosed, Pimephales notatus	1	52	.....	50	50	.....	.....	.....	.....	.....	.....	.....	.....
Perch, Perca flavescens	43	112	.5	34.1	8	.....	.5	3.2	.....	28.6	10.7	.....	+
Pickerel, Esox lucius	24	445	97	.....	.....	.....	.....	.....	.....	.....	.....	.....	1
Pumpkinseed, Eupomotis gibbosus	5	146	.....	59.5	.....	.....	.....	.....	.....	.....	.....	.....	.....
Rock bass, Ambloplites rupestris	12	134	.....	11.8	.6	.....	4.2	64	.....	2.9	12	.....	.2
Smallmouth black bass, Micropterus dolomieu	11	114	13.6	31.9	7.8	5	.....	.....	.....	4.1	37.6	.....	.....
Sucker, Catostomus commersonii	3	445	.....	19	.....	.3	.....	.....	.....	40.7	.....	.....	.7
Top minnow, Fundulus diaphanus menona	12	44	.....	21.7	13.7	.....	.....	.....	.....	35.2	16.6	.....	6.4
Average	[1] 198	177	9.6	21.7	6.7	3.3	.4	7.8	.3	16.5	7.6	.1	3

Common and scientific name.	Clams.	Snails.	Leeches.	Oligochætes.	Nematodes.	Sponges.	Plants.	Algæ.	Bottom ooze.	Sand.	Unknown.
Bluegill, Lepomis incisor	.....	0.5	.....	.....	.....	0.5	21.3	1.7	2.2	2.2	.....
Bullhead, speckled, Ameiurus nebulosus	0.6	31.4	.....	7.2	.....	.....	22	.8	.....	.....	5.6
Bullhead, yellow, Ameiurus natalis	.....	.....	.....	.....	.....	.....	10	.....	.....	.....	.....
Carp, Cyprinus carpio	15	.....	.....	.....	.....	.....	3	.....	10	2	.....
Cisco, Leucichthys birgei	9.9	.8	.....	.....	.....	.....	.7	.....	8.2	.....	.3
Johnny darter, Boleosoma nigrum	.....	.....	.....	.....	.....	.....	.....	.....	.....	15.3	.....
Largemouth black bass, Micropterus salmoides	.....	.....	.....	.....	.....	.....	5.2	.....	.....	.1	.....
Minnow, blunt-nosed, Pimephales notatus	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Perch, Perca flavescens	.2	6.6	0.2	1.2	.....	.....	3.8	.....	.5	1	.5
Pickerel, Esox lucius	.....	.....	.....	.....	.....	.....	2	.....	.....	.....	.....
Pumpkinseed, Eupomotis gibbosus	6.5	26.5	7.5	.....	.....	.....	.....	.....	.....	.....	.....
Rock bass, Ambloplites rupestris	.....	.....	.....	.....	.....	.....	.....	.....	.....	4.2	.....
Smallmouth black bass, Micropterus dolomieu	.....	.....	.....	.....	.....	.....	.2	.....	.....	.2	.....
Sucker, Catostomus commersonii	29.9	.4	.....	.....	.....	.3	.....	.....	3	5.7	.....
Top minnow, Fundulus diaphanus menona	.....	.....	.....	.....	+	.....	.....	.....	.....	5.9	.....
Average	4.1	4.4	.5	.6	+	+	4.5	.2	2	2.5	.4

[1] Total.

Table 9 gives the foods eaten by the fishes caught in Lake Mendota during the time covered by the observations in Green Lake. It will be noted that a greater variety of fishes was caught in Lake Mendota (22:15), and that foods differ somewhat in the two lakes. Fishes in Green Lake eat an excess of: Amphipods (13.6), larval insects (11.4), oligochætes (5.6), clams (4.1), insect pupæ (0.4), mites (0.4), and Mysis (0.3). Those in Lake Mendota excel in: Adult insects (13.8), fish (7.2), algæ (5), plants (3.7), copepods (1.5), cladocerans (1.4), ostracods (0.7), bottom ooze (0.7), sand (0.3).

TABLE 9.—FOOD OF FISHES OF LAKE MENDOTA, AUG. 10 TO SEPT. 15, 1919.

Common and scientific name.	Number examined.	Average length in millimeters.	Fish.	Insect larvæ.	Insect pupæ.	Insect, adults.	Mites.	Crayfishes.	Amphipods.	Cladocerans.	Copepods.	Ostracods.
Bluegill, Lepomis incisor	4	127	.....	0.5	.....	11.2	.....	.....	.....	.....	.....	.....
Bream, Notemigonus crysoleucas	2	96	.....	.....	.....	75	.....	.....	.....	.....	.....	.....
Bullhead, speckled, Ameiurus nebulosus	5	131	.....	41.8	1	.....	.....	3	12	3.4	+	2
Bullhead, yellow, Ameiurus natalis	3	221	.....	1.3	.....	.....	.....	75	10	3	0.3	.....
Carp, Cyprinus carpio	7	383	35	.....	.....	.....	.....	.....	.....	.....	.....	.....
Cisco, Leucichthys sp.?	5	366	.....	47	10.8	7.2	.....	.....	.....	35	.....	.....
Crappie, Pomoxis sparoides	6	131	16.6	13.3	10.8	19.2	.....	.....	.....	16	4.2	6.6
Gar, Lepisosteus osseus	2	278	100	.....	.....	.....	.....	.....	.....	.....	.....	.....
Johnny darter, Boleosoma nigrum	10	46	.....	62.9	.....	.....	.....	.....	.....	.....	.....	.....
Largemouth black bass, Micropterus salmoides	7	135	45	.....	.....	10.7	.....	12.1	13.4	.8	.....	.....
Minnow, Notropis heterodon	6	58	.....	.....	47.5	51.7	.....	.....	.....	.....	.....	.....
Perch, Perca flavescens [1]	50	166	.....	20.1	3.3	.8	+	8.3	1	42.2	.1	.....
Pickerel, Esox lucius	5	408	93	.....	.....	.....	.....	.....	.....	.....	.....	.....
Pike, wall-eyed, Stizostedion vitreum	2	410	100	.....	.....	.....	.....	.....	.....	.....	.....	.....
Pumpkinseed, Eupomotis gibbosus	9	118	.....	29.3	.5	4.2	.....	.....	3	.....	.....	29.5
Rock bass, Ambloplites rupestris	10	128	.....	2	.....	5	.....	50	5.8	14	.....	.....
Shiner, Pimephales notatus	7	46	.....	.....	.....	25.6	.....	.....	.....	31.4	14.1	.....
Silversides, Labidesthes sicculus	7	59	.....	.....	53.6	5.7	.....	.....	.....	40.1	.....	.....
Smallmouth black bass, Micropterus dolomieu	4	356	.....	.5	.....	82.5	.....	.....	2.5	.....	.....	.....
Sucker, Catostomus commersonii	5	304	.....	4.7	.....	.....	.....	.....	4	+	1.7	.....
Top minnow, Fundulus diaphanus menona	5	61	.....	3.2	7	1.4	.....	.....	11.4	15	15	40
White bass, Roccus chrysops	6	235	12.2	.....	.2	75	.....	.....	.....	.....	.....	.....
Average	[2] 166	194	16.8	10.3	6.1	17.1	+	6.8	2.9	9	1.6	3.7

Common and scientific name.	Clams.	Snails.	Leeches.	Oligochætes.	Protozoa.	Plants.	Algæ.	Bottom ooze.	Sand.	Unknown.
Bluegill, Lepomis incisor	.....	0.8	.....	0.8	.....	75.6	10	.....	.....	.....
Bream, Notemigonus crysoleucas	.....	.....	.....	.....	.....	.....	25	.....	.....	.....
Bullhead, speckled, Ameiurus nebulosus	.....	.6	7	.....	.....	10.6	17.1	1.4	0.6	.....
Bullhead, yellow, Ameiurus natalis	.....	1.7	.....	.....	.....	.....	10.1	.....	.....	1.3
Carp, Cyprinus carpio	.....	32.8	.....	.....	.....	2.8	.....	27.9	.....	.....
Cisco, Leucichthys sp.?	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Crappie, Pomoxis sparoides	.....	.....	.....	.....	.....	13.3	.....	.....	.....	.....
Gar, Lepisosteus osseus	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Johnny darter, Boleosoma nigrum	.....	.....	.....	.....	.....	.....	13.6	2.9	20.7	.....
Largemouth black bass, Micropterus salmoides	.....	.....	.....	.....	.....	3.6	14.2	.....	.....	.....
Minnow, Notropis heterodon	.....	.....	.....	.....	.....	.8	.....	.....	.....	.....
Perch, Perca flavescens [1]	0.7	6.2	.....	7.6	.....	6.5	.5	.9	.....	.....
Pickerel, Esox lucius	.....	.....	.....	.....	.....	7	.....	.....	.....	.....
Pike, wall-eyed, Stizostedion vitreum	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Pumpkinseed, Eupomotis gibbosus	.....	11	5.9	.....	.....	5.5	.....	.....	11.1	.....
Rock bass, Ambloplites rupestris	.....	.....	.....	.....	.....	10	3	.....	11.2	.....
Shiner, Pimephales notatus	.....	.....	.....	.....	.....	14.3	10	4.3	.....	.....
Silversides, Labidesthes sicculus	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Smallmouth black bass, Micropterus dolomieu	.....	.....	.....	.....	.....	5	.....	9.5	.....	.....
Sucker, Catostomus commersonii	.....	57	.....	.....	0.1	10	10	11.7	.....	.....
Top minnow, Fundulus diaphanus menona	.....	.....	.....	.....	.....	4	.....	.....	9	.....
White bass, Roccus chrysops	.....	.....	.....	.....	.....	12.2	.....	.....	.....	.....
Average	+	5	.6	.4	+	8.2	5.2	2.7	2.8	.1

[1] No perch were examined in 1919. These are figures for 1915 during the same season of the year. [2] Total.

TABLE 10.—COMPARISON OF FOODS EATEN BY FISHES OF GREEN LAKE AND LAKE MENDOTA, 1919.

	Green Lake.	Lake Mendota.		Green Lake.	Lake Mendota.		Green Lake.	Lake Mendota.
Fish	9.6	16.8	Cladocerans	7.6	9	Sponges	+	−
Insect larvæ	21.7	10.3	Copepods	.1	1.6	Protozoa	−	+
Insect pupæ	6.7	6.7	Ostracods	3	3.7	Plants	4.5	8.2
Adult insects	3.3	17.1	Clams	4.1	+	Algæ	.2	5.2
Mites	.4	+	Snails	4.4	5	Bottom ooze	2	2.7
Crayfishes	7.8	6.8	Leeches	.5	.6	Sand	2.5	2.8
Mysis	.3	−	Oligochætes	6	.4	Unknown	.4	.1
Amphipods	16.5	2.9						

It will be noted (Tables 8, 9, and 10) that the foods eaten in excess in Green Lake are largely those associated with the bottom; those most eaten in Lake Mendota are found for the most part in shallow water with plants, or in the open water. These differences are in part accounted for by the stagnation of the deeper water and in part by the greater abundance of food resources in the latter lake. In Lake Mendota there is an abundance of food in the deeper parts, but such supplies are not easily accessible to fishes in summer because there is no oxygen below 8 to 12 m. Birge and Juday have recently made observations with mud dredges which, with the earlier work of Birge (1897) and Marsh (1903), indicate clearly that there is actually less food in Green Lake, as regards both bottom fauna and plankton, than in Lake Mendota. There are some common fishes in Lake Mendota (silversides, crappie, gar, white bass) which are rare or absent in Green Lake. These "extra" fishes feed to a considerable degree on plankton, insects (in or on the surface of the water), and fishes. There is apparently no chance for them to be abundant in Green Lake.

DISCUSSION AND CONCLUSIONS.

Green Lake is a fine clear body of water, with sandy and pebbly shores, and great depth. Seventeen species of fishes were caught in it during the summer. The lake stratifies in summer, but the lower water always contains oxygen, and of course remains cool (5° C.).

Lake Mendota has nearly twice the area of Green Lake but is only a third as deep. It stagnates during the summer in its depths and a large part of its water is without oxygen for about three months. Notwithstanding this handicap, Lake Mendota has more than twice as many fishes (as judged by the catch per hour in gill nets) in a unit area.

During the summer the distribution of the fishes in Green Lake shows definite stratification. From the surface down to a depth of 10 m. all species of fishes caught in the lake, except adult ciscoes, were found; from 10 to 20 m. only large pickerel, smallmouth black bass, and suckers occurred; from 20 to 40 m. no fishes were caught; from 40 to 70 m. ciscoes were the only fishes caught, and were abundant. Reighard's (1915, p. 246) idea that ciscoes inhabit the intermediate water and are not caught in gill nets set on the bottom is no longer tenable in the light of results presented in this paper. A. R. Cahn has also caught many ciscoes in gill nets set on the bottom in Oconomowoc Lake.

While gill nets were being set in Green Lake, 22 species of fishes were caught in Lake Mendota by the same methods. There are, then, not only more individuals, but a greater number of species in Lake Mendota. There were no fishes caught in gill nets in this lake in the lower, stagnant water, except an occasional perch. Most fishes stay above the thermocline, where oxygen is plentiful but the water warm. The perch apparently congregate just above the thermocline and make short excursions into the stagnated region to take advantage of the food offered by the rich bottom fauna.

The most abundant species in each lake is one which feeds very largely from the bottom in deep water. In Green Lake this species is the cisco; in Lake Mendota, it is the perch. Both species are present in both lakes, but a single and different species is dominant in each lake. The cool water in the depths of Green Lake abounds with ciscoes; the perch is not abundant and, in fact, was never caught in deep water. Al-

though ciscoes are present in Lake Mendota they are few in number and the perch is the abundant fish in deep water, except when stagnation forces it out during the summer (Pearse and Achtenberg, 1920). The perch appears to be about equally abundant in both lakes in shallow water.

There are perhaps two reasons why ciscoes are not abundant in Lake Mendota and why perch are comparatively scarce in Green Lake. These are concerned with temperature and food. The perch may live in shallow water at rather high temperatures, but because the summer stagnation has made Mendota unsuitable for ciscoes, it has also been able to dominate the deep water. To flourish, the cisco appears to require cold water in summer and finds ideal conditions in the depths of Green Lake. There appears to be no good reason why the perch should not occur in the deeper parts of Green Lake. Perhaps it has never crossed the "barren zone" between the depths of 20 and 40 m. Perhaps the "attractive" food which takes it to the bottom of Lake Mendota is lacking. The characteristic animals in the bottom of Lake Mendota are enormous numbers of midge larvæ (Corethra, Chironomus, Protenthes, etc.). Little clams, oligochætes, crustaceans, and protozoans are also present. On the bottom of Green Lake the fauna is much the same, except that the crustaceans (particularly amphipods) are very abundant and midge larvæ are few.

The relatives of the cisco are usually found in the depths of lakes and in the cooler parts of the ocean. The relatives of the perch are mostly found in shallow regions of fresh water. The ciscoes apparently invaded fresh water from the ocean as the glaciers receded and have remained in the cooler parts. The perch has probably migrated into the depths of lakes from adjacent shallow waters to take advantage of the abundant stores of food there. Reighard (1915, p. 242) even classifies the perch in his "Vegetation Community," though he also found it in deeper water in Douglas Lake.

Not only are the fishes which feed on the bottom most abundant in both lakes, but the animals found in or on the bottom are most used for food by all the fishes in the lakes; that is by all species of fishes considered together. In Lake Mendota, however, more plankton is consumed by the fishes than in Green Lake, and this probably for two reasons: (1) There is actually more plankton in the lake, and (2) a large portion of the bottom is not readily accessible on account of stagnation.

The shallow waters in the two lakes under consideration are quite different. Green Lake has sandy and stony shores, with comparatively little vegetation; Lake Mendota has varied shores and large numbers of aquatic plants. These differences are reflected in the two basses, the smallmouth being the common one in Green Lake and the largemouth in Lake Mendota. The smallmouth in Green Lake feeds largely on shallow water cladocerans, insect larvæ, and fishes. The most important foods of the largemouth in Lake Mendota during the summer are fishes, adult insects, crayfishes, amphipods, and algæ. In this lake the smallmouth partakes largely of *adult* insects. The largemouth apparently becomes the dominant bass because it feeds more during the summer, which is its chief growing period, on food which is found in the shore vegetation rather than on the bottom.

Why is it that Lake Mendota has a greater number and variety of fishes than Green Lake in spite of the fact that (1) it has half the volume and (2) that a considerable portion of its bottom with much food is cut off by stagnation for three months during each year? The writer has thought over the whole question with care and

can see no answer except—mud. The thick layer of soft mud on the bottom of Lake Mendota is rich in organic materials and contains a very abundant fauna of detritus feeders.[1] The mud and its animals form an enormous store of organic material. This makes aquatic plants and plankton abundant; this in turn gives opportunity for fishes (silversides, etc.) which feed on pelagic organisms to flourish and makes those which feed on plants and small fishes more abundant. Green Lake is a fine, healthful habitat for fishes in somewhat the same way that a desert on land is healthful. Its possibilities are limited because it lacks mud. Rich "soil" is just as important for raising animals from aquatic pastures as it is for those on land. Petersen (1918) has recently made a similar generalization in regard to the ocean.[2]

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[1] Birge and Juday have found as many as 30,000 Corethra larvæ per square meter in the mud on the bottom of Lake Mendota.

[2] Dr. R. E. Coker, after reading the manuscript for this paragraph, suggests that the richness of food stores in a lake may perhaps be connected with the fertility of the soil in the surrounding drainage area. Dr. R. H. Whitbeck, professor of geography in the University of Wisconsin, assures the writer that the drainage basin of Green Lake is less fertile than that of Lake Mendota.