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The major vegetation of Lake Okoboji consists chiefly of submersed seed plants. The algae are always in evidence and play an important part in the life of the lake since they are used as food by many lower animals, but with the exception of *Chara* they are seldom conspicuous and never large.

The aquatic seed plants present a wide range in size, structure, and flowering habits, but with the exception of the duckweeds, (which are only visitors on the main lake), they are good sized plants, and some of them are very large. The botanist sees in these submersed Angiosperms a group of plants of special interest since they present a double set of adaptations. Each must in the past have gained high achievement as a land plant, and they subsequently taking to the water, there has been superimposed another set of habits and structures especially related to the present environment.

Most people realize in a general way at least that there must be some such relation between the animal and plant life of the lake as there is between these groups on land. The lake animals are dependent directly, or indirectly, upon the associated plants for food, excepting of course such food materials as are washed into or fall upon its waters. The water plant is eaten directly by some of the fish, but usually it is transmitted to some of the higher lake animals through a series of lower organisms who derive their food from the plants. So intimate is this relationship that the success or failure of one form influences in corresponding proportion the welfare of other organisms which seem remote and independent.

The major vegetation also provides shelter, attachment, and breeding places, as well as food for the animals. All of which suggests that the life of a permanent fresh water lake, like Okoboji, presents a complex series of inter-relationships between the various forms that dwell in its waters. With this in view various studies carried out at the Iowa Lakeside Laboratory have been directed towards determining the number and kinds of organisms in Lake Okoboji, and the establishment of values for the many partners in the life-program of its waters. There must

be a knowledge of the animals and plants present, with information as to their numbers, seasonal changes, and distribution. Gradually as these facts are assembled certain relationships may be made out. Obviously the question of main interest and importance is the bearing of all this upon the fish. It is hoped that the Laboratory, preferably in coöperation with state and national agencies, may contribute something toward this problem.

As a part of the program there was carried out in the summer of 1919 a general survey of the larger plants of Lake Okoboji. The beginning of the work was delayed until the vegetation had reached full development for that year. During August a group of three workers from the Laboratory surveyed the shore zone of this lake, recording the kinds, relative abundance, and distribution of the submersed seed plants. No account was taken of the vegetation of cut off ponds or bordering swamps, as the study was limited to the plants of the lake proper.

Nearly two hundred stations were established on the borders of Lake Okoboji and cross sections were surveyed out at right angles to the margin until the water became too deep for larger plants. Dredgings along these lines were made with a many pronged hook, and depth measurements were taken with a weighted line. This survey was made possible largely through the courtesy of Mr. W. E. Albert, State Fish and Game Warden, who kindly loaned the Laboratory a small motor-boat for the work.

The location of the boat was determined in part by estimating distances and also by sighting across headlands, etc., to known points on other parts of the shore and subsequently by use of map to plot in the points of observation. Owing to periods of windy weather it was not possible to study all parts with equal care. While the exact location could not always be known, especially on rough water, the results are sufficiently accurate to outline the submersed vegetation, the extent of the beds, and certain relations to depth, bottom, and shore configurations. A chart showing the results of this general survey has been prepared; it may be useful as a guide in the more intensive study of the various parts and also of the lake as a whole. The map accompanying this article, prepared from these data, is much simplified as it shows only the total areas occupied by the larger plants. It is very difficult to indicate on a small map the distribution of all the species. The portions filled in with small circles show the distribution of *Ceratophyllum demersum*. The dotted

areas represent portions of the lake bottom having large plants, other than *Ceratophyllum,* and including *Chara* beds (Fig. 12).

Since Okoboji is much the deepest of this group of lakes and has large areas of considerable depth one is surprised to learn the extent of the weed-beds in its waters. According to this survey about eleven hundred acres of lake bottom are occupied by larger plants. The total area of the lake is approximately 3700 acres which means that nearly thirty per cent of its area was underlaid with plants in 1919. This does not mean of course that they showed at the surface over that proportion of the lake; in most places they were entirely out of surface view.

In discussing these findings it should be borne in mind that the extent and character of these weed-beds vary somewhat from year to year. Modifications of the season, particularly the spring and early summer, would likely alter the relative proportion of the various species. Obviously changes in the lake level, from year to year, would markedly influence their lateral distribution. With lower water level the deeper species could grow out farther into the lake. Since these forms are very sensitive to depth a depression of a foot or two in lake-level would permit a marked encroachment under the open waters of bays where the substratum is suitable for these species. All attempts to artificially modify the level of the water should take into account the certain influence such changes would have upon the vegetation of the lakes. Lower water would mean not only considerable extensions of weed-beds, but would bring to the surface areas of weeds not suspected at higher levels.

The following list includes the species that are most commonly found in Lake Okoboji:

Bidens Beckii Torr.
Ceratophyllum demersum L.
Elodea ioensis Wylie.
Heteranthera dubia (Jacq.) MacM.
Myriophyllum spicatum L.
Naias flexilis (Willd.) R. & S.
Potamogeton amplifolius Tuck.
Potamogeton natans L.
Potamogeton prectinatus L.
Potamogeton praelongus Wulf.
Potamogeton pusillus L.
Potamogeton Richardsonii (Benn.) Ryd.
Potamogeton zosterifolius Schum.
Ranunculus circinatus. Sibth.
Scirpus validus Vahl.
Vallisneria spiralis L.
Zannichellia palustris L.

Other species of aquatic plants are occasionally encountered but the above named forms constitute the chief formations of the lake. Forms like the duckweeds are frequent migrants from ponds having outlet into the lake but do not thrive in the open

water except in the most sheltered places. All free floating plants in the open lake are soon beached, where they die.

Most of the plants are fairly constant in their expression in the open lake, having definite relations to depth, substratum, and exposure to wave action. But some of the above list are typically pond plants which in the lake proper do not find favorable habitat. *Heteranthera* and *Elodea* might be cited as examples and these are sometimes encountered in the most unexpected places. The former has not been noted flowering at the surface of the water in Lake Okoboji though it sets seeds regularly through a cleistogamous pollination. The species of *Elodea* could not be determined in many cases as it flowers sparingly in the open lake while blossoming profusely in the ponds and shallower lakes of the region. All plants noted in bloom were *E. ioensis.*

Favorable habitats have well marked formations consisting usually of a number of associated species having similar requirements. The shallower portion of Millers Bay, partly cut off from the larger body of water by a submerged bar, contains an assemblage that has remained remarkably constant through the ten years it has been under observation. Within a couple of hundred yards of the grounds of the Lakeside Laboratory are found all the plants noted in the above list for the lake. Each of the other major bays would give a similar list, but the less desirable habitats would give fewer species.

The character of the bottom is of great importance in determining the make up of the formations in any given area. In most places rocky shores are associated with greater exposure to wave action, so it is difficult to weigh, from observation, the relative merits of these two factors. Such places have usually more abrupt slopes so do not offer anchorage for a zone of plants wide enough for much mutual protection. The headlands on the west side and much of the eastern side of the lake exhibit these conditions and are the barer borders. In these regions *Chara* is a prominent and often the dominant plant. The region between Elm Crest and Gull Point with similar stretches on other shores present vast *Chara* beds with relatively few Angiosperms with them. *Potamogeton natans* is very commonly admixed and in many cases this is true of *Potamogeton Richardsonii.* Certain of the smaller and well rooted forms are abundant in the shallow margins — here are frequently found such as *Heteranthera dubia, Naias flexilis,* and occasionally *Zannichellia.*

Sandy beaches on concave shores offer a very different set of

conditions. There is usually a relatively barren zone of shifting sandy bottom into which creep a number of seed plants, *Potamogeton Richardsonii, P. pectinatus, Naias, Elodea, Vallisneria,* etc. Such shores soon deepen off into the bay-formations containing *Potamogeton amplifolius, P. praelongus, P. natans, P. zosterifolius, Ceratophyllum, Myriophyllum, Ranunculus,* etc.

Depth plays a most important part,— light probably being the determining factor. About fifty per cent of the light falling on open water is reflected, and the remainder diminishes rapidly through absorption with increasing depth. Most of the species of seed plants are eliminated at a depth of twelve feet, and plants that flower at the surface may be prevented from setting seed at lesser depth than that just given. In Lake Okoboji *Ceratophyllum demersum,* discussed briefly below, is the conspicuous plant at depths greater than seven or eight feet. It forms extensive beds, where the bottom is favorable, at depths ranging from six to nearly twenty feet, ending rather abruptly at about the latter depth. It is limited to areas with soft bottoms, and in such situations is a most efficient and successful plant. According to this preliminary survey *Ceratophyllum* occupied about 700 acres of the bottom of Lake Okoboji in 1919. The accompanying map has the Ceratophyllum beds marked by small circles.

Ceratophyllum demersum forms great masses of vegetation in Millers Bay, Emerson Bay, and at the north end of the lake. Lesser beds occur in Smiths Bay, and Haywards Bay. A glance at the map shows that it forms a narrow zone most of the way along the west side of the lake except on convex shores and the barren stretch from Elm Crest to Gull Point. The east side of the lake below Haywards Bay shows relatively little *Ceratophyllum,* due to the abrupt slope and stony bottoms.

It will be noted that *Ceratophyllum* thrives only on shelving shores and in bays; in such places sufficient mud may accumulate to insure a soft bottom. *Ceratophyllum* has no roots but modified branches are buried in the soft substratum, and afford feeble anchorage. The plants have a specific gravity only slightly less than water even when fully active in midsummer. The stems sink in water but the buoyancy of the leaves keep the plants upright. Detached plants, however, will not float on the water. Recalling their ability to grow at considerable depths it will be seen that they are relatively unharmed by wave action. Following heavy storms it is the rooted plants rather than the rootless *Ceratophyllum* that are thrown up on the beach.

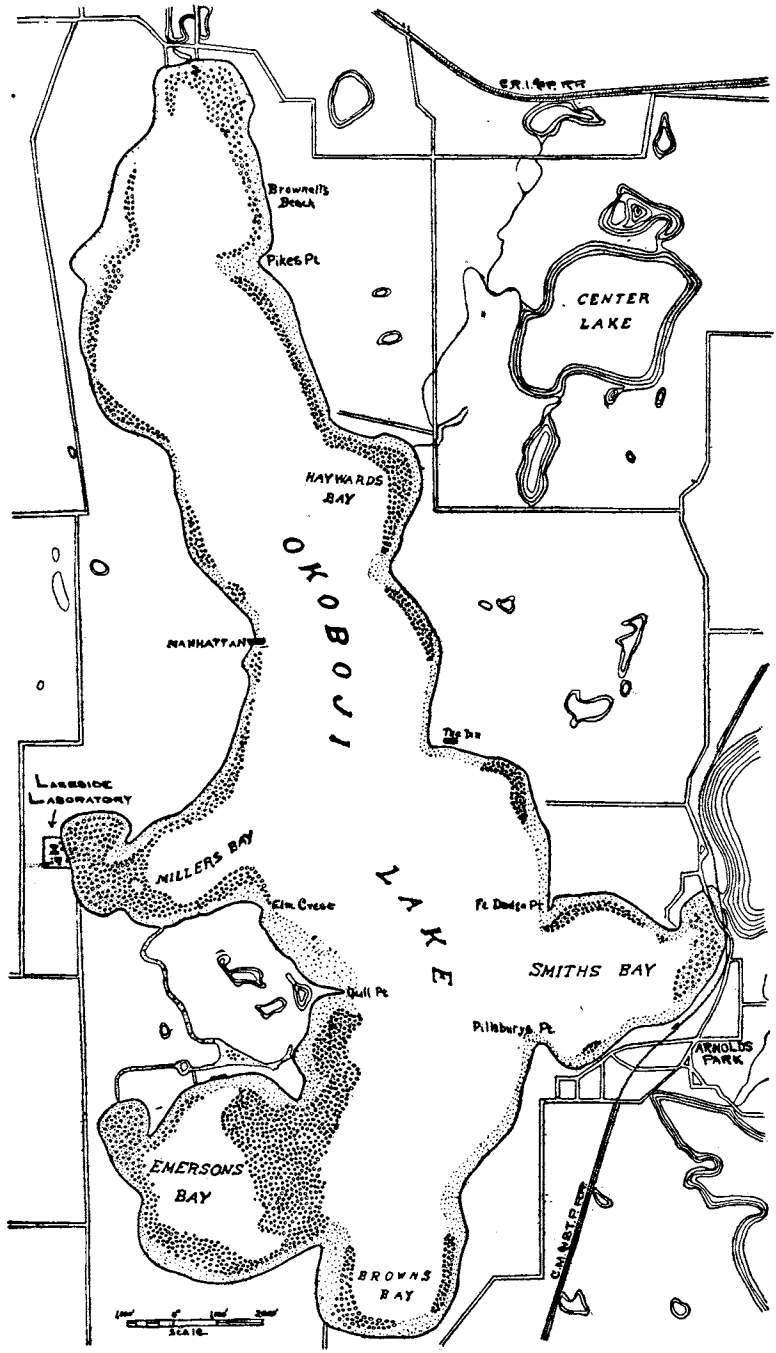

Fig. 12. Map showing distribution of larger plants in Lake Okoboji. Dotted areas indicate mixed larger plants, including Chara. Regions marked by small circles have *Ceratophyllum demersum*.

Ceratophyllum seems also to enjoy relative immunity to annoying algæ. The gelatinous species of *Rivularia* do not adhere to it in great numbers as compared with *Myriophyllum* and others that are fairly swamped by these epiphytes. Similarly, since *Ceratophyllum* typically remains submerged it does not offer anchorage to the free floating filamentous forms which make so much trouble for plants that bring their flower stalks to the surface.

Algæ regularly enter all these assemblages of seed plants and play an important part, usually to the detriment of the larger plants. Cyanophyceæ, especially *Rivularia,* attach to all their submersed parts, except that *Ceratophyllum* has partial immunity. These epiphytes must seriously interfere with their functions as frequently a large part of the leaves and stems is gummed over by them. As noted above the filamentous algæ form extensive masses over shallow waters where the flower stalks and other parts of submersed plants project above the surface. In quiet water *Rhizoclonium* forms heavy "blankets" that bring disaster to all entangled forms.

The Chara beds are very extensive, covering hundreds of acres of the bottom of Lake Okoboji. Their biological significance is rather obscure. Animals seem not to eat them freely and these formations constitute what might be called the desert areas of the lake. Studies of the Chara beds are being taken up to determine their extent, the component species, depth relations, etc., and to outline their relations to other plants and to animals. They constitute one of the unknown factors in the life of Lake Okoboji.

These "water weeds" sustain a very close relation to the whole question of fish in these lakes. The results of this survey are merely preliminary to the more intensive and detailed study of the various parts of Lake Okoboji and the other lakes of the group. It is of some significance at least that during the entire month given to this survey, and during which time hundreds of people were observed fishing in various parts of Lake Okoboji, no fish were being caught except in or along the edge of these masses of major vegetation.

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