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blooms generally dissipate by the middle of November their presence results in a disagreeable odor that detracts from the recreational value of the lake.

Cladophora is abundant during summer and fall, usually attached to rocks along the northern and western shoreline and along the spillway.

Extensive growths of *Hydrodictyon reticulatum* were found throughout late summer and fall along the spillway and in the shallow pools at station 2. This species occured in large masses containing colonies of various sizes.

One species of *Spirogyra* was prevalent at stations 1, 2 and 3, especially in the shallow pools of the spillway. It was found at all other stations in lesser numbers.

The six most common and widespread genera of algae found in the lake are *Cladophora, Hydrodictyon, Spirogyra, Aphanizomenon, Microcystis* and *Oscillatoria.* Initial observations of some of these genera during the collecting period indicate considerable fluctuations in the numbers of individuals. Studies now underway will attempt to correlate the seasonal variation and distribution of these and other species of algae with both the physical and chemical factors of the lake water.

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Changes in the Aquatic Vascular Flora of Lake East Okoboji in Historic Times

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Abstract: The submerged, floating, and emergent vascular flora of Lake East Okoboji, Dickenson County, Iowa, was surveyed by the senior author in the summer of 1961, with collections made at 21 stations. Emergent species and one hybrid, and 7 submerged or floating species were found. A comparison is made with a 1915 survey in which a very rich flora of about 18 emergents and 26 submerged or floating species was reported. Pollution by sewage and by agricultural fertilizers and other factors that may have caused changes in the vascular flora are discussed.

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Introduction

This paper not only serves as a record of the aquatic flora of Lake East Okoboji in 1961, but also presents a comparison with the flora recorded in 1915 (6).

Most of the work on the fauna and flora of the Okoboji lakes has been done at Lake West Okoboji by workers at the Iowa Lakeside Laboratory. Papers on the plants of the Lake West Okoboji were published early in this century by Ewers (5), Jones (7), and Wylie (17). In 1960 Bovbjerg and Ulmer (3) compared the present snail population in Lake West Okoboji to collections made earlier by Shimek (12). With the exceptions of the work of Weber (16) and Volker (14, 15) Lake East Okoboji has rarely been included in such studies. The two lakes, however, are quite different in many ways although they are connected by a narrow channel. Data obtained at Lake West Okoboji therefore cannot readily be applied to Lake East Okoboji.

Lake West Okoboji is deep enough to form a thermocline and become stratified, whereas Lake East Okoboji is so shallow that it does not become stratified. Lake West Okoboji is a long, single body of water with several large bays, whereas Lake East Okoboji is actually a chain of three lakes connected by narrow, shallow channels. Lake East Okoboji always supports a dense bloom of blue-green algae (according to our observations principally *Aphanizomenon*) in summer, whereas the populations of blue-green algae seldom reach bloom proportions in Lake West Okoboji.

Lake East Okoboji extends from the southeastern side of Lake West Okoboji east and northeast for two or three miles, then bends north for about four miles and almost meets the southern end of Big Spirit Lake. Big Spirit Lake empties into East Okoboji at Orleans through a small creek which was formerly periodically dammed at its mouth by gravel deposited by ice and waves (6, p. 53), but the flow is now regulated by a weir. The outlet into the Gar Lakes at the south end of East Okoboji has been controlled by a small dam since before 1916. Lake East Okoboji is about 1½ miles wide at its widest point, about seven miles long, and varies in depth from about 7 to 24 feet. It and the surrounding lake are apparently glacial in origin (4, 9). The water chemistry as reported by Bachman (1) and in more detail by Volker (14) appears to be generally similar to other Iowa lakes in the Wisconsin glacial sheet region, including Lake West Okoboji.

Most of the watershed is used intensively for agriculture. The town of Spirit Lake and many homes and cabins line much of the shore.

The 1915 Survey

The flora of Lake East Okoboji and 14 other lakes in northern Iowa was reported by L. H. Pammel in 1916 as part III of the State Highway Commission report on Iowa Lake and Lake Beds. Field work was conducted by Pammel and L. W. Durrell in 1915. The abundance of each species for each lake was scored on a five-point scale from "very abundant and dominant" to "less frequent". Water-depth ranges for each species also were recorded. Collection stations at each lake unfortunately were not included in the report. Part II of the same report includes brief descriptions of the lakes.

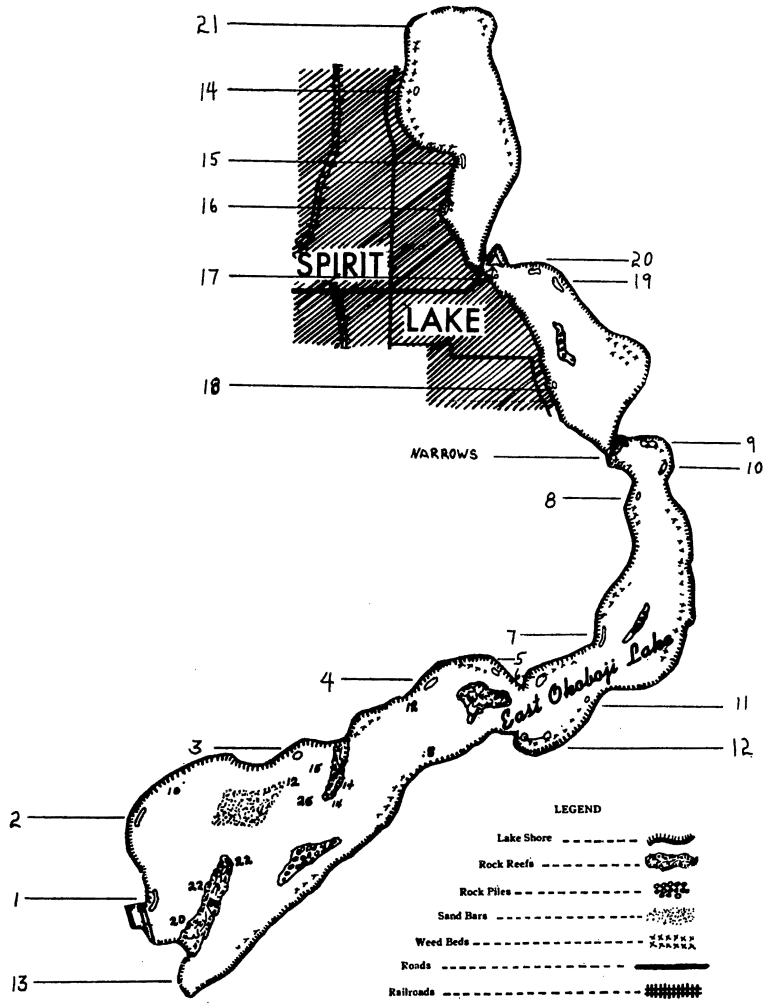

Figure 1. Collecting stations used in the 1961 survey of aquatic vascular plants of Lake East Okoboji.

The vascular flora of Lake East Okoboji in 1915 was exceptionally rich and almost identical to that of Lake West Okoboji. It included at least 2* species of submerged or floating plants and 18 emergents, or a total of 44 species of acquatics (excluding several strictly wet-soil plants such a *Caltha palustris* listed by Pammel. The next richest aquatic flora reported by Pammel consisted of only 16 species, recorded from Spirit Lake. The genus *Potamogeton* alone was represented at East Okoboji by all 13 species recorded in the entire 15-lake survey. Although most of the species were recorded as rather infrequent (?) (4-5 on the frequency scale), the submerged species *Elodea ioensis* (*E. nuttallii*), *Myriophyllum spicatum* and *Ceratophyllum demersum* were reported to be very common in water 3 to 5 feet deep. Data from the 1915 survey is summarized and compared with data from the 1961 survey in Tables 3 and 4.

Table 1. Aquatic vascular plants found at each collection station in the 1961 survey of Lake East Okoboji

Narrows	*Lemna minor*
	Phalaris arundinacea
	Phragmites communis
	Sparganium eurycarpum
	Spirodela polyrhiza
	Typha angustifolia
	Typha X glauca
	Typha latifolia
Station 1	*Ceratophyllum demersum*
	Potamogeton foliosus
	Potamogeton pectinatus
	Potamogeton richardsonii
	Scirpus validus
	Zannichellia palustris
Station 2	*Potamogeton richardsonii*
Station 3	*Scirpus validus*
Station 4	*Scirpus validus*
Station 5	*Potamogeton pectinatus*
	Potamogeton richardsonii
	Scirpus sp.
Station 6	*Potamogeton pectinatus*
Station 7	*Potamogeton pectinatus*
Station 8	*Phalarus arundinacea*
	Scirpus validus
Station 9	*Lemna minor*
	Scirpus acutus
	Scirpus heterochaetus
	Scirpus validus
	Spirodela polyrhiza
	Typha angustifolia
	Typha X glauca
	Typha latifolia
Station 10	*Scirpus acutus*
	Scirpus validus
Station 11	*Potamogeton pectinatus*
Station 12	*Sagittaria sp.*
Station 13	*Scirpus acutus*
	Scirpus validus
Station 14	*Scirpus fluviatilis*
Station 15	*Potamogeton pectinatus*
	Scirpus acutus
	Scirpus fluviatilis
	Scirpus validus
	Typha angustifolia
	Typha X glauca
	Typha latifolia
Station 16	*Ceratophyllum demersum*
	Potamogeton pectinatus
	Scirpus fluviatilis
	Typha angustifolia
	Typha latifolia
Station 17	*Lemna minor*
	Scirpus fluviatilis
	Scirpus validis
	Sparganium eurycarpum
	Typha angustifolia
	Typha X glauca
	Typha latifolia
Station 18	*Phalaris arundinacea*
	Potamogeton pectinatus
Station 19	*Potamogeton pectinatus*
Station 20	*Scirpus acutus*
	Scirpus fluviatilis
	Scirpus validus
Station 21	*Scirpus validus*

The 1961 Survey

In early August, 1961, the senior author made collections at each of 21 stations on Lake East Okoboji as indicated in Figure 1, using a small boat.

We identified the plants from both dried and fresh material, retaining dried herbarium specimens as vouchers. The species collected at each station are listed in Table 1 and the cumulative species list is given in Table 2.

Table 2. Cumulative species list of aquatic vascular plants found at Lake East Okoboji in 1961

Species	Number of stations where it occurs	Species	Number of stations where it occurs
Scirpus validus	13	*Potamogeton richardsonii*	3
Potamogeton pectinatus	9	*Ceratophyllum demersum*	2
Scirpus acutus	7	*Spirodela polyrhiza*	2
Scirpus fluviatilis	5	*Sparganium eurycarpum*	2
Typha angustifolia	5	*Phragmites communis*	1
Typha latifolia	5	*Potamogeton foliosus*	1
Typha X glauca	4	*Sagittaria spp.*	1
Lemna minor	3	*Scirpus heterochaetus*	1
Phalaris arundinacea	3	*Zanniehellia palustris*	1

Discussion

In the 46 years between 1915 and 1961, the total number of aquatic vascular species in Lake East Okoboji apparently has been reduced by about 60% from about 44 to 18 species. The reduction in the submerged flora is especially striking (Table 3). Of 23 species recorded in 1915, only five were recorded in 1961. Among the species apparently eliminated from the flora are *Elodea nuttallii* and *Myriophyllum spicatum*, both of which were very common in 1915 and are among the commonest aquatics in Iowa today (2). In addition, *Ceratophyllum demersum*, also very common in Iowa, was recorded as the most abundant plant in 1915 but was found at only two stations in 1961. The only fairly common species in 1961 was *Potamogeton pectinatus*, which is remarkably tolerant of brackish, very hard, and turbid waters. In addition to containing a depauperate flora, Lake East Okoboji in 1961 was nearly barren in many places with shallow water apparently ideal for vascular plant growth. This condition contrasts markedly to that reported by MacBride in 1899: ". . . . the shallow waters are now rapidly filling up with vast quantities of aquatic vegetation."

Records of emergent plants (Table 4) are more difficult to compare in the two surveys than are records of the submerged plants. This is partly due to difficulties in defining an aquatic, for

Table 3. Comparison of submerged or floating vascular plants reported from Lake East Okoboji in 1915 and 1961

Species	*Frequency 1915	1961
Heteranthera dubia	4	..
Potamogeton americanus (P. nodosus)	4	..
Potamogeton amplifolius	4	..
Potamogeton dimorphus (P. diversifolius)	4	..
Potamogeton epihydrus	4-5	..
Potamogeton friesii	5	..
Potamogeton foliosus	4	5
Potamogeton heterophyllus	5	..
Potamogeton natans	3-4	..
Potamogeton pectinatus	3	2
Potamogeton praelongus	5	..
Potamogeton pusillus	4	..
Potamogeton richardsonii	5	5
Vallisneria spiralis	3-5	..
Ceratophyllum demersum	1	5
Rannuculus aquatilis	5	..
Myriophyllum spicatum	1-3	..
Bidens beckii	3	..
Lemna minor	..	5
Lemna trisulca	4	..
Spirodela polyrhiza	4	5
Wolffia punctata	5	..
Potamogeton zosteriformis	5	..
Zannichellia palustris	5	5
Najas flexilis	4	..
Elodea canadensis	4-5	..
Elodea ioensis (E. nuttallii)	2-3	..
Totals	26	7

* EXPLANATION OF FREQUENCY NUMBERS:

1915	Freq. No.	1961
"Very abundant to dominant"	1	13 or more stations
"Abundant"	2	10-12 stations
"Common"	3	7-9 stations
"Frequent"	4	4-6 stations
"Less frequent"	5	1-3 stations

some emergent species recorded as aquatics in 1915 may have been interpreted as non-aquatic in 1961 and therefore not recorded. Also, in contrast to the submerged aquatics, of which all of the species recorded in 1961 were also recorded in 1915, four emergent species and a hybrid recorded in 1961 were not recorded in 1915. Of these, the hybrid cattail *T.* X *glauca* (*T. angustifolia* X *latifolia*) was not recognized in North America until recently (13) and the round-stemmed bullrushes *Scirpus acutus* and *S. heterochaetus* hybridize with *S. validus* so that their distinctions are confused (8 and Smith, unpublished data) and all three could have been named *S. validus* in 1915. On the other hand, the observations of one of us (Smith, l.c.) also indicate that *Typha angustifolia, T.* X *glauca* and *Scirpus acutus* usually occupy disturbed habitats. It therefore is reasonable that these taxa were introduced since 1915 and survived because of man-caused disturbances of the ecology of the lake.

Even allowing for problems in comparing the two surveys, the changes in the vegetation as herein described are striking

Table 4. Comparison of emergent aquatic vascular plants reported from Lake East Okobojie in 1915 and 1961

Species	*Frequency 1915	1961
Typha latifolia	4	4
Typha angustifolia	..	4
Typha X glauca	..	4
Sparganium americanum	4	..
Sparganium eurycarpum	3	5
Sparganium simplex	4	..
Sagittaria latifolia	3-4	5
Echinodorus cordifolius	5	..
Alisma plantago-aquatica	4-5	..
Phragmites communis	4-5	5
Glyceria nervata	4-5	..
Glyceria grandis	4-5	..
Phalaris arundinacea	..	5
Eleocharis acicularis	3-4	..
Eleocharis ovata	5	..
Eleocharis palustris	4	..
Scirpus fluviatilis	4-5	4
Sirpus validus	3-4	1
Scirpus acutus	..	3
Scirpus heterochaetus	..	5
Iris versicolor	4	..
Radicula palustris	4	..
Bidens cernua	4-5	..
Totals	18	11

* See footnote in Table 3 for explanation.

and not likely to be due to chance alone. The responsible factors appear to us to be related to the increasingly intense human use of the land and water of the Lake East Okoboji region as follows:

1. Increased nutrient content of the water of the lake, resulting from (a) increased use of agricultural fertilizers on the land and (b) increased sewage effluent from the growing human population.

2. Increased blooms of planktonic algae, principally blue-greens, probably due to the increased nutrient concentrations.

3. Increased siltation due to more intense cultivation of the land.

4. Use of copper sulfate and other chemicals to control algal blooms (10, 11) and aquatic vascular plants.

5. Changes in the amount and timing of fluctuations of water level and currents due to the construction of a wier at the inlet and a dam at the outlet.

The actual elimination of many of the submerged vascular plants from Lake East Okoboji may have been accomplished by shading due to algal blooms or silt, by toxins produced by the algae, by low oxygen content due to decomposing algal masses, or by other, less apparent factors such as the copper sulfate used in control of algae. Blooms of blue-green algae are so massive and frequent on Lake East Okoboji that copper sulfate has been

applied to the lake at the extremely high rate of about 25 pounds per acre per season over the past four seasons (11), and it is difficult to escape the conclusion the algal blooms somehow are responsible for changes in the vascular flora.

Our data on the vascular flora of Lake East Okoboji are strikingly parallel to published data on gastropods. Bovbjerg and Ulmer (3) and Shimek (12) reported a marked reduction in both numbers of individuals and species of gastropods in Lake West Okoboji between about 1915 and 1935 and related this change to pollution by sewage effluents. The obvious common factors in the two lakes are increased sewage effluents and perhaps agricultural fertilizers. It therefore is reasonable to assume that these forms of pollution are the major causes of the observed changes in the vegetation of Lake East Okoboji. The present flora of Little Miller's Bay on Lake West Okoboji however is almost identical to the flora described in 1915. Pollution of Lake East Okoboji is therefore evidently much more severe than Lake West Okoboji.

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