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Ecological Impacts of Harvesting Macrophytes in Halverson Lake, Wisconsin

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ABSTRACT

Mechanical harvesting removed 50 to 70% of submersed macrophyte standing crop in June and July 1980 and 1981 from Halverson Lake, a 4.2-ha impoundment in southwestern Wisconsin. Coontail (*Ceratophyllum demersum* L.) and Berchtold's, curly-leaf, and sago pondweeds (*Potamogeton* spp.) together comprised about 75% of total standing crop and covered 40 to 70% of the lake bed for three summers before harvesting. Macrophytes quickly regrew after the June 1980 harvest, reaching preharvest biomass within a few weeks and even becoming denser. However they took until spring to recover from both July harvests. Species composition shifted a year later to dominance by water stargrass (*Heteranthera dubia* [Jacq.] MacM.). Rare before harvesting, it spread into three-fourths of all sampling plots and comprised 70% of total standing crop by August 1982. It continued to dominate until 1988 when the pondweeds took over. Bluegills (*Lepomis macrochirus* Raf.), largemouth bass (*Micropterus salmoides* [Lacepède]), and macroinvertebrates (mostly snails and chironomid larvae) were also removed during harvesting. But harvesting had little effect on phytoplankton, though blooms of blue-green algae (chiefly *Anabaena* and *Microcystis*) were least dense when water stargrass remained dominant.

Key words: bluegill, *Ceratophyllum, Heteranthera*, largemouth bass, *Myriophyllum*, macroinvertebrates, *Potamogeton*.

INTRODUCTION

Mechanical harvesting of submersed macrophytes has steadily gained in popularity since the 1950s (Grinwald 1968). Unlike mechanical cutters, harvesters both cut and remove foliage. Herbicides in Wisconsin are still used on more lakes, but harvesting can account for larger treatments. For example, herbicides were permitted on 342 Wisconsin waters in 1983, more than seven times as many lakes as were harvested. Yet chemical treatment averaged 3.4 ha, whereas harvested sites were rarely less than 10 ha and sometimes exceeded 100 ha.

Because harvester machines cost at least $40,000, and few regulations exist to control them, harvester operators remove as much foliage as time, machine, and budget permit. This enlarges the area harvested, creating a greater potential for environmental change.

Ecological impacts of harvesting result from plant removal and habitat disturbance. Lake water can become turbid from suspended sediments, algal blooms, or drifting foliage (Wile 1978, Bedrosian 1983). Macroinvertebrates can be removed or their habitat destroyed. Harvesting can remove 2 to 3% (Mikol 1985), or more than 30% (Haller *et al.* 1980), of all fishes from the harvested area. Fry are mainly taken, especially sluggish ones (Somerville 1988). Slower ecosystem changes are less studied and involve shifts in macrophyte community composition, algal growths, and trophic interactions (Nichols 1973, Wile 1978, Carpenter *et al.* 1985).

This study assessed how macrophytes, macroinvertebrates, fishes, and phytoplankton in a Midwestern lake respond to harvesting, and how many invertebrates and fishes are removed with the plants. Samples collected before and after harvesting compared (1) macrophyte growth, distribution, and species composition; (2) fish diet and cover; and (3) blue-green algal blooms. The study was part of a broader effort to evaluate the role and interactions of submersed macrophytes in aquatic ecosystems (Engel 1985, 1988).

PROCEDURES

Halverson Lake was chosen for studying harvesting effects because it was free from most human disturbances. Built in 1959, the 4.2-ha impoundment has received no herbicides or fish poisons, does not experience fish winterkill, contains no carp (*Cyprinus carpio* L.) or Eurasian watermilfoil (*Myriophyllum spicatum* L.)[2], and has almost no motor boating. The 250-ha watershed, located in a sparsely populated area of Wisconsin's Iowa County, is covered with woods (48%), fields (43%), and wetlands (4%) and contains no houses or farms.

The elongated lake basin averages 2.6 m deep and is 7.1 m at its deepest (Engel 1988). A thermocline forms in summer below 3.4 m, leaving 80% of the water column free to circulate. Surface waters in summer have a mean total alkalinity of 130 to 190 mg CO_3/L, pH of 7.4 to 8.6, and total phosphorus concentration of 20 to 60 ug/L (Engel 1985). Secchi disk visibility exceeds 3.5 m in spring, but reaches as low as 0.5 m during summer blooms of phytoplankton. Ice covers the lake typically from early December to late March.

An Aquamarine Corporation "Chub" harvester[3] cut and removed plants throughout the lake, leaving only an adjoining 0.1-ha bay uncut. This harvester operated for 2 to 4 days each in June and July 1980 and 1981, for a total of four harvests in the two years. Swaths were cut 1.4 m

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[2]Table 1 lists scientific names of plants from Halverson Lake that are mentioned in the text.

[3]Mention of commercial products does not imply an endorsement by the author or his employer.

wide to a water depth of 1.5 m. Floating milk jugs marked the harvester's path, preventing areas from either not being cut or cut twice on any date.

Harvested vegetation was brought to shore, loaded onto a truck weighing scale, and dumped outside the watershed. Fishes and macroinvertebrates were examined in 125-liter plant samples, grabbed when the harvester unloaded.

Macrophytes were sampled in situ on a total of 20 dates in June, July, and August 1977 through 1982. Transect lines were stretched perpendicular to shore, usually across the entire width of the lake, at 15 random sites on each date. Divers removed a 0.2-m^2 sample every 5 m along each line. Samples were cleaned, sorted to species, and oven dried at 105 C for 48 to 72 hours. Roots were removed before weighing, giving a dry weight estimate of above-ground standing crop rather than total biomass. Total standing crop will refer to the weight of all species sampled either on the harvester or throughout the lake.

Plant cover was mapped on the 20 dates by two methods: diving along the transects to pinpoint underwater species and taking aerial photographs with normal color and false-color infrared films. Plant community composition and water clarity were observed throughout the lake for six more summers (1983-88), although only chlorophyll samples of phytoplankton were collected.

Fish movements were observed every year from a boat and by diving. Fish diet was studied using fishes removed from harvested plants and those caught by electrofishing a few days before and after each harvesting. Stomachs were dissected from fishes under 150 mm total length; larger fishes were released after flushing their stomachs using Foster's (1977) method.

Phytoplankton were collected every few weeks from two pelagic stations. A Kemmerer sampler collected water at depths of 0.5, 1.5, 2.5, and 3.5 m. Samples from each depth were combined for counting algal cells, but kept separate for analyzing chlorophyll. Algal cells were identified and counted on unfiltered samples using an inverted compound microscope with phase contrast. Trichromatic chlorophyll *a* was measured on samples filtered through a 0.45-um membrane filter. Each filtered extract was then incubated for about 24 hours in a chilled solution of 90% acetone and 10% magnesium carbonate, and analyzed on a spectrophotometer at wavelengths of 750, 663, 645, and 630 nm. Calculations were based on the trichromatic SCOR/UNESCO equation (Strickland and Parsons 1972). Means of chlorophyll *a* were weighted for volume differences in sample depth.

RESULTS AND DISCUSSION

Halverson Lake grew 12 species of submersed macrophytes (Table 1), dominated for three summers before harvesting by narrow-leaved pondweeds, curly-leaf pondweed, and coontail (Figure 1). They comprised 75 to 80% of total standing crop. The plants grew to a water depth of 3.5 m, covered 40 to 70% of the lake bottom area, and spread across 20 to 30% of the water surface (Figure 2). Curly-leaf pondweed dominated in spring, Berchtold's and sago pondweeds in midsummer, and coontail in late summer.

TABLE 1. SUBMERSED MACROPHYTES FOUND IN HALVERSON LAKE[1].

Text name	Scientific name
Berchtold's pondweed	*Potamogeton berchtoldii* Fieber[2]
Bushy pondweed	*Najas flexilis* (Willd.) Rost. and Schmidt
Coontail	*Ceratophyllum demersum* L.
Curly-leaf pondweed	*P. crispus* L.
Elodea	*Elodea canadensis* Fernald
Horned pondweed	*Zannichellia palustris* L.
Leafy pondweed	*P. foliosus* Rafinesque
Sago pondweed	*P. pectinatus* L.
Wild celery	*Vallisneria americana* Michaux
Watermilfoil	*Myriophyllum exalbescens* Fernald
Water smartweed	*Polygonum amphibium* L.
Water stargrass	*Heteranthera dubia* (Jacq.) MacMillan

[1]Identification and nomenclature follow Voss (1972) for *Potamogeton* spp. and Fassett (1966) for the other plants.
[2]Considered synonymous with *P. pusillus* L., according to Voss (1972).

This preharvest community was a mosaic of vertically stratified beds, consisting of 3 to 8 species arranged into canopy, midwater, and basal layers. A floating canopy of sago pondweed and macroscopic algae (*Spirogyra*), reaching 60 cm thick, formed in June and July. An inconspicuous carpet of shade-tolerant plants, often no more than 5 to 20 cm high, formed at the base of the taller pondweeds. It variously consisted of bushy pondweed, coontail, elodea, and water stargrass. The alga *Cladophora* extended the basal layer beyond the vascular plants by forming a sparse mat to a depth of nearly 5.5 m.

Mechanical harvesting removed about 50% of the entire macrophyte standing crop in 1980 and up to 70% in 1981. Berchtold's, curly-leaf, and sago pondweeds constituted over 80% of the biomass from each harvest (Table 2). The harvester removed plant species in proportion to their standing crop in the lake, but plants of the basal layer went underharvested.

Greater harvesting effort and rapid warming in spring meant a June harvest four times larger in 1981 than in 1980. Clear lake ice and early ice out in 1981 favored growth of curly-leaf pondweed, which comprised two-thirds of the June 1981 harvest. But die back of curly-leaf pondweed meant a smaller July harvest in 1981 than in 1980.

Macrophytes took just 2 to 3 weeks to recover from the June harvests, but stayed low after the July harvests (Figure 1). Curly-leaf pondweed wilted in early July when water temperature exceeded 20 C, but the narrow-leaved pondweeds continued to grow and even reached their former biomass when harvested again in July 1980. Declining daylength and water temperature after July no doubt slowed their recovery until spring; the pondweeds grew little after mid-August in preharvest years (Engel 1985, 1988). Long-season plants like Eurasian watermilfoil, in contrast, can recover rapidly from July harvests (Perkins and Sytsma 1987).

The same harvesting effort (16 hours each month) yielded twice the biomass in July as in June 1980 (Table 2). Thus macrophytes not only regrew but became denser.

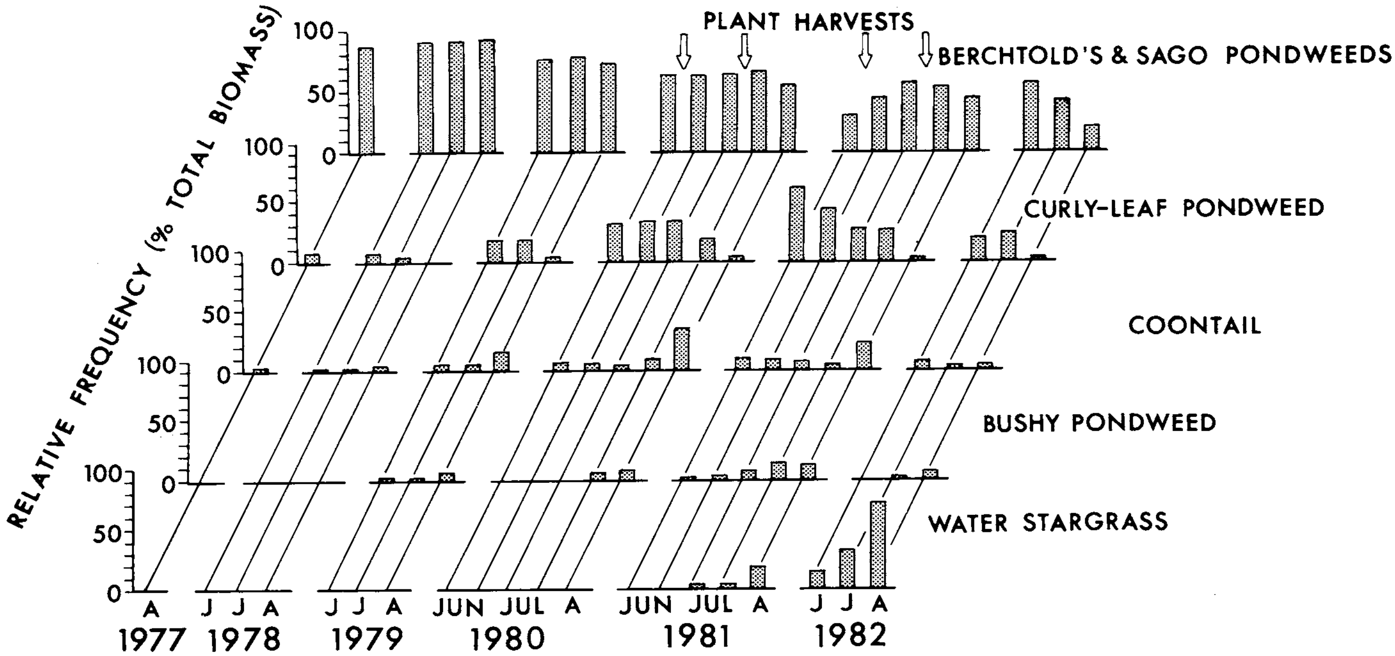

Figure 1. Relative frequency of submersed macrophyte species in June, July, and August 1977-82, expressed as percent dry weight of all macrophytes sampled above ground. Arrows show when plants were harvested.

A more intensive harvesting effort in June 1981 (28 hours) slowed plant recovery, because curly-leaf pondweed died back in early July after starting to recover.

Many plants escaped mechanical harvesting, because the harvester removed foliage mainly from the upper two-thirds of the water column. This left a stubble of cut stems and understory leafage to regrow. At least 30% of total standing crop remained, because macrophytes grew in waters too deep or shallow for operating the harvester. The machine could not reach plants growing deeper than 1.5 m and often ran aground inshore. Its paddle wheels stirred up the sediments creating turbidity that hid plants below the water surface. Occasional stumps and boulders forced the harvester operator to raise the cutter bar and snip foliage well above the bottom.

Many plants were removed by hand. Uprooted or cut foliage washed around the harvester to drift ashore, decay, or eventually take root. From 7 to 15% of the total biomass from each harvest was removed from shore with pitch forks.

TABLE 2. SUBMERSED MACROPHYTES HARVESTED FROM HALVERSON LAKE IN 1980 AND 1981,

	1980		1981	
Plants harvested	9-10 JUN	9-10 JUL	9-12 JUN	14-16 JUL
Total biomass (kg wet wt)	5,700	10,500	21,800	6,600
Harvesting effort (hours)	16	16	28	16
Berchtold's and sago pondweeds (%)	64	64	30	57
Curly-leaf pondweed (%)	31	34	61	27
Coontail (%)	5	2	9	6
Bushy pondweed (%)	0.1	0.1	1	6
Water stargrass (%)	0	0	0.1	3

These limitations left islands of vegetation just below the water surface, cut stems on the bottom, and uncut plants along shore. Harvesting in June thus had little impact on total bottom cover and reduced surface foliage for just a few weeks (Figure 2). Both surface and bottom growth declined after the July harvests, due mainly to natural senescence of the pondweeds.

Pondweeds still dominated in the weeks following each harvest, but other species soon spread. Coontail invaded harvested sites, along with some bushy pondweed, elodea and watermilfoil. Together they occupied as much as 22% of sampling plots and by August 1982 accounted for one-third of total standing crop. For a few weeks after harvesting, therefore, more varied plant beds developed.

Water stargrass also spread after each harvest, but it alone produced a lasting dominance. It spread from just one site in 1980 to occupy 75% of sampling plots and comprise 70% of total standing crop by August 1982 (Figure 1). Harvesting removed competing pondweed foliage and likely spread water stargrass propagules about the lake. Monotypic beds of water stargrass replaced most species and remained dense until November, extending surface and bottom cover by at least two months. It dominated each summer and fall until 1987, when pondweeds and coontail regained the water surface to restore the preharvest community. Water stargrass was left as an inconspicuous understory growth.

Harvesting both removed and dislodged plant-dwelling macroinvertebrates. Patches of displaced snails, caddisfly larvae, and chironomids drifted about the lake and onto shores after harvesting. Each harvest in 1980 removed about 3 million macroinvertebrates (Table 3), amounting to 22% in June and 11% in July of all plant-dwelling macroinvertebrates in the lake (Engel 1985). Snails (Mollusca: *Gyraulus, Helisoma,* and *Physa*) and midge large (Diptera:

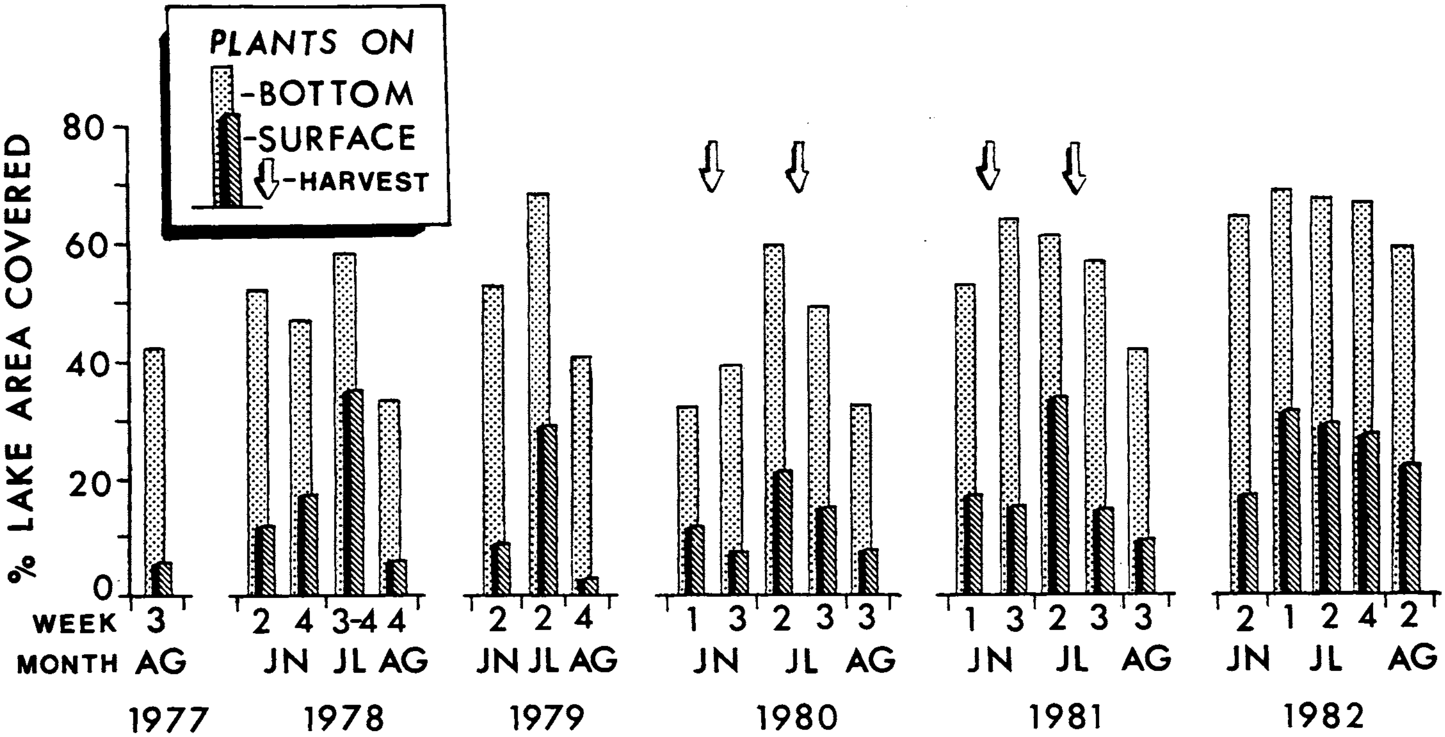

Figure 2. Plant cover, expressed as percent area of water surface and lake bottom occupied by submersed macrophytes. Arrows depict harvesting dates.

Chironomidae and some Ceratopogonidae) comprised over 90% of those lost. Finger-nail clams (Mollusca: *Sphaerium*) and caddisfly larvae (Trichoptera: *Leptocerus* and *Nectopsyche*) were next most commonly removed. Insects alone constituted one-half of all macroinvertebrates harvested.

Harvesting removed about 21,000 fishes in 1980 and 31,000 in 1981 (Table 4). This constituted about one-fourth of all fry in the lake, based on 1978 and 1979 electrofishing surveys (Engel 1985). Over 90% were young-of-the-year, measuring 15 to 60 mm long. The 1980 catch was mostly largemouth bass; the 1981 catch, bluegills and black crappies (*Pomoxis nigromaculatus* [Lesueur]). Some painted turtles (*Chrysemys picta* [Schneider]) also were taken aboard and released.

Whether fishes were removed during harvesting depended on their number, size, and location inshore; thickness of the vegetation; and handling of the harvester. About 20 to 40 times as many fry were harvested in July as in June. Most fry hatched in late May or early June, remained offshore during the June harvests, and congregated inshore before the July harvests. Bluegills spawning in July added more fry inshore. Dense plant beds near spawning grounds attracted the most fry.

About 75% of fishes however escaped harvesting. Many darted toward shore or open water when the harvester approached. Others were swept around the harvester by currents. Small fishes fell off the front conveyor screen as plants were hauled aboard. Yet large ones could swim ahead of the harvester if the plants were sparse. Channels cut across weedy bays in 1981 allowed bass to escape, but resulted in harvesting more crappie fry (Table 4). Electrofishing determined that bass up to 550 mm long used these channels as crusing lanes.

Bass and bluegills fed mainly on macroinvertebrates in the littoral zone during and after harvesting. Both grazed mainly chironomid larvae, but the bass diet was more varied and included larger insects and some fry (Engel 1987). Both fish species were seen devouring insects dislodged during harvesting; bass took them mostly at the

TABLE 3. LIVE MACROINVERTEBRATES REMOVED WITH HARVESTED PLANTS IN 1980.

Macroinvertebrates removed	9-10 JUN	9-10 JUL
Total number (thousands)	3,050	3,170
Total number/kg wet wt plants	530	300
Diptera (%)	50	38
Mollusca (%)	38	49
Trichoptera (%)	3	4
Amphipoda: *Hyalella* (%)	3	3
Acari (%)	3	1
Other insects (%)	3	5

TABLE 4. FISHES REMOVED WITH HARVESTED PLANTS IN 1980 AND 1981.

	1980		1981	
Fishes removed	9-10 JUN	9-10 JUL	9-12 JUN	14-16 JUL
Total number	1,100	20,000	700	30,000
Total number/100 kg wet wt plants	20	190	10	450
Largemouth bass (%)	98	86	0	1
Bluegills (%)	2	13	93	58
Black crappies (%)	1	1	7	41

water surface or on floating mats of pondweeds, while bluegills ate them at the bottom or on attached plants.

Plant harvesting had no immediate effect on phytoplankton. Secchi disk visibility and chlorophyll *a* varied so much among summers before and after harvesting that differences were not significant, based on one-way ANOVA (Table 5). The lake water stayed clear and nearly free of phytoplankton from April to June, when most macrophytes developed (Engel 1988). Then summer blooms of blue-green algae developed, causing mean chlorophyll *a* to climb from 12 to over 40 ug/L and Secchi disk visibility to drop from 3.5 m to as low as 0.5 m. The blooms averaged 24,000 cells/ml (biovolumes, 9 mm^3/L) in August 1977-79, when most pondweeds decayed. *Anabaena* and *Microcystis* constituted 72% by cell number (96% by volume) of these blooms.

Dominance of water stargrass in summers after harvesting seemed to delay and reduce blooms of blue-green algae. This improved water clarity, as indicated by Secchi disk visibilities from 1.7 to 4.4 m in August and September 1982 through 1987.

The major harvesting impacts in Halverson Lake centered on changing macrophyte community composition, removing or dislodging macroinvertebrates and fry, and altering feeding behavior of bass and bluegills. But during summer drought in 1988 water stargrass declined, the narrow-leaved pondweeds returned, and blue-green algae again kept Secchi disk visibility under 0.9 m and chlorophyll *a* above 40 ug/L. Thus the ecological impacts of harvesting macrophytes lasted but a few years.

TABLE 5. SECCHI DISK VISIBILITY, TRICHROMATIC CHLOROPHYLL *A*, AND CELL COUNTS OF BLUE-GREEN ALGAE FROM HALVERSON LAKE IN MID-AUGUST 1977-82.[1]

Sampling year	Secchi disk (m)	Chlorophyll *a* (ug/L)	Blue-green algae (n/L)
1977	0.7	66 ± 25	34
1978	0.6	50 ± 27	32
1979	1.6	31 ± 7	17
1980	0.5	71 ± 35	27
1981	1.5	22 ± 2	18
1982	1.7	40 ± 15	15

[1]For each date Secchi disks are single readings at one site; chlorophylls are averages of four depths (mean ± 1 SE); blue-green algae are single counts from a sample drawn equally from these depths.

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