Aquatic Plant Problems in Recreational Lakes of Southern Michigan
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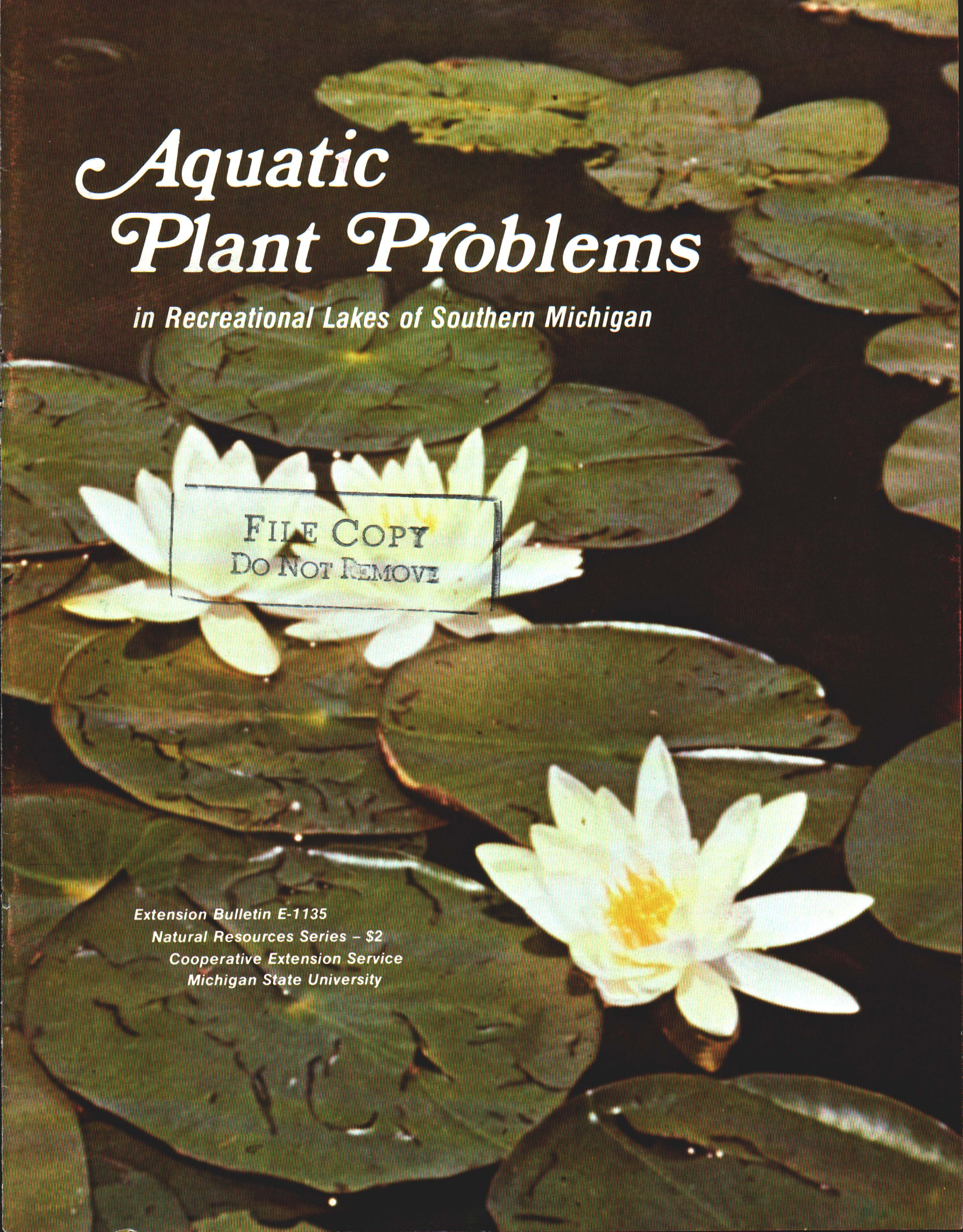

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in Recreational Lakes of Southern Michigan

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By Clarence D. McNabb, Jr.
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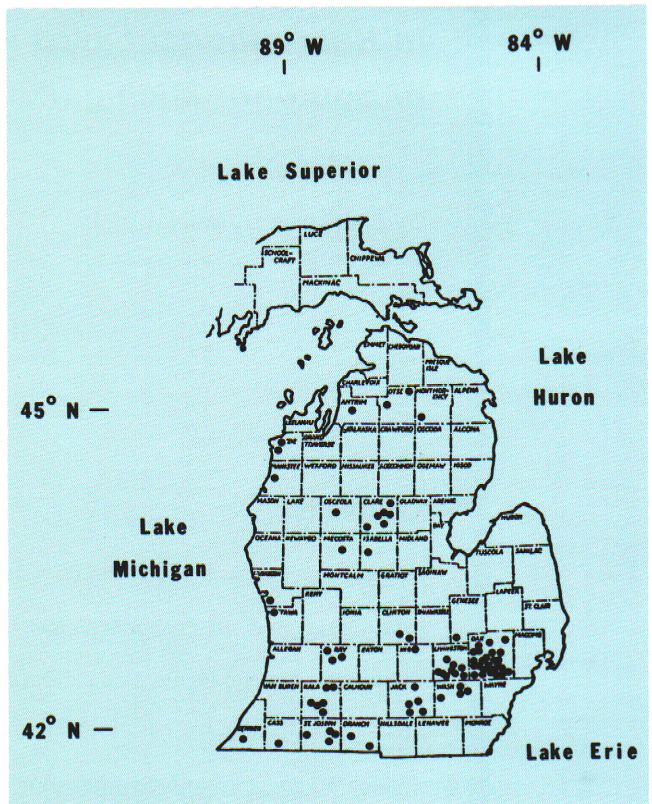
Recreational Lakes in Southern Michigan: The Physical Setting

THIS PUBLICATION is intended to acquaint Michigan citizens with nuisance aquatic plant conditions and their causes. It results from a study of southern Michigan lakes which have had household development on the shoreline for several decades. Many years earlier, the land had been cleared and farmed, changing the rate of nutrient runoff to the lakes. Pristine lakes, in the proper meaning of the term, do not exist in the region. However, there are broad differences in types and amount of plants among these lakes. In some, the plant aggregations have undoubtedly been modified by decades of in-lake weed management.

Nevertheless, from observations of the dominant plant groups in a large number of these lakes, we can recognize recurring patterns of plant association. This suggests common processes are controlling the development of these self-organizing plant communities. The patterns and processes are described in this bulletin.

The descriptions may change over time, as our views are modified by new knowledge from field and laboratory. No attempt should be made to apply these generalities to lakes other than those of the glacial moraines of the southern Michigan region.

After studying this publication, you should be familiar with the types of aquatic plants that, under the right conditions, can reduce the aesthetic and recreational value of the lakes. The text and pictures will help you interpret the plant associations in a lake in relation to the abundance of nutrients in the basin. The specific manner in which various plants grow, and the relationships between the plants and animals, are considered in the hope that this information will be useful for selecting the most appropriate controls of nuisance plant situations.



The Michigan lakes analyzed in this report occupy basins in calcareous (limestone) moraines. They are hard-water lakes with varying patterns of lake use in their watersheds. Year-round residences are developed on the shores, and recreation in varying intensity is their prime use.

Minerals essential to plant growth come to a lake from the land. In the past, native forest vegetation tended to keep these elements on the land or allow them to leach into lake basins only slowly. Human activities cause nutrients to come off this land faster than from undeveloped land. Plant species respond differently to the abundance of these elements. Therefore, shoreline and watershed practices determine, to a large extent, the dominant plants in the community and their density.

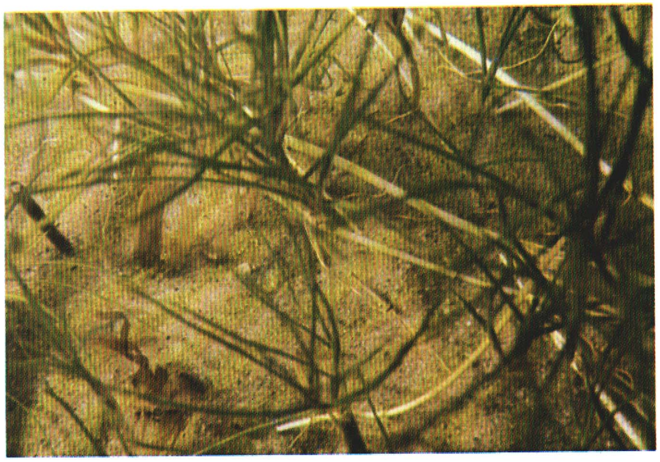
For recreational use, low to moderate plant density is considered most desirable. Some lakes in this region are nutrient-poor compared to others. In these, plants grow scattered in clumps or tufts attached to the bottom in clear water. This presumably represents an earlier condition when the rate of nutrients added over the year from protected forest or grassland watersheds was not enough to allow luxuriant growth of rooted or free-floating plants.

Native (North American) Vegetation: Its Response to Nutrient Enrichment

Chara is a common plant in nutrient-poor environments. It is short (6 to 8 inches) and grows in scattered tufts or clumps. This clump is approximately 15 cm (6 inches) high. *Chara's* structure is simple, and its plant cells are much alike. It does not have true leaves and roots. This feature, combined with its reproductive mode (without flowers and seed), classifies it as an alga. Whorls of leaf-like parts come off an upright central column of tissue.

In the water, *Chara* has a brown cast which can be seen from a distance on a calm, clear-water lake. To identify *Chara*, remove a handful and check it for its distinctive smell. Other submersed aquatic plants ordinarily have no musty odor.

A broad array of plants with true leaves, stems and roots grows with *Chara* in the relatively nutrient-poor lakes.
They can form flowers and set seed. Like *Chara*, they grow in isolated patches without abundant nutrients. They tend to be short and frequently do not set seed. Under nutrient-poor conditions they are stunted and have low density. They can grow several feet long under richer nutrient conditions. (The intervals on the scale are 5 cm or approximately 2 inches.)



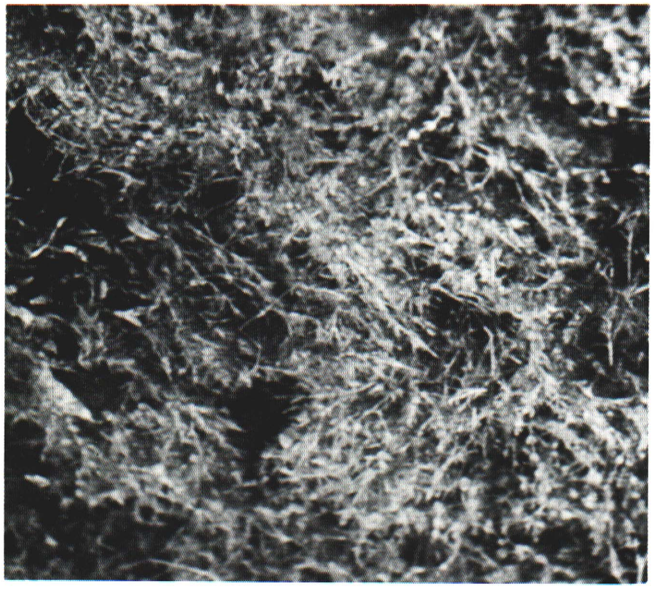
The spread of these plants depends upon the growth of runners much like those of the strawberry plant. Periodically, an upright stem with leaves is produced along the runner.

When nutrients are not abundant, the runners grow slowly, and the upright shoots are widely spaced. As nutrients become more available, density of the community and the vigor of the shoots increase.

When nutrients are plentiful, seed is set, thus increasing the potential abundance of the plants in the next growing season.

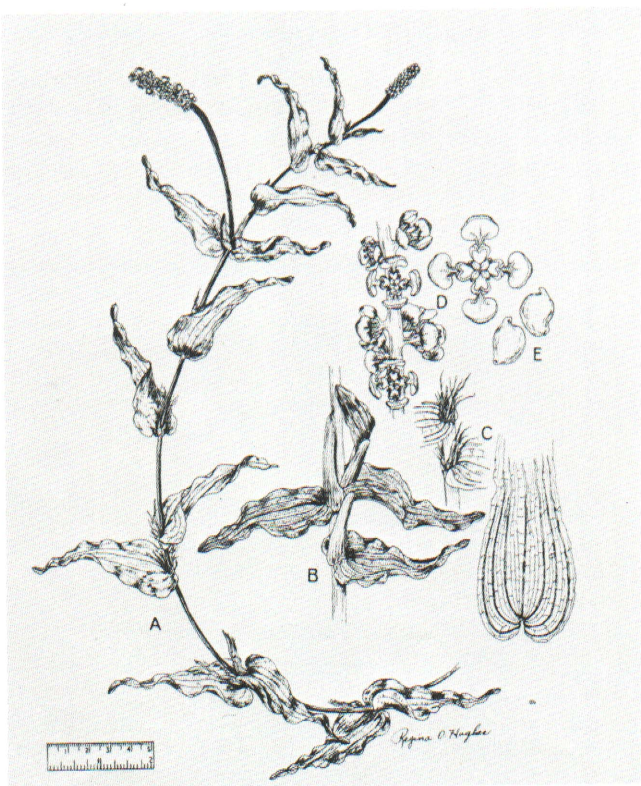
In summary, in the absence of high rates of nutrient input, these lakes have clear water (little plankton and detritus) and a low-vigor, low-density plant community. Plants attached to the bottom grow in the shallows to depths where adequate light is available. Chara is commonly present in this community, growing with a large variety of seed plants.

Phosphorus and nitrogen are the nutrients most likely to be limiting in lakes of this region. These are washed off the land in solution; phosphorus is also carried into lakes attached to clay particles coming from eroded soil areas. Both nutrients are deposited also from the atmosphere when dust particles fall out or precipitation washes the air. Atmospheric additions have increased in recent decades as various industrial and agricultural practices have enriched the air. Plants respond to the increased supply of nutrients by growing abundantly. This is **the first stage response** to nutrient enrichment of the lakes.

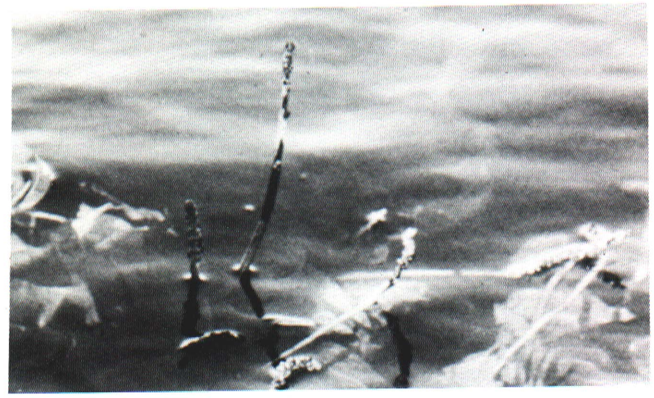


Short, isolated clumps of *Chara* grow into solid carpets of algae. The plants do not die all the way back in winter. Each season new growth starts higher and higher in the water. As the bases of the plants are buried by growth, they die and partially decompose. The thickness of the carpet grows deeper each year. In some lakes, growth has filled the water to a depth 2 to 3 m (6 to 9 feet) with a wiry tangle of *Chara* at the surface and organic remains below. While the lake water remains relatively clear, much of the surface area can be lost to recreational use by prodigious *Chara* growth.

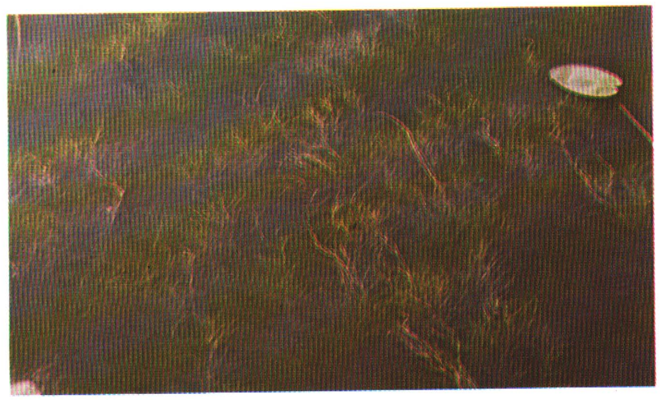
Native seed-bearing plants also grow into dense "forest-like" stands that fill the water. Where short and scattered plants with relatively little seed production previously occurred, now tall, lush seed-producing plants grow on the fertilizer supplied to them. This native pondweed is common in the early stages of increased nutrient addition to lakes.



Plants of this type are commonly called broad-leafed pondweeds (species of *Potamogeton; P. richardsonii* shown here). Roots attach the plants to the bottom. Runners are common. Broad-bladed leaves come off of the stem, and flowers and seeds are most frequently produced at the tip. These broad-leafed plants (with many species in this group) may grow abundantly in relatively clear water. If algae growth cuts light penetration, these broad-leafed pondweeds will not persist as do some other species of rooted plants.

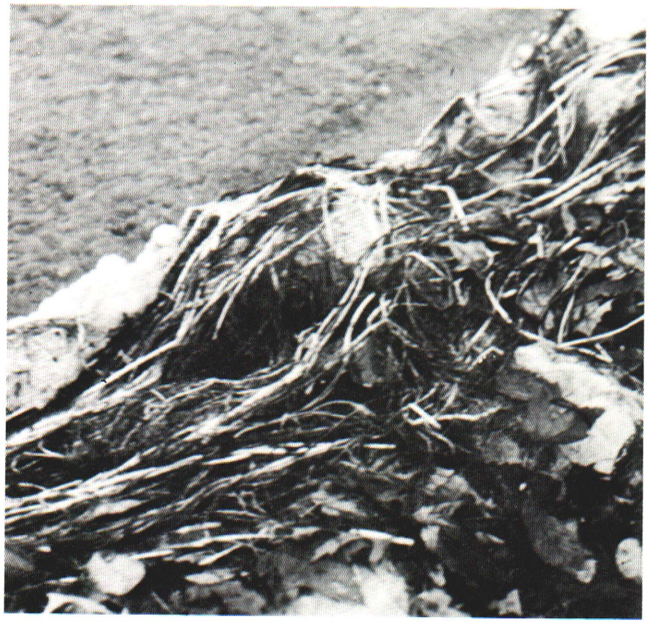


The large-leafed pondweed, *Potamogeton amplifolius,* is a typical member of this group.



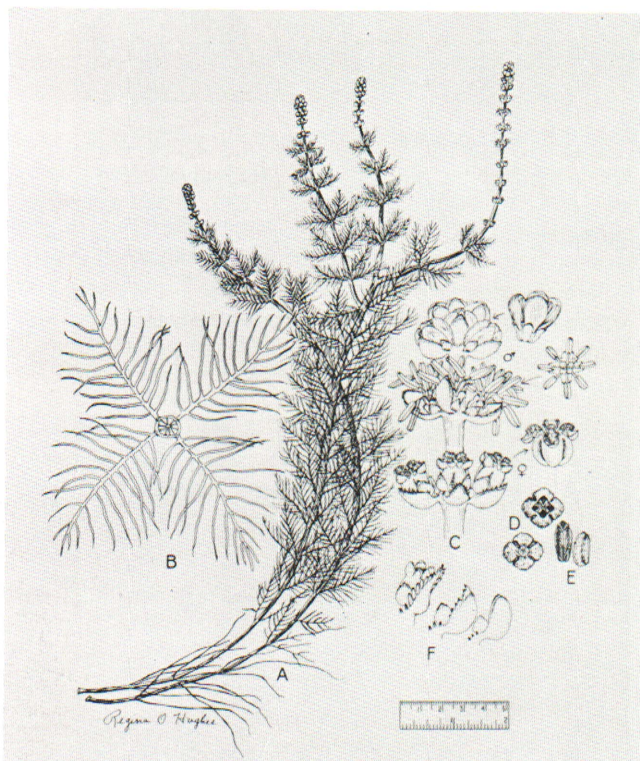
Not all seed-producing plants that respond to early nutrient enrichment have broad leaves. Some have slender leaves; these are the thin-leafed pondweeds (species of *Potamogeton*). They grow mixed with *Chara* and the pondweeds of the previous group, reaching high density with nutrient enrichment. As a group, the thin-leafed pondweeds tend to persist longer than the broad-leafed pondweeds as light penetration is diminished by an increase in suspended materials. Sago pondweed *(Potamogeton pectinatus)* is a common native North American plant.

Notice how slender sago pondweed leaves are. The plant runners are large and succulent, and tubers are produced along the



runner. These succulent parts are preferred by ducks as food during migration.

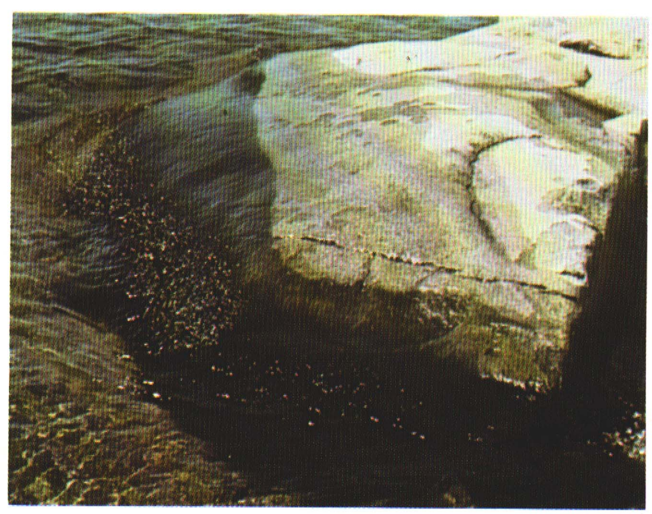
Diving ducks tear up beds of this plant, and windrows of sago pondweed are common in the fall along shorelines.



A number of seed-bearing submersed aquatic plants growing with *Chara* in the mixed flora of relatively nutrient-poor lakes are neither broad-leafed nor thinned-leafed pondweeds (not in the genus *Potamogeton*). Examples are native North American water milfoils *(Myriophyllum spicatum* var. *exalbescens* is shown). The leaf and the leaf arrangement differ from the pondweeds. A European water milfoil has become a principal weed in lakes of our region. It is important to distinguish the native plants from the invader. Native water milfoils tend to have 12 or fewer pairs of leaf subdivisions, while the European plant has 14 to 21 pairs. The water milfoils produce flowers and seeds at their tips.

Native water milfoils expand with the rest of the aquatic plant community as a first sign of excessive nutrient enrichment. Like the others, it can help fill the well-lighted shallows with vegetation, making those portions of the lake less useable for swimming, boating and fishing.

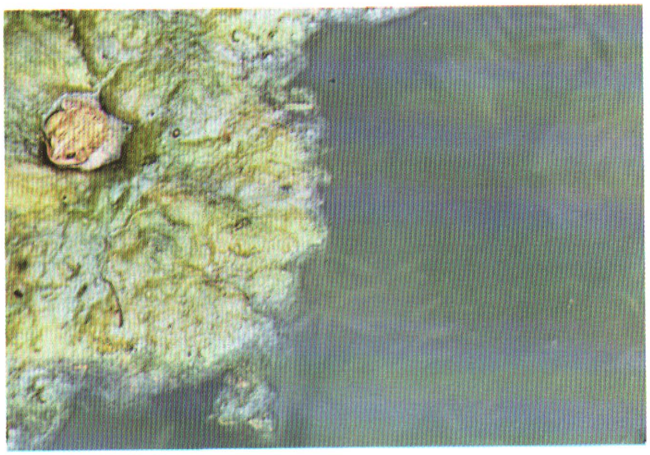
In summary, the first response in the lake plant community to accelerated nutrient input is an increase in the density of the annual crop of Chara and its companion seed-bearing plants. This expanding flora is diverse in species. The seed-bearing plants can be grouped as broad-leafed pondweeds, thin-leafed pondweeds and those others from other taxonomic groups.



In the **second stage response** of aquatic plants to continuing nutrient enrichment, filamentous algae move toward dominance. These algae are called **filamentous** because of their fine, thread-like parts. They are present in nutrient-poor lakes but are generally not noticed because of their low density. As the supply of nutrients becomes adequate for expansion of the *Chara*-rooted plant aggregations, the filamentous algae begin to grow luxuriantly on rocks, piers and other solid objects along the shoreline.

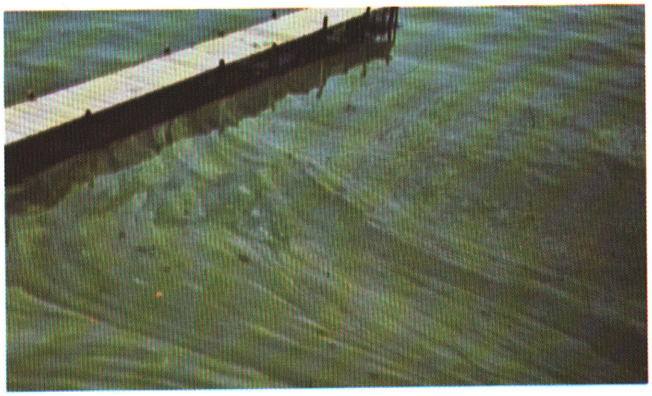
On occasion, they break loose and float about as patches of greenish-brown scum. Notice the difference in water clarity in these two pictures. Filamentous algae begin to expand in relatively clear lakes. They persist, as well, in lakes clouded with free-floating algae.

Filamentous algae also grow in association with rooted aquatic plants in lake shallows when nutrients are sufficiently abundant. Here the thread-like filaments begin to grow along the surface of the sediments between the rooted plants early in the summer. As growth continues, light greenish "clouds" of this material appear beneath the surface. These "clouds" of algae eventually surface and over-lay the rooted plants. Decomposition turns them greenish-brown.



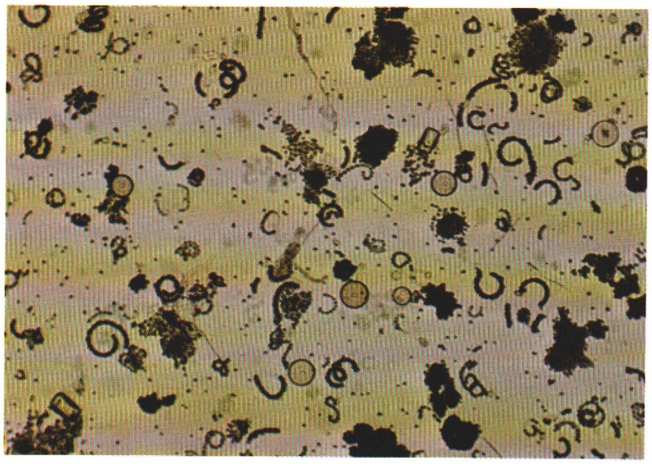
This material floats because gas bubbles accumulate within the mass of filaments. Overgrown rooted plants are shaded out by these algae.

*Early in the **second stage response** of abundant development of filamentous algae, the water of the lake may remain relatively clear. However, at the point of nutrient enrichment where the Chara-rooted plant aggregation has reached its maximum density and is being overgrown with filamentous algae, recreational use of the lakes is already in jeopardy. A continuing high rate of nutrients added from the watershed will eventually push these relatively clear-water lakes into the third stage response of aquatic plants to excess enrichment.*



In the third stage, abundant microscopic algae (phytoplankton) float freely in the water. During the summer these algae turn the lake water green and severely impede recreational and water supply (domestic and industrial) use. Since the larger aquatic plants and the filamentous algae discussed earlier begin their growth along the bottom, the shading effect of the free-floating microscopic algae puts those plant groups at a competitive disadvantage. In particular, *Chara* and the broad-leafed pondweeds at this stage are no longer the principal components of the vegetation. Vigor of the thin-leafed pondweeds is reduced, and only two or three native flowering species are able to persist in abundance. When the surface of a heavily enriched lake is quiet, most commonly at night, the buoyant microscopic algae float to the surface. They can be seen in the morning as accumulations along shorelines.

These scums have a blue-green cast because of pigments in the cells of the microscopic algae. The algae receive their common name, **blue-greens,** from this feature. This group is particularly buoyant because small gas bubbles accumulate in the cells. Therefore, the plant material tends to decompose at the surface rather than at the bottom. Blue-green cells have a high protein content, and the decay of this protein material gives rise to offensive odors similar to those of rotting animal materials. If the algae could sink and decompose along the bottom of the lake, their odors would be less pronounced and their presence less obnoxious.



Blue-greens look like this seen under the microscope magnified about 100 times. The darker-colored bodies *(Microcystis* and *Anabaena)* are various species of blue-green algae that are distinguished from one another by their shape. The brownish bodies are cells of another type of algae called diatoms. *(Stephanodiscus* is the circular, brownish form). These occur commonly with the blue-green algae under extreme nutrient enrichment.

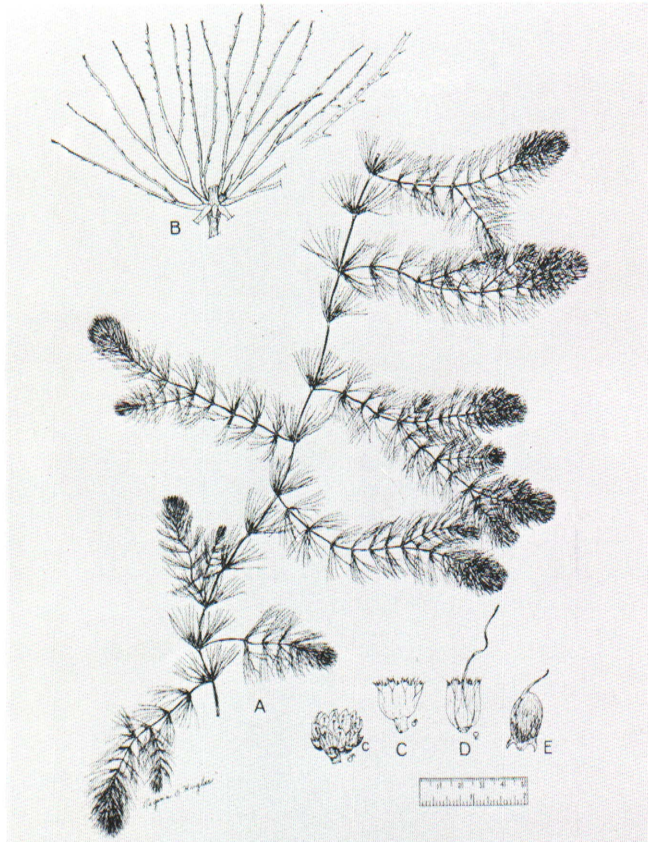
The end-point of plant response to enrichment in these lakes is a basin filled with greenish murky water ***(the third stage response).*** *Only a few species of the larger leafy plants can persist with these so-called "blooms" of microscopic algae.*

Elodea *(Elodea canadensis)* is one plant that can usually be extracted from murky water. Its occurrence in large monotypic stands (containing only elodea) that dominate the rooted-plant flora of the lakes indicates a luxuriant level of nutrients.

Elodea can occur as a bushy growth that fills the available space in the water. It produces flowers of each sex on a separate individual. Patches of vegetation are frequently of one sex or another. The plants of a particular lake may be all one sex. Therefore, since seed production cannot occur, this plant depends strongly upon the survival of vegetative parts between years.

At the end of the growing season, elodea tends to sink to the bottom where the previous year's stems lie horizontal and may be covered over in the shifting of the bottom sediments. In the spring, new buds come up from these old stems and branch profusely to give rise again to abundant vegetation.

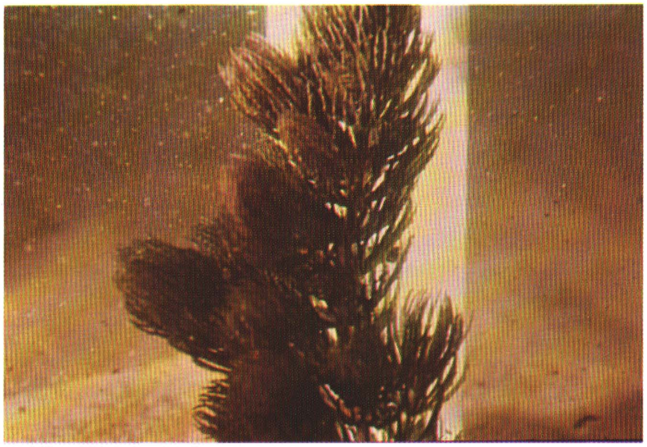
Since elodea dominance indicates excess nutrients, it is helpful to identify the plant *(Elodea canadensis)* by its appearance. The leaves are relatively broad, in whorls of three, and tend to be recurved.



Coontail *(Ceratophyllum demersum)* grows with elodea in nutrient-rich lakes. Its common name describes the appearance of its growing tips. The plant has whorls of narrow leaves along its stem, arranged somewhat like those of *Chara* and the water milfoils. It differs from them by the presence of small teeth on the leaves, shown in the upper left. Like elodea, abundant coontail indicates an abundant nutrient supply.

Under these conditions, coontail can develop into very dense stands. The plant does not grow roots, unlike other submersed flowering plants. In late fall, stems and leaves produced in a season settle to the bottom where the stems are covered by shifting sediments. This layer of sediments serves as a weak anchor in the next growing season. If wind conditions are suitable, a mass of vegetation can pull from the bottom and a floating mat of coontail can be blown freely about the lake.

Note the general features of an individual plant. When growing in a light-poor environment, which it does exceptionally well, the stem is elongated between whorls of leaves. Bushy branching occurs as the plant reaches the zone of good light near the surface. In that zone, the leaves produce food for further growth of upper plant parts. Food is not moved downward to support a root system, as it must be for plants such as pondweeds and elodea.

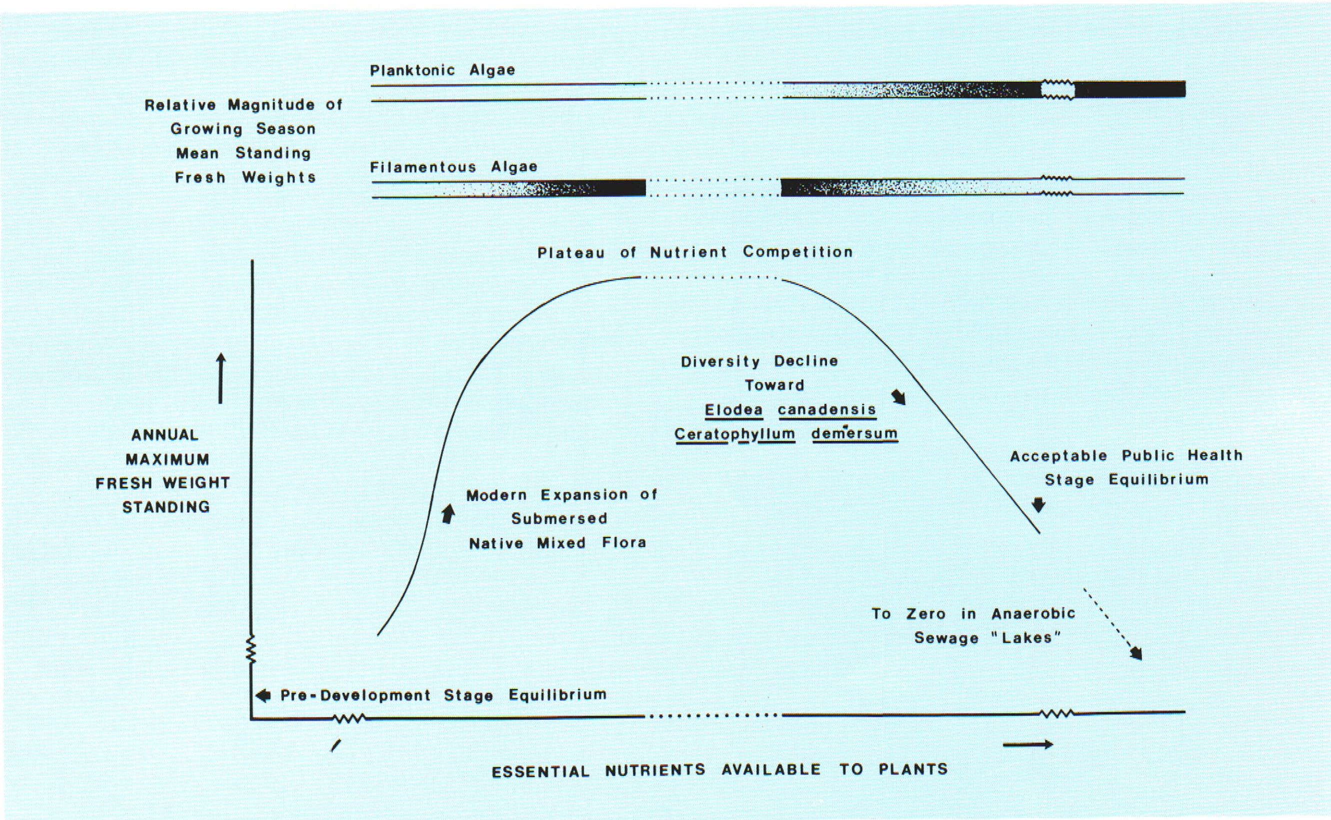


An abundance of coontail (like elodea) indicates abundant nutrients in a lake. These two plants dominate portions of Michigan's sewage lagoon systems. Coontail and elodea occur very commonly in channels dredged in marshy portions of the lakes to provide additional waterfront footage for residential development. Materials needed for the growth of these particular plants are made available by the dredging.

Another member of the plant community in nutrient-rich waters is the plant with the smallest of flowers — commonly called duckweed because waterfowl feed heavily upon it. Individual plants are very small. Compare their size with the oak leaf floating among the duckweed. Although duckweed may have roots, it is not attached to the bottom and floats freely, frequently pushed about by the wind. (Species of *Lemna, Wolffia* and *Spirodela* are common).

The finger tip in this picture provides further appreciation of the size of the plant. From a distance, it is commonly confused with microscopic algae scums or floating mats of filamentous algae. It can be distinguished from them by its lime-green color when growing well, its small leaves, or its mealy character when rolled in the hand. Duckweed requires a quiet, wave-free surface on which to grow. It may become a considerable problem in sheltered, weed-choked embayments. Abundant submerged plants tend to quiet the water surface, thus allowing duckweed to expand and compound the obnoxious state of heavily enriched recreational lake waters.

The end-point in this sequence of plant responses to continuing nutrient enrichment is a lake in which the water in the warmer months is clouded by microscopic blue-green algae and associated diatoms. Only a few species of native flowering plants will grow from the bottom in this murky water. As these grow, they tend to become overlain with mats of filamentous algae and duckweed. Partial decomposition of this mass causes a build-up of organic materials in the sediments. The bottom along formerly sandy shores becomes soft and mucky. Recreational uses of the lake are all but obliterated.



This graph summarizes the sequence of plant development in the lakes. Portions of the model are likely to be modified, and other portions strengthened in the years ahead. The principle points are:

A. The vertical axis of the graph reflects increasing nuisance density of macrophytes (large aquatic plants, not microscopic or filamentous algae) going upward on the axis.

B. On the horizontal axis, available nutrients increase to the right.

C. In the lower left-corner, the arrow and label imply plant growth in the lakes was low prior to modern development of surrounding land. The amount of nutrients available to the plants was low and growth-limiting. Lakes were in a stage of low and relatively constant annual production of plants.

D. The rising portion of the curve implies an expansion of the *Chara*-rooted plant aggregations **(first stage response)** native to the lakes with an increase in available nutrients. Human uses of the watersheds (farm, industrial, municipal) make elements of the land more available in the lakes throughout the growing season than in the past.

E. A plateau is reached at the top of this curve when environmental conditions other than nutrients (e.g., space and light) limit growth of the submersed macrophytes.

F. Density bars at to the top of the figure, are presented for the free-floating microscopic algae (planktonic) and filamentous algae. Greater abundance is implied by increasing density along the bars. Compare these bars to the curve just considered. The implication is that filamentous algae **(second stage response)** reach their maximum mean annual crop as the submersed plant flora levels off at its maximum. Further, filamentous algae and submersed plants, together at their maximum growth, take up the available nutrients and hold in check the mean growing season density of planktonic algae.

G. There is an important implication for submersed weed control in the left portion of the figure. At the available nutrient levels involved, eliminating the submersed plant community with herbicides specific for this group, will favor expansion of the filamentous algae, rather than planktonic algae, as the algae compete for nutrients that are suddenly made available by death of the submersed plants.

H. The horizontal dotted lines in portions of the figure imply that this nutrient competition will persist and hold the planktonic algae in check across a narrow or broad range of available nutrients depending upon the peculiarities of particular watersheds and lake basins.

I. The figure implies that sudden elimination of submersed weeds by the use of herbicides will more strongly favor subsequent expansion of the planktonic algae as we move to the right and continue off the plateau of submersed plant development.

J. An additional prediction about recent weed control practices concerns the aesthetic benefit of cutting and harvesting submersed plants. This practice can keep the weed crop in a state of rapid growth throughout the summer season. Cutting will best depress planktonic algae density when it is applied at the right side of the plateau of nutrient competition.

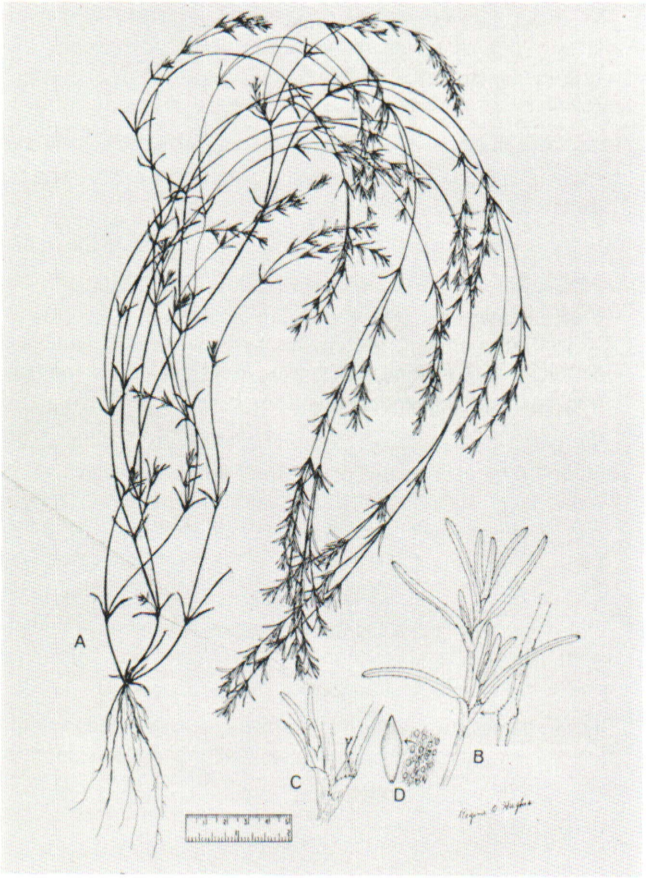
K. Move to the right-hand side of the figure. As nutrients become available in excess of the amounts used by maximum crops of submersed plants and associated filamentous algae, the planktonic algae become more dense in the water **(third stage response).** Partial decomposition of submersed plants and filamentous algae, year to year, also adds suspended organic fragments to the circulating water. As light conditions become poor, the annual maximum crop of filamentous algae and submersed flowering plants declines. The originally diverse submersed plant flora is replaced by those few species that cope well with the conditions of excessive enrichment.

L. For recreational lakes, there comes a point on the curve where nutrient enrichment will lead to conditions unacceptable by public health standards. Presumably at this point, public demand will regulate nutrient input to the lakes. This could result in a new stage of equilibrium of plant production, one quite different from the original. Alternatively, if nutrient addition is limited to a rate lower than that for minimum protection of public health, this lower rate may lead to partial lake recovery.

M. Finally, maximum enrichment of the type received in recreational lakes is observed also in pond systems constructed in our region to treat municipal wastewater. The figure shows maximum growing season mean standing crops of planktonic algae in these ponds as shown. In the most heavily enriched ponds, prolonged periods without oxygen (because of rapid use in organic decomposition) prevent the growth of submersed macrophytes. While roots of these plants frequently persist in sediments without oxygen, non-specialized (not special tissues for resting stage or over-wintering) stems and leaves of the plants die without oxygen. This model is modified in the lakes in important ways that are discussed in the following section.

Submersed Aquatic Plants: Special Cases

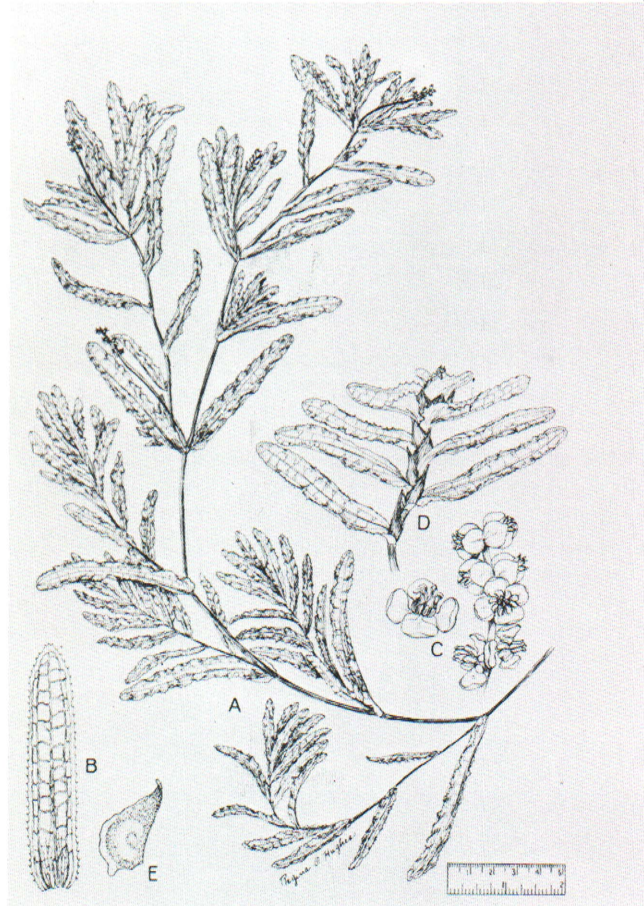
A few of the submersed aquatic plants that become abundant within the general scheme presented above deserve special comment. Each of these plants can grow to nuisance density and be a weed problem. The first, *Najas flexilis,* is sometimes confused with elodea. Both have whorls of leaves spaced along the stem but the leaves of *Najas,* unlike elodea, clasp the stem at their base and tend to be more slender. When growing well, this plant produces abundant seed. The seed pods are tucked down in the space between a leaf and the stem.



Note the protrusion on the *Najas* seed pod in the lower left portion of the vegetation. The spacing on the backdrop is in units of 2 cm, or somewhat less than an inch. *N. flexilis*, *N. guadalupensis* and *N. marina* are the most abundant species in that order. *Najas* is unusual among native species of submersed

aquatic plants because it is an annual plant and depends on annual seed germination rather than growth from over-wintering roots, rhizomes, tubers, buds or stems. Perhaps this is why bushy nuisance stands of *Najas* tend to appear later in the growing season than most nuisance plants. In particular, seeds of the previous year tend to escape herbicide treatment in weed beds. Delayed germination of these seeds may cause what appears to be a weed regrowth in late July through August. *N. flexilis* (shown here) is one of the most widely distributed species. It is found across the range of conditions described in Graph 1.

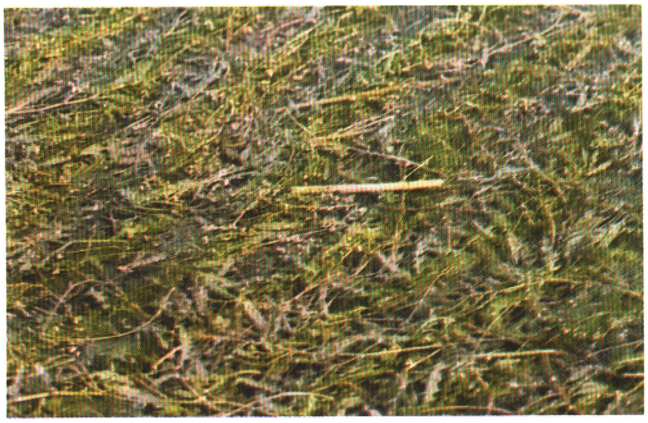
Non-native plant species have become major weed problems when transplanted from their normal range to new environments with different competitive conditions. A major nuisance plant is the curly-leafed pondweed *(Potamogeton crispus)*. It was introduced from Europe into eastern North America before 1814. Another is eurasian water milfoil *(Myriophyllum spicatum)*, introduced in North America in this century. Both occupy extensive acreage in the lakes.



Curly-leafed pondweed *(P. crispus* shown here) has many close relatives in North America. They fall in the category of broad-leafed pondweeds. The principal feature of this plant is the crinkled (or wavy) margins of the alternately placed leaves. Seeds are produced above the water at the tip of the shoot as they are in many native pondweeds.

Although the green chlorophylls are present in the leaves of this plant, they tend to be masked by reddish pigments. This is not unusual in the broad-leafed pondweeds as a group.

Like native plants that achieve high density with abundant nutrients, curly-leafed pondweed can fill the water out from shore to a depth of 4 to 5 feet. Unlike *Najas,* this plant tends to grow from



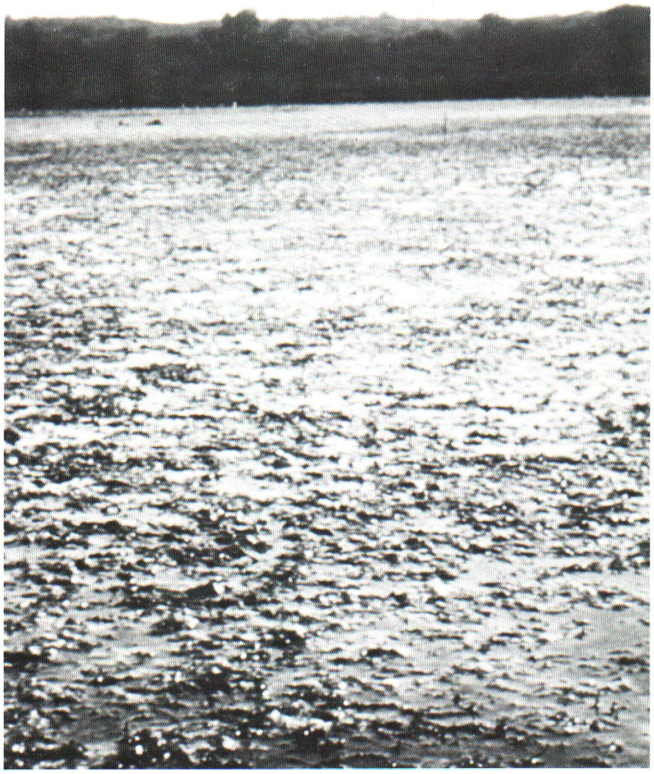
vegetative parts. It appears early in the growing season and most often achieves its maximum density by early June. Notice the distinctive curled margin of the leaf. A further distinguishing feature of this plant is its habit of producing short woody branches along the stem when vegetation reaches maturity.

Close-up, these short woody branches look like this. These structures measure 2 to 5 cm across (3 inches or so) and break away from the parent plant after being produced. They fall into the sediments directly or are carried about a lake by currents before settling. The darkened central column of this structure, unlike the rest of the mature plant, is very hard and woody. The leaves shown here disintegrate in the sediments, leaving the central column to give rise to new roots and stems at some later time, often the next growing season.

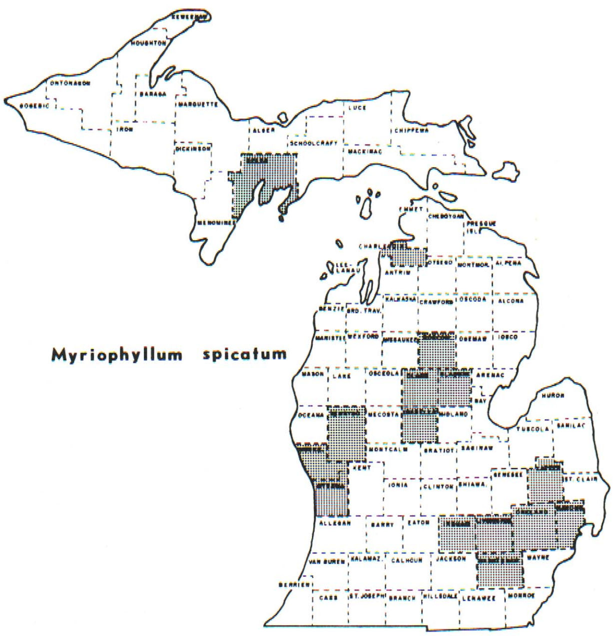
Curly-leafed pondweed is widely distributed in Michigan lakes. It grows side-by-side with native North American flora in moderately enriched lakes. As lakes become excessively enriched and tend toward high density blooms of microscopic algae, curly-leafed pondweed persists in the rooted aquatic plant flora longer than native broad-leafed species. In fact, it is frequently found as a co-dominant with native species that persist longest as the microscopic algae turn a lake green (namely, *Elodea canadensis, Ceratophyllum demersum,* and *Najas flexilis)*.

A more recent introduction that has a severe impact on our native aquatic flora is eurasian water milfoil. This invader, like curly-leafed pondweed, has close relatives in the native North American aquatic flora, but differs from them and other aquatic species in important ecological ways. Native submersed plants are relatively short (1 to 2 m or 3 to 6 feet). Eurasian water milfoil will reach the surface of the lake while rooted in the bottom at substantially greater depths (4 m or 11 to 13 feet). When this plant is present, the weed zone in a lake can be extended outward from the shore, rendering additional surface acreage over deeper water useless for recreation. Additionally, unlike native curly-leafed pondweed, this introduced species tends not to grow mixed with the native flora, but replaces it by overgrowth. In relatively nutrient-poor lakes, it can significantly reduce the diversity of the common plant types present. Since it is a major weed problem in the lakes of southern Michigan, learn to recognize it. It has whorls of feathery leaves spaced regularly along the stem. Flowers and seed are produced on reddish stem-tips that protrude above the surface of the water. The plant can be distinguished from native water milfoils by more delicate-appearing leaves. This is caused by greater subdivision of the leaf parts. There are 14 to 21 pairs of leaf parts along the central axis of the leaf. Native water milfoils have 6 to 12 pairs.

Features of the leaf can be distinguished in this underwater close-up.



The ability of this plant to dominate the flora as a weed can be appreciated here. Keep in mind that because it is able to grow to the surface in deeper water than native vegetation, it may substantially increase the surface area choked with vegetation, destroying boating and water skiing areas.



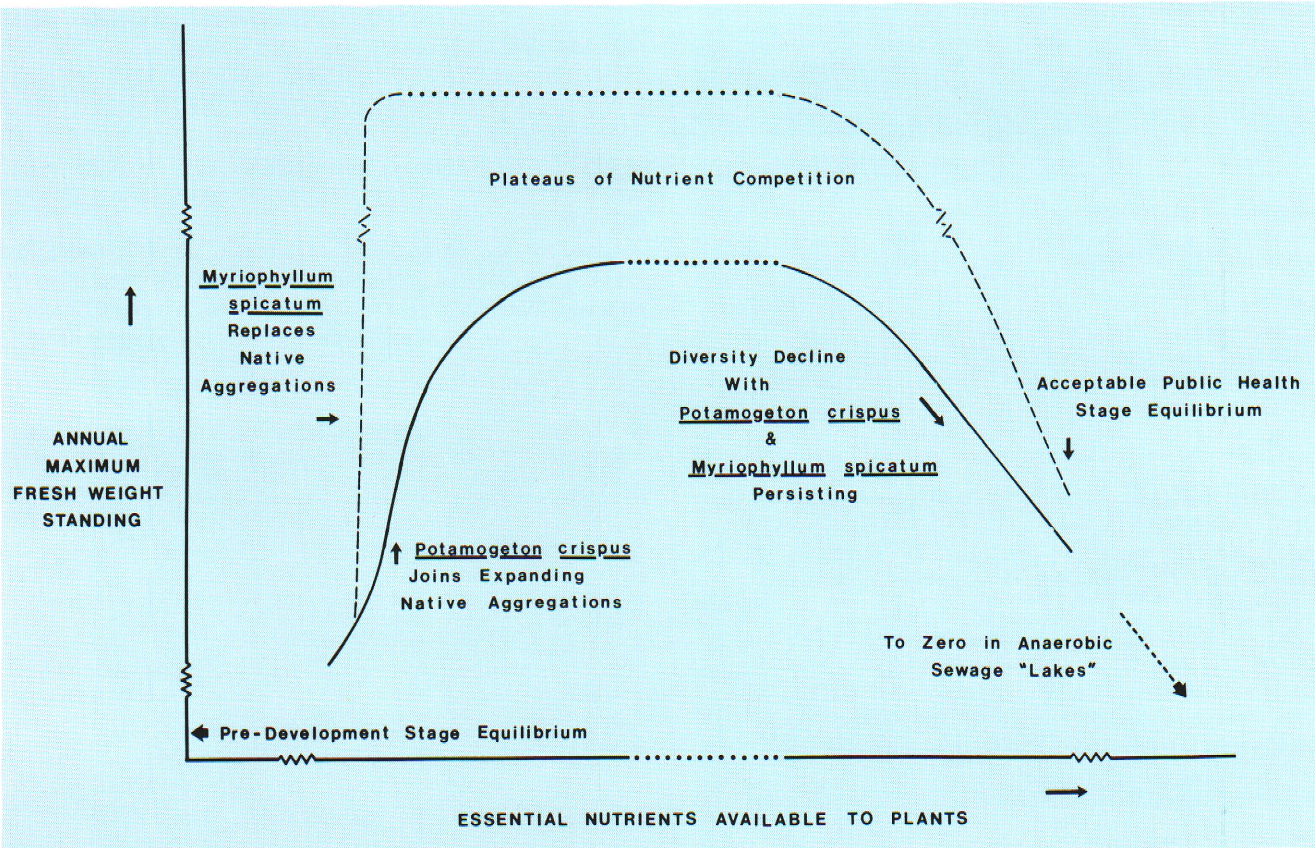
The first confirmed record of its occurrence in Michigan was made in 1965. By 1973, lakes in counties shown here had high density stands. It is now generally distributed throughout the lower peninsula of Michigan.

Eurasian water milfoil was first collected in the Chesapeake Bay region in 1902. It became a nuisance there late in the 1950s. In 1960, approximately 20,000 hectres (50,000 acres) of tide water in the bay were overgrown. Three years later it covered nearly 80,000 hectares (200,000 acres). After 1950, the plant had begun to spread to other areas. It came westward along the waterways of the Hudson River, and then through the Great Lakes, reaching Michigan about 1960.

The plant can be spread from place to place as undigested seeds in the droppings of waterfowl. However, transport of sprigs on boats, motors and boat trailers appears to be a principal means of spreading. Its initial infestation on lakes is frequently noted at marinas and boat landings.

If this plant is recognized at an early stage of infestation, the control alternatives are much different from those following its rapid expansion. A single plant looks harmless enough, but the species can severely alter the ecological state of a lake. It is important to get to know this plant. Note, again, the characteristic red color of the upper stem and the character of the leaves (whorled with 14 to 21 segments along each side of the central axis).

Eurasian water milfoil will expand to a maximum density in the recreational lakes of southern Michigan that are relatively nutrient-poor. It will replace native vegetation by over-growth. It will persist across the range of moderate and excessive nutrient enrichment, being a major component of the relatively sparse rooted vegetation in lakes dominated by microscopic planktonic algae.



This graph shows the interplay of the native flora and exotic species. Graph No. 1 is modified in that:

A. Eurasian water milfoil *(Myriophyllum spicatum)* can invade and persist as a weed in recreational lakes at nearly all nutrient levels occupied by the native vegetation.

B. In lakes where it reaches optimum growth, it tends to replace the diverse *Chara*-rooted plant aggregations.

C. In such lakes, the annual maximum crop of eurasian water milfoil is greater at the plateau of growth than the maximum crop of native vegetation. This plant not only fills the shallows with vegetation but the deeper portions of the basin as well. As the deeper portions of a basin are filled by growth, nutrients are extracted from sediments (as well as from water) not formerly tapped by rooted plants; that is — this species uses available nutrients not used by the native vegetation, and thus, can potentially achieve a higher maximum crop in a basin.

D. In lakes where macrophyte flora is dominated by a maximum crop of eurasian water milfoil, the algae face intensified competition for nutrients. The increase in mean standing crops of filamentous and planktonic algae shown in Graph 1 tends to be displaced to the right.

E. The weed control comments made earlier for Graph 1 generally hold for nuisance-density eurasian water milfoil. Most large-scale cutting and harvesting programs in the upper Great Lakes region are conducted on *M. spicatum*. Deep water development of this species makes this control method more feasible than it tends to be for nuisance stands of native vegetation growing to 1 to 2 m (3-6 feet).

F. Curly-leafed pondweed *(Potamogeton crispus)* does not appear to be as aggressive as is eurasian water milfoil. Perhaps its additional century of experience in competition with the native North American flora has allowed better integration. It frequently co-exists with native species in the expandable native flora. Or where curly-leafed pondweed stands dominate the lake, its annual maximum crop has a weight close to that of native species.

G. As indicated on the right-hand side of this figure, the exotic plant species (curly-leafed pondweed and eurasian water milfoil) persist as diversity and the annual maximum standing crop of macrophytes decline in a basin (planktonic algae tend toward a maximum mean standing crop as in the earlier graph.) Both invader species are found with *Elodea canadensis*, *Ceratophyllum demersum* and *Najas* spp. as codominants in excessively enriched recreational lakes.

H. Finally, neither *P. crispus* nor *M. spicatum* are found with elodea and coontail in sewage ponds serving Michigan cities. Their tolerance limit is exceeded in such ponds, as has been demonstrated by their failure in transplanting experiments. This is suggested on the right-hand side of the figure for eurasian water milfoil by the slope of the dotted line showing its decline.

This section has discussed the pattern of responses in the plant community of recreational lakes as the nutrient supply increases. Generally of lesser nuisance to property owners on well-developed shorelines are the water lilies and other floating-leafed types, and plants of the emergent-leafed type (e.g., cattails, bulrushes, and arrowhead). They are considered in the sections that follow.

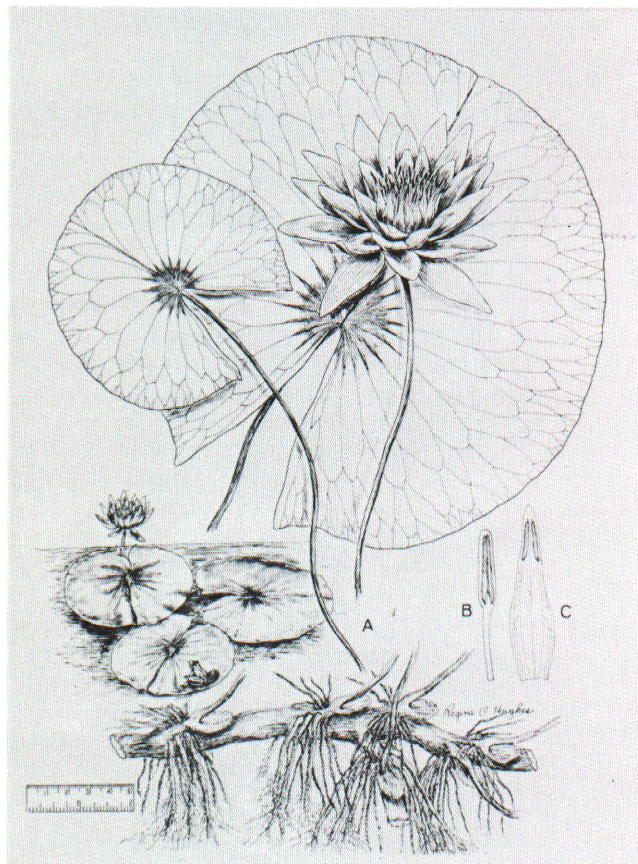
The Floating-Leafed Plants

Two additional forms of aquatic plants generally cause less concern on recreational lakes of southern Michigan than types discussed earlier. One is floating-leafed plants, the other marsh vegetation. Floating-leafed plants root in the sediments of the lake-bottom and produce leaves with waxy coverings that float at the surface of the lake. The white water lily is representative of this group.

The white water lily (*Nymphaea odorata* and *N. tuberosa* are common species) can be distinguished from the common yellow

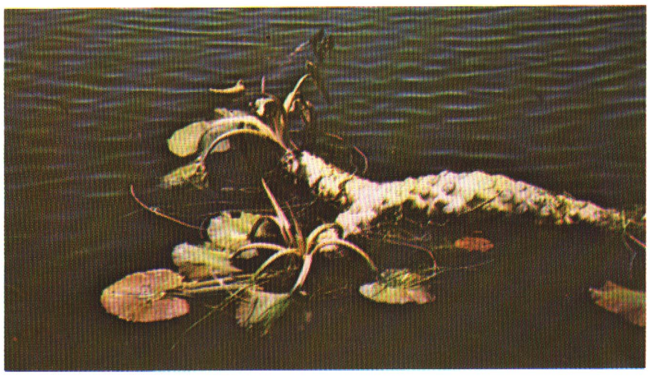
water lily, not only by the color of the flower, but by the arrangement of the veins in the leaves. In the white water lily, the veins of the leaf blade radiate from the point of attachment of the leaf petiole toward the leaf margin, branching profusely as they go. The leaves about the flowers in this picture are of this type. In the left foreground, the leaf of the yellow water lily (*Nuphar advena* and *N. variegatum* are two common types) can be seen with its strong mid-vein and pinnate arrangement of branching veins.

Looking up from the bottom of the lake at a well-developed canopy of white water lily leaves, one can appreciate that they form a shield against light penetration. The submersed vegetation below them is generally sparse. To a fish moving through this community, it is quite different from the forest-like stands of submersed vegetation considered previously.



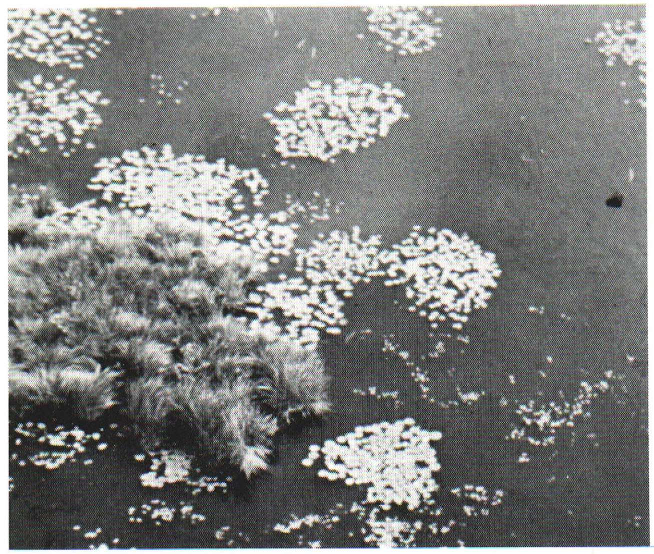
The distinguishing features of the white water lily are shown here (*Nymphaea odorata*). Notice, in particular, the rhizome (underground stem). It grows from year to year through the bud at the tip, sending out periodic groups of roots and producing leaves along its length that grow to the surface. The rhizome of the white water lily is 2 to 5 cm in diameter (1 to 3 inches) and grows to 20 to 30 cm deep in the sediments (7 to 10 inches).

Another difference between the yellow and white water lilies is that the yellow water lily often stands above the water surface because it develops supporting tissue in its stalk. The white water lily does not stand above the water.

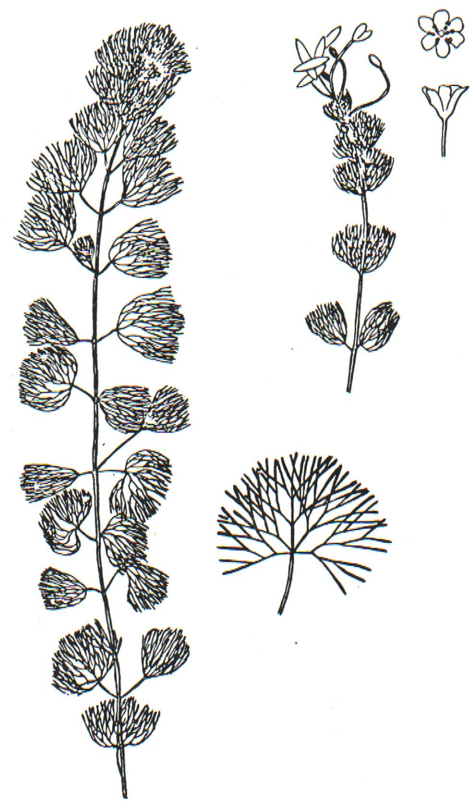


The yellow water lily puts up its leaves from a horizontal stem or rhizome. This rhizome is much heavier than that of the white water lily and may measure 10 to 15 cm in diameter (4 to 6 inches). These rhizomes frequently grow in very soft sediments and may pull from the bottom when disturbed. We see here the beginning of an annual growth from the tips of the branches on the left. Evidence of deterioration of older parts of the rhizome is seen on the right.

Over time, the yellow water lily can occupy a considerable area in the shallows of lakes. The massive underground tissue of this plant depends upon food production in the green leaves for its survival. To control plants that develop from such perennial structures, destroy enough green tissue to prevent adequate food production for maintenance of horizontal stems and runners.



This aerial view reveals water lilies spreading out to dominate the water surface. The plants tend to grow in clumps. As a seed germinates, it establishes a horizontal stem with its attached roots, and the branching of the stem produces a cluster of leaves. Lily clusters can be mechanically trimmed to a desirable size. This general approach can be used on certain other plant types as well. It requires an understanding of how the plant grows and attention to the plants at the time they become established or are first spreading. This kind of interest has been infrequently seen on the lakes; major weed problems develop before their control is considered.

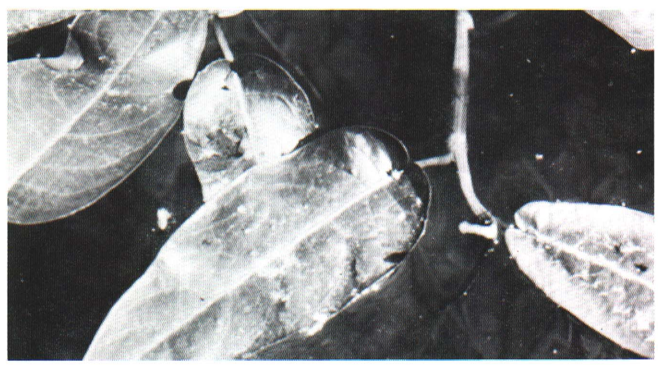


The fanwort *(Cabomba caroliniana)* should be considered with the water lilies. It is a member of the water lily family *(Nymphaeaceae)* and has the flowers of a lily, but possesses submersed leaves that are superficially like those of coontail *(Ceratophyllum demersum)* and water milfoils. In Michigan, it has been recorded only in Sunset Lake at Vicksburg in Kalamazoo County. Dense stands of vegetation fill the wtaer space to depths of 1 to 1.5 m (3 to 5 feet). The fanwort is a weed in lakes in the eastern U.S., particularly New England. Because of its potential for spreading in Michigan, be on the lookout for this plant. The leaves have a fan-like arrangement of parts. They are not whorled on the stem as are coontail and water milfoil leaves. If flowers are present (they are abundant in the Sunset Lake material) they too are characteristic. They occur singly on a stalk, clustered near the tip of the stem with small, floating leaves that reach the surface of the water. Unlike similar submersed plants, the segmented parts of the fan-wort leaf are a little wider near the tip than at their base.

There are two other floating-leafed plants that can be, but seldom are, abundant in these recreational lakes. One is water shield *(Brasenia schreberi)* seen in the center of this picture. Compare it with leaves of a common water lily, also shown here (large leaf seen in foreground). A distinguishing feature of water shield is the central attachment of the leaf stalk on the floating blade, without the notch typical of other water lily leaves. On occasion, water shield grows in patches dense enough to cover the water surface.

The last of the floating-leafed plants that can become a nuisance in lakes is the smartweed *(Polygonum amphibium* is a common form). This plant belongs to the buckwheat family, rather than to the water lily family.

The leaves are elongated and pointed and arise from a stem that appears jointed. The stem creeps along the bottom and may rise up in water from depths of 1 to 2 m (3 to 6 feet). The plant generally flowers abundantly in mid-summer, with the flower stalk protruding several inches above the water. The flower clusters are distinctly pinkish or reddish, and this feature can identify the plant from a distance.

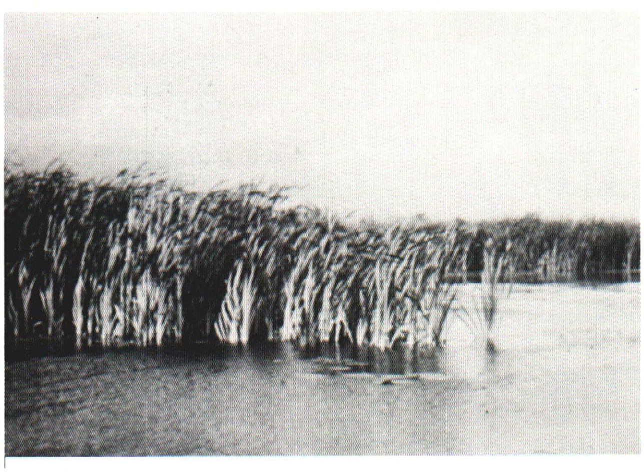


When growing profusely, the smartweed can be a considerable nuisance to boating, and its woody stem tends to hold tenaciously to fishing lures.

In summary, while the floating-leafed plants can be locally abundant, they are not nearly the weed problem of recreational lakes of southern Michigan that the submersed forms are. As a group, they are susceptible to mechanical damage to the leaves. This leads to a depletion of food on which the horizontal stems depend to continue rigorous spread of the plants. The special case of Cabomba, *a member of the lily family, bears watching, since this plant has the potential to spread and become a weed problem in the lakes.*

The Emergent Vegetation: Holding Back the Marsh

Many Michigan lakes have dwelling sites developed in areas previously occupied by marsh vegetation. Dominant marsh plants grow rooted in the sediments, have horizontal stems in the sediments, and send up leaves that emerge from the water. **The plants of the marsh form one of the most productive communities on earth.** Therefore, diverting the marsh on the edge of a lake to human use frequently requires continual maintenance of the shoreline for recreational use. An appreciation of the growth adaptations of the dominant plants is essential to a well conceived maintenance program.

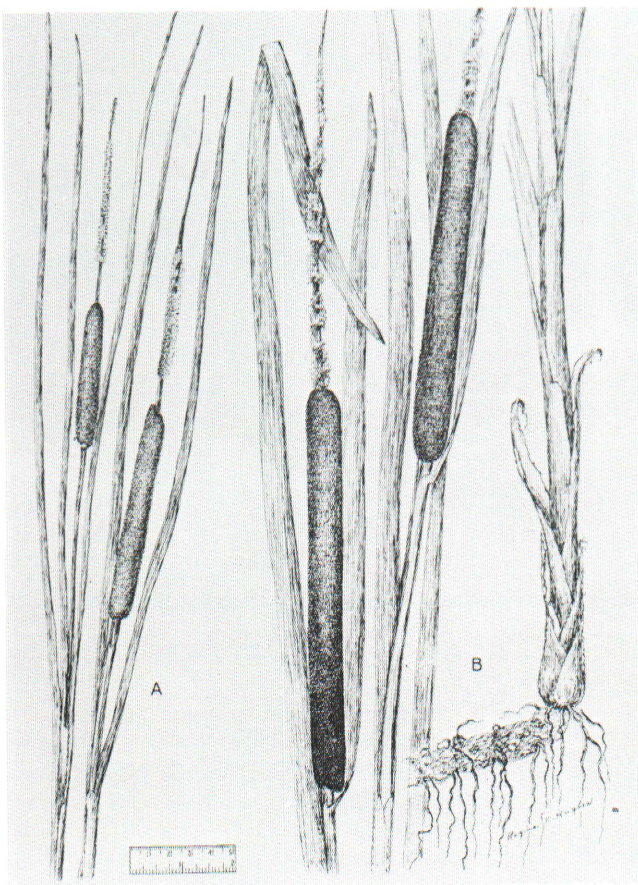


Among the dominant marsh plants is the cattail *(Typha latifolia, T. angustifolia,* and the hybrid between them are common forms). It tends to establish itself inshore and migrate outward in the shallows of a lake.

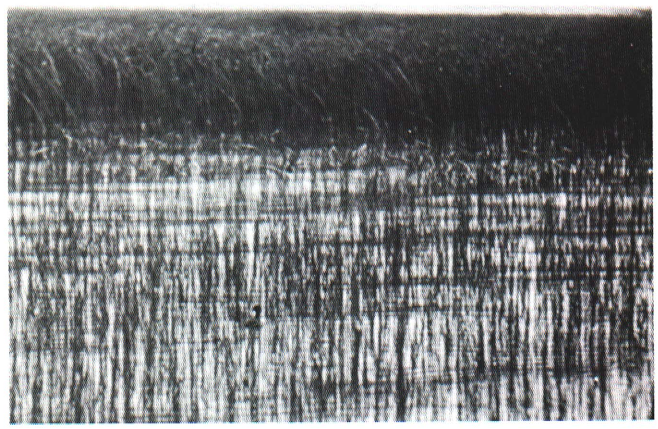
The prodigious proliferation of seeds from flowering stalks is well known. The seeds are wind borne. Great numbers of them, blown to a shoreline, can germinate in a season. Once the seed germinates, the plant establishes an underground system of branching stems.

This underground growth is produced by the continual elongation of hardened, pointed, horizontal stem tips. Roots and upright green shoots are closely clustered on this extensively developed underground stem system.

To appreciate the extent of this underground system, consider that it constitutes 2 to 3 times the weight of the above ground portions of the plant.



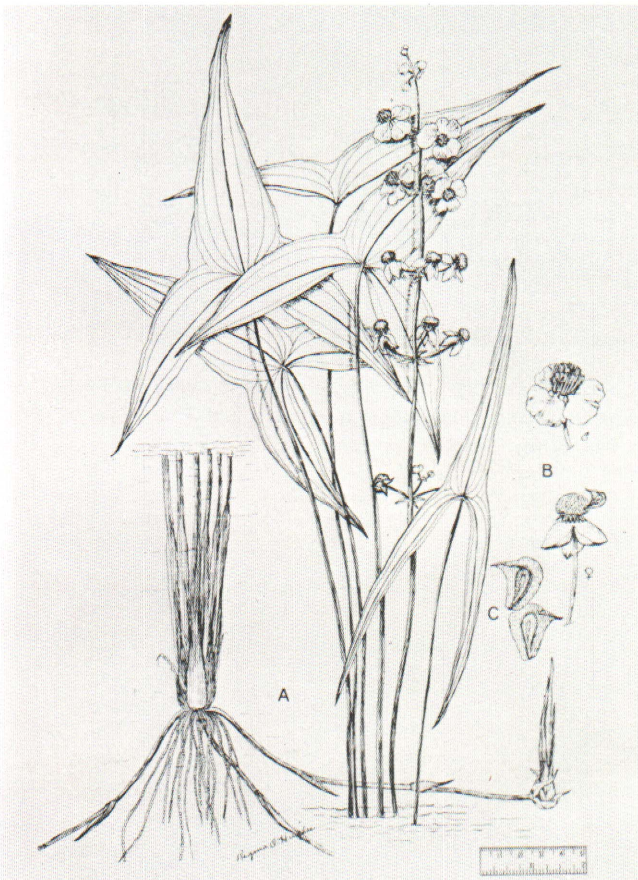
Successful control of cattails depends upon considerations similar to those for water lilies. The underground stem system is dependent upon food production in the green leaves *(Typha angustifolia* on left, *T. latifolia* on the right). Diligently removing this green tissue will starve the underground parts. Any control procedures should be accomplished early in the growing season before seed is set. This is generally true for emergent aquatic vegetation.



Here we see the widely spaced, leafless stalks of the bulrush *(Scirpus validus,* the soft-stem bulrush, and *S. americanus* grow in this form).

The pickerel weed *(Pontederia cordata)* with its clusters of heart-shaped leaves and stalks of closely spaced purple flowers is another marsh plant.

The pickerel weed superficially resembles the duck potato (*Sagittaria* spp.) shown here. It is also called arrowhead because of the leaf shape.



Sagittaria latifolia Willd. Common arrowhead. *A*, Habit—× 0.5; *B*, flowers—× 0.5; *C*, achenes—× 5.

Duck potato flowers, arranged differently from pickerel weed flowers, are loosely clustered along the stem on which they are produced, and they are white. This plant tends to spread by underground parts as seen here.

The plant is commonly called duck potato because it occurs in areas used by waterfowl, and it produces a food storage tuber beneath the sediments (shown). The tuber has been used on occasion by humans as food.

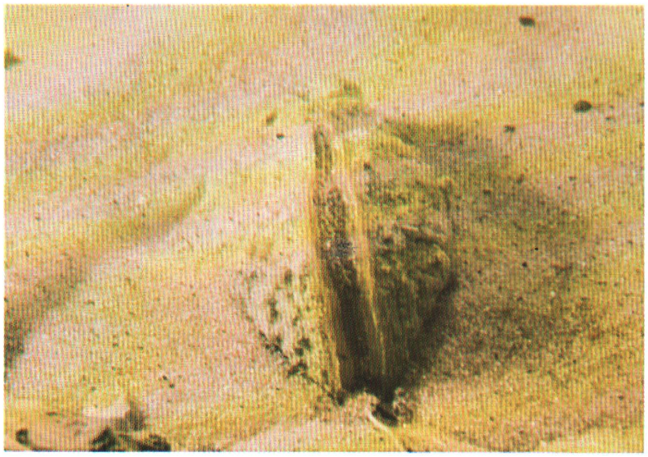
Emergent vegetation of the recreational lakes can cause severe and reoccurring problems along shorelines that have been developed by marsh reclamation. The plants in this group are extremely prolific. Various mechanisms responsible for prolific growth have been discussed (high seed production, extensive rhizomal systems and tubers). If you choose to build a residence in a marsh, appreciate the particular environment on which you are intruding. The marsh will attempt to maintain itself despite your presence.

Controlling Aquatic Weeds: Preliminary Considerations

A number of strategies are used today to control the nuisance growth of aquatic plants in recreational lakes. The cause of the problem is related to land use. An increase in the amount of nutrients entering the lakes from developed watersheds — over the amount entering from the undeveloped watersheds of earlier times — causes an increase in the abundance of large aquatic plants and microscopic algae. Any reasonable hope for successfully controlling aquatic plants and maintaining suitable water quality for recreation depends upon minimizing this rate of nutrient input. If the shoreline of a lake is undeveloped so that alternatives for land use still exist, plan any development cautiously! For example, areas that are essentially marshes might be better left alone. Stagnant water areas, such as channels through marshy land, become impassable and unsightly with age. They have been developed over and over again for the purpose of increasing on-water footage of real estate. Countless examples exist to condemn this strategy.

In the absence of effective watershed planning, problems with plants have occurred in recreational lakes, or will be at hand in the next few decades. The alternatives available for in-lake treatment of excessive plant growth are costly in dollars and energy. Short of sterilizing the lake with chemicals, the results are, to some degree, unpredictable. One reason for this is because the plants or their dead remains serve as the food-base for microbes and larger animals of the system. Changing the condition of the food base causes a cascade of effects through the microbe and animal populations.

Sponges grow attached to submersed plant stems. By creating currents of water that run through their tissues, they aid in the removal and breakdown of fine suspended particles. Sponges, thus, participate in the processes that keep the water clear.



Clams accomplish the same sort of thing as they circulate water through the tissues enclosed in the shell (by means of the ports that are visible head-on in the picture).

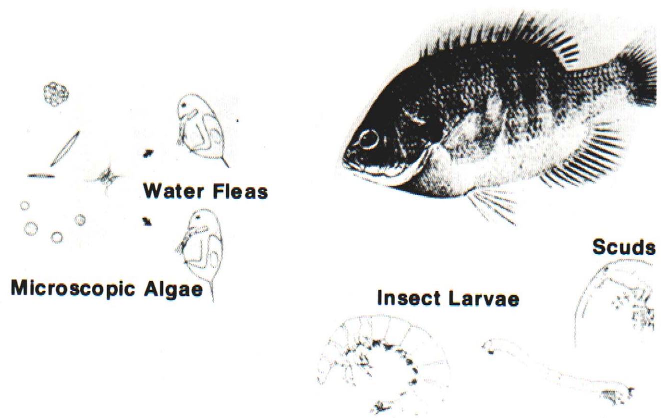
Through experiments, we know that clams can contribute substantially to the clearing of water. Fine-particulate suspended matter is removed from the water and compacted as living tissues or fecal material. The net result of this compaction is deposit of suspended particles in larger pieces on the bottom.

These delicate creatures, mayflies, eventually emerge on the lake surface to wing through a mating flight. While in the immature stage in the lake, they gather fine particles and pass them through their intestinal tracts. In the process, particles break down leaving remains that are compacted for settling.

Suspended in the water, the familiar water fleas (seen here in close-up) collect particles with their antennae. This is *Daphnia pulex* with antennae visible on individuals in the field.

There is evidence that *Daphnia* populations at a density comparable to that seen here contribute very significantly to the removal from the water of suspended particles, including free-floating microscopic algae. Mayfly nymphs seen in the disintegrating vegetation in this field (lower right, for example) are busy at work processing their portion of the food base.

The mayfly, the water flea, the clam and the sponges are representatives of the particle-gathering fauna. Their gathering and breathing surfaces are swamped by the abundance of suspended particles present in excessively enriched lakes **(third stage response)**. As they disappear from the system under the stress of such conditions, their collective effort at maintaining water clarity is lost.



Game fish populations are in some balance with these animal groups. They depend upon them for food. When they are small, these fish eat the water flea. As the fish grow larger, they turn to larger organisms seen below them in the picture. An abnormally high density of rooted aquatic vegetation is associated with stunted fish populations. Numerous stunted individuals can deplete populations of the water flea and bottom-dwelling bugs. That, in turn, can slow down removal of particles from the water and sediment compaction, and can contribute to an expansion of the crop of microscopic algae (as suggested in the picture).

In relatively nutrient-poor recreational lakes of the region, the plants and animals relate to each other in ways that tend to prolong desirable water clarity in these lakes. An excessive shift in plant production causes changes in the animal populations that, in turn, contribute to an accelerated development of murky water.

Management strategies for protecting or returning the balance of the resource must begin with problems of drainage from the land. The results of in-lake treatments of various sorts tend to be discouraging over time, since treatments disrupt in unpredictable ways the interplay of biological components of the lakes.

Redevelopment of a misused recreational lake, if the will exists to accomplish that, will likely be costly. And why should we have thought otherwise? Development costs of the land resources in the lakes watersheds have been immense over decades past.

For information of specific weed control methods, contact: Land Resources Programs Division, Inland Lake Management Unit, Department of Natural Resources, Stevens T. Mason Building, Lansing, Michigan 48926. Phone: (517) 373-8000

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