9. AQUATIC WEEDS: ECOLOGY, PROBLEMS, AND MANAGEMENT

INTRODUCTION

When people talk about plants in water, the terms "seaweed", "algae", and "weed" are frequently used incorrectly. There are no seaweeds in Minnesota. Seaweeds grow in seas, in salt water.

Algae are simple, more primitive plants than the seed-bearing plants typical of the land. Algae may be one-celled or may form colonial masses of small or great size. Algae do not have stems, roots, leaves, or flowers. Algae either float freely in the water or attach themselves to underwater surfaces, including the leaves and stems of rooted aquatic plants. The floating algae as a whole are called the phytoplankton; the attached layer, including some primitive animals like hydra, is collectively called the periphyton.

A lake's phytoplankton is usually its main source of primary productivity. These algae obtain their energy to grow from sunlight, and are eaten by zooplankton, the minute animals which are in turn eaten by small fish. The phytoplankton draws all its nutrients from the water, and lush growth is a characteristic of nutrient-polluted waters. Lake Winona is nutrient-polluted.

When conditions are optimum for algal growth, the phytoplankton is capable of rapid, excessive growth. This produces algal blooms, which are generally offensive to people. The upper layers of the lake become green and opaque with the suspended living green cells; windrows of fine green material may wash onto the beach. To people, the lake becomes uninviting. Lake Winona has algal blooms, especially in late summer, but this is not considered to be Lake Winona's weed problem.

A "weed" is any plant which grows where it is not wanted. The aquatic plants referred to as weeds in this text are specifically called rooted aquatic macrophytes. They are almost all flowering plants with roots, stems, leaves, and which produce seeds from flowers. They grow completely underwater, though their tops may float at the surface and be visible from a distance. Like the algae, they require sunlight for growth, but may take root in water too deep for algae and grow upward toward the sunlit surface. Beyond a certain depth, which depends upon water clarity, rooted aquatic macrophytes will not grow.

Most aquatic weeds are important beneficial members of the ecosystem. Weeds remove nutrients from the water, inhibiting noxious algal blooms. Weeds provide a place for many species of animals and plants to live and feed. Not many aquatic animals actually eat weeds, but most find cover in weed beds, and eat other, smaller animals also seeking cover there. Snails graze on algae which grow upon the surfaces of weeds. Weeds add oxygen to water, improving its quality in many respects.

But people do not like weeds. The same attitude which says that a lawn should be closely and smoothly mowed also says that lake water should be clear and blue. In fact, such lakes are rare and usually occur only in infertile areas such as the northeastern corner of Minnesota. In the Mississippi River Valley where soils and water are fertile, plants grow well and water often looks murky and green.

Some rooted aquatic macrophytes, such as the waterlilies and the American lotus, are attractive. Others are inconspicuous, grow underwater, and are seldom seen except by fishermen. Several kinds form thick beds which interfere with swimming and boating, and reach the surface where they are visible from a distance.

Weed growth is considered excessive when it interferes with people's enjoyment of a lake. Excessive weed growth can create a danger of summerkills of fish. If a large amount of plant matter dies and begins to decompose in late summer, dissolved oxygen may be reduced to concentrations which are too low for fish to survive. Extensive weed beds provide hiding places for small bluegills and crappies, hindering predators' access to their prey(Fig. 9-1). This contributes to overpopulation, overcrowding, and stunted growth. Weeds hinder circulation of the water, promoting stagnant conditions.

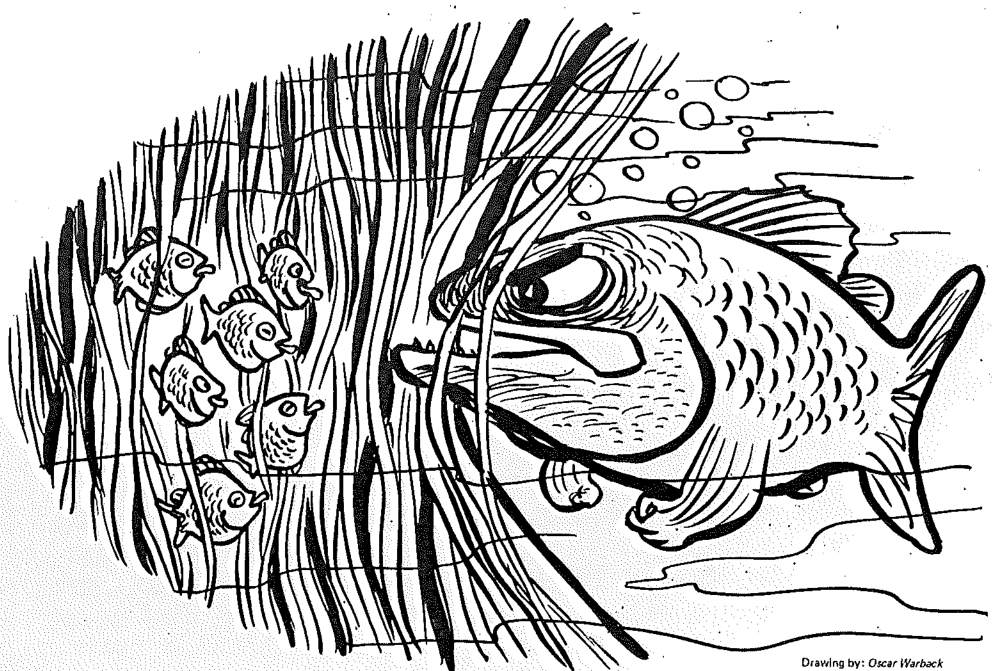


Figure 9-1. Extensive weed beds provide hiding places for small bluegills and crappies, which become overabundant and stunted if protected from predators.

The management of aquatic plants is very complex, and it cannot be said that simple and effective methods exist which will achieve the objective of clearer, weed-free water. Lakes are ecosystems, and they function in cycles of energy and nutrient flow. Left undisturbed, they tend to change toward more stable conditions. But because they are so complex, no one element of a lake ecosystem can be manipulated without affecting other elements of that system. Often when people undertake the reclamation and management of a lake, it is because man's activities have caused degradation of the lake in the first place.

LAKE WINONA'S EARLY WEED HISTORY

Lake Winona is naturally weedy. Even if no nutrient pollution or sediments from agricultural lands had ever been washed into the lake, it would still be a weedy, marsh-like backwater of the Mississippi River. One need only look about the river valley for examples of what Lake Winona might look like if it had not become one of Winona's city parks.

Man has had two types of impact upon Lake Winona, degradation and reclamation. Initially, input of nutrients and sediments caused accelerated aging of the lake. This process, called eutrophication, occurs naturally at varying rates. Lakes become richer, shallower, and eventually die by filling to become dry land. Lakes are mortal. Normally this process requires many years to complete, but man has caused the process to speed up in Lake Winona, by causing erosion and nutrient pollution.

When the first Europeans settled in the Winona area, Lake Winona was a flood-plain marsh which flooded when river levels rose. Unwise farming practices in Lake Winona's watershed caused excessive flooding and rapid filling in of the marsh with soil washed down by the floods. Lake Winona has been dredged three times in its history to remove soil eroded into the lake basin.

Lake Winona has also received nutrient pollution, making its waters richer. Agricultural fertilizers and runoff from pastures account for some of the nutrient pollution, but most comes from the city of Winona (Fig. 9-2). The storm sewers of about half the city empty directly into the lake or adjacent County Ditch No. 3 (See Fig. 4-1). Lake Winona was originally weedy. Man has accelerated eutrophication and made it weedier.

In their July 1953 Lake Survey Report, Minnesota DNR biologists noted that dredging had reduced the amount of submerged vegetation in shoal areas, and that aquatic plants were very scarce. Common species were listed as: American elodea (Elodea canadensis), coontail (Ceratophyllum sp.), burreed (Sparaganium sp.), softstem bulrush (Scirpus sp.), and pondweed (Potamogeton sp.). Of these, only elodea, coontail, and pondweed are submerged aquatics, and they were reported to grow at depths of 7 feet or less, which indicates that the lake was quite turbid. Burreed and bulrush grew along the shore.

In their September 1960 Lake Survey Report, Minnesota DNR biologists listed coontail (Ceratophyllum sp.) and sago pondweed (Potamogeton pectinatus) as being common along the entire shore, but showing very sparse growth. One small patch of water lily was listed on the west lake along Highway 61. The marshy area at the west end of the west lake contained cattails and Phragmites, a tall cane-like grass. Only a few small patches of hardstem bulrush were found. Submerged plants grew only to a depth of four feet. Heavy algal blooms that year necessitated three applications of copper sulfate.

ROUGH FISH AND THE 1965-1974 WEED-FREE EPISODE

The long term trend has been for Lake Winona to become increasingly weedy. This increase has been interrupted three times by dredging, and by an uncharacteristic

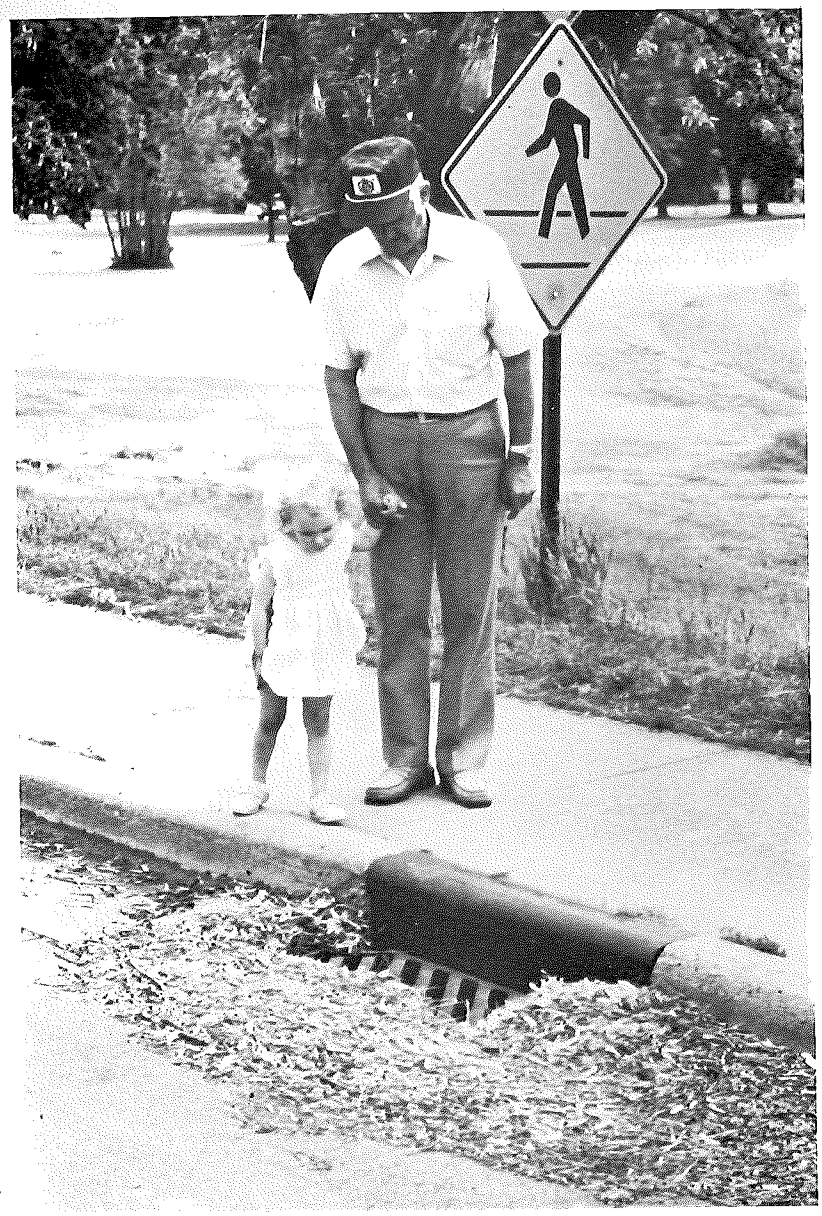


Figure 9-2. About half of Winona's storm sewers drain into Lake Winona, adding nutrients in the form of lawn fertilizers, leaves, grass clipping, seeds, etc.

weed-free episode from 1965 to 1974. This brief weed-free period has created some confusion about Lake Winona's weed problem and has provided a demonstration of the complex interrelationships found in even a small ecosystem like Lake Winona.

Winterkills caused by oxygen depletion killed nearly all the fish in Lake Winona in 1965 and 1969. Such events favor the development of large populations of prolific rough fish, some of which can tolerate lower oxygen concentrations than game fish, and, whose predators (the game fish) are largely destroyed by the winterkills. Accordingly, a large population of buffalofish, carp, and bullheads developed in Lake Winona. Some large fish were found, but soon the pressures of overpopulation caused severe stunting of most species.

Rough fish, such as carp, feed by rooting through the upper several inches of the lake bottom. In doing so, they dislodge plant roots (one of the food items they seek) and whole plants. They also disturb the bottom sediments, making the water turbid. The murky water transmits less sunlight, shading out plant growth except for the uppermost layers of water. Thus, the rough fish, by a combination of uprooting plants and roiling the water, destroyed all the weeds in Lake Winona. In 1973, Lake Winona was virtually weed-free, but what remained was not considered a desirable recreational lake. The water was always muddy and the main fish to be caught were stunted rough fish and panfish. Stagnant conditions were encouraged, and coliform bacteria counts were high.

To eliminate the rough fish and reestablish a game fishery, Lake Winona and much of its watershed were treated with rotenone in 1973. Aerators were installed to prevent oxygen depletion and fishkills. These management efforts were successful in eliminating most rough fish and enabling game fish to thrive.

CHANGES FOLLOWING RECLAMATION

It was anticipated that Lake Winona would again become weedy after the destroyers of the weeds, the rough fish, were eliminated. The magnitude of that change has exceeded expectations, however, and the principal management problem for Lake Winona has become the weeds. Immediately following the rotenone treatment, the weed-free lake was extremely clear (visibility 22 feet) and attractive. This state did not last long. The lake was like a newly-plowed field, where no native plants grew to impede the invasion of the empty niche by undesirable plants. By 1976, Lake Winona was completely overgrown with a plant called curlyleaf pondweed (*Potamogeton crispus*) (Fig. 9-3, 4, 5)

In May 1981, WSU biology student Gregory Munson attempted to determine the standing crop of *P. crispus* in Lake Winona. Using SCUBA and a 1/6 square meter frame, he sampled three locations in the lower lake in water about 8 feet deep. By examining aerial photos, Munson concluded that about 90% of Lake Winona was occupied by *P. crispus* beds, for a total area of 1.16×10^6 m^2. The ash-free dry weights of his samples were determined using standard laboratory methods. These data were then extrapolated to estimate the standing crop of the lake as a whole. The data in Table 9-1 are based on Munson's observations. It should be recognized that these observations included not only the *P. crispus* plants, but also marl and microscopic animals.

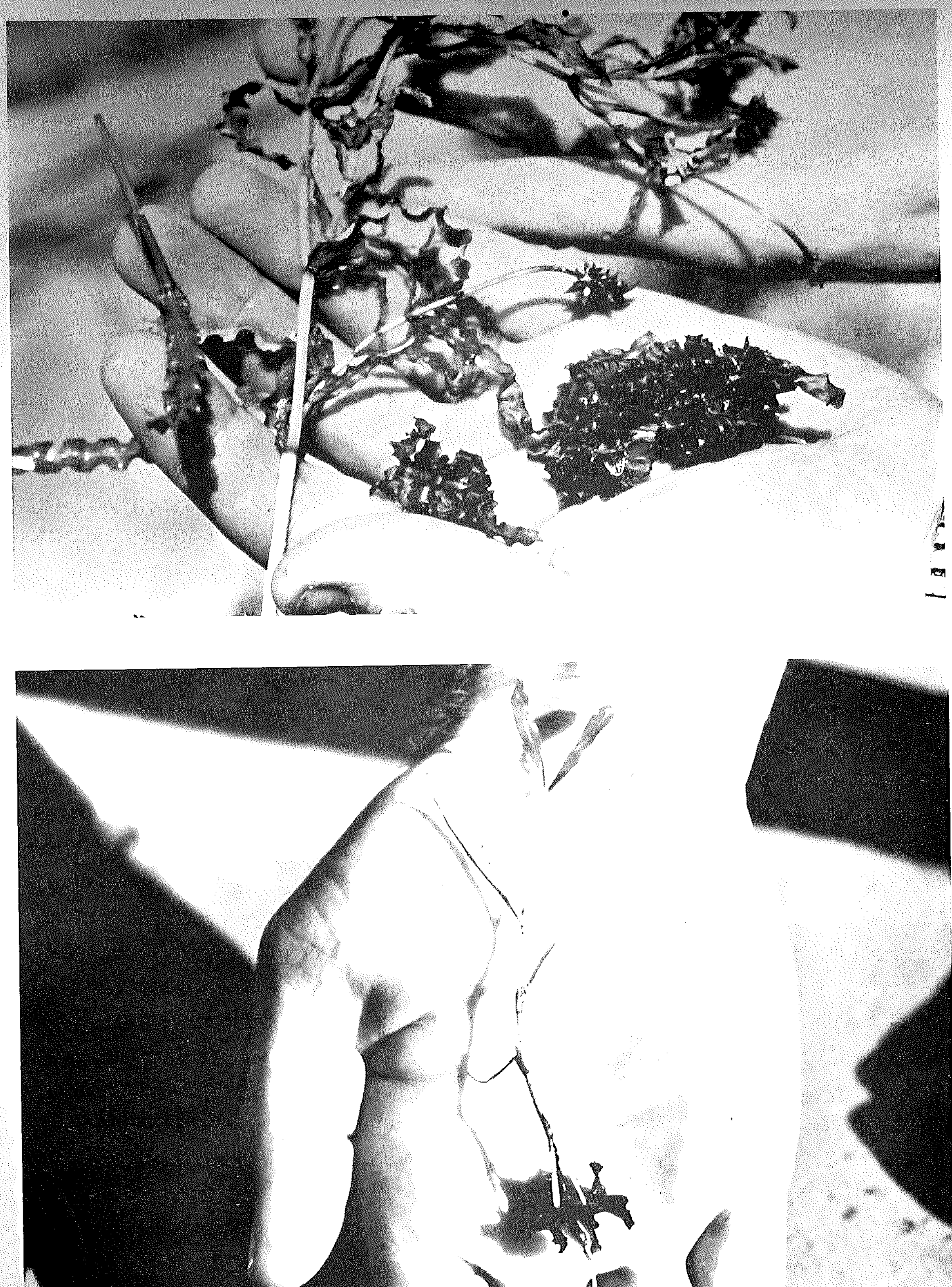


Figure 9-3. Curlyleaf pondweed. Above: Note characteristic wavy edges of leaves and mace-like seed heads. Winter buds are seen in left palm. Below: Germinating winter bud.

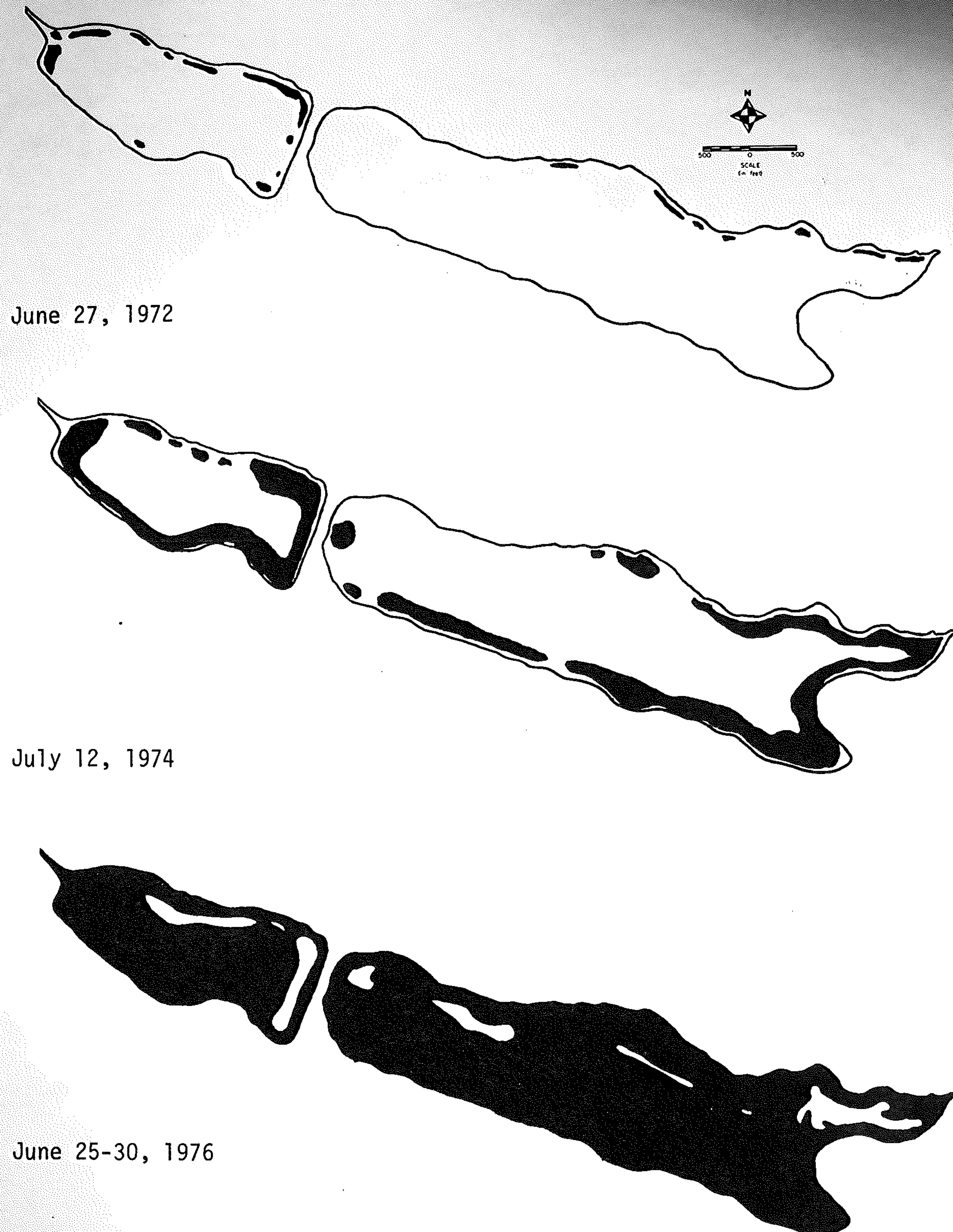


Figure 9-4. Distribution of curlyleaf pondweed in Lake Winona before and after reclamation. Data by Professor J. P. Emanuel's aquatic plants class.

Table 9-1. Estimates of P. crispus standing crop, based on three 0.16-m^2 samples. Data from Munson, 1981.

Average of three samples:

Damp weight	1680.0 gm
Dry weight (105 C)	281.8 gm
Ash weight (500 C)	15.1 gm
Ash-free dry weight	266.7 gm

Average weights/Meter^2:

Damp weight	10,080.0 gm/m^2
Dry weight (105 C)	1691.0 gm/m^2
Ash-free dry weight	1600.0 gm/m^2

Multiplying these weights by the lake area of $1.16 \times 10^6 \times m^2$ gives a rough estimate of the standing crop of P. crispus in Lake Winona:

	Total Lake	Tons/Lake	Tons/Acre
Damp weight	1.2×10^{10} gms	12,800	44.9
Dry weight (105 C)	2.0×10^9 gms	2,160	7.5
Ash-free dry weight	1.9×10^9 gms	2,050	7.1

For comparison, hay crops harvested in Winona County yield an average of 8-15 tons/acre dry weight, obtained through three or more cuttings throughout the growing season.

Figure 9-5. Curlyleaf pondweed, early June 1976. Floating portions of the plants are festooned with filamentous algae and cottonwood seeds.

CURLYLEAF PONDWEED

During spring and early summer, nearly all the weeds in Lake Winona are of one species, Potamogeton crispus. It is a flowering plant, a rooted aquatic macrophyte, and a relatively new addition to the flora of North America, having come here in the late 1700's with European immigrants. The oldest dated specimen obtained in America was collected in the Philadelphia area in 1841. By 1914, P. crispus had established itself in the eastern United States as far south as Virginia.

The westward spread of P. crispus was aided by the fact that the seedheads of this and other pondweeds make excellent forage for migratory waterfowl. These far-ranging birds disperse the seeds along their migration routes. The first documented specimen in Minnesota was collected in 1931 in the Mississippi River bottoms just below Winona. Iowa has enjoyed a later introduction to P. crispus, where it appeared in 1954 in the Iowa Great Lakes region. At present, P. crispus can be found from Canada to Mexico, and from east to west coasts.

P. crispus is different from all other species of the pondweeds in a number of ways visible to the unaided eye. The most distinctive feature is the wavy indentation of the leaf margins, which gives the leaves a serrated feel and appearance (Fig. 9-3). Another character is the horny, mace-like seedhead which forms in early summer.

P. crispus grows best in relatively clear, cool waters. In Minnesota, P. crispus occurs in waters with a pH range of 7.6 to 8.4 and 100 - 300 ppm total alkalinity (as calcium carbonate). It prefers areas with rich organic bottoms and little current. It thrives in cool water and dies back during the heat of summer.

In Lake Winona, it grows upward to the lake surface in the shallows as early as May 8 and becomes an eyesore and a nuisance about May 20. Flowering begins in the shallows as early as May 11, but the major flowering period occurs between May 20 and June 6. By June 20, seeds are well formed throughout the lake and the lower portions of the stems of deep water plants have turned brown. The browning proceeds rapidly as the lake warms. As they die the plants lose their buoyancy and sink to the bottom where they decay. By July 10, the lake is virtually free of P. crispus.

In late May, as peak flowering is reached, masses of the seedheads appear on the lake's surface and give the lake a brown, scummy appearance which is made worse by masses of fast growing filamentous green algae which become entangled in the seedheads and stems (Fig. 9-5). Cottonwood trees release their fluffy white seeds at about the same time, causing patches of white "scum" among the brown and green patches. Without closer examination, the casual observer would interpret the "scum" as some type of pollution, not realizing that water quality is at its best then because nutrients are "tied up" in the weeds. The lake's waters are clearest when the weeds are thickest.

The decay of P. crispus creates a sudden biochemical oxygen demand (BOD) which may cause summer-kills of fish. It also releases nutrients to the water, causing blooms of green and blue-green algae. The dense population of algae makes the lake pea-soup green; this decreases the depth to which light can penetrate, hastening the die-back of P. crispus.

In addition to seedheads, P. crispus forms winter buds (Fig. 9-6). These prickly structures superficially resemble green, opened pine cones. They enable the plant to reproduce vegetatively. The winter buds sink to the lake bottom and lie dormant until fall when cooling water temperatures stimulate them to "sprout". SCUBA divers find the bottom of the lake literally carpeted with winter buds in the fall.

New plants grow during the fall and winter. Their rate of growth is regulated by light intensity and temperature. In years with little snow cover, the plants get enough sunlight through the transparent ice to grow slowly throughout the winter. Water clarity is usually good in winter. By spring, the plants in areas up to 10 feet deep may have grown until they are touching the ice. In years of little snow, when the ice is bare, the spring P. crispus growth occurs explosive~~ly after ice-out~~, as water temperatures warm.

Sudden appearance of the plant may be caused in another way. If the water level of Lake Winona is high in the spring for a prolonged period because high river levels have necessitated the closure of the gates at the lake outlet, the plants grow upward for a longer period as they "try" to reach the surface to flower. When the river flood crest is past, the flood gate at the outlet of the lake is opened and the lake level may drop about a foot in a two-day period. This causes the sudden appearance of P. crispus throughout a wide area, temporarily overwhelming the weed harvesters who were previously unable to cut because they could not see the weeds.

SCUBA diving and snorkeling are best in Lake Winona during the period of lush P. crispus growth. The water is clear then, and a good observer can see that the P. crispus is covered with a gray fuzzy layer of hydras and other small animals and plants. The snails which seem to be browsing on the plants are actually eating the periphyton and not the P. crispus. The upper surfaces of the leaves are covered with a white film of marl (lime). This chalky precipitate is formed when the plants extract carbon dioxide from the surrounding water for photosynthesis. This lowering of the water's carbon dioxide concentration causes water-soluble calcium bicarbonate, $Ca(HCO_3)_2$, to lose CO_2 and become water-insoluble marl, $CaCO_3$. The marl forms a white cloud if the plants are shaken. Marl is a good indicator of a hard water, nutrient-rich lake.

P. crispus spread rapidly throughout upper and lower Lake Winona in the years following reclamation (Fig. 9-4), but there are signs that other more desirable native plants may be succeeding P. crispus in an ecological succession similar to that seen on land. Coontail (Ceratophyllum demersum), which does not die back in warm water, now replaces P. crispus as the dominant plant in late summer. Coontail will probably become more widely established in time. Because its leaves, flowers, and seedheads do not conspicuously break the water surface, coontail is less offensive to lake users. Coontail is a native North American plant.

In their 1980 Lake Survey, Minnesota DNR biologists recorded the following aquatic plants in Lake Winona:

Common Name	Scientific Name	Abundance
Coontail	Ceratophyllum demersum	Abundant
Sago pondweed	Potamogeton pectinatus	Common
Mud plaintain	Heteranthera dubia	Rare
Wild celery	Vallisneria americana	Present
Yellow waterlily	Nuphar variegatum	Present
Canada waterweed	Elodea canadensis	Occasional
Curlyleaf pondweed	Potamogeton crispus	Abundant

P. crispus occurred everywhere except in the deepest holes; it was also found within all stands of other species, which were generally restricted to waters less than six feet deep. One small stand of common cattail was located adjacent to the east boat ramp in the lower lake basin.

Detailed maps of weed distribution in Lake Winona are presented in Appendix 9-1,2,3.

WEED CONTROL

As the extent of the weed growth became apparent, the Lake Winona Committee investigated ways to control the weeds. All possible methods were studied. There are four types of aquatic plant control, referred to as: 1) habitat manipulation, 2) biological control, 3) chemical control, and 4) mechanical control.

Habitat manipulation

Habitat manipulation includes shading the plants with dyes, covering the bottom with various sterile blanketing and shading materials such as sand or black plastic sheeting, and dredging. Lake Winona is too large for blanketing or shading methods. Dredging would be an excellent way to control P. crispus. By making parts of the lake too deep for aquatic macrophytes (more than 15 feet deep), open water areas could be created. Unfortunately, this would be prohibitively expensive, and would not curtail the nutrient input to the lake, which would probably result in earlier, more extensive algal blooms without the weeds to take up nutrients in early summer.

Biological control

Biological controls of aquatic plants may be the most sophisticated and effective solution, if actual methods could be prescribed. Biological controls usually involve "adjustment" of the ecosystem to include the elimination of the undesirable plants, usually by their becoming food for something else. Unfortunately, there are not many things which eat aquatic weeds. Crayfish do, but to fill Lake Winona with crayfish would be a drastic solution. The introduced red crayfish (Orconectes rusticus) has caused so many problems in Wisconsin that it is illegal to use them there as bait. No insects are known which eat significant amounts of P. crispus. An exotic plant-eating fish called the amur (grass carp) (Ctenopharyngodon idella) would eat weeds, but they are illegal to use in Minnesota and Wisconsin. Amurs have been successfully used in other states, but they are a threat to desirable duck food plants and wild rice beds. Plants ingested by amurs are inevitably voided as nutrient-rich feces which would stimulate growth of undesirable algae. The best biological controls may be those which happen naturally, slowly, as the plant community in Lake Winona undergoes ecological succession.

Chemical control

Chemical weed control was tried in small scale experiments in 1978 and 1979 (Fig. 9-6). Emulsifiable Aquathol K was applied to areas along the lakeshore which receive heavy recreational use. The lake's margins near the fishing pier, the swimming beach, and the various docks and boat ramps were sprayed using a 3-hp pontoon-mounted sprayer. In both years, the spraying was accomplished in one day. The public had to be advised of restrictions on lake use during and following the chemical application. Swimming was not allowed within 24 hours of treatment; fish were not to be used for food within three days of treatment. In 1978, 4 gal/acre were applied to approximately 6 acres. In 1979, 6 gal/acre were applied to the same areas. The chemical application was made by Winona city employees. To appreciate the problems associated with this operation, the reader is referred to the City forester's "Lake Winona Weed Control Reports" (Appendix 9-4,5).

Aquathol K did not give satisfactory control of *P. crispus* in these experiments. Application in 1978 was on June 15; the plants soon began to die back, but *P. crispus* does this anyway in early summer, as water temperatures rise. In 1979, the application was made on May 31, and the plants commenced to die back in a few days. It took several weeks for decomposition to advance, and tangled masses of live weeds became tangled masses of dead weeds for a while. Wave action diluted the herbicide; other factors such as weather conditions acted to reduce the effectiveness of the treatments along the lake margins, and it was apparent that the whole lake would have to be treated to achieve weed control. Because treating the entire lake would have been prohibitively expensive, and would still have left the decomposing weeds in the lake, it was decided after 1979 not to continue chemical control of *P. crispus* in Lake Winona.

Mechanical control

Mechanical control includes methods of destroying or removing plants by the use of powered machinery. This technology has been developing since the 1950's in the Great Lakes states, where there are many recreational lakes. Some machines are hand made, one of a kind. Others are manufactured by several companies which specialize in them. Sizes range from small, outboard motorboat-mounted cutters, which leave the weeds where they are cut, to self-propelled systems which cut and pick up the weeds and transport them to the shore for hauling and disposal by truck. Removal of the weeds is called harvesting, to distinguish it from simple cutting. While it requires a set of expensive equipment, harvesting is a desirable method of weed control because an area can be cleared of weeds directly, leaving it available for immediate use. Removing the weeds from the water prevents them from taking root elsewhere. It also interrupts the return of the plants' nutrients to the water, where they would cause algal blooms. Harvesting reduces the biochemical oxygen demand (BOD) of decaying weeds.

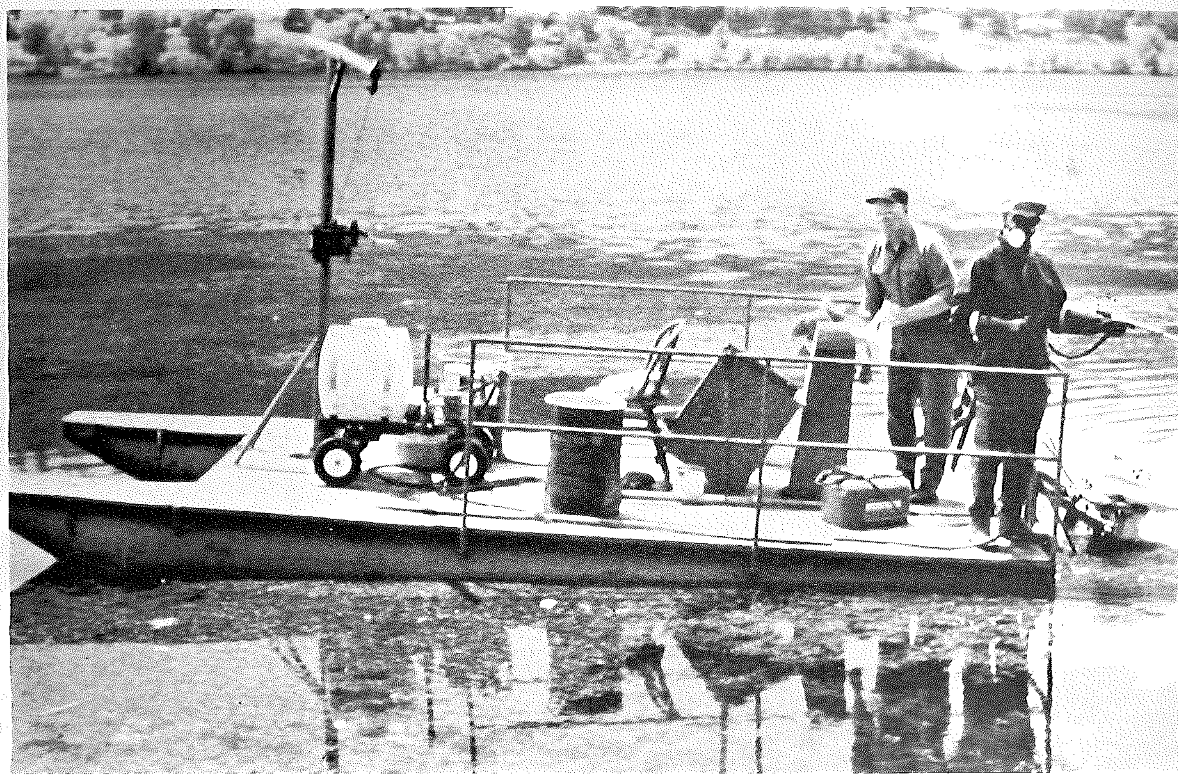


Figure 9-6. Attempts were made to control curlyleaf pondweed in high-use areas in 1978 and 1979. Spot treatments were generally unsuccessful.

MECHANICAL CONTROL OF WEEDS IN LAKE WINONA

A Hockney HC-10 cutter and three Air Lec WR-30 weed rakes were purchased by the city in 1977 (Fig. 9-7). The cutter worked very well, but it did not harvest the cut weeds which formed heavy, tangled masses. Each boat-mounted weed rake required two people, one to operate the boat and another to handle the rake. Outboard motor propellers became clogged by weeds; loads of weeds which were brought to shore had to be dragged onto shore by other workers and loaded into trucks. The weeds, when wet, were bulky and very heavy. It soon became evident that the system was too labor intensive to be practical.

In 1981, and after studying several cutter-harvester systems, in consultation with community businesses and interested persons, the Lake Winona Committee began a drive to raise money to buy a more efficient system.

Early in 1982, the Lake Winona Committee raised $52,200 in a three-month period, purchased a cutter-harvester, a shore conveyor, and a trailer, manufactured by the Altosar Company of Ontario, Canada, and deeded them to the City of Winona. The Altosar system began operation in mid-summer, 1982.

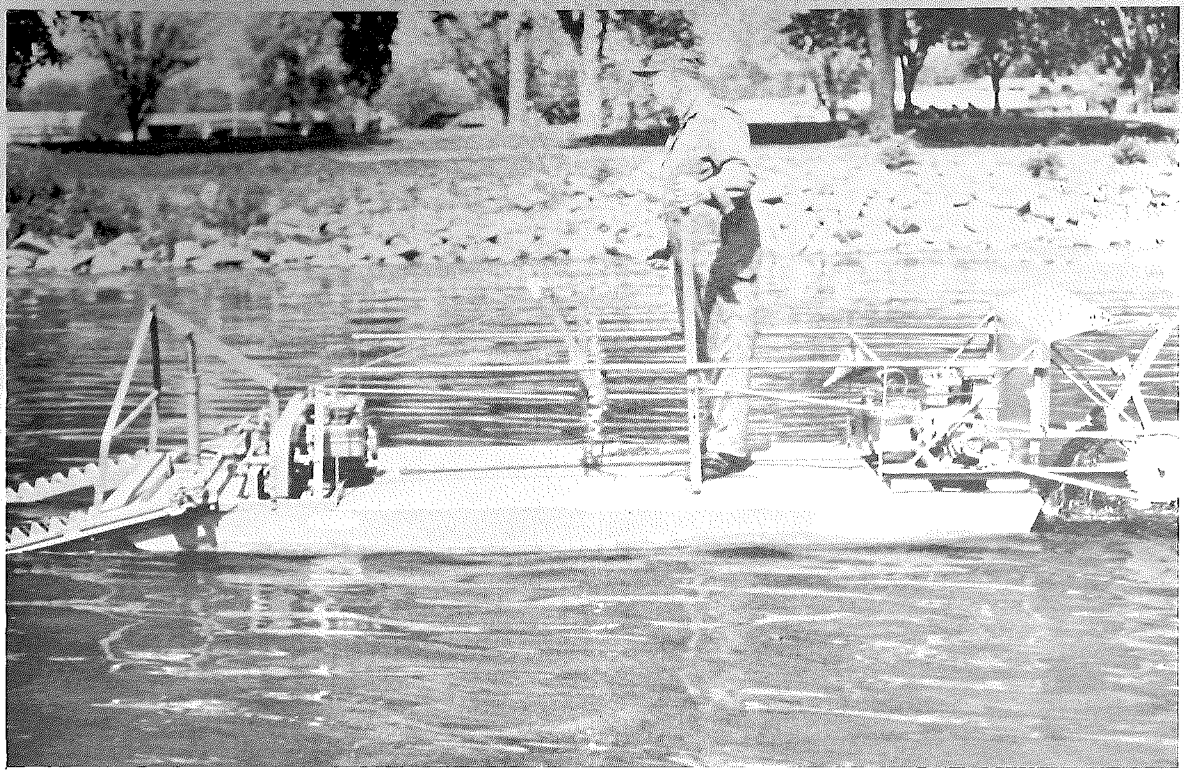


Figure 9-7. Above: City employee operating a Hockney C-10 weed cutter. Below: City crew using Air Lec WR-30 weed rakes to gather cut weeds.

The Altosar system consists of a pontoon-mounted cutting assembly which uses a conveyor to pick up the weeds as it cuts them (Fig. 9-8). When full, the Altosar is maneuvered to shore where the weeds are unloaded by conveyor to a second conveyor which loads them into a dump truck for hauling and disposal (Fig. 9-9). Only two persons are required to operate the system, one for the Altosar and one for the truck.

The cutter-harvester cost $37,900. It is powered by a 40.5 diesel engine. Two hydraulic pumps drive hydraulic motors for the 4 paddle wheels and sickle bars. It cuts a swathe 6 feet wide and 0-5 feet deep. The onshore conveyor cost $8,500 and the trailer cost $5,800.

The cutter-harvester was used only part of the season in 1982. About 200 loads were cut and hauled to a composting site on Shive Road near the municipal wastewater treatment plant. Loads varied in weight from about 900 lbs. to 2400 lbs. In 1983 and 1984, full harvesting seasons were completed. Results are tabulated in Tables 9-1,2,3.

The Altosar system appears to satisfactorily control the weeds in Lake Winona. It does not begin to eliminate all weed growth, but is used to first clear areas with high recreational use, such as the fishing piers and the swimming beach. When these areas are cleared, the cutting is done in the thick weed beds which occupy the central area of the lake.

It is not anticipated that the harvesting of weeds with this system will affect the nutrient budget of the lake. Using standing crop determinations and total seasonal harvesting results, it can be calculated that as little as 2.5% of the weeds are being removed per year. The effectiveness of the cutter-harvester lies in its ability to quickly clear high-use areas in the lake's margins.

Cutting in the spring and early summer is restricted by DNR regulations which limit cutting in largemouth bass spawning areas until early July, when the year's brood has dispersed. Bass spawn in the shallows where P. crispus surfaces first, and most of the lake's shoreline remains uncut and unusable until mid-summer.

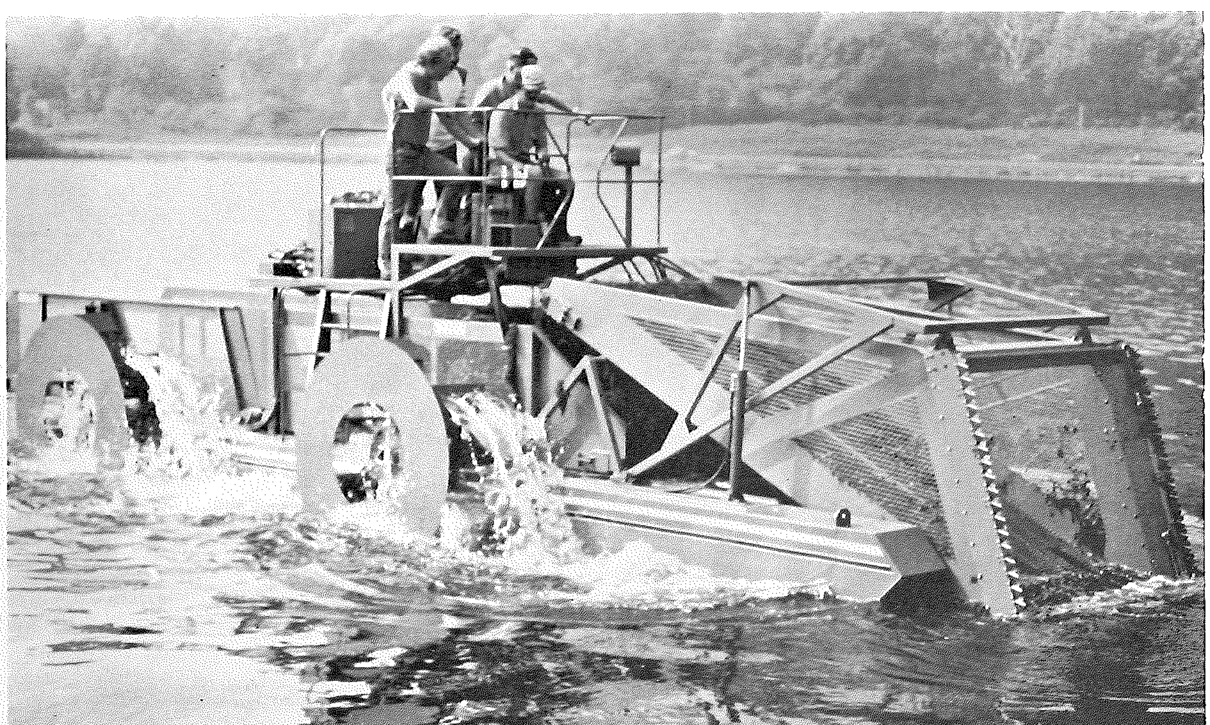


Figure 9-8. Altosar cutter-harvester at work on Lake Winona. Only one operator is needed; the other three men are trainees.

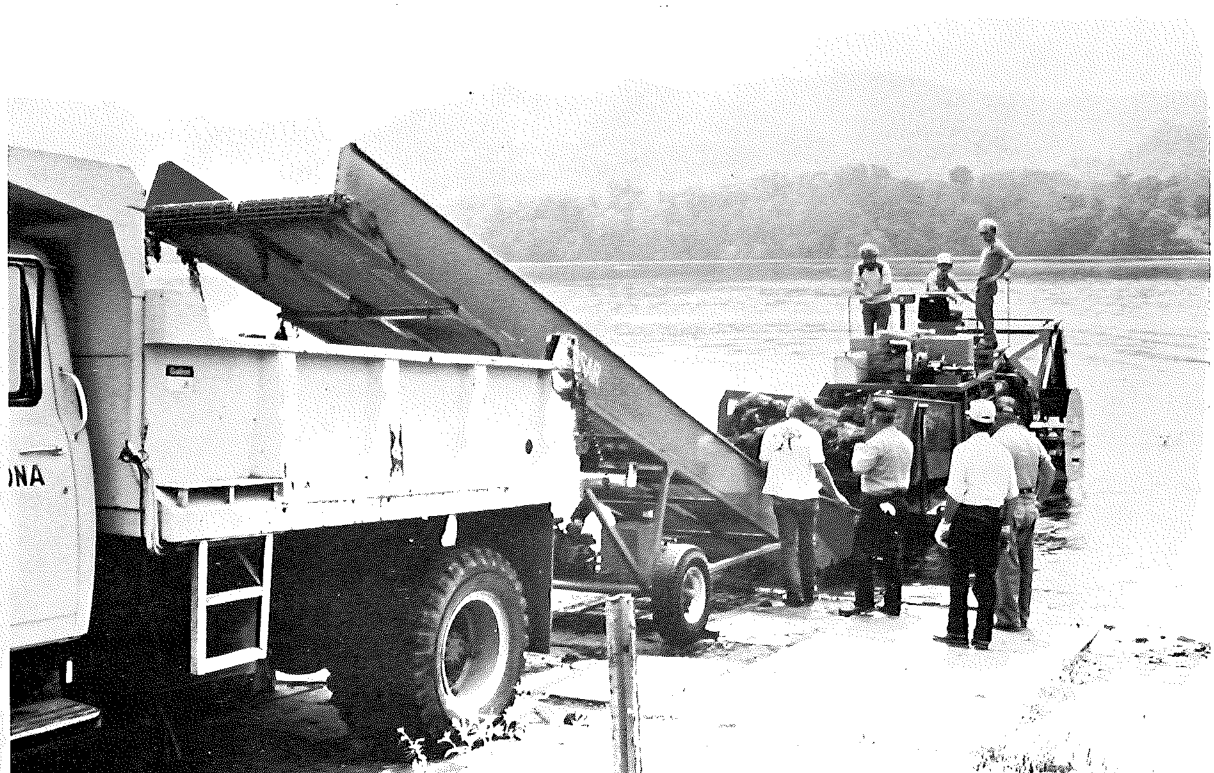


Figure 9-9. When the hopper of the cutter-harvester is full, the unit is backed into shore and its contents are conveyed to an on-shore conveyor which loads them into a truck.

All weed cutting on Lake Winona must be done by annual permit from the Minnesota DNR. In summary, the permit allows cutting and removal to be done as necessary in water deeper than five feet. It does not permit the cutting of the water lily bed on the south shore of the upper lake. Except in prescribed high-use areas (see Appendix 9-6 for map), cutting is not permitted in water less than five feet deep because of bass spawning.

The following is an excerpt from a letter dated May 20, 1983, from the Minnesota DNR Area Fisheries Manager to Robert Welch, Winona City Park Director, explaining the near-shore cutting restrictions:

> "....the major concern is with the interference to largemouth bass spawning attempts created by the removal of vegetation and the physical disturbance of the bottom by the cutter/harvester. Electrofishing in the shallow zone (two to five feet) of Lake Winona on Monday, May 16, revealed that large numbers of adult bass were occupying this zone. A small amount of nest construction was observed, indicating that the spawning process was just being initiated. Water temperature of 61°F on this day is additional evidence that spawning was just getting underway. If water temperatures progressively warm during the next two weeks, most of the bass spawning should be completed at the end of this period. Add on an additional 10 days or two weeks for egg incubation, hatching and absorption of the yolk sac and another 30 days for dispersal of the brood and most of the bass spawning effort and progeny should be safe from the effects of cutting.
>
> Therefore, for the next two months we will ask that cutting be limited within the zone of water near shore less than five feet deep. Recognizing the need to remove vegetation in this area in order to provide ease of fishing, boat passage, etc., we have these recommendations for cutting within this zone. These recommendations are based on our observations of where most of the recreation takes place and on the distribution of bass based on our recent electrofishing. Cutting within the shallow zone will be permitted as shown on the attached map.
>
> In addition to this, swaths three times the width of the cutter/harvester may be made at intervals of not less than 100 yards. Cutting on the remainder of the lake at depths greater than five feet is without restriction. We advise that all the near shore cutting as described above proceed as soon as possible with the hope that most of it can be completed in advance of the peak of the bass spawning."

Each season is different, and the progress of the bass spawning and brood dispersal is monitored by Minnesota DNR personnel. Though the date when the restrictions are lifted varies, the permitting process precludes cutting along most of the shoreline until about July 15. Although this procedure is biologically important to the bass, it is very unpopular with most lake users because the weeds make the shallows unswimmable, unfishable, and to some, unattractive.

Sailors have been critical of the reclamation project because the lake is now too weedy for sailing until early July when the P. crispus die-back is well along. Their sport was favored in the 1965 - 1973 weed-free period.

The Altosar has cut the aerator hoses near the swimming beach on several occasions. The bottom there drops off gradually, and the air-filled hoses bow upward between their anchors, which are spaced about 15 feet apart. When the Altosar strikes a hose it usually pulls hard enough to disjoint the hose at a coupling. Repair of such breaks is very difficult. A SCUBA diver must find the ends of the uncoupled hose in a very hostile environment. The diver's movements stir up silt which cuts off all light (lanterns do not help). The water in the hypolimnion is so cold (55^{o}F) that a wet suit must be worn.

Prior to 1984, any such diving had been done by volunteers. In the summer of 1984, two professional divers were hired to repair the hose when the usual volunteers were unavailable. The total bill for these services was $716.00, which was paid by the city.

RESULTS OF AQUATIC WEED HARVESTING

The Altosar aquatic weed harvesting system began operation in the summer of 1982. Because this was the middle of the weed harvesting season, a full harvest was not obtained in 1982. The first full season of harvesting began in May 1983. One load (area 20B, May 18) was sorted and analyzed for species composition by limnology students from Winona State University.

The total drained weight of the sample was 922.6 lbs.(920 lbs. curlyleaf pondweed, 2.5 lbs. coontail, 0.1 lbs. Elodea). It also contained a 0.75 lbs. of small fish (46 2-5 inch bluegills; 3 7-inch black crappies). By extrapolating from an 11-lb. sample, the following load totals were estimated for invertebrates: Gammarus sp. amphipods - 3,427; Helisoma sp. snails - 3,344; Chironomus sp. midge larvae - 3,929; Odonata damselfly nymphs - 167. Many Hydra were also observed. Weed leaves were covered with marl.

During the remainder of the 1983 weed harvesting season, Winona State University biology student Mark Veloske sampled 10 loads of weeds chosen at random from normal operations. He estimated species composition of the loads by volume and counted and identified the fish in each load. He also submitted kiln-dried composite samples of weeds for nutrient analysis to the chemistry laboratory at the J. R. Watkins Company of Winona, MN. Veloske's data are presented in Tables 9-1, 9-2.

Table 9-1. Composition of Weeds Harvested from Lake Winona During the Summer of 1983.

SAMPLE	I	II	III	IV
DATE	May 18	June 28	Aug. 9	Sept. 1
SAMPLE SITE	B-26,27; A-28	F-5; D-5; F-4,5,6	B-17,18,19, 20; C-16,17	D-5; E-2,5; F-2,3,4,5
SPECIES COMPOSITION (% VOLUME)				
CURLYLEAF PONDWEED	98.0	100		
COONTAIL	1.9		75.0	100
ELODEA	0.1		6.3	
LEAFY PONDWEED			12.5	
SAGO PONDWEED			3.1	
BUSHY PONDWEED			3.1	
SUB-SAMPLE (lbs)				
WET	46.2	16.5	16.5	15.5
ROOM DRY	4.6	1.6	1.2	0.8
KILN DRY	4.1	1.5	1.1	0.7
ENTIRE TRUCK LOAD (lbs)				
WET	923	1,807	2,340	1,342
ROOM DRY	92	175	167	65
KILN DRY	82	159	149	59
% COMPOSITION OF KILN-DRIED WEEDS (BY WEIGHT)				
MOISTURE	0	0	0	0
DRY MATTER	100	100	100	100
DIGESTIBLE FIBER	24.0	21.3	24.4	13.3
INDIGESTIBLE FIBER	55.6	58.0	50.3	70.5
CRUDE PROTEIN	13.8	13.4	18.4	11.8
NITROGEN (N)	2.2	2.1	2.9	1.9
PHOSPHORUS (P_2O_5)	0.4	0.3	0.3	0.2
CALCIUM (Ca)	6.2	7.0	6.6	4.2

Table 9-2. Fish Harvested With Weeds During Summer of 1983.

SPECIES	AV.NO./LOAD	AV.LENGTH(in)	LOADS/SUMMER	EST.TOTAL/SUMMER
*SUNFISH	59.5	3.8	419	24,930
LARGEMOUTH BASS	12.5	2.4	419	5,238
BLACK CRAPPIE	4.4	7.8	419	1,844
YELLOW PERCH	0.8	4.8	419	335
BLACK BULLHEAD	0.4	8.9	419	168
FLATHEAD CATFISH	0.1	6.7	419	42

*predominantly greens, some bluegills.

On June 21, 1984, a 32-gallon container was heaped with 99.5 lbs. of packed weeds (99% P. crispus, 1% C. demersum by volume) which had been allowed to drain for one hour (Fig. 9-10). They were composted anaerobically in the plastic container and were composted aerobically after the original water had evaporated. The resultant air-dry compost weighed 2.5 lbs. (Figure 9-10). An analysis of this compost by Minnesota Valley Testing Laboratories showed that it contained, by weight: moisture 40.3%, nitrogen (N) 1.7%, phosphorus (P_2O_5) 0.74%, potassium (K_2O) 0.71%.

These results indicate that Lake Winona's composted weeds would make good soil conditioner, compost material, and mulch. Fresh weeds are especially good for garden mulching because they contain few seeds from land plants.

Table 9-3

1982-1983 WEED HARVESTING COST ANALYSIS. DATA PROVIDED BY ROBERT WELCH, DIRECTOR OF PARKS, RECREATION AND FORESTRY - CITY OF WINONA.

I. Original purchase cost: $52,200 (cutter-harvester, shore conveyer, trailer)

II. Repair & Maintenance Cost: (Parts, labor, gas, oil, lube.)

1982	1983
$570.38	$2,207.04

III. Labor Cost for Running the Project.

	1982		1983	
	Hrs.	Cost	Hrs.	Cost
Part-time	41	$ 137.35	85	$ 286.45
Full-time	304	2,674.62	594	5,302.31
Totals	345	$2,811.97	679	$5,588.76

IV. Fuel Consumption - 1983
208 Gals. of Diesel (Harvester)
15 Gals. of Gas (Shore Conveyer)

V. Transportation of Weeds to Shive Road (1983)
- 1 Ton Truck = .24 per mile
- Approximate mileage round trip

East	West	
3 miles*	5 miles*	
.24	.24	
.72 per trip or load	1.20 per trip or load	
201 loads	218 loads	
$144.72	$261.60	= Total $406.32

*Approximate

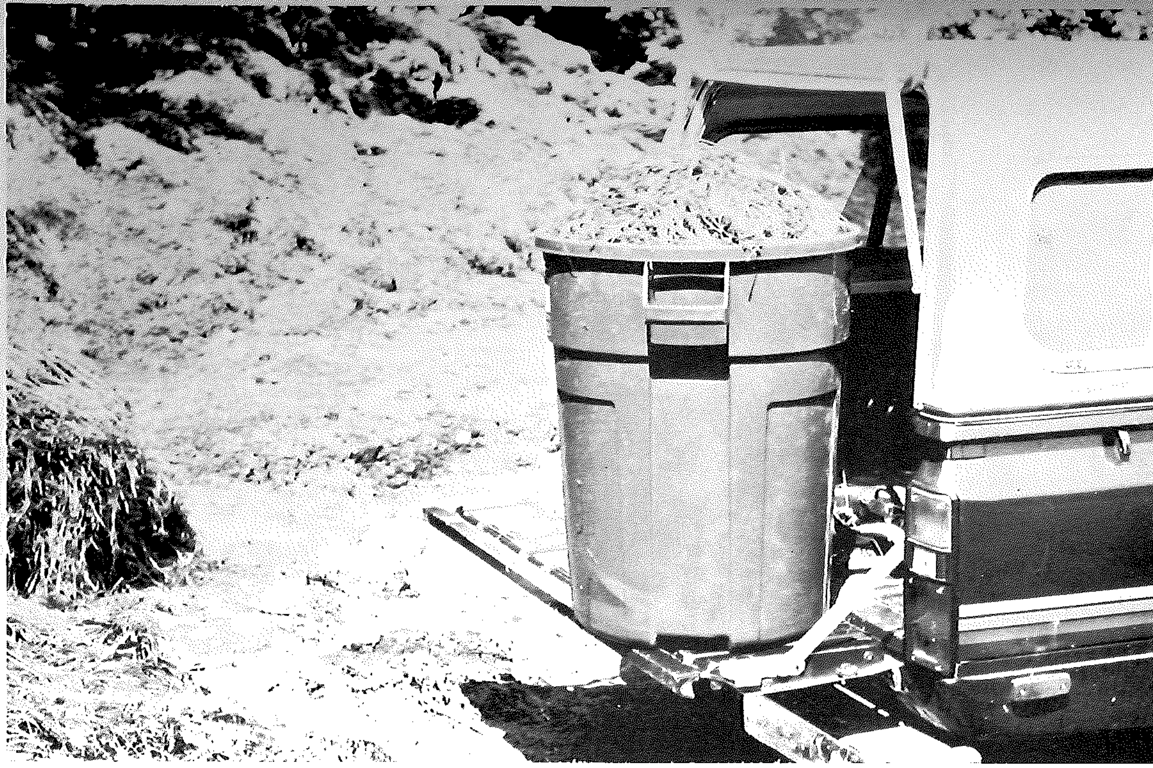
VI. Loads, etc. - 1983

	Loads	Cubic Feet*	Wet Tons*
East	201	65,325	251
West	218	70,850	272
	419	136,175	523

*Approximate

VII. Total

Cost - 1983	
- Repair & Maintenance	$ 2,207.04
- Insurance (12 months)	365.40
- Depreciation (based on 13 years)	3,999.96
- Labor for Operating	5,588.76
- Transportation	406.32
Total	$12,567.48



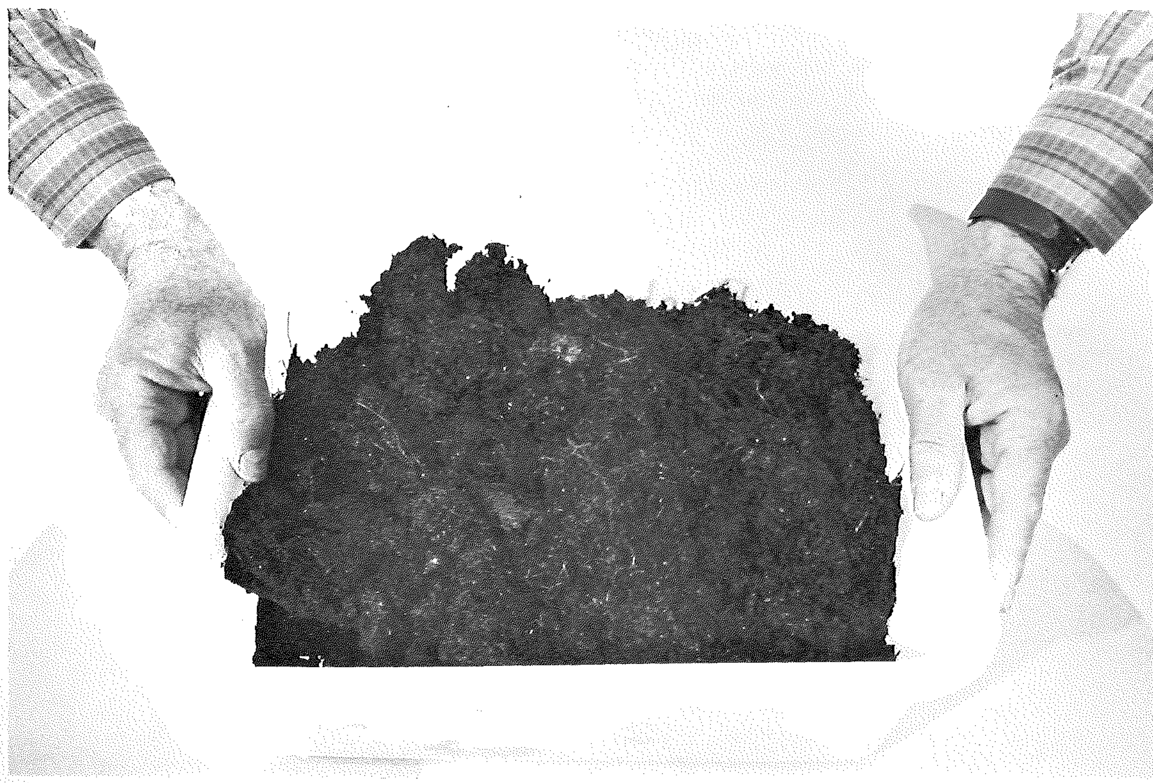


Figure 9-10. Composted lake weeds make good soil conditioner, mulch and compost because they contain few seeds of terrestrial weeds. About 97% of the weight of wet weeds (above) is lost when they are converted to air-dry compost (below).