A STUDY OF TWIN LAKES, COLORADO, WITH ESPECIAL CONSIDERATION OF THE FOOD OF THE TROUTS.

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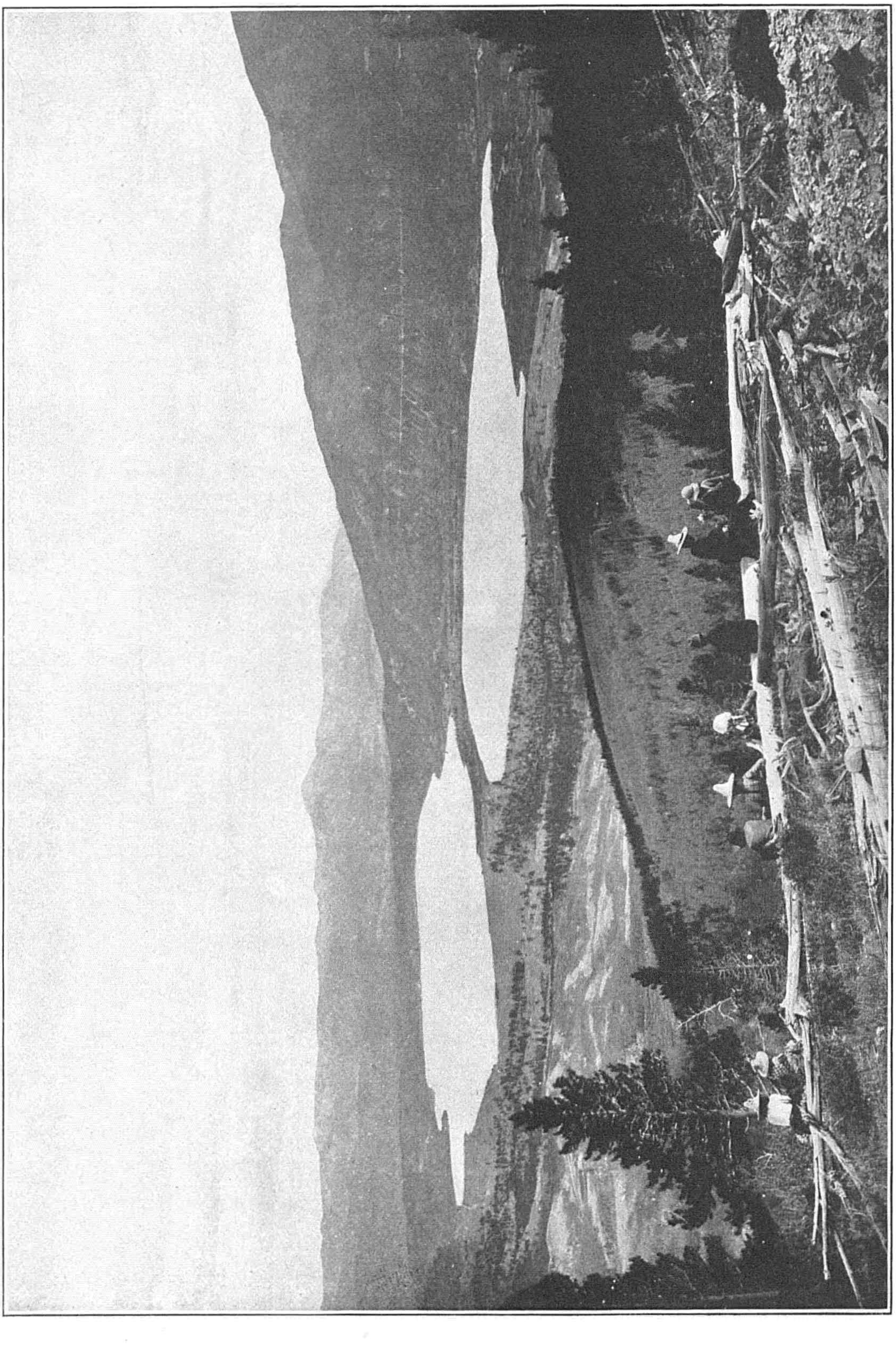

VIEW OF TWIN LAKES FROM SIDE OF MOUNT ELBERT. LOOKING SOUTH OF EAST.

A STUDY OF TWIN LAKES, COLORADO, WITH ESPECIAL CONSIDERATION OF THE FOOD OF THE TROUTS.[a]

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PHYSICAL CHARACTERISTICS OF THE LAKES.

LOCATION.

These two beautiful sheets of limpid water lie in the southern part of Lake County, Colorado, about 15 miles south-southwest of the city of Leadville, nestled at the base of the highest mountains in the state. Viewed from the east, they have for a background the loftiest peaks of the Sawatch Range, which extends north and south immediately behind them. Rising from the lake basin on the northwest are spurs and ridges which lead up to Mount Elbert. This mountain has an altitude of 14,421 feet (4,395.5 meters), and is only 3 feet lower than Mount Massive, its neighboring peak on the north, which is said to be the highest in Colorado. La Plata peak, rising but a short distance southwest of the lakes, has an altitude of 14,342 feet (4,371 meters), while between La Plata and the lakes are lofty ridges with peaks having an altitude of probably 13,000 feet (4,000 meters) or more. As the ridges extend down to the lakes, the southern shores are very steep. The general contour of the country surrounding the lakes is shown in plate III.

ORIGIN AND SIZE.

The lakes lie a short distance below the mouth of Lake Creek Canyon. This canyon extends westward between Mount Elbert and La Plata, and there are many evidences to show that it was once occupied by a glacier which probably came down and joined the glacier that occupied the canyon of the Arkansas River. Much of the débris brought down by the Lake Creek glacier was deposited in the lateral moraines which form high ridges on either side of the lower valley. Thus the lakes are entirely surrounded by morainal detritus with no rock in place exposed along the shores except for a short distance along the north shore of Lower Lake. The glacier was no doubt active in scooping out the lake basins, and then as it receded two terminal moraines were formed, one which maintains the water in Lower Lake and a second one, about 225 yards (200 meters) wide in its narrowest part, which separates the two lakes. These lateral and terminal moraines are well shown in sketch maps by Holmes in Hayden's Report for 1874 (between p. 48 and 49).

[a] Study made for the United States Bureau of Fisheries during the summers of 1902 and 1903.

Upper Twin Lake at its usual stage of water about midsummer has an area of about 474.5 acres (192 hectares) and Lower Lake about 1,440 acres (582 hectares). Both lakes were, no doubt, considerably larger during their earlier stages. The portion of Lake Creek below Lower Lake has worn a channel over 20 feet (6 meters) deep through the old terminal moraine, and it therefore seems probable that the lake was several feet deeper at some time in its past history, which greater depth would increase its size very materially. An increase in the depth of Lower Lake would soon affect Upper Lake also, as the fall between the two is only about 6 or 7 feet (2 meters). Moreover, Upper Lake, at no distant time, geologically speaking, probably extended much farther west than it does at the present time. The débris brought down by the various streams that flow into its western end has formed a swampy meadow of considerable extent, and it seems probable that much, if not all, of this area was covered with water during the early history of the lake, and thus constituted a part of it.

DEPTH AND VARIATION IN LEVEL.

In Hayden's Report for 1873, figure 11 is a sketch map showing the results of a number of soundings in each lake. The greatest depths found by him were 79 feet (24 meters) in Upper Lake and 76 feet (23 meters) in Lower Lake. Powell also published a map of the lakes (1891, pl. LXXXI). He states that 44 soundings were made in Upper Lake and 86 in Lower Lake but gives no results in figures.

In the present investigations 94 soundings were made in Upper Lake and 85 in Lower Lake, the lines being run in a general north and south direction across each lake in order to make them as short as possible and thus reduce the chance of error to a minimum. On July 8, 1902, the greatest depth found in Upper Lake was 82 feet (25 meters) and two weeks later the maximum depth found in Lower Lake was 74 feet (22.5 meters). When these soundings were made the water in Upper Lake was at about its normal stage, but Lower Lake was about a foot lower than usual at this time of year. While the maximum depth of Lower Lake is only 8 feet (2.5 meters) less than that of Upper Lake, its average depth is very much less, as much of the eastern half of Lower Lake is comparatively shallow.

It was impossible to determine the natural fluctuation in the level of the lakes. Since the spring of 1901 they have been used as a storage reservoir by the Twin Lakes Reservoir Company. The surplus water of the basin is stored here during the flood season and later is withdrawn for the purpose of irrigating lands in the vicinity of Sugar City, Colo. A dam 18.5 feet (5.6 meters) high is now maintained in the old outlet and the present outlet is a canal. The dam and the canal are so constructed that there is a difference of 25.5 feet (7.8 meters) between extreme high water and extreme low water in Lower Lake. The possible variation in the level of Upper Lake is about 6 or 7 feet (2 meters) less, as already indicated. It is proposed, however, to dredge the creek connecting the two lakes so that they may have the same possible fluctuation in level. Concerning the natural fluctuation in level previous to the building of the dam, Powell stated, in 1891, "it is not likely that the surface of the lakes varies more than 2 feet in altitude during the year."

AFFLUENTS.

The principal affluent is Lake Creek, which rises in the Sawatch Range. Some distance above the lakes the creek divides into two branches. The north or main branch has its beginnings in amphitheaters up near the crest of the mountains, a little to the northwest of Mount Elbert. It flows south and southeast for a distance of about 10 miles (16 kilometers), and then east about 8 miles (12.8 kilometers) into Upper Lake. The south fork rises in amphitheaters lying west and southwest of La Plata, flows northeast about 8 miles, and joins the north fork. Powell (1891) states that Lake Creek drains about 102 square miles (261 square kilometers) of high mountain country. At present, however, not all the water of the creek reaches the lakes. About 5 miles (8 kilometers) above Upper Lake considerable water is diverted into a ditch which furnishes a water supply for placer mining in the vicinity of Granite. During the late summer, when the water in Lake Creek is especially low, it is said that so much is removed by this ditch that frequently portions of the creek below are entirely dry and large numbers of brook trout perish there. At the point where Lake Creek emerges from its canyon there was formerly a fall of sufficient height to prevent the trout from ascending the stream, but a few years ago much of this rock was removed by blasting and trout may now ascend the creek without difficulty.

About a dozen other streams of various sizes contribute their quota of water to the lakes.

CHARACTER OF SHORES AND BOTTOM.

As stated before, the lakes are entirely surrounded by morainal detritus, so that the shores are composed very largely of sand and gravel. In places, however, there are rocks varying in size from mere cobblestones to huge bowlders. At present the cutting action of the waves on the shore is very slight in most places. At two points on Lower Lake, however, one on the north side and the other on the south side, the waves have recently been cutting the shores very rapidly. The increased height of the water caused by the dam has directed wave action at these points against loose morainal banks that are steep and easily cut away. Along some parts of Upper Lake the action of the ice on the shores was well illustrated by the small ridges of shore material that had been pushed up just a few feet back of the water's edge.

The bottom of the shallower parts of the lakes is sandy and gravelly for the most part, but it is composed of bowlders of various sizes in some places. In the deeper water a marly deposit covers the bottom.

TRANSPARENCY OF THE WATER.

The transparency of the water of both lakes varied somewhat during the period of these observations. It was found that, in general, a Secchi's disk just disappeared from view at a depth of about 18 feet (5.5 meters) early in July, and the water gradually became more transparent as the season advanced, so that, by the middle of August, this depth had increased to a maximum of 29.5 feet (9 meters). The low transparency early in the season was due to the fact that the snow on the mountains was melting rapidly and the streams in consequence were swollen and more or less roily. As summer advanced they became smaller and their water became clear.

The transparency of the water of the lakes was quickly affected by roily affluents. If a heavy rain occurred in Lake Creek Canyon so as to fill the water of the creek with silt, the water of the lakes soon responded with a marked decrease in transparency.

The maximum transparency of these lakes exceeds by 10 feet (3 meters) that which the writer found in several lakes in southeastern Wisconsin in 1900, and it also exceeds by 21 feet (6.5 meters) that found in Winona Lake, Indiana, in 1901. These waters are not so transparent as Lake Tahoe, however. Le Conte (1883) records that in August, 1873, he found that a white plate was still visible at a depth of 108 feet (33 meters) in Lake Tahoe, and in June, 1904, the present writer found the transparency to be 65 feet (19.8 meters).

TEMPERATURE OF AIR AND WATER.

The lakes are about 9,200 feet (2,804 meters) above sea level, consequently the water does not attain a very high temperature during the summer because of the climatic conditions at this altitude. In 1902 snow fell as late in the summer as July 5 and as early in the fall as August 25. In 1903 two or three inches of snow fell on June 10, and flurries were recorded for July 3. No snow was noted down as low as the lakes until September 6, but some of the surrounding mountains were covered as early as August 24.

Some observations of the temperature of the air were made, but on account of other work, they were not taken on some days; and it was found impracticable, also, to make them each day at exactly the same hour. The average results, however, will give a general idea of the daily range of temperature. The following table shows the maxima, minima, and averages of readings taken between 6 and 7 a. m., 12 noon and 1 p. m., 6 and 7 p. m., and 9 and 10 p. m.

Year.	Month.	Hour.	Number of readings.	Maxima.		Minima.		Averages.	
				Degrees Fahrenheit.	Degrees Centigrade.	Degrees Fahrenheit.	Degrees Centigrade.	Degrees Fahrenheit.	Degrees Centigrade.
1902	July	6-7 a. m.	15	56.0	13.3	40.5	4.7	48.5	9.2
1902	....do	12-1 p. m.	18	85.0	29.4	47.5	8.6	71.0	21.6
1902	....do	6-7 p. m.	20	77.0	25.0	48.0	9.0	64.3	18.0
1902	August	6-7 a. m.	20	54.0	12.2	41.0	5.0	48.0	9.0
1902	....do	12-1 p. m.	15	81.5	27.5	56.0	13.3	67.8	19.9
1902	....do	6-7 p. m.	21	72.0	22.2	52.5	11.4	61.2	16.2
1903	July	6-7 a. m.	15	60.0	14.4	38.8	3.8	50.3	10.2
1903	....do	12-1 p. m.	11	84.8	29.3	65.5	18.6	74.7	23.7
1903	....do	6-7 p. m.	16	73.0	22.8	38.8	3.8	60.9	16.0
1903	....do	9-10 p. m.	10	58.8	14.9	38.0	3.3	49.8	9.9
1903	August	6-7 a. m.	14	48.5	9.2	31.0	– 0.5	43.0	6.1
1903	....do	12-1 p. m.	17	82.5	28.0	60.5	15.8	75.0	23.9
1903	....do	6-7 p. m.	7	75.0	23.9	53.0	11.7	66.3	19.0

The days are usually warm and pleasant in summer, but the temperature falls rather rapidly after sunset. The nights are very cool, generally, and hoar frost may be expected every month of the year.

These climatic conditions explain why the water of the lakes never attains a very high temperature. In fact the lakes are generally covered with ice for a period of about five months each year. The following table shows the dates on which the lakes became completely covered with ice early in the winter, and those on which it disappeared from them in the spring, with a third column containing the number of days the lakes were covered with ice. I am indebted to Mr. Charles L. Willis for the data concerning Upper Lake, and to Mr. John J. Hartman for that pertaining to Lower Lake.

Periods in 1901–1905 during which Twin Lakes were icebound.

Date of freezing over.	Date of opening.	Number of days covered.	Date of freezing over.	Date of opening.	Number of days covered.
Upper Lake:			Lower Lake:		
December 16, 1901	May 8, 1902	143	December 15, 1900	May 12, 1901	148
December 13, 1902	May 16, 1903	149	December 16, 1901	May 12, 1902	147
December 16, 1903	May 3, 1904	138	December 11, 1902	May 15, 1903	155
December 19, 1904	May 8, 1905	140	December 11, 1903	May 12, 1904	152
			December 28, 1904	May 19, 1905	142

The records of the freezing over show only the dates on which the lakes became completely covered with ice. For some time previous there was considerable ice on both lakes, particularly around the edges and in the protected bays. Thus, it will be seen that Upper Lake was icebound for 138 to 149 days, and Lower Lake for 142 to 155 days each winter during the period covered by these observations. While no temperature observations were made during these periods, it can safely be said that the temperature of the water must have been tolerably low for a period of at least five months each year. It will also be noted that Upper Lake was not covered with ice quite so long as Lower. For the winter 1902–3, Mr. Hartman reported the maximum thickness of ice on Lower Lake as 34 inches (86 centimeters), and Mr. Willis found a maximum of 28 inches (71 centimeters) on Upper Lake. For the latter lake also, Mr. Willis reported a maximum of 24 inches (60 centimeters) for the winter 1903–4.

Several sets of temperature observations were made on these two lakes during the months of July and August in 1902 and 1903. In general the temperature conditions during the summer were found to be similar to those that have been observed in lakes of corresponding size and depth at much lower altitudes—that is, the same three regions were noticeable. There was an upper stratum of water, or superthermocline region, whose temperature increased materially during the summer; a bottom stratum, or subthermocline, whose temperature changed very little during the summer; and a more or less distinct transition zone or thermocline between these two strata. The thermocline region is always characterized by a considerable change in the temperature of the water within a comparatively thin stratum. This stratum was found to be from 3 to 4 meters (10 to 13 feet) thick in these lakes, and the water in the lower portion of it was about 5° C. (9° F.) colder than that in the upper portion. The decrease in temperature with increasing depth both above and below this region, was much more gradual. This transition zone was not nearly so pronounced, however, in these lakes in late summer as has been found by the writer in lakes in southeastern Wisconsin and northern Indiana, but it agrees very closely with this zone in the latter lakes when their upper stratum of water has a corresponding temperature early in the summer. During these observations westerly winds blew with considerable regularity, beginning usually about 10 a. m., and lasting till late in the afternoon. As a result the water of the superthermocline region was kept quite thoroughly stirred up, so that its temperature was tolerably uniform, thus producing a fairly distinct thermocline. The superthermocline was considerably thicker in Lower than in Upper Lake, on account of the fact that the wind was more effective in disturbing the upper water of the former because of its much larger size.

In the accompanying temperature curves the vertical spaces represent the depth of the water in meters, and the horizontal spaces show the temperature in degrees centigrade.

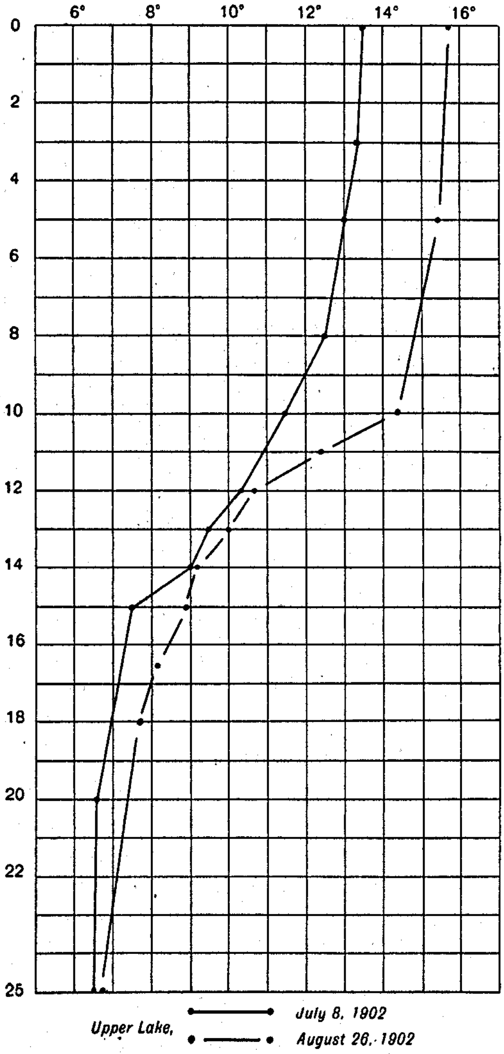

FIG. 1.

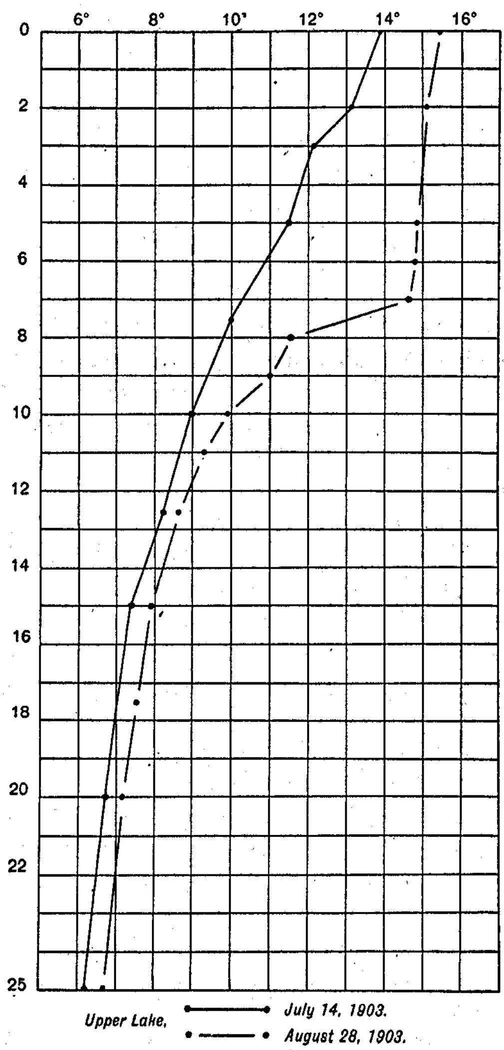

FIG. 2.

Figures 1 and 2 indicate the temperature changes that occurred in Upper Lake in 1902 and 1903 during the time of the observations. It will be noted that the superthermocline was not so thick in 1903 as in 1902, but that the thermocline was more sharply defined in the former year. In 1902 the upper 5 meters (16 feet) of water reached the summer maximum of 16.6° C. (62° F.) on August 4, remained practically the same for ten days, and then gradually decreased. In 1903 a maximum of 16.1° C. (61° F.) was noted on August 7. The bottom temperature was about the same both summers and changed very little during the two months, averaging about 6.5° C. (43.8° F.).

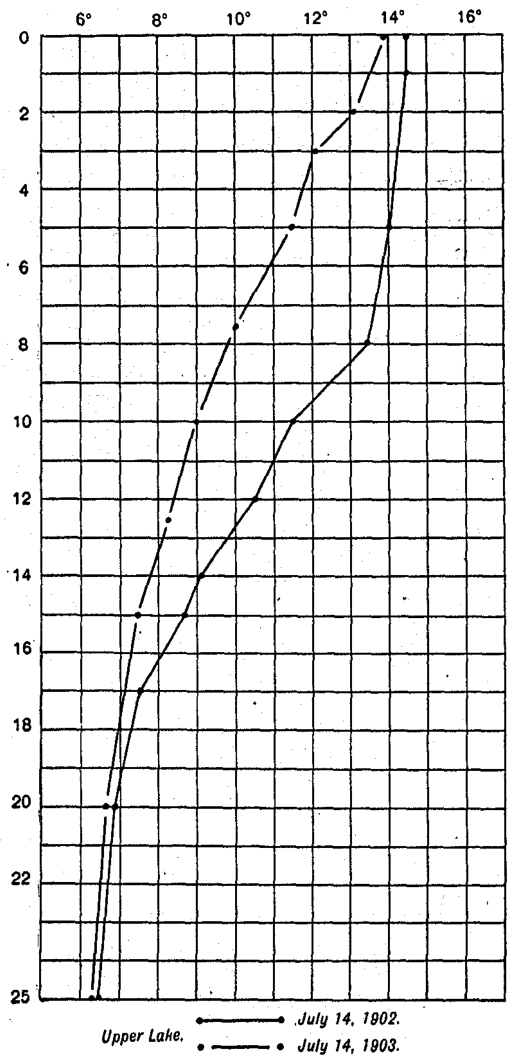

FIG. 3.

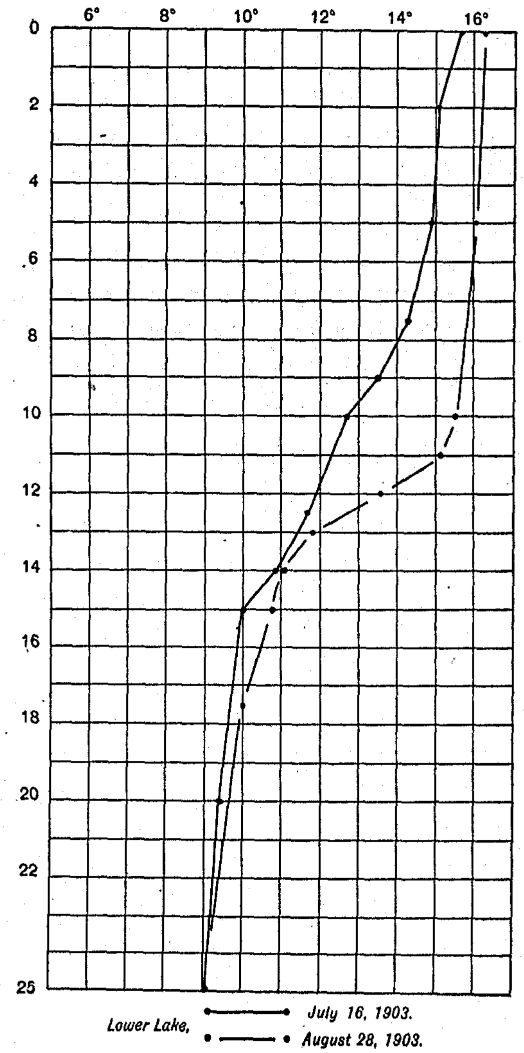

FIG. 4.

Figure 3 represents two sets of observations on Upper Lake which were made just one year apart. These curves show that down to a depth of 17 meters (55 feet) the water was considerably warmer in 1902 than in 1903, and slightly warmer thence to the bottom.

Figure 4 shows the comparatively slight change in temperature that occurred in Lower Lake between July 16 and August 28, 1903. The upper stratum became somewhat warmer and more thoroughly mixed, thus making the thermocline a little more pronounced. In 1902 the surface water had a temperature of 17.1° C. (62.8° F.) on August 21 and a maximum of 17° on August 7, 1903.

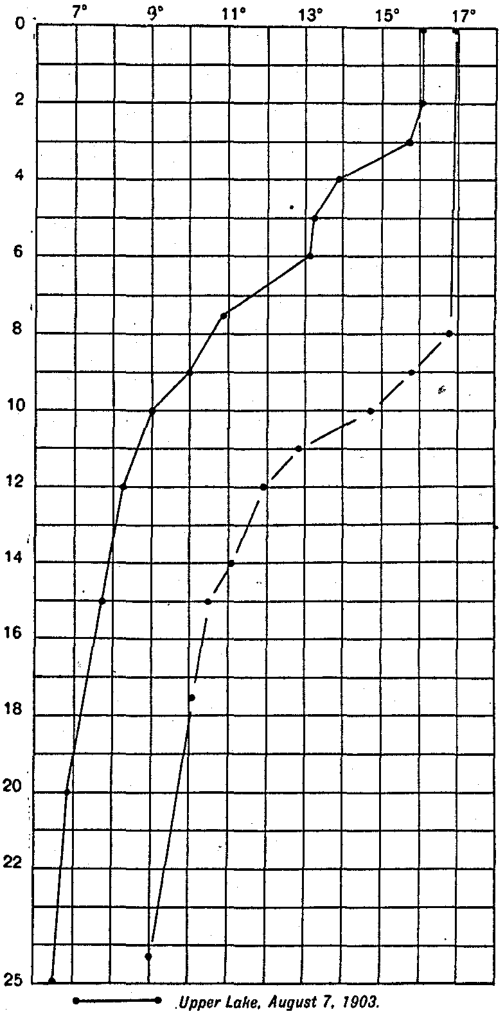

FIG. 5.

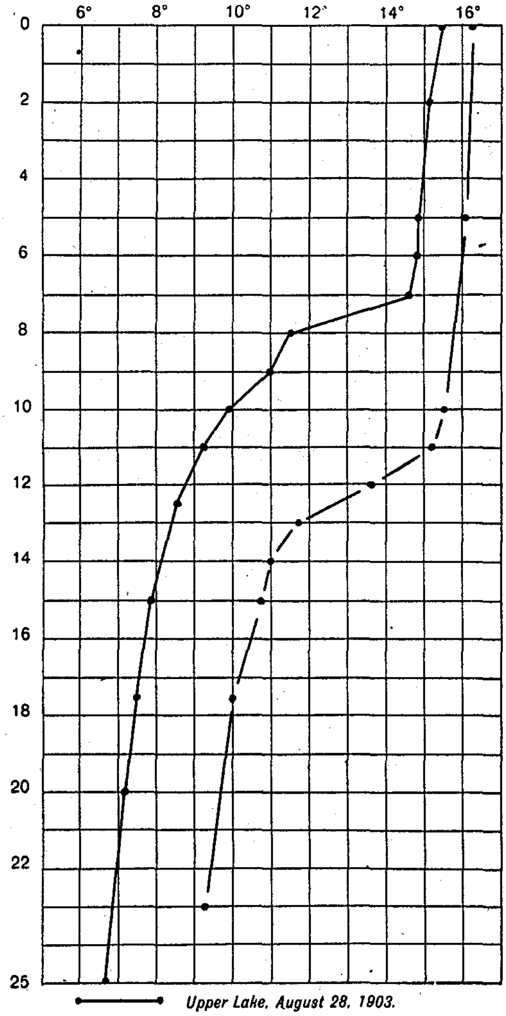

FIG. 6.

Figures 5 and 6 are comparisons of the temperature readings obtained for the two lakes on August 7 and 28, 1903. During these three weeks the thermocline moved down about 3 meters (10 feet) in each lake. Both summers the temperature of Lower Lake throughout its entire depth was somewhat higher than that of Upper Lake. This condition may be attributed to the following factors:

By far the greater part of the water which flows into Lower Lake during the summer comes from Upper Lake and thus has about the same temperature as the surface of the latter. The water flowing into Upper Lake, however, through all except one of its affluents was found to be 3° to 4° C. colder than the water above the thermocline. In 1903, for instance, the temperature of the water in Lake Creek, which is the chief affluent of Upper Lake, was 13.6° C. (56.5° F.) on August 7 and 11.2° C. (52.2° F.) on August 28. On these dates the surface temperatures of Upper Lake were, respectively, 16.1° C. (61° F.) and 15.4° C. (59.7° F.). On August 7 the temperature of the water in some of the other affluents was as follows: Willis Creek, 12.6° C. (54.7° F.); creek flowing into Elbert Bay, 25.5° C. (78° F.); creek on Royston Point, 12.5° C. (54.5° F.), and the water of a spring on Royston Point had a temperature of 6.4° C. (43.5° F.). Lower Lake is a little more than three times as large as Upper, and the wind is thus much more effective in disturbing the water of the superthermocline region. As one result this stratum of water was about two and a half times as thick in Lower Lake as in Upper. On August 7, 1903, for example, it was 3 meters (10 feet) thick in Upper and 8 meters (26 feet) thick in Lower Lake.

Likewise this greater disturbance of the water would affect the subthermocline by producing currents strong enough to affect the water throughout its entire depth. So large a portion of Lower Lake is comparatively shallow that its average depth is much less than that of Upper Lake. Thus, the sun is much more effective in warming the water of the former. In the shallower water the light that is not absorbed by the water itself is changed to heat when it reaches the bottom, and most of this heat will be absorbed by the water above, so that nearly all the sun's energy is used up in warming a tolerably thin stratum. Where the water is deeper the light will penetrate to a greater depth and the same amount of energy falling on an equal area will be distributed through a much larger quantity of water and will thus not raise its temperature so much.

The following table shows two sets of temperature observations on each lake:

Temperatures in Twin Lakes in summers of 1902 and 1903.

Depth.	UPPER LAKE.				LOWER LAKE.			
	August 4, 1902.		August 7, 1903.		August 21, 1902.		August 7, 1903.	
Meters.	° *C.*	° *F.*	° *C.*	° *F.*	° *C.*	° *F.*	° *C.*	° *F.*
0.0	16.6	62.0	16.1	61.0	17.1	62.8	17.0	62.7
3.0	....	....	15.7	60.2	....	....	....	....
4.0	....	....	13.9	57.0	....	....	....	....
5.0	16.6	62.0	13.8	56.0	16.3	61.4	16.9	62.5
6.0	....	....	13.2	55.7	....	....	....	....
7.5	....	....	10.8	51.5	....	....	....	....
8.0	15.3	59.5	....	....	16.0	60.8	16.8	62.3
9.0	13.5	56.4	10.0	50.0	....	....	15.8	60.5
10.0	11.5	52.8	9.0	48.3	15.9	60.5	14.7	58.5
11.0	....	....	....	....	....	....	12.8	55.0
12.0	10.0	50.0	8.3	47.0	15.0	59.0	11.9	53.5
13.0	10.0	50.0	....	....	....	....	....	....
14.0	8.3	47.0	....	....	13.5	56.8	11.1	52.0
15.0	7.8	46.0	7.7	45.8	12.5	54.5	10.5	51.0
18.0	....	....	....	....	11.9	53.4	10.1	50.2
20.0	6.8	44.3	6.8	44.3	10.7	51.3	....	....
22.0	....	....	....	....	10.1	50.2	....	....
25.0	6.5	43.7	6.5	43.7	....	....	9.0	48.2

AQUATIC VEGETATION.

Potamogeton was found to be more abundant than any of the other large forms of aquatic plants. It grew in considerable abundance at the west end of Upper Lake, along the north side of Lower Lake, from North Bay west, and also in the shallow water of the east end. In some places where the water was 10 feet (3 meters) deep it came almost to the surface. Three different species and one variety were found, *Potamogeton nuttallii*, *P. perfoliatus*, *P. perfoliatus richardsonii*, and *P. prælongus*. One or two species of *Carex* were found in the pools of the swampy meadow west of Upper Lake and in a very few places along the edges of the lakes. *Batrachium trichophyllum* also was found in the pools and in a few places in the lakes.

PLANKTON.

FORMS.

A comparatively small amount of phytoplankton was found in the lakes, and it consisted chiefly of diatoms, *Fragilaria*, *Asterionella*, and *Melosira*. A small portion of it consisted of some colonies of a green alga, apparently a species of *Protococcus*, and an occasional desmid, *Staurastrum*.

The following animal forms were found in the plankton of the two lakes:[a]

ROTIFERA.

Anurea cochlearis Gosse.
Anurea aculeata Ehrenberg.
Notholca longispina Kellicott.
Triarthra longiseta Ehrenberg.
Polyarthra sp.
Asplanchna sp.

COPEPODA.

Diaptomus judayi Marsh.
Cyclops pulchellus Koch.
Cyclops serrulatus Fischer.
Cyclops albidus Jurine.
Cyclops viridis americanus Marsh.

CLADOCERA.

Daphnia hyalina richardi Burckhardt.
Latona setifera O. F. Müller.
Drepanothrix dentata Eurén.
Eurycercus lamellatus O. F. Müller.
Camptocercus rectirostris biserratus Schoedler.
Alona affinis O. F. Müller.
Alona guttata Sars.
Graptoleberis testudinaria Fischer.
Pleuroxus procurvatus Birge.
Chydorus sphæricus O. F. Müller.

The following Cladocera were obtained from pools in the swampy meadow west of Upper lake:

Daphnia pulex De Geer.
Scapholeberis mucronata O. F. Müller.
Simocephalus vetulus O. F. Müller.
Ceriodaphnia pulchella Sars.
Eurycercus lamellatus O. F. Müller.
Camptocercus rectirostris biserratus Schoedler.
Pleuroxus procurvatus Birge.

Some plankton material was collected in a lakelet above the town of Twin Lakes on Mount Elbert. This small body of water has an altitude of about 10,000 feet (3,050 meters). The Cladocera were represented by *Daphnia pulex*, *Simocephalus vetulus*, *Pleuroxus procurvatus*, and *Chydorus sphæricus*.

Some material was obtained also from Willis Lake, which is situated near the head of Willis Gulch, a little southwest of Twin Lakes, and has an altitude of about 12,000 feet (3,660 meters). The water was found to be very cold, the banks of snow which were the source of supply being only a short distance away. *Gammarus* was plentiful, and the Cladocera were represented by two forms, *Macrothrix hirsuticornis* Norman & Brady and *Eurycercus lamellatus* O. F. Müller.

QUANTITY.

The plankton observations on the two lakes were few in number and consisted only of vertical hauls. In 1902 the observations on Upper Lake consisted of two series of catches in July and four in August. A single set of catches was made in Lower Lake in August. In 1903 three sets of catches were made on each lake. The observations

[a] I am indebted to Dr. C. Dwight Marsh for this list of Copepoda. The *Diaptomus* proved to be a new species and Dr. Marsh has recently described it.

were so few in number and covered such a brief period of time each year that they give only a fragmentary notion of the plankton life of the lakes. Likewise the vertical haul method is by no means a satisfactory one and both of these factors must be taken into consideration in the results given below. The following table shows the number of thousands of individuals per square meter of surface. With the exception of a few figures for the rotifers, these numbers are averages of either two or three hauls. The rotifers were not counted in all the catches, so that in a few instances the numbers given for them represent only the individuals of a single catch.

Quantity of plankton in Twin Lakes, as shown by series of vertical hauls during summers of 1902 and 1903.

[Average number of thousands of individuals per square meter.]

Species.	UPPER LAKE.									LOWER LAKE.			
	1902.						1903.			1902.	1903.		
	July—		August—				July—	August—		August—	July—	August—	
	14.	20.	4.	14.	18.	26.	14.	7.	28.	21.	16.	8.	28.
Anurea cochlearis	3.7	1.0	2.7	1.6	4.0	2.0	1.0	1.6	2.0	....	38.1	40.2	12.4
Anurea aculeata	7.5	18.0	14.0	.4	6.0	7.0	35.8	28.0	......	1.1	52.4	8.5	......
Notholca longispina	26.2	37.5	10.7	7.5	5.3	5.9	19.7	33.4	31.2	30.0	37.0	32.5	30.4
Triarthra longiseta	76.0	66.9	30.0	18.2	10.2	5.5	101.0	96.0	30.0	....	30.5	17.1	1.0
Polyarthra sp	......	......	......	......	......	......	8.5	8.0	8.8	....	9.0	24.0	2.7
Asplanchna sp	7.5	8.1	24.2	34.7	26.3	33.8	7.5	9.6	5.3	9.6	1.5	7.5	13.9
Diaptomus judayi	47.0	25.1	27.8	15.0	18.4	22.5	20.3	107.6	77.7	57.6	99.5	68.9	52.6
Cyclops	71.9	47.1	35.3	51.3	52.6	101.8	40.1	33.2	47.1	45.4	88.4	54.6	55.0
Nauplii	300.0	237.5	175.5	145.5	122.4	104.0	202.0	201.0	84.0	84.5	181.0	142.3	51.3
Daphnia hyalina, young and adult	157.9	130.5	58.2	48.3	25.0	30.4	27.8	96.3	64.2	28.2	151.0	68.0	64.6
Daphnia hyalina, adult	37.0	19.3	12.4	16.3	5.3	6.4	9.0	21.8	20.3	12.2	58.4	27.8	28.0

DISTRIBUTION.

With respect to vertical distribution, *Anurea cochlearis*, *Notholca longispina*, and *Asplanchna* were confined almost exclusively to the upper 10 meters. *Anurea aculeata* and *Triarthra longiseta* were found almost entirely below a depth of 10 meters, rarely occurring in the upper 10 meters. *Polyarthra* was rather evenly distributed throughout the entire depth of both lakes.

There was no diurnal movement of *Diaptomus*, *Cyclops*, and *Nauplii*. *Daphnia hyalina* showed a diurnal movement of half a meter in July and 1 meter in August.

The phytoplankton, as stated above, composed a comparatively small portion of the total plankton, and the few forms remained practically uniform in quantity during the two periods of these observations. The Crustacea made up by far the greatest bulk of the total plankton.

FISHES.

Catostomus commersonii Lacépède. Common Sucker; White Sucker.

This sucker is very abundant in the lakes. At times immense numbers were seen swimming at the surface with the dorsal fin and a part of the back projecting above the water. This habit was noted when the water was quiet, either early in the morning or in the evening. As food fish, the sucker does not stand very high in the estimation of local fishermen, consequently little attention is paid to it except as bait for trout. A few are caught in Lake Creek by means of grab hooks. Some of the trout feed rather extensively on young suckers.

Rhinichthys cataractæ dulcis Girard.

This minnow was found to be rather common in Lake Creek, both above and below the lakes, but only a few were noted in the lakes. Sometimes the fishermen use them for bait.

Salmo sebago Girard. Landlocked Salmon.

The landlocked salmon was introduced several years ago, but apparently has not multiplied very rapidly. Only a few are caught. The fish attains a rather large size, however, one that was caught weighing 6 and another 4½ pounds.

Salmo stomias Cope. Greenback Trout.

The greenback is one of the two indigenous species of trout. It is common in the lakes, apparently a little more abundant in Lower than in Upper lake. It does not attain a very large size, rarely exceeding a pound in weight. It is caught chiefly by trolling in shallow water.

Salmo macdonaldi Jordan & Evermann. Yellow-fin Trout.

The yellow-fin is the other indigenous trout—in fact, it has been found nowhere else as yet. Jordan (1891) has the following concerning its habits: "The Yellow-fin is largely on the gravels and about the north or sunny side of the lake. It is not often taken in deep water. It spawns in spring and the suckers devour the spawn in the streams and spawning beds." This trout appears to be very scarce now. No specimens of it were obtained.

Salmo irideus shasta Jordan. McCloud River Rainbow Trout.

This trout has steadily increased in numbers since its introduction, and is now the most abundant trout. It grows to a rather large size; one specimen was caught in 1903 which weighed 10 pounds. The larger ones are caught chiefly by trolling; the smaller ones are frequently obtained by fly-fishing in shallow water. Fairly large ones are often caught at the mouth of Lake Creek by bait-fishing from the shore.

Cristivomer namaycush Walbaum. Mackinaw Trout; Great Lakes Trout.

This trout has not increased very rapidly in numbers since its introduction into Twin Lakes, but it seems to find conditions favorable for its growth. During the first half of June, 1903, a number of specimens were caught which weighed from 15 to 20 pounds. Most of them were caught in the upper end of Lower Lake by still-fishing. The fishermen used large hooks baited with pieces of suckers.

Salvelinus fontinalis Mitchill. Brook Trout; Speckled Trout.

Brook trout are abundant in Lake Creek above the lakes, and many are caught in the lakes themselves. They are obtained chiefly by fly-fishing. In some cases, also, the fisherman baits his fly hook with grasshoppers or maggots.

IMPORTANCE OF STUDY OF FISH FOOD.

In considering the life conditions of a living organism, one of the most important factors to be taken into account is, naturally, the food. It is essential to know something about the quantity and kind of food required not only for existence, but also for the best and most complete development of the organism. In agriculture this question has received the attention of many investigators, and the results of their labors are apparent everywhere. To mention only two instances: We know that plants and soils have been studied to determine what plants are best adapted to the different kinds of soil; where certain food elements are lacking in a soil, fertilizers are added, or the soil is inoculated with bacteria which will produce the desired results. In stock feeding much has been done to determine the relative value and nutritive qualities of the various kinds of food generally employed, so that this industry may now be conducted along scientific lines. Comparatively little attention has been given to the food of our useful aquatic animals, however. The whole subject of aquiculture, in fact, has been very much neglected. Analyses have been made and we have been told that our regular food fishes are very nutritious and make an excellent food for us, but our knowledge as to what produces this nutritious food is entirely too limited. The whole question of the relation of quantity and quality of food to the rate of growth and physical well-being of fishes needs much more thorough investigation than it has yet received.

This neglect of aquiculture is certainly not due to its slight economic importance, or perhaps it would be better to say to small possibilities of its great economic importance. It has been estimated that a body of water of average fertility will produce five times as much as an equal area of average land. Sweeney (1898) calls attention to the fact that a small fish pond (60 by 120 feet) in Indiana produced 1,000 pounds of black bass and 250 pounds of yellow perch in fifteen months without being supplied with any artificial food. At the price of 8 cents per pound, he estimated that, if the natural waters of Indiana had been relatively only about a tenth as productive as this pond, the fish products would have been almost equal in value to the corn crop of the state in 1896, the year of this experiment, and a little more than twice the value of the wheat crop. Yet, in spite of the great possibilities of our natural waters from an economic standpoint, most of them receive little or no attention except annually or biennially when our legislators wrestle with the complex problem of devising laws for the protection of fish and aquatic birds. There is little doubt that, if more attention was given to investigations relative to increasing the producing efficiency of our natural waters, many of the stringent protective laws that now adorn our statute books would become superfluous.

Like other living organisms, fishes are affected by both the quantity and quality of the food available for them. The quantity of suitable fish food found in a stream or lake determines not only the number of fish that may be supported but also the physical condition of those that do survive. When food is scarce, a smaller number will be able to win in the struggle for existence, and those that do win will usually be poor and stunted in their growth. Fish epicures have persistently maintained that the flavor of a poorly fed fish is much inferior to that of one which has had an abundant supply of food. They also assert that the flavor is affected very much by the kind of food on which the fish feeds. It is stated, too, that the kind of food affects the growth of a fish very materially. Baird (1857) cites an experiment in which young trout, presumably the same number and of the same size, were placed in three separate tanks and were fed upon different kinds of food. The trout in one tank were supplied with worms; those in another were given live minnows; while those in the third were fed upon "water-flies." The trout which subsisted upon worms grew slowly and had a lean appearance; those which were supplied with live minnows became much larger; "whilst those which had flies alone given to them attained in a short time prodigious dimensions, weighing twice as much as both the others together." It is true, of course, that there is a very marked difference in the rate of growth of trout, even under apparently the same food conditions. Trout culturists, for instance, find it necessary to sort the young trout of a pond at regular intervals after they are a few months old, and separate the larger, precocious individuals from the smaller, weaker ones, in order to keep the former from preying upon the latter. But, in spite of this apparent contradictory evidence, there is little doubt that the great difference in the results obtained in the above experiment was due, in some measure at least, to the different kinds of food supplied.

As long ago as 1653 Walton appreciated the importance of the quality of the feeding ground, for he says: "And certainly, as some pastures breed larger sheep, so do some rivers, by reason of the ground over which they flow, breed larger trouts." Francis (1868) makes the assertion that "trout in one stream will be much larger, firmer, redder, and better shaped than in others. This may, in a measure, be owing to the greater abundance of food, but I have every reason to believe that it proceeds quite as much from the kind of food that they are enabled to obtain." Further on he says: "In lakes also it is a very common thing to find the trout in one lake large, bright, and well fed and in another, very similar in appearance and perhaps only a bare half mile distant from the other, they will be long, black, and lean, with heads out of all proportion to the thickness of the body. In another, probably but a similar distance from the first two, the trout will be abundant, but very small, though bright and well colored." To exemplify this he cites a group of small lakes in which he had fished and attributes the superior condition of the trout in the smallest lake of the group to the abundance and greater variety of the food found in it. Baird (1857) cites a similar difference between the trout of two streams, one of which is a tributary of the other, and he ascribes it to the great difference in the quantity and variety of the fish food which he found in the two waters.

Thus it is evident that a knowledge of both the quantity and kinds of food found in a stream or lake is of very great importance when it comes to the question of trout culture. This, doubtless, is true also of the culture of all other fishes, and this knowledge would be very valuable in the introduction of a species of fish into new waters. If we know the kind of food on which the fish thrives best and if we also know the quantity and kinds of food available in the water to be stocked, then the problem of stocking the water can be attacked in such a way as greatly to increase the chances of success. Until such knowledge is acquired we must continue to experiment more or less blindly.

FOOD OF THE TROUTS.

Walton tells us that the trout "lies at watch for any fly or minnow that comes near him; and he especially loves the May-fly." In the two and a half centuries since Walton wrote, relatively little has been added to his observations on the feeding habits of most of the trouts, though several writers, especially writers on trout-culture, have commented in a general way upon the great variety of trout food. There is very little definite information as to the quantities and proportions of the various component elements, however. From general statements we learn that the food includes various kinds of worms, all kinds of insects (both adults and larvæ), mollusks of one sort or another, crustaceans, small fish, fish eggs—in fact, almost anything that is digestible, as well as many things that are not digestible. Trout are regarded as carnivorous from choice, but omnivorous in cases of necessity.

EXAMINATIONS OF TROUT STOMACHS.

During the investigation at Twin Lakes the stomachs of 394 trout were obtained and the contents studied. Twenty-six specimens were fry that were too small to be positively identified, and the other 368 belonged to six different species. The specimens were obtained during July and August, 1902, and between the middle of June and the 10th of September, 1903. They were caught by various methods, such as by trolling with a spoon-hook or baited hook, by fly-casting, with a seine, in gill-nets, and on trout-lines or set-lines. The fry, of course, were taken with a dip net. They were caught at various hours of the day, and under as favorable conditions as possible, so that the results might represent the natural food of the specimens.

Only a very general classification of the different elements of the stomach contents was attempted. They are recorded under twenty-two different heads. *Chironomus* and *Simulium* were noted separately from the other Diptera, because they were represented chiefly by their aquatic larvæ. The term "insect fragments" includes all fragments of insects that were too small to be identified. The other terms are self-explanatory.

In recording the contents of a stomach an estimate was first made as to the relative amount of food it contained; that is, whether it was well filled, half, or a quarter full, or contained only a little. Then the various constituents were sorted out, and the percentage of each in the entire quantity was carefully estimated. In the first six of the following tables the first column shows the number of specimens in which the respective elements appeared, and the second column shows the average per cent of each element in all the specimens that contained it. An explanation of the last table is given below.

Landlocked salmon (*Salmo sebago*).—Twenty-four specimens of landlocked salmon were examined. Twenty-three were obtained from Lower Lake and one from the pool just below the gates, or dam, in the outlet canal. The length of the specimens varied from 8 to 23.5 inches (20 to 70 centimeters). Two stomachs were entirely empty, another contained only a grain of oats, while two others contained only a few grains of coarse sand. Thus nineteen are accounted for in the following table:

Contents of stomachs of 19 landlocked salmon.

Food elements.	Number of specimens in which found.	Average per cent of element.	Food elements.	Number of specimens in which found.	Average per cent of element.
Fish remains	7	100.0	Hymenoptera (ants)	1	20.0
Trichoptera (larvæ and pupæ)	2	95.0	Insect fragments	1	20.0
Lepidoptera	1	40.0	Crustacea (Gammarus)	1	5.0
Diptera	2	52.5	Mollusca	1	1.0
Chironomus (larvæ and pupæ)	1	2.0	Vegetable débris	4	62.0
Simulium (larvæ)	1	100.0	Sand and gravel	6	61.0
Coleoptera	4	73.0			

The specimen containing *Simulium* larvæ was the one caught in the pool below the dam. The intestines of several specimens contained a great deal of sand and mud and the shell of a small bivalve mollusk was found in one.

Greenback trout (*Salmo stomias*).—The stomachs of 72 greenback trout were examined. Eight of them were empty, leaving 64 to be accounted for in the table. Of this number, 18 were obtained from Upper Lake, 1 from Lower Lake, and 53 from the pool below the dam.

Contents of stomachs of 64 greenback trout.

Food elements.	Number of specimens in which found.	Average per cent of element.	Food elements.	Number of specimens in which found.	Average per cent of element.
Fish remains	4	70.0	Chironomus (larvæ and pupæ)	10	17.75
Orthoptera	7	59.7	Coleoptera	25	42.7
Hemiptera	2	6.0	Hymenoptera (ants)	5	19.4
Trichoptera	1	10.0	Insect fragments	29	51.7
Lepidoptera (moths)	14	42.0	Crustacea (Entomostraca)	14	77.0
Diptera	29	30.8	Vegetable débris	7	38.4

Specimens from all three localities contained *Daphnia*. One stomach contained 4,500 *Daphnia* and another 2,250. Two of the specimens had eaten both copepods and *Daphnia*, but the other 12 of the 14 that had eaten Entomostraca contained *Daphnia* only.

The vegetable débris consisted chiefly of *Potamogeton* leaves.

A feather was found in one stomach and a few pieces of twine in another.

Jordan (1891) says, concerning the food of this species: "At the hatchery of Dr. Laws, it appears that this trout will not willingly eat young suckers and minnows, its food being largely young crustacea." It will be noted in the above table that only 4 stomachs out of 64 contained remains of fishes.

Rainbow trout (*Salmo irideus shasta*).—The stomachs of 114 rainbow trout were examined. Out of this number 8 were empty, 36 were estimated to be a third full or more, and the other 70 a quarter full or less. The specimens varied in length from 6 to 18 inches (15 to 45 centimeters). Twenty-two of them were caught in Upper Lake, 24 in Lower, and 68 in the pool below the dam in the outlet canal.

Contents of stomachs of 106 rainbow trout.

Food elements.	Number of specimens in which found.	Average per cent of element.	Food elements.	Number of specimens in which found.	Average per cent of element.
Mammal remains	1	42.0	Chironomus (larvæ and pupæ)	12	10.3
Fish remains	42	67.3	Simulium (larvæ)	3	68.3
Araneida (spiders)	1	10.0	Coleoptera	37	22.2
Odonata	2	2.5	Hymenoptera	21	5.6
Orthoptera	3	4.3	Insect fragments	61	55.1
Hemiptera	11	2.6	Crustacea	16	37.3
Trichoptera	3	4.7	Mollusca	1	40.0
Lepidoptera (moths)	27	13.6	Vegetable débris	26	35.6
Diptera	35	8.9	Sand and gravel	19	41.8

About a fourth of the fish remains were positively identified as remains of young suckers (*C. commersonii*) but the rest were not recognizable. These results do not agree with the observations of Chambers (1887), who states that the rainbow trout introduced into England "is more delicate in its appetite than other varieties of Salmonidæ, and therefore is not prone to the same temptations to cannibalistic attacks upon its congeners." In the present case, out of a total of 106 specimens containing food, 42 had partaken of fish; and while all the remains that could be identified were found to be suckers, it does not seem at all unlikely that the rainbow occasionally preys upon young trout too, since small fish constitute such an important element of its food.

Of the 16 specimens that contained Crustacea, one had eaten *Gammarus*, one copepods, another Diaptomi and *Daphnia*, while the other 13 had partaken of *Daphnia* only. One stomach contained 1,350 *Daphnia*.

The vegetable débris consisted of spruce leaves, pieces of wood, *Potamogeton* leaves, and algæ. One stomach contained a piece of cotton twine and another a feather. Much of the vegetable débris was probably taken by accident, but some had apparently been eaten on purpose. Much of the sand was probably derived from the cases of trichopter larvæ.

Mackinaw trout (*Cristivomer namaycush*).—Two Mackinaw trout were obtained. One was 30 inches (76 centimeters) long, and its stomach contained a trout 7 inches (17.5 centimeters) long and a few insect fragments; the other specimen was 33 inches (84 centimeters) long, but its stomach was empty. Mr. Willis examined the stomachs of several large specimens caught in 1903 and found that they contained almost nothing but young suckers.

Milner (1874) states that in the Great Lakes this trout feeds principally on the cisco (*Argyrosomus hoyi*). "It is not an unusual thing for a trout to swallow a fish too large for its stomach and the tail protrudes from his mouth until the forward part is digested." He also says that it eats refuse from the tables of passing steamers; such articles as peeled potatoes, pieces of liver, green corncobs, and fragments of ham bones having been found in stomachs. Goode (1884) says that Mackinaw trout are as omnivorous as cod.

Small brook trout (*Salvelinus fontinalis*).—Twenty-nine specimens of small brook trout from 1 to 2 inches (2.5 to 5 centimeters) long were obtained in July and August, 1902. They were caught in Lake Creek, above and between the lakes, and in Upper Lake. The stomachs of all of them contained food, and most of them were estimated to be from a third to two-thirds full.

Contents of stomachs of 29 small brook trout.

Food elements.	Number of specimens in which found.	Average per cent of element.	Food elements.	Number of specimens in which found.	Average per cent of element.
Ephemerida	11	59.0	Chironomus (larvæ and pupæ)	11	20.3
Plecoptera	1	25.0	Simulium (larvæ)	4	46.2
Orthoptera	2	22.5	Coleoptera	1	5.0
Lepidoptera (moths)	1	20.0	Insect fragments	22	63.6
Diptera	10	33.7	Vegetable débris	1	10.0

Large brook trout (*Salvelinus fontinalis*).—The specimens of larger brook trout numbered 127 and varied in length from 4 to 13 inches (10 to 33 centimeters). Of this number, 117 were caught in Lake Creek above Upper Lake, 7 in Upper and 3 in Lower Lake. Only one stomach was empty; 79 were estimated to be a third full or more and the remainder a quarter full or less.

Contents of stomachs of 126 large brook trout.

Food elements.	Number of specimens in which found.	Average per cent of element.	Food elements.	Number of specimens in which found.	Average per cent of element.
Fish remains	2	92.5	Diptera	18	14.0
Araneida	8	12.4	Chironomus (larvæ and pupæ)	42	11.0
Hydrachnidæ (water mites)	13	4.4	Coleoptera	43	15.7
Ephemerida	2	34.0	Hymenoptera	35	32.8
Orthoptera	10	47.0	Insect fragments	85	44.8
Hemiptera	8	13.6	Crustacea (Entomostraca)	2	4.5
Neuroptera	2	10.0	Vegetable débris	71	64.0
Trichoptera	4	22.5	Sand and gravel	20	15.5
Lepidoptera (moths)	9	16.4			

The fish remains consisted of young suckers. All of the specimens that had eaten Araneida and Hydrachnidæ came from Lake Creek. About one-fourth of the Hemiptera were *Corixa*, and about one-half the Hymenoptera were ants.

One of the two specimens containing Entomostraca was taken in Upper Lake and had eaten only *Daphnia*, while the other was caught in Lower Lake and had eaten both *Daphnia* and *Cyclops*.

Nearly all the vegetable material found was in the stomachs of specimens that were caught with a seine in Lake Creek, just a short distance above Upper Lake. It consisted, for the most part, of pieces of the small roots of the willows growing along the creek, and was probably taken by accident.

Needham (1901) states that *Chironomus*, *Corethra*, and Trichoptera were the most important food elements found in the brook trout he examined. In this case, however, the four chief elements of animal food, named in the order of their importance, were Hymenoptera, Coleoptera, Orthoptera, and *Chironomus*.

Fry.—Twenty-six specimens of fry were obtained from Lake Creek in August, 1902. They were too small to be positively identified, varying in length from ⅞ to 1¼ inches (2.2 to 3 centimeters). The stomachs of all except one contained food, but it was found to be in such condition that very little of it could be recognized.

Contents of stomachs of 26 fry.

Food elements.	Number of specimens in which found.	Average per cent of element.	Food elements.	Number of specimens in which found.	Average per cent of element.
Ephemerida (nymphs)	1	50	Diptera	5	72
Orthoptera	1	60	Chironomus (larvæ and pupæ)	5	22
Lepidoptera (moths)	2	40	Insect fragments	23	80

SUMMARY AND DISCUSSION OF RESULTS.

The following table shows the average per cent of the different elements composing the stomach contents of all the trout examined. The percentages given for each species were obtained by dividing the sum of the per cents of the different food elements by the number of stomachs containing food.

	Land-locked salmon.	Green-back trout.	Rainbow trout.	Small brook trout.	Large brook trout.	Fry.
Mammal remains			0.04			
Fish remains	36.84	4.40	26.55		1.48	
Araneida (spiders)			.10		.80	
Hydrachnidæ (water-mites)					.46	
Ephemerida				22.61	.54	2.00
Odonata			.50			
Plecoptera				.86		
Orthoptera		6.55	.12	1.55	3.80	2.40
Hemiptera		.20	.27		.87	
Neuroptera					.16	
Trichoptera	10.00	.16	.13		.72	
Lepidoptera	2.11	9.20	3.46	.69	1.18	3.20
Diptera	5.53	13.95	2.93	11.60	2.00	14.40
Chironomus (larvæ, pupæ)	.11	2.80	1.17	7.60	3.75	4.40
Simulium (larvæ)	5.26		1.93	6.48		
Coleoptera	15.31	16.68	7.75	.17	5.40	
Hymenoptera	1.06	1.52	1.18		9.15	
Insect fragments	1.51	23.44	31.70	48.10	31.10	73.60
Crustacea	.27	16.90	5.62		.07	
Mollusca	.06		.38			
Vegetable débris	13.05	4.20	8.70	.34	36.05	
Sand and gravel	8.83		7.47		2.47	

Twenty-two items appear in the above table, and all except one (sand and gravel) may be regarded as sources of nourishment. While much of the vegetable matter had no food value and was probably taken largely by accident, still, in a considerable number of cases, it was digestible material which would afford nourishment, and was present in such quantities as to indicate that it had been eaten purposely.

The table shows that there was considerable difference in the diet of the different species. The landlocked salmon (*Salmo sebago*) had partaken of 12 out of the 21 items of food; the greenback trout (*S. stomias*) 12; the rainbow trout (*S. irideus shasta*) 17; small brook trout (*Salvelinus fontinalis*) 10; and large brook trout 16. Thus the rainbow had the greatest variety in its diet.

The mammal remains consisted chiefly of the bones of a small mammal, apparently a mouse, eaten by a rainbow trout.

These four species of trout differed very widely in the relative amount of fish consumed. The landlocked salmon had partaken most freely, fish remains constituting an average of more than 1-third of the stomach contents; the rainbow trout ranked second in this respect; while the brook trout had eaten most sparingly of this kind of food. It is interesting to note in this connection, however, that all the fish remains that could be identified were found to be young suckers.

The last table shows how important insects are in the food of these trout during the summer. On an average, they constituted 40.9 per cent of all the material found in the stomachs of landlocked salmon; 74.5 per cent in greenback trout; 50.1 in rainbow trout; 99.6 in the small brook trout; and 58.6 in the large brook trout. The fry that were examined were entirely dependent on insects for their food. With the exception of the small brook trout and the fry, the insect material found in the specimens consisted chiefly of such forms as fell into the water accidentally. In view of this fact, and also in view of the dietetic importance of these insects, a study of the food of these trout during the long winter period when the lakes are covered with ice would be very interesting, as well as necessary to a good understanding of their food habits. The winter period is, undoubtedly, the most critical for them so far as food is concerned. That food was sufficiently abundant during the summer was shown by the good physichal condition of the trout, and by the quantity of fat that was found in most of them.

The rainbow and the large brook trout had the greatest variety of insect diet. Each had partaken of 10 of the 13 items listed, while the greenback trout had partaken of 8 and the landlocked salmon 7. Not more than three or four forms of insects, however, played an important rôle in the food supply of any species of trout. Named in the order of their importance, Coleoptera, Trichoptera, Diptera, and *Simulium* constituted by far the greater bulk of the recognizable insect food of the landlocked salmon, the four together making up an average of 36.1 per cent of the stomach contents in all the specimens. Coleoptera, Diptera, Lepidoptera, and Orthoptera were the important insect elements in the food of the greenback trout, and together constituted 46.3 per cent of the stomach contents. The rainbow trout had eaten most freely of Coleoptera, Lepidoptera, and Diptera, but these three made up only 14.1 per cent of the stomach contents.

A comparison of the results obtained for the small and the large brook trout shows that they differed greatly in their insect food. The small ones fed freely on May-fly nymphs and on the larvæ and pupæ of *Chironomus* and *Simulium*. Adult Diptera ranked second in importance, however, being exceeded only by the May-fly nymphs. These four groups together made up a little over 48 per cent of the food of these specimens. Hymenoptera, Coleoptera, Orthoptera, and *Chironomus* formed the most important part of the insect food of the large brook trout, and together constituted 22.1 per cent of the stomach contents.

Diptera, *Chironomus*, and Lepidoptera were the most important elements of the food of the trout fry. The Ephemerida were represented almost entirely by nymphs, and the Trichoptera by larvæ. The Lepidoptera consisted almost entirely of moths, and by far the greater part of the Hymenoptera were ants. The high percentages of Coleoptera were undoubtedly due, in a great measure, to the resistance of the chitinous elytra and other coverings to the process of digestion.

Examination of some trout from streams in the region of Mount Whitney, California, revealed the fact that in those waters also only a few forms of insects were an important part of the trout food. In 12 specimens obtained from the South Fork of the Kaweah River, the three most important elements of the food, which consisted entirely of insects, were chironomid larvæ and pupæ 15 per cent, Coleoptera 15, and trichopter larvæ 11.2. In 6 trout from Soda Creek, the most important elements were as follows: Trichopter larvæ, 30.8 per cent; Plecoptera, adults and nymphs, 9.2; and Orthoptera, Coleoptera, and Hymenoptera each 4.1 per cent. In 41 specimens from Little Kern River, Coleoptera and Hymenoptera were each 15 per cent of the food. The following percentages of insect food were obtained for 18 specimens of the golden trout (*Salmo roosevelti*) from Volcano Creek: Plecoptera (adults and nymphs), 12.2; Trichoptera (adults and larvæ), 7.2; ephemerid nymphs, 7.

Thirty-three specimens of Twin Lakes trout in all had eaten Crustacea. Of this number, 26 had eaten only *Daphnia*, 1 had eaten only copepods, 4 had eaten both *Daphnia* and copepods, and 2 had eaten only *Gammarus*. The insignificance of *Gammarus* as an element of food was rather surprising, as it was abundant in both lakes.

The vegetable matter that was found in the various stomachs consisted of such things as small pieces of wood, spruce leaves, seeds and seedpods of land plants, roots, *Potamogeton* leaves, and algæ. It seems probable that most of the sand and gravel was taken by accident. Much of it was, no doubt, derived from the cases of some of the trichopter larvæ. Judging from the difference in the percentages of sand and gravel, it seems that the landlocked salmon and the rainbow trout feed on the bottom much more extensively than either the greenback or the brook trout.

PLANKTON CRUSTACEA AS FISH FOOD.

It is frequently stated that the Entomostraca are very important factors in the food of many fishes, but we have very little definite information as to the kinds, the relative proportions, or the numbers of these small crustaceans eaten by the different fishes. It is known, of course, that plankton crustacea are an important element of the food of some fishes, such as the whitefish and herring, but here, even, we know little of the relative importance of the different Entomostraca. There is likewise great need of extending our knowledge as to the importance of these minute crustaceans in the diet of fishes that are not regarded as plankton feeders; and in spite of the emphasis that has been laid on the fact that they are of supreme importance to fish fry, here, too, definite information is by no means as extensive as it should be. A brief summary of some of the results obtained by several observers is given below.

Knox (1834) observed that the vendace (*Coregonus*) fed exclusively on microscopic animals of the class Entomostraca. Baird (1857) mentions the fact that "delicate little crustaceans" were found in the stomachs of Loch Leven trout (*Salmo fario levenensis*), of the charr *Salmo salvelinus*, and of the vendace (*Coregonus willughbii*). The crustaceans mentioned in this connection are *Daphnia*, *Bosmina coregoni*, and *Cypris*.

Jardine (1857) states that stomachs of the vendace (*Coregonus*) were found filled with Entomostraca. In speaking of the food of the trout in Loch Leven, Francis (1868) says that large quantities of Entomostraca were often found in their stomachs. Smith (1874) found *Daphnia* in the stomachs of six specimens of *Coregonus albus*. Barfurth (1874) found microscopic Entomostraca in the stomachs of *Alosa vulgaris*.

Between 1878 and 1888 Forbes made a careful study of the food of many Illinois fishes. He examined young belonging to 12 families and 26 genera, and found that the representatives of only one genus had not been feeding more or less extensively on Entomostraca. In examining both young and adults, he found that specimens belonging to more than 50 genera, representing 16 families, partook of Entomostraca during some period of their lives. He also states (1893) that two specimens of young trout taken at the mouth of Bridge Creek, Wyoming, had been feeding on *Polyphemus pediculus* and *Daphnia pulex*.

Ryder (1881) says that the food of young shad consists almost entirely of very small crustaceans, in reality for the most part Daphnidæ and Lynceidæ. In speaking of the adult shad, he states that he found a large quantity of a copepod, apparently a *Cyclops*, in the stomach of a spawning female. He says that there were probably a hundred thousand of these copepods in the stomach.

Brook (1887) found that very young cod and saith fed almost entirely on copepods. Brook and Calderwood (1886) state that copepods supply the principal food of the herring during the summer months, and ostracods were found occasionally.

Frič and Vávra (1894 and 1901) found plankton Crustacea in the stomachs of several species of fresh-water fishes.

Herdman (1894) states that by far the most important constituent of the food of young plaice (*Pleuronectes platessa*) seems to be the Harpacticidæ, especially the species *Jonesiella hyænæ*. Records for nearly 900 specimens show that sizes of about an inch (2.5 centimeters) in length live mainly on Copepoda. He also found that copepods form a part of the food of specimens 3 inches (7.5 centimeters) or more in length. Herdman and A. Scott (1895) state that after the larval marine fishes which they studied have absorbed the food supply stored up in the yolk-sac they pass to the stage in which copepods form their chief food. In his investigations on Lake St. Clair, Reighard (1894) found that Daphnidæ and Copepoda were eaten by various fish larvæ and the lake herring. Peck (1894 and 1896) found ostracods in the stomachs of menhaden and copepods in the stomach of a scup. In speaking of his investigations on the Great Lakes, Ward (1896) says that the smaller forms of crustaceans are eaten by the fish fry directly, and are sometimes the immediate food of the larger fishes.

Walter (1895–1899) obtained some interesting results in this respect in his studies of the food of fishes. I have not seen his own statements concerning these results, but Steuer (1901) says the following of them: "Nach den Untersuchungen E. Walter's können wir den Satz aufstellen, dass ganz allgemein die Menge des vorhandenen thierischen Planktons direkt proportional ist der Menge der in dem Teiche überhaupt vorhandenen Fischnahrung. Die Gesammtproduction an thierischen Plankton steht somit in geradem Verhältniss zum Zuwachs der Fische, d. h. je mehr Plankton, desto grösser der Zuwachs, je weniger Plankton, desto geringer der Zuwachs."

In describing an observation made on Lake Mendota, Wisconsin, Birge (1897) says that "The surface water was crowded with *Daphnia*, and an immense number of perch were feeding on them."

Scourfield (1898) states that three specimens of the three-spined stickleback (*Gasterosteus aculeatus*) and three roach (*Leuciscus rutilus*) which he examined had been feeding extensively on several forms of Entomostraca. Huitfeldt-Kaas (1898) found 50,000 *Bosmina* in the stomach of a *Coregonus lavaretus*. He says that *Bythoreptes longimanus* was the usual species found in the stomachs of trout and *Coregonus*, and next came *Bosmina obtusirostris* and *Daphnia galeata*.

Nordgaard (1900) says that *Calanus finmarchicus* constitutes the main part of the food of the herring along the coast of Norway, and also (1905) that the ostracod *Cypridina norvegica* was found to constitute part of the food of the cod (*Gadus callarias*).

T. Scott (1901) notes that the smaller crustaceans (schizopods, amphipods, and copepods) form a very important part of the food of the young marine fishes which he studied. Steuer (1901) found that 39 specimens of fresh-water fishes, varying in length from 5.5 to 13.5 centimeters and belonging to five different species, had partaken more or less freely of plankton crustacea. He found that a specimen of *Scardinius erythrophthalmus* 7 centimeters long had eaten 2,000 to 3,000 *Chydorus sphæricus*, and a slightly larger *Carassius* (Karausche) about 5,000 *Acroperus harpæ*. Needham (1903) notes the presence of *Daphnia* in the stomachs of two brook trout out of 25 which he examined. Kofoid (1903) found that the annual production of plankton and the output of the fisheries of the Illinois River show some correlation in their changes from year to year.

Considered with respect to whether plankton crustacea form any part of their food supply at any stage of their existence, trout readily fall into two groups, resulting from differences in habitat. The one group includes the trout that live in mountain streams. They can not depend upon these minute crustaceans for a supply of food because the waters of these streams are generally too wild and rapid for the development of plankton life. Occasionally, of course, there may be favored localities where pools are quiet enough for the growth of such organisms, but these are rare. The fry of trout which regularly inhabit lakes, but which ascend streams to spawn, must depend upon some other source of food while they are in the streams. This was well illustrated by the fry obtained in Lake Creek, whose food consisted entirely of insects. The other group is composed of trout that inhabit lakes. Here the conditions are favorable for the development of plankton organisms, and the trout may draw upon the plankton crustacea for food. That these crustaceans may form an element of the food of some trout for a considerable period of time is shown by the fact that they were found in stomachs of specimens that had reached a length of 12 to 15 inches (30.5 to 38 centimeters). It seems a little strange that trout of this size should be able to obtain such large numbers of these small crustaceans with an apparatus apparently so very poorly adapted to procuring such minute organisms.

The investigations relating to the food of marine fishes show that copepods are by far the most important element of the entomostracan part of their food, the Cladocera being negligible. Almost the reverse of this, however, was found to be true of the trout of Twin Lakes. Out of 31 specimens that had eaten Entomostraca, 26 had eaten only Cladocera (*Daphnia*), 1 only copepods, and 4 both *Daphnia* and copepods. In the four instances in which both had been eaten, the *Daphnia* constituted thirteen times as much of the stomach contents, on an average, as the copepods. Huitfeldt-Kaas (1898) says concerning his results, "Im Ganzen genommen die Daphnien viel häufiger in dem Fischemagen anzutreffen als die Copepoden." He thinks the explanation of this lies in the fact that the Daphnidæ, with their slow, regular movements, are more easily obtained than the copepods with their irregular, jumping movements. Steuer (1901), however, thinks that the predominance of Cladocera is due chiefly to their greater size, and secondly to their greater abundance. It is true, of course, that the copepods found in Twin Lakes are more powerful swimmers than the *Daphnia*, and are more irregular in their movements, so that it would be more difficult for the trout to capture them. It is also true that *Daphnia* are slightly larger than the copepods, and for this reason could be more easily obtained, while, also, the latter, being long and slender, would be more likely to pass through the straining apparatus of the trout. The differences in size and shape would be particularly effective in permitting the copepods to escape from the larger trout, which have a rather coarse straining apparatus.

With respect to size, however, it may be said that the only Entomostraca represented in the food of some specimens of *Salmo henshawi* from Lake Tahoe were two species of *Daphnia*, while the large copepod *Epischura nevadensis* was found to be more abundant in the lake at the time than *Daphnia*. So far as size is concerned, therefore, it would seem that this copepod could be obtained by the trout as easily as the *Daphnia*. As to the point that the Cladocera are more abundant, it is only necessary to say that adult copepods were nearly as abundant in Twin Lakes in 1902 as *Daphnia*, and were more abundant in 1903. Also, at the time of the above observation on Lake Tahoe in 1904, the copepods were much more abundant than *Daphnia*.

There is some doubt, however, as to whether the very great predominance of *Daphnia* over copepods in these instances is fully accounted for by the three factors that have been considered—namely, differences in movement, size, and shape. But no other factors were apparent. It was thought, at first, that possibly small swarms of *Daphnia* might contribute to the explanation, but no evidence whatever of any unusual aggregations of these was found. A single catch of trout will serve to show, still further, the striking difference in the rôle played by these two forms of Crustacea as sources of food. Ten rainbow trout whose stomachs contained Entomostraca were caught in the pool below the dam in the outlet canal of Twin Lakes within an hour one afternoon. Of this number 9 had eaten only *Daphnia*, while the tenth had eaten both copepods and *Daphnia*. The specimens were all about the same in size—6 to 8 inches (15 to 20 cm.)—so that their straining apparatus should have been equally effective. Since one trout was able to secure copepods, and it was one of the larger specimens, it hardly seems probable that the other nine were unable to secure them also, either on account of the irregular movements, the small size, the slender form, or the scarcity of the copepods, as these were more abundant than *Daphnia* in the water that was flowing into the pool.

From what has already been said, it will be seen that many species of fish are important factors in the destruction of plankton crustacea. Hence, this fact must be taken into account in a quantitive consideration of this element of the plankton of a body of water inhabited by these fishes. Immense numbers of minute crustaceans are destroyed by the trout in Twin Lakes. One greenback trout 12 inches (30 centimeters) long had eaten 4,500 *Daphnia;* another 14 inches (35 centimeters), 2,250, and the stomach of a rainbow trout 15 inches (38 centimeters) long contained 1,300. Over 16 per cent of the greenback and rainbow trouts whose stomachs contained food, had eaten *Daphnia*, the number eaten by each individual varying from about 50 or 75 up to 4,500. When it is considered that these figures represent the number consumed by each trout at a single meal, and also that the lakes were well populated with these two species of trout, we can see how enormously they affect the numbers of Daphnias. In this connection it is interesting to note also that the stomach of a 15-inch Tahoe trout (*Salmo henshawi*) which was examined during the summer of 1904 contained 1,700 Daphnias, about two-thirds of which were *D. hyalina* and one-third *D. pulex*. The above numbers, moreover, do not represent the entire drain upon these small crustaceans. The great majority of the adult females had either eggs or developing embryos in their brood chambers. Whether the eggs are destroyed during their passage through the alimentary canal or not is still an open question. Frič and Vávra (1894) found that summer eggs sometimes pass through the canal undigested, but they did not determine whether these eggs had lost their vital power. Steuer (1901), however, raised a *Ceriodaphnia* from an ephippium which was taken from the intestine of a fish. But, even if the majority of the eggs escaped digestion and developed afterwards, it hardly seems probable that the embryos escaped also, and they alone represented a very large additional loss.

Steuer (1901) calls attention to the likelihood of overestimating the value of Entomostraca as a direct source of food for fishes. He thinks that, in very many cases, they enter the digestive tract of the fish only indirectly; that is, after being eaten by some animal which is in turn eaten by the fish. There was no room for doubt as to their being eaten directly by the trout in these cases. In a number of instances there was nothing else in the stomachs; and in stomachs which contained additional food the additional food in most instances consisted of insects that had accidentally fallen into the water, and these of course had not been feeding on Entomostraca.

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