

1943

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Recommended Citation

Eddy, S. (1943). Limnological Notes on Lake Superior. *Journal of the Minnesota Academy of Science, Vol. 11 No.1*, 34-39.

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come cushion-shaped. There is no white fringe of white hairy hyphae at the margin, though there is a tendency for young hyphae of small size to fringe the edges.

The stromata form under the cork layer and cause swellings of this tissue to the point where it eventually breaks and thus permits eruption of the stromata. The hyphae then grow into the characteristic fruit bodies, frequently somewhat stiped at base. This species is easily recognized by the characteristic moniliform paraphyses in the hymenium. A hand lens is sufficient to reveal these diagnostic necklace-like hyphae. Sometimes they give the appearance of conidiophores budding off their conidia. They may extend above the hymenial surface as far as the protruding basidia.

A. amorphus has been described as growing on spruce and even on the Western Giant Arborvitae, *Thuja plicata*, though the writer has never seen it on any species other than Balsam Fir.

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LIMNOLOGICAL NOTES ON LAKE SUPERIOR

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Although Lake Superior is the largest freshwater lake in the world, very few limnological studies have been made of this important body of water. Brief surveys by Agassiz (1850) and Smith (1871) have yielded scanty information about the fauna. Some studies on fishes have been made by various workers, such as Koelz (1929) and Greene (1935).

In 1930 a study of the plankton of Lake Superior was undertaken in cooperation with the Minnesota State Board of Health and the Duluth Water Department. The investigation was enlarged in 1933 and 1934 with the aid of grants from the Graduate School of the University of Minnesota to include the bottom fauna and the general limnological features of the waters off the Minnesota North Shore. In 1935 the data were assembled, and it seemed desirable to secure more data particularly from the deeper water before making a complete report. However, other work intervened, and further investigations were postponed indefinitely. As it is uncertain as to when further studies can be resumed, and as so little is known about the limnological conditions of Lake Superior, a preliminary report may be of some value.

Lake Superior has an area of 31,000 square miles, and a mean depth of 475 feet. Depths as great as 1,040 feet have been reported, but the greatest depth found in the north shore area was about 900 feet about seven miles off Grand Portage. Depths of 800 feet were found about four miles off Beaver Bay. Farther out the lake became more shallow.

The studies made in 1930 to 1933 were confined to plankton. In 1933 and 1934 studies on conditions of the lake, and on the bottom fauna and fishes were made during the summer months. This work was carried on largely off Grand Portage and Beaver Bay.

Most of the Minnesota shore of Lake Superior is rocky and in many places is very precipitous. Bays and sand beaches are very rare. The only really enclosed bay (except St. Louis Bay) is that of Grand Portage near the Canadian border. In the vicinity of Grand Marais and Grand Portage beaches of coarse gravel or small boulders are common. Small sandbars sometimes occur at the mouths of the small rivers. Elsewhere the Minnesota shore is rocky. Frequently the bottom drops steeply from the shore often to a depth of several hundred feet when only the same distance offshore. Usually these steep bottoms consisted of rock and boulders down to a depth of 300 feet or more. Below this depth and down to the deepest bottoms studied, the bottoms were composed of layers of tightly packed blue and red clay. No black ooze was found on any of the deeper bottoms. The bottoms at depths below 500 feet contained very little organic matter. Samples of the bottom when ashed lost only 3% of their weight.

The water level of Lake Superior is relatively stable, although fluctuations of approximately four feet have been reported by Army Engineers over a period of many years. Seasonal fluctuations usually range from 1.0 to 1.5 feet. Currents undoubtedly exist as gill nets were distinctly curved in the center by currents sweeping along shore. Pronounced seiches as great as 20 inches within 30 minutes were sometimes observed.

The water is very clear. The Secchi disc could be observed at depths of 65 to 75 feet. The alkalinity* as expressed in carbonates was only 37 to 40 p.p.m. This is relatively low as compared to most Minnesota lakes which are much higher. In spite of the low bicarbonate content, the pH ranged from 7.8 to 8.0. Total dissolved solids ranged from 50 to 53 p.p.m. Clarke (1924) reports 60.0 p.p.m. for Lake Superior. The following mineral analyses of water collected seven miles off Grand Portage, July 9, 1934, showed calcium and silica to be the outstanding elements present, although small amounts of others were found.

<i>Depth collected</i>	<i>Surface</i>	<i>300 ft.</i>	<i>600 ft.</i>	<i>900 ft.</i>
Silica	2.00	1.80	3.00	10.50
Iron	0.00	0.00	0.00	trace
Aluminum	0.50	0.00	5.30	2.30
Manganese	0.15	0.00	0.00	trace
Calcium	13.00	14.70	8.5	14.1
Magnesium	1.30	1.8	1.4	1.4
Sodium	1.80	1.9	1.7	2.1
Potassium	1.80	1.5	1.6	1.5
Chlorides	0.50	0.5	trace	trace
Sulfates	3.0	3.1	2.6	3.2

* Phenolphthalein and brome cresol green alkalinity.

The temperature of the water is low throughout the year, and shows only relatively slight seasonal changes. During the summer months the bottom temperatures below a depth of 100 feet were below 4°C. At 900 feet the temperature was always 3.6°C. This drop below 4°C., at which temperature water ordinarily reaches its greatest density, is probably caused by the pressure (Wright, 1932). The temperature of the surface waters varied considerably through the summer and at different places. Temperatures near shore were often 7°C. and sometimes much higher. In Grand Portage Bay the surface temperature reached 15°C. by the first of August. In June most of the surface waters offshore were slightly above 4°C. In July and August the offshore surface waters usually ranged from 4.7° to 5.0° C. Occasionally patches of warmer water with temperatures up to 10°C. were encountered offshore. Sometimes these warm areas were several miles in extent and ranged downward to about 100 feet. These were probably inshore waters which had been carried out by winds or currents.

At no time in the many series of temperature readings made offshore was a definite thermocline observed. There was usually only a slight and gradual drop in temperature from the surface to the bottom. The difference between the summer surface and bottom temperatures offshore was always much less than that of small lakes. When an occasional patch of warm surface water was encountered, the temperature at its lower limit showed a sudden drop resembling a thermocline, but as this patch disappeared or was elsewhere a day later, this temperature change could not be defined as a thermocline.

Total dissolved oxygen determinations were made at all depths through June, July and August of 1933 and 1934. The oxygen usually ranged from 8 to 11 p.p.m. at the surface. Usually it was almost as abundant at the bottom even in the deepest water. Several times the total dissolved oxygen at the bottom was found to be slightly more than that at the surface.

The marginal plant and animal life was practically absent from most of the Minnesota shore due to the heavy wave action. No submerged rooted aquatic plants were found at any place along the Minnesota shore. Boulders below three feet of depth and down to twenty feet in sheltered coves were usually coated with a heavy ooze of diatoms and detritus. Green vegetation consisted chiefly of small tufts of filamentous algae, usually *Cladophora* and *Spirogyra*, in sheltered waters. Collections from these algae contained flat clinging mayfly nymphs, *Hydropsyche* nymphs, stonefly nymphs and chironomid larvae. These were organisms characteristic of swift streams rather than of lakes. They undoubtedly found similar conditions on these wave washed rocks.

On the bottoms of Grand Portage Bay, Bryozoa were common on the rocks down to a depth of 20 feet. Snails were rare in the

shallow waters of the north shore. The only snails found were *Stagnicola walkeriana* Baker and species of *Ammnicola* and *Gyraulus* on sheltered marginal rocks at Beaver Bay and Grand Portage.

On exposed shores practically no organisms were found until a depth of 8 to 10 feet was reached. No Unionid clams were found although several species occurred in the sheltered waters of St. Louis Bay at Duluth and elsewhere. It was only in the sheltered areas that any appreciable bottom fauna occurred in waters less than 10 feet deep.

Series of collections of the fauna from the deeper bottoms were made with a Petterson bottom sampler in June, July and August of 1933 and 1934. Frequently collections were difficult to obtain because of the rocky nature of the bottom. This was especially true of the bottoms ranging down to a depth of 300 feet. After many attempts on such bottoms, small areas or pockets of softer materials were found at all depths and satisfactory collections were obtained. At depths ranging from 10 feet to 70 feet the bottom fauna consisted mostly of annelid worms, larvae of chironomids, species of *Asellus* and *Gammarus*, and the amphipod *Hyalella azteca* (Sausure).

The bottom fauna characteristic of deeper bottoms was found at depths usually below 70 feet. This bottom fauna was characterized by the deep water amphipod *Pontoporeia hoyi* Smith. In addition to this amphipod, the deep water bottom fauna was composed chiefly of annelid worms, species of sphaeriid clam *Pisidium*, nematode worms, ostracods, and larvae of chironomids. These organisms were very abundant at depths between 100 and 200 feet, and were abundant down to the depth of 400 feet. Most of these organisms were found in fewer numbers down to the depth of 800 feet. At the depth of 900 feet the only bottom fauna found in ten bottom samples were several specimens of *Pontoporeia*.

At depths down to 600 feet, pebbles were often collected to which were attached filaments of the green alga *Cladophora profunda* var. *Nordstediana* Brand. This alga has been reported by Kindle (1915) at 150 feet in Lake Ontario.

Plankton collections were made monthly from 1930 to 1934 at the Duluth Pumping Station about 7 miles northeast of Duluth. Series of collections at various depths from offshore waters were made off Grand Portage and Beaver Bay in the summers of 1933 and 1934. A detailed report of the plankton will be made in a later paper.

The phytoplankton was largely represented by cold water diatoms. Green and blue green algae were almost absent from the plankton. The zooplankton was represented largely by several species of rotifers, cladocerans and by several characteristic copepods. The cladocerans which were most common were *Bosmina longispina* Leydig and *Daphnia longispina* O. F. Müller. The most abundant

copepods were *Diaptomus sicilis* Forbes, *Epischura lacustris* Forbes and *Limnocalanus macrurus* Sars. These were abundant at most times and were present at all depths, although never as abundant at the greater depths as at the surface. In the offshore waters at all depths below 50 feet, the deep water crustacean *Mysis relicta* Lovén was common in the plankton. It ranged from near the surface to the deepest bottoms and was even found in the deepest bottom samples where it was undoubtedly trapped by the dredge from the water just over the bottom.

Fishes were not collected extensively in this study. Most of the collecting was done during several trips with local fishermen to lift their nets. Small fishes in shallow waters were collected by a large minnow seine in Grand Portage Bay and several other places where small beaches were found. A considerable number of species were found in the shallow waters inshore. In the deeper waters offshore lake trout and various species of the whitefish family (*Coregonidae*) were practically the only fishes present.

The common sucker (*Catostomus commersonnii commersonnii* (Lacépède)) and the northern sturgeon sucker (*Catostomus catostomus* (Forster)) were abundant on the shallow bottoms down to 100 feet. The lake sturgeon (*Acipenser fulvescens* Rafinesque) formerly occurred here, but is rare now in Minnesota waters. Walleyes (*Stizostedion vitreum* (Mitchell)), northern pike (*Esox lucius* Linnaeus) and perch (*Perca flavescens* (Mitchill)) occurred along shore in sheltered bays and among the islands. They were seldom found in deep water offshore. Burbot (*Lota lota maculosa* (LeSueur)) ranged over the bottom down to depths of at least 300 feet. Brook trout (*Salvelinus fontinalis* (Mitchill)), rainbow trout (*Salmo gairdnerii irideus* Gibbons), and brown trout (*Salmo trutta fario* Linnaeus) ranged along shore, but never ventured far into deep water. The last two species are introduced. Lake Trout (*Cristivomer namaycush* (Wallbaum)) occurred in the open waters offshore and ranged down to depths of over 200 feet. During the late summer and early fall they migrate inshore to spawn. Several species of minnows were common in bays and mouths of rivers. The ninespine stickleback (*Pungitius pungitius* (Linnaeus)) was very common everywhere along the shallow margins. Among the rocks along shore, the muddler (*Cottus bairdii* Girard) was common. The spoon head muddler (*Cottus ricei* Nelson) has been reported by Greene (1935). At depths of 600 to 800 feet the deepwater sculpin (*Triglopsis thompsonni* Girard) occurred. The only specimens collected were found in stomachs of siscowets. The siscowet or fat trout (*Cristivomer namaycush siscowet* (Agassiz)) was taken at depths ranging from 200 feet to at least 800 feet. They rarely come near the surface.

The whitefish family (*Coregonidae*) was represented by at least eight species, some of which form the most conspicuous part of the

fish population of Lake Superior. The Lake Superior herring or cisco (*Leucichthys artedii arcturus* Jordan and Evermann) is one of the most common and best known fishes. It ranged along shore and out into the open water to depths of at least 200 feet. The common whitefish (*Coregonus clupeaformis* (Mitchill)) and the short-nose chub (*Leucichthys reighardi dymondi* Koelz) ranged down to depths of at least 400 feet. The Menominee whitefish (*Prosopium cylindraceum quadrilaterale* (Richardson)) ranged in shallow water offshore, but was never very common.

Other members of this family are not as well known, especially those which live at great depths. These have been studied by Koelz (1929) and are the shortjaw chub or cisco (*Leucichthys zenithicus* Jordan and Evermann), the Great Lakes bloater (*Leucichthys hoyi* (Gill)), the Michigan Kiyi (*Leucichthys kiyi kiyi* Koelz), and the bluefin (*Leucichthys nigripinnis cyanopterus* (Jordan and Evermann)). These usually ranged at depths between 200 and 700 feet.

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DEER AND THE FOREST IN ITASCA PARK

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ABSTRACT

For over 15 years the deer population in Itasca Park has been too great for the carrying capacity of the area and serious damage