INTRODUCTION

The shallows of lakes, clear and densely carpeted with summer plants, can be fascinating and mysterious. The confusion of foliage greeting a diver's descent, gives way to thoughtful contemplation of form and function, of habitat and diversity. Panfish dart among **macrophytes*** riddled with colonizing insects and snails. Busy neighborhoods from below the waves become scorned by boaters and swimmers on the water surface.

Underwater macrophytes pose a challenge to lake management. They can grow too dense or too sparse. Dense beds of macroscopic algae, mosses, stoneworts, or vascular plants (angiosperms) can impede boating, fishing, and swimming. Decomposing plants can release noxious odors, litter beaches, and remove dissolved oxygen from the water. Young fishes can grow poorly in dense vegetation, from overgrazing their food, as well as in sparse flora, from a scarcity of habitat for prey.

Attempts to eradicate nuisance vegetation belie their usefulness and relationships with other organisms. Macrophytes support a diverse community of **benthos** (Allee 1912, Krecker 1939, Rosine 1955). By intercepting runoff, storing nutrients, and stabilizing sediments, macrophytes retard algal blooms and improve water clarity (Kofoid 1903, Goulder 1969, Modlin 1970, Kogan 1972). Suddenly removing macrophyte beds could reduce water clarity, force fishes to graze zooplankton offshore, and stimulate phytoplankton blooms from the unstored nutrients and reduced pressure of invertebrate predation. Widespread ecosystem changes can result from unwittingly removing macrophyte beds.

This study aimed to determine how the macrophyte community of a Wisconsin lake (1) is organized, (2) changes seasonally and yearly, and (3) interacts with other biota. The role of submerged macrophytes in other lakes was reviewed to provide managers with a broader base of information relevant to Wisconsin. Field sampling was designed to assess the impact of submerged macrophytes on (1) macroinvertebrate composition and distribution; (2) fish activity, diet, and growth; (3) zooplankton composition and seasonal changes; and (4) phytoplankton blooms, primary productivity, and water clarity. These interactions were further evaluated by harvesting 30-70% of the vegetation midway through the study.

The study originated from widespread concern about underwater macrophytes in lakes, an extensive literature search, and recommendations by management staff in a 1976 Departmental survey (Research Advisory Council Report to the Natural Resources Board, "Programs, Problems and Research Needs in Water Resources Research").

STUDY AREA

Halverson Lake, Iowa County, Wisconsin was selected as a research site because it has extensive vegetation in summer, yet contains no carp (*Cyprinus carpio* L.) that uproot plants and create turbidity, never winterkills, receives little public use, has never been treated with plant or fish toxins, and allows access to a plant harvester (Engel 1979). Absence of these interfering factors would permit the broadest application of research findings.

Halverson Lake was built as a private fish hatchery in 1959 by damming a headwater branch of Mill Creek, a north flowing tributary of the Wisconsin River. It is located in Governor Dodge State Park, in the steep unglaciated driftless area, and drains into Twin Valley Lake. Surrounding ridges tower 14-66 m above the lake surface. The drainage basin of about 250 ha is over 80% covered with woods and grassy fields in secondary succession (Table 1). The fields were pastured and lightly cropped before the lake was built, but are now undeveloped.

Surrounding soils range from poorly drained silty loams (Etrick and some Fayette series) near the lake to more permeable sandy soils (Dubuque and Fayette series) on upland slopes (Klingelhoets 1962). The soils have been eroded from sandstone slopes and limestone bluffs. They are underlain by a bedrock of Cambrian sandstone and Galena dolomite, yielding ground water of moderate but varying hardness. The lake bottom consists of dark organic mud and scattered patches of sand, clay, and marl.

The lake and adjoining wetlands form a ground water discharge unit. Springs upwell on the lake bottom. Two permanent streams arise from upland springs and enter the north end of the lake. Temporary streams flow to the lake after snow melt in March and heavy rains in summer. Wetlands of Type II inland fresh meadows (Shaw and Fredine 1956) and nine upland ponds (less than 0.3 ha) intercept these stream flows. They function as settling basins to reduce lake turbidity. Lake water level is set by a drop inlet structure at the dam (Linde 1969).

TABLE 1. *The Halverson Lake drainage basin.*[a]

Land Use	Area (%)
Woods	48
Dry fields	38
Croplands	5
Wetlands	4
Roads	2
Halverson Lake	1.4
Upland ponds	0.9

[a] Total area = 250 ha.

* All terms defined in the glossary are shown in **bold face** type the first time they are used in the text.

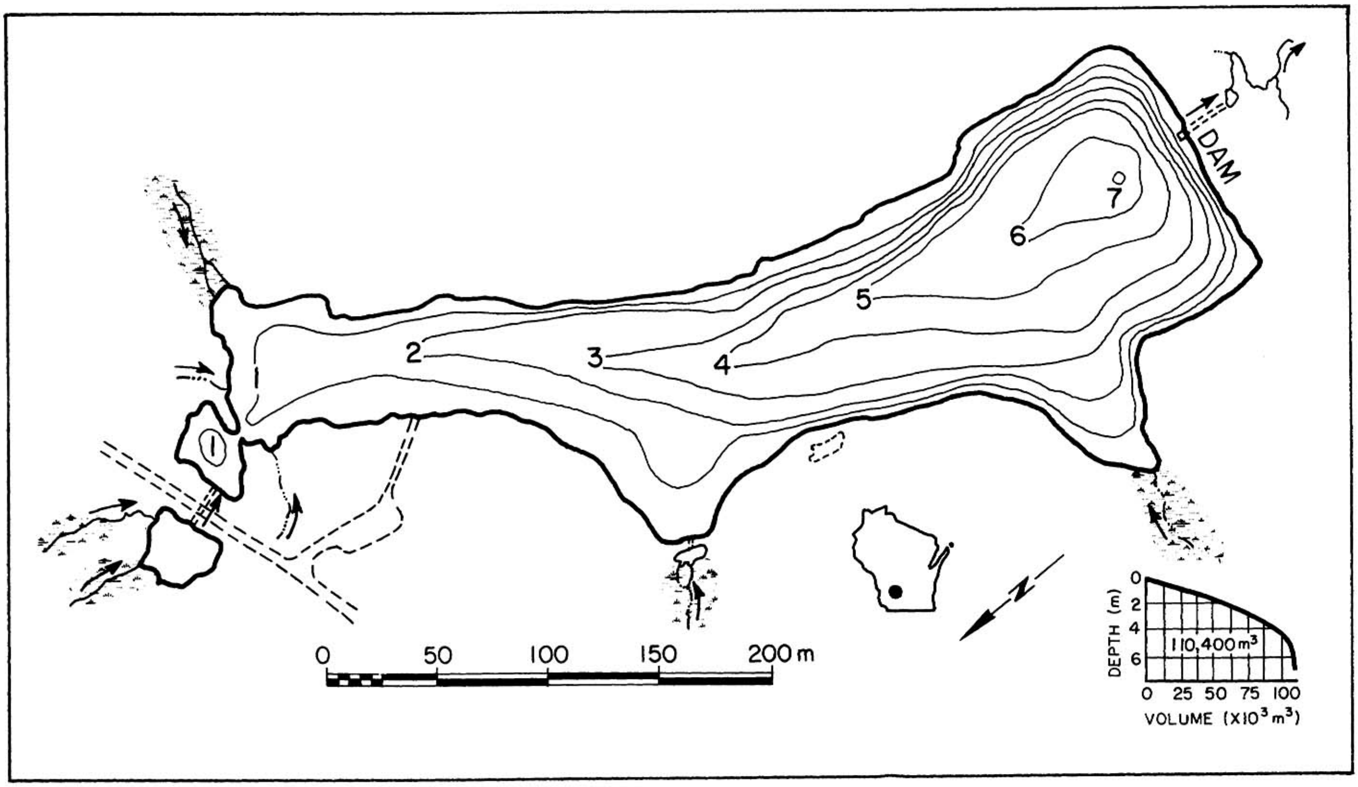

FIGURE 1. *Bathymetric map of Halverson Lake, sounded in 1978 and 1979.*

TABLE 2. *Morphometry of Halverson Lake.*[a]

Parameter	Distance (m)
Shoreline length	1,440
Maximum total length	504
Maximum wind fetch	469
Maximum width	190
Mean width	90
Maximum depth	7
Mean depth	2.6
Relative depth (%)	3.1
Surface area (ha)	4.2
Shoreline development	1.99
Volume development	1.12
Total volume (m^3)	110,400

[a] Terminology and calculations follow Welch (1948).

The lake basin has an elongated dendritic shape, with several shallow bays, reflecting the confluence of former stream channels (Fig. 1). The basin covers 4.2 ha, averages 2.6 m deep, and increases in depth to 7 m before the dam (Table 2). About 45% of the lake volume lies within 1.5 m of the water surface, the depth limit of many plant harvesters. A thermocline forms in summer from 3.5 m to the bottom, leaving 80% of the open water homoiothermal and mixed.

Epilimnetic water has a mean total hardness of 130-190 mg $CaCO_3$/L, total alkalinity of 120-180 mg $CaCO_3$/L, pH of 7.4-8.6, and total phosphorus of 20-60 µg P/L. Dissolved oxygen becomes depleted below 4 m in summer and winter.

Bluegills (*Lepomis macrochirus* Raf.), black crappies (*Pomoxis nigromaculatus* (Lesueur)), and largemouth bass (*Micropterus salmoides* (Lacepède)) were stocked in 1959-60 (M. Halverson, pers. comm.). Motor trolling is prohibited and only battery-powered electric motors are allowed on the lake. Anglers mostly fish from shore. Lake use is discouraged by absence of an improved boat access, remote location of the lake in the 2,000-ha park, and presence of two larger reservoirs nearby for bathing and boating.