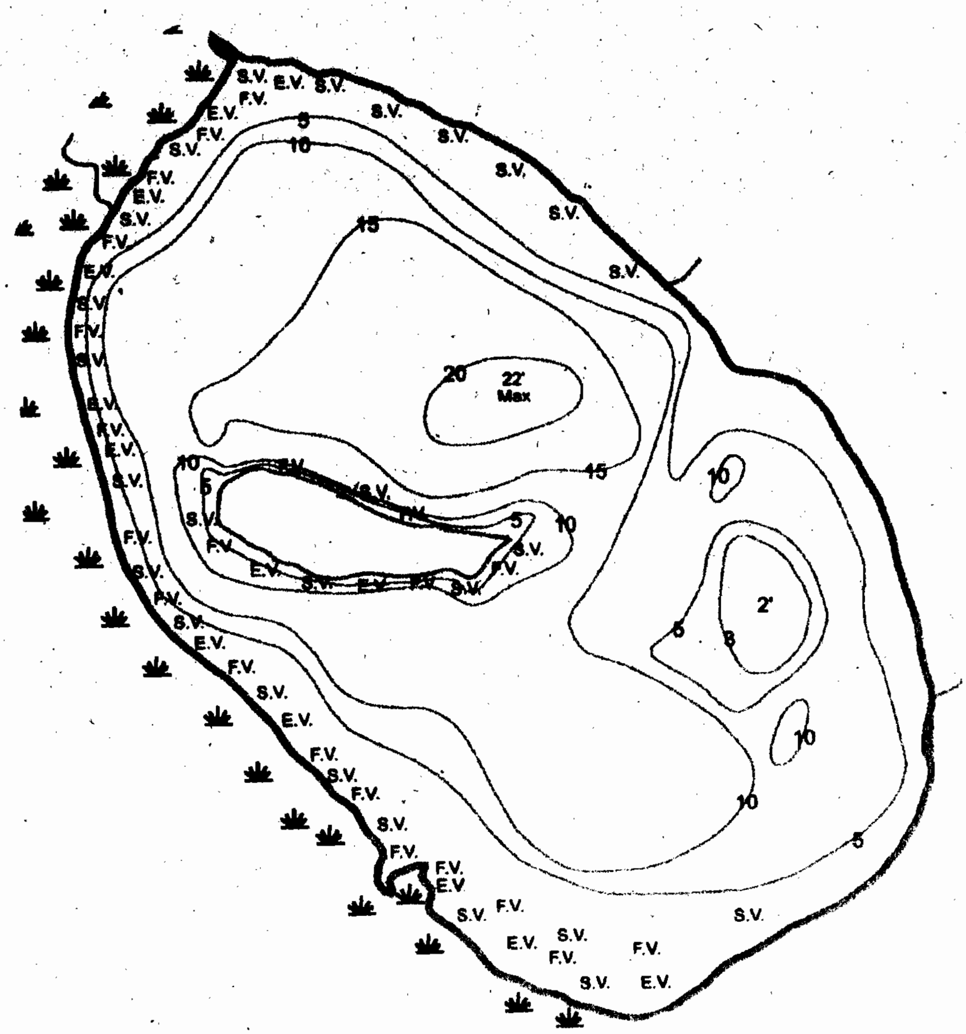
Loon Lake

Comprehensive Survey Results and Management Plan

February 6, 2003



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1.0 Abstract

In 2002, the Loon Lake Management District retained Aquatic Biologists, Inc. to conduct a comprehensive survey of Loon Lake, Shawano County, Wisconsin, and to develop a management plan directed at controlling Eurasian watermilfoil. The survey involved assessing aquatic plant communities, mapping Eurasian watermilfoil distribution, analyzing water quality parameters, assessing watershed influences, and studying the efficacy of a two year milfoil weevil stocking program that had been implemented on the lake.

The survey found a very high diversity of submergent and emergent aquatic plants. The submergent plant community was dominated by Eurasian watermilfoil. This exotic species covered 87.7 acres, or 28.8% of the total lake area. Water quality was generally good, although water clarity was reduced from tannins. Water quality had declined slightly from the previous survey. The Loon Lake watershed was found to cover 8465 acres. Predominant cover types were upland forest and swamp forest. The lake was well buffered by numerous wetlands. Nutrient inputs from the watershed were not a major concern. Analysis of groundwater flow patterns found that contamination from lakefront septic systems was unlikely. Weevil studies concluded that weevil stocking effort were unlikely to have impacted weevil density or milfoil density.

A review of milfoil management options concluded that the best strategy for Loon Lake will be to implement an aggressive treatment program utilizing the herbicide, 2,4D. Goals for milfoil reduction and restoration of native plants were established. Future plant surveys were recommended to assess program effectiveness.

2.0 Introduction

2.1 Description of Study Area

Loon Lake, located in Shawano County, has a surface area of 305 acres and a maximum depth of 22 feet. The east side of the lake is upland and is developed with cottages. The west side of the lake is predominantly wetland and remains in a natural state. The lake is fed by two inlets: Lulu creek and Loon Creek, and is drained by one outlet: Loon Creek. A public boat launch and a church camp are located at the south end of the lake. The Loon Lake Management District was created to represent the interests of riparian property owners and other lake users.

Due to its shallow, fertile nature, Loon Lake has had a history of nuisance aquatic plant growth. Since at least 1995, Loon Lake has been infested with Eurasian watermilfoil (*Myriophyllum spicatum*), an invasive exotic plant. This species formed dense beds that occupied more than 25% of the lakebed by 2001. Invasion of this plant greatly impaired recreational uses and aesthetics – making control of the plant the primary concern of the Loon Lake Management District.

2.2 History of Management Activities

During 1991 and 1992 a two phase study was conducted by Foth & Van Dyke of Green Bay, Wisconsin. Phase I focused on assessing U.S. Geological Survey data on phosphorus concentrations for inflowing tributaries to determine lake nutrient loading concerns, surveying aquatic plants, and assessing watershed impacts. The Phase I report concluded that 1) nutrient loading from inflowing streams was a minor concern, 2) mechanical weed harvesting should be continued to control nuisance plants, and may serve as a mechanism for nutrient removal, and 3) that soil types around the lake were not suitable for private septic systems.

The Phase II study continued the sampling design of the Phase I study, but focused more on nutrient loading from riparian sources. The Phase II report recommended that the Lake District gain control of nutrients discharged into the lake. Specific recommendations included restricting riparian lawn fertilizer use and abandoning private septic systems in favor of sanitary sewer hookup. Intensifying weed harvesting was discussed as a method of reducing in-lake nutrients, but was not recommended for the risk of altering the aquatic plant community to less desirable forms, such as algae. Dredging of bottom sediments was also discussed as a method for reducing internal nutrient cycling, but was considered too ecologically disruptive and was not recommended either.

A mechanical weed-harvesting program ran concurrently with the Foth & Van Dyke study. This program was directed a controlling nuisance growths of coontail (*Ceratophyllum demersum*) and bushy pondweed *(Najas flexilis*). The weed-harvesting program continued after Eurasian watermilfoil invaded the lake. However it was thought to be encouraging dispersal of the plant and was not providing adequate control, and therefore was discontinued.

In 2000, the Loon Lake Management District retained EnviroScience, Inc. of Stow, Ohio to implement a milfoil control program on Loon Lake that involved stocking milfoil weevils (*Euhrychiopsis lecontei*). Prior to any stocking activities, EnviroScience conducted an assessment of Loon Lake and found a strong native weevil population. Nonetheless 15,000 weevil "eggs and larvae" were stocked in 2000, and 9,500 weevil "eggs and larvae" were stocked in 2001. Following the 2001 stocking, EnviroScience again assessed weevil densities in the lake. Weevil populations were found to have declined sharply at all sample locations. Despite the recorded decrease in weevil density, EviroScience concluded that weevil populations had actually increased in the lake as evidenced by extensive milfoil stem damage. However these claims were met with skepticism by Lake District members.

In 2002, the Loon Lake Management District retained Aquatic Biologists, Inc. to conduct another comprehensive survey of Loon Lake. This study also researched the efficacy of the weevil stocking program, and researched alternative methods for Eurasian watermilfoil control. This report presents the findings of this study and provides recommendations for the future management of Loon Lake.

2.3 Project Goals

The ultimate goal of this project was to formulate a strategy for returning Loon Lake as closely as possible to pre- Eurasian water milfoil conditions, and also to maintain the lake in that condition for the long term. Secondary goals were to assess water quality, and watershed land use influences, and develop management strategies for other exotic species.

The work elements of this project included:

- Conducting line transect surveys of aquatic plants throughout the lake.
- Conducting shoreline transect surveys of emergent plant around the entire lake.
- Mapping the distribution of Eurasian watermilfoil
- Analyzing in-lake physical and chemical parameters
- Studying milfoil weevil densities and assessing stocking effectiveness
- Assessing watershed characteristics and potential influences
- Researching lake management options

3.0 Methods

3.1 Aquatic Plant Surveys

The aquatic plant surveys utilized reproducible methods so that future surveys can accurately assess changes to the plant community. For the first survey, a series of twelve transects (labeled A through L) were laid out on the lake – radiating at 60 degree intervals from two central points in the lake basin (**Figure 1**). While all species encountered were recorded, this survey was more likely to encounter submergent plants and was called the Submergent Plant Survey. Plant samples were collected at four quadrants along each transect at 2.5, 5, 7.5, and 10-foot depths. Samples were collected with a tethered short-toothed rake. Four rake tows were made at each quadrant, for a total of 192 rake tows. All samples collected were identified to *genus* and to *species* whenever possible. Data tabulated included species composition, percent frequency and relative abundance. GPS coordinates for transect starting points are given in **Table 1**.

The second survey, the Emergent Plant Survey, employed transects that ran parallel to shore. Eight transects of approximately equal length followed the entire shoreline. These transects were labeled S1 through S8. Two additional transects circumscribed the island and were labeled I1 and I2 (**Figure 2**). For this survey, only emergent and floating-leaf plants were identified and recorded. Each species encountered was then given a relative abundance ranking based on the following criteria:

0	*Absent*	not found along transect
1	*Rare*	found along less than 5% of transect
2	*Present*	found along 5 – 25% of transect
3	*Common*	found along 25 – 50% of transect
4	*Abundant*	found along more than 50% of transect

From this data, species composition, percent frequency and relative abundance were calculated.

3.2 Eurasian Watermilfoil Mapping

The location and extent of Eurasian watermilfoil beds was identified visually and with rake tows. The dimensions of the beds, minimum and maximum depths, and distances from shore were measured and recorded on a contour map. The map drawings were then superimposed upon an acreage grid to determine the area of the beds.

3.3 Analysis of Physical and Chemical Parameters

A complete water chemistry and limnology analysis was done in June and included:

- Dissolved (ortho) phosphorus
- Total phosphorus
- Total Kjeldahl nitrogen
- Nitrate + nitrite as N
- Ammonia as N
- Chloride
- Chlorophyll *a*
- Color
- Suspended solids
- Total dissolved solids
- Conductivity
- Alkalinity
- Dissolved oxygen profile
- Temperature profile
- Secchi depth
- pH

Seasonal water chemistry and limnology analysis was done during three other time periods: April (spring turnover), October (fall turnover) and January (mid-winter). These analyses included:

- Total phosphorus
- Nitrate + nitrite as N
- Chlorophyll *a*
- pH
- Dissolved oxygen profile
- Temperature profile
- Secchi depth

Water samples were taken one foot below the surface and one foot above the lakebed at the deepest point for all analyses except Chlorophyll *a,* which was collected at the surface only. All samples not analyzed in the field were sent to the State Lab of Hygiene for analysis. Data was used to assess water quality and trophic state. Comparisons were made with past survey data to assess changes in the lake.

3.4 Milfoil Weevil Study

Eurasian watermilfoil density, milfoil weevil density and extent of milfoil stem damage were assessed on Loon Lake and on Lulu Lake – a nearby lake infested with Eurasian watermilfoil that had never been stocked with weevils. Methods for both lakes involved cutting the top 12 inches of Eurasian watermilfoil stems within a 1-meter quadrant, then counting the number of stems, the number of insect damaged stems, and the number weevils per apical stem. All stems with obvious insect burrowing were considered insect-damaged. Apical cuts, which may have arisen from boat props, were not counted. For Loon Lake, the established plant survey transects were used. One quadrant per transect was sampled. Sampling was done in the first dense bed of milfoil encountered while traveling out from shore. A similar set of transects, spaced 60° apart, were established on Lulu Lake. The same methods and criteria used on Loon Lake were then used on Lulu Lake.

The number of milfoil stems per quadrant will be used to gauge milfoil density – or the level of milfoil control. A correlation between weevil density and milfoil density was sought. These data were then used to assess whether augmented weevil populations had a greater impact than natural weevil populations.

3.5 Watershed Assessment

Assessment of the Loon Lake watershed and its potential impacts on the lake included delineation of watershed boundaries, area determination, identification of land uses and cover types and their acreage, surface water imports and exports, and groundwater flow patterns. Boundaries and land features were determined from topographic maps and ground surveys. Water imports and exports were determined with the aid of an electronic flow meter. Groundwater flow patterns were determined with portable piezometers.

Figure 1. Loon Lake 2002 submergent plant survey transects.

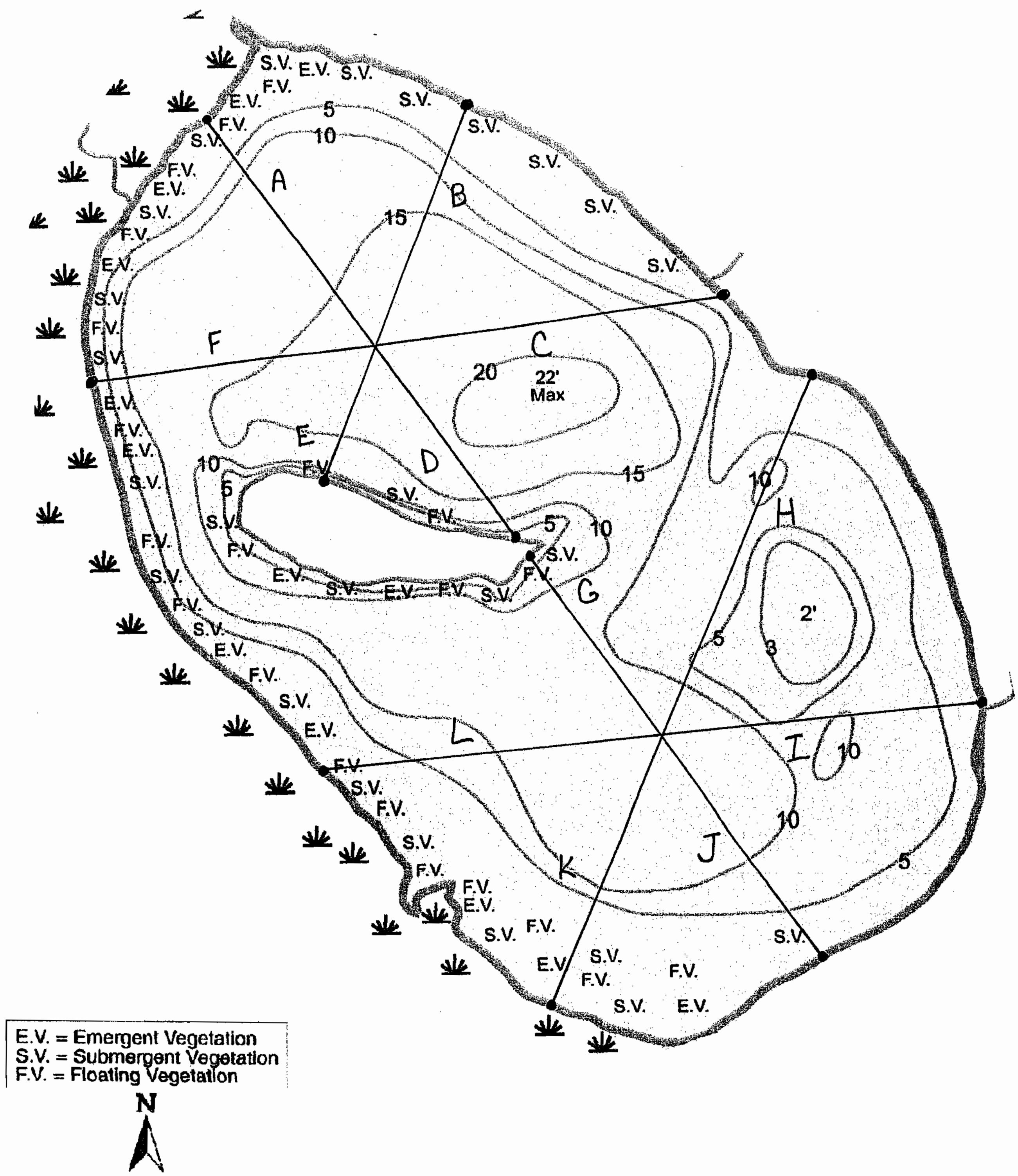


Figure 2. Loon Lake 2002 emergent plant survey transects.

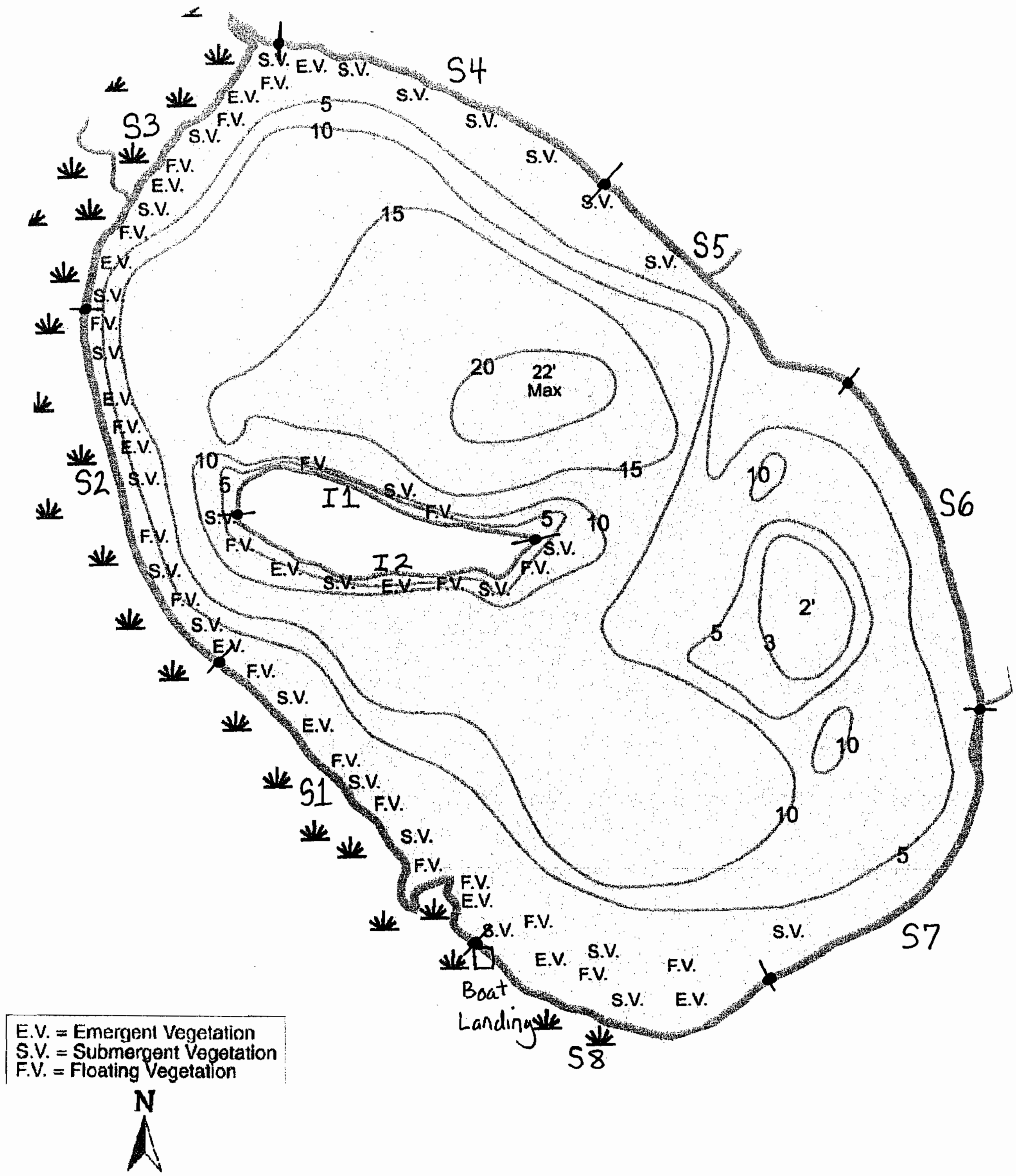


Table 1. Submergent plant survey transect starting point coordinates and direction of travel.

Transect	GPS Coordinates	Compass Direction°
A	N44° 50.353' W088° 31.002'	140
B	N44° 50.376' W088° 30.679'	200
C	N44° 50.231' W088° 30.419'	260
D	N44° 50.017' W088° 30.624'	320
E	N44° 50.072' W088° 30.871'	20
F	N44° 50.186' W088° 31.124'	80
G	N44° 50.006' W088° 30.643'	140
H	N44° 50.142' W088° 30.331'	200
I	N44° 49.835' W088° 30.148'	260
J	N44° 49.663' W088° 30.340'	320
K	N44° 49.676' W088° 30.645'	20
L	N44° 49.897' W088° 30.940'	80

4.0 Results and Discussion

4.1 Aquatic Plants

4.11 Submergent plant survey results

A total of thirty species of aquatic plants were found in the submergent plant survey. The results are shown in **Table 2**. This is a very rich diversity of aquatic plants. Unfortunately, the plant community was clearly dominated by Eurasian watermilfoil, an invasive exotic. Eurasian watermilfoil was found in 63.5% of rake tows, and made up 24.4% of the total plant composition. Coontail was next most abundant, at a distant 22.4 % frequency and 8.6% composition. Fern pondweed (*Potamogeton robinsii*), musk grass (*Chara spp.*) and elodea (*Elodea canadensis*) followed in abundance. Aside from Eurasian watermilfoil, the only other exotic species found was curly-leaf pondweed (*P. crispus*). No plants were found in 6.8% of rake tows.

Species occurrences by transect are shown in **Table 3**. Transect C had the highest diversity with 18 species. Transect I had the lowest diversity with only five species. Eurasian watermilfoil was the only plant found in all 12 transects. Coontail and fern pondweed were also widely distributed, found in 11 and 10 transects, respectively.

Table 2. Results of the submergent aquatic plant survey conducted on Loon Lake during June 2002.

Species common name	scientific name	Percent Frequency	Percent Composition
Eurasian Watermilfoil	*Myriophyllum spicatum*	63.5	24.4
Coontail	*Ceratophyllum demersum*	22.4	8.6
Fern Pondweed	*Potamogeton robinsii*	21.9	8.4
Musk Grass	*Chara spp.*	16.7	6.4
Elodea	*Elodea canadensis*	14.6	5.6
Illinois Pondweed	*Potamogeton illinoiensis*	12.5	4.8
Water Celery	*Valisneria americana*	11.5	4.4
Large Leaf Pondweed	*Potamogeton amplifolius*	9.9	3.8
Bladderwort	*Utricularia vulgaris*	9.4	3.6
Bushy Pondweed	*Najas flexilis*	9.4	3.6
Stonewort	*Nitella spp.*	9.4	3.6
Spadderdock	*Nuphar variegata*	8.3	3.2
Watershield	*Brasenia schreberi*	7.3	2.8
Curly Leaf Pondweed	*Potamogeton crispus*	6.8	2.6
Dwarf Watermilfoil	*Myriophyllum tenellum*	5.2	2.0
White Water Lily	*Nymphaea odorata*	4.7	1.8
Flatstem Pondweed	*Potamogeton zosteriformis*	3.6	1.4
White Stem Pondweed	*Potamogeton praelongus*	3.1	1.2
Leafy Pondweed	*Potamogeton foliosus*	2.6	1.0
Star Duckweed	*Lemna trisulca*	2.6	1.0
Water Stargrass	*Zosterella dubia*	2.6	1.0
Needle Rush	*Eleocharis acicularis*	2.1	0.8
Ribbon Leaf Pondweed	*Potamogeton epihydrus*	2.1	0.8
Water Moss	*Drepanocladus spp.*	2.1	0.8
Filamentous Green Algae	*Spirogyra spp.*	1.6	0.6
Water Marigold	*Bidens beckii*	1.6	0.6
Bur-reed	*Sparganium eurycarpum*	1	0.4
Clasping Leaf Pondweed	*Potamogeton richardsonii*	1	0.4
Floating Leaf Pondweed	*Potamogeton natans*	0.5	0.2
Sago Pondweed	*Potamogeton pectinatus*	0.5	0.2
No Plants Found		6.8	

Table 3. Loon Lake submergent aquatic plant survey data by transect.

Species	Transect / Occurences												
common name	**A**	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**	**J**	**K**	**L**	**total**
Bladderwort	4	1	2		3	3	2				2	1	18
Bur-reed	2												2
Bushy Pondweed		4	1		1		2	3		4	3		18
Clasping Leaf Pondweed				2									2
Coontail	5	1	2	2		13	1	5	5	2	2	5	43
Curly Leaf Pondweed	2	2				1	1	1		1	2	3	13
Dwarf Watermilfoil		1	2	1	1		2	2		1			10
Elodea	2	3	3			5		1		5	7	2	28
Eurasian Watermilfoil	13	10	12	7	12	11	11	8	9	10	11	11	125
Fern Pondweed	4		4		1	6	2	6	1	2	6	10	42
Filamentous Green Algae	3												3
Flatstem Pondweed	2	1		1	1						1	1	7
Floating Leaf Pondweed											1		1
Illinois Pondweed		1	1	5	6		4	5		2			24
Large Leaf Pondweed	2	2	3	1		1	3				5	2	19
Leafy Pondweed		3	1					1					5
Musk Grass		3	6	6	4	1	4	6		2			32
Needle Rush		1						1	2				4
Ribbon Leaf Pondweed	2		1			1							4
Sago Pondweed				1									1
Spadderdock	2				7	2	1				3	1	16
Star Duckweed	1		1			3							5
Stonewort			2				2	7		3	4		18
Water Celery	3	4	3		1		1	5	1	4			22
Water Marigold		1	1				1						3
Water Moss			2		2								4
Water Stargrass	1	1				2		1				1	6
Watersheild	4					2					4	4	14
White Stem Pondweed		2	3					1					6
White Water Lily						4					2	3	9
No Plants Found	1	2		3	2				4			1	13
Number of species found	**16**	**17**	**18**	**9**	**11**	**14**	**14**	**15**	**5**	**11**	**14**	**12**	

4.12 Emergent plant survey results

The results of the emergent plant survey are shown in **Table 4**. A total of 16 species of emergent and floating-leaf plants were found. Six of these species were also found in the submergent plant survey, thus the total number of aquatic plant species found in Loon Lake between the two surveys was 40. Spadderdock or yellow water lily (*Nuphar variegata*) was most abundant, at 70% frequency and 22.2% composition. Water willow (*Justicia americana*) followed closely at 64% frequency and 20.6% composition. Watershield (*Brasenia schreberi*), sweet gale (*Myrica gale*) and white water lily (*Nymphaea odorata*) were also found in abundance.

Emergent plant communities provide critical habitat for many species of fish, birds and mammals. These habitats are most likely to be destroyed when lakeshores are developed with homes and summer cottages. Indeed, species diversity by transect (**Table 5**) correlated with the degree of development along shore (**Table 6**). The highest diversity, 14 species in transect S3, was found along the undeveloped north shore near the Loon Creek inlet. In contrast, only one specie was found along transects S6 and S7 – where cottages were tightly spaced along the southeast shore. Along the northeast shore where cottages were more widely spaced (presumably where property owners did not feel a need to clear the entire shoreline of emergents) species diversity was similar to that of undeveloped shorelines.

Table 4. Results of the emergent aquatic plant survey conducted on Loon Lake during June 2002.

Species common name	scientific name	Percent Frequency	Percent Composition
Spadderdock	*Nuphar variegata*	70	22.2
Water Willow	*Justicia americana*	65	20.6
Watershield	*Brasenia schreberi*	37.5	11.9
Sweet Gale	*Myrica gal*	30	9.5
White Water Lily	*Nymphaea odorata*	30	9.5
Pickerelweed	*Pontederia cordata*	17.5	5.5
Bur-reed	*Sparganium eurycarpum*	10	3.2
Sago Pondweed	*Potamogeton pusillus*	10	3.2
Three-square Bulrush	*Scirpus pungens*	10	3.2
Canada Bluejoint Grass	*Calamagrostis canadensis*	7.5	2.4
Floating Leaf Pondweed	*Potamogeton natans*	7.5	2.4
Blue Flag Iris	*Iris versicolor*	5	1.6
Broad Leaved Cattail	*Typha latifolia*	5	1.6
Large Leaf Pondweed	*Potamogeton natans*	5	1.6
Hardstem Bulrush	*Scirpus acutus*	2.5	0.8
Tussock Sedge	*Carex stricta*	2.5	0.8

Table 5. Loon Lake emergent aquatic plant survey data by transect.

Species		Transect/Abundance Ranking										
common name	**scientific name**	**S1**	**S2**	**S3**	**S4**	**S5**	**S6**	**S7**	**S8**	**I1**	**I2**	**Total**
Blue Flag Iris	*Iris versicolor*			1	1							2
Broad Leaved Cattail	*Typha latifolia*			1		1						2
Burreed	*Sparganium eurycarpum*			2	1	1						4
Canada Bluejoint Grass	*Calamagrostis canadensis*			1	1	1						3
Floating Leaf Pondweed	*Potamogeton natans*			2					1			3
Hardstem Bulrush	*Scripus acutus*			1								1
Large Leaf Pondweed	*Potamogeton amplifolius*				1	1						2
Pickerelweed	*Pontederia cordata*	1	1	2						1	2	7
Small Pondweed	*Potamogeton pusillus*		2	2								4
Spadderdock	*Nuphar variegata*	4	4	4	1	2	1	1	3	4	4	28
Sweet Gale	*Myrica gale*	2	3	2						3	2	12
Three-square Bulrush	*Scripus pungens*					1					3	4
Tussock Sedge	*Carex stricta*			1								1
Water Sheild	*Brasenia schreberi*	4	4	4					3			15
Water Willow	*Justicia americana*	4	4	4	1	1			4	4	4	26
White Water Lily	*Nymphaea odorata*	4	4	2	1				1			12
Species per transect		**6**	**7**	**14**	**7**	**7**	**1**	**1**	**5**	**4**	**5**	

Relative abundance Ranking	1 Rare	found along less than 5% of transect
	2 Present	foung along 5-25% of transect
	3 Common	found along 25-50% of transect
	4 Abundant	found along more than 50% of transect

Table 6. Riparian habitat types found along the emergent plant survey transects.

S1	Undeveloped. Predominantly a bog community - tamarack swamp. 100-foot fringe of floating-leaf plants along shore.
S2	Undeveloped. Bog community – tamarack, alder, poison sumac. 100-foot fringe of floating-leaf plants.
S3	Undeveloped. Bog, shrub-carr. Loon Creek inlet. Increased diversity of emergents. 50 – 100-foot fringe of floating-leaf plants.
S4	Developed with cottages and homes – more widely spaced. Low, flat terrain, predominantly pine-oak-birch forest. most of shoreline is rock riprap.
S5	Developed with cottages and homes – more widely spaced. Low, flat terrain, predominantly pine-oak-birch forest. Scattered small areas of undisturbed shoreline.
S6	Developed with tightly spaced homes and cottages. Pine-oak-birch over story. Manicured lawns. Rock riprap. Very few emergent plants.
S7	Developed with tightly spaced homes and cottages. Manicured lawns. Extensive areas of solid cement seawall. Poorest shoreline habitat on lake.
S8	Developed with homes and summer camp. Most of shoreline has been left in a natural state, predominantly shrub-carr community. About half of the shoreline has a 100 – 200-foot fringe of floating-leaf plants.
I1	Undeveloped Island, partially inundated. Mostly dead pines and tamaracks. Bog and shrub-carr communities. 25 – 50-foot fringe of floating-leaf plants.
I2	Undeveloped island, Similar to I1. More variation in extent of floating-leaf plant fringe.

4.13 Importance of aquatic plants

Rooted aquatic plants play a vital role in the health of lakes. Plants affect chemical, physical and biological characteristics of aquatic environments. Rooted aquatic plants maintain lake water quality and clarity by stabilizing shorelines and bottom sediments, and by tying up nutrients that would otherwise be utilized by algae. Aquatic plants provide food and substrate for a host of invertebrates. Many species of fish require aquatic plants for feeding, spawning and nursery areas. Likewise aquatic plants provide important food and habitat for many species of birds, reptiles, amphibians and mammals.

The high diversity of aquatic plants found in Loon Lake is indicative of a healthy aquatic ecosystem. Preserving native plant communities for the long-term will be essential to preserving Loon Lake's water quality, aesthetics, ecology and recreational values. A physical description of aquatic plants commonly found in Loon Lake and a brief description of their importance is given in **Table 7**.

Table 7. Description and ecological value of native aquatic plants commonly found in Loon Lake.

Species	Description	Ecological Value
Bladderwort *(Utricularia vulgaris)*	Floating stems grow 2-3 meters long and are made up of finely divided leaf-like branches containing bladders that trap prey	Provides food and cover for fish; grow in very loose, soft sediment where other aquatic plants have a hard time establishing
Bur-reed *(Sparganium eurycarpum)*	Long, sword-like leaves resemble cattails at a glance, but are triangular in cross-section. Produces white bur-like flowers on zig-zag stems	A favorite food of muskrats. Seeds are commonly eaten by waterfowl and marsh birds.
Bushy Pondweed *(Najas flexilis)*	Submersed plant with a finely branched stem growing up to 1 meter; leaves are narrow, pointed, and grow in pairs	Very important food for many species of waterfowl and marsh birds; provides a good source of shelter and food for fish
Coontail *(Ceratophyllum demersum)*	As its name implies, it produces whorls of narrow, toothed leaves on a long trailing stem that often resembles the tail of a raccoon	Provides shelter for young fish and is home to insects which provide food for fish and waterfowl; captures a large amount of sediment and phosphorus which greatly helps water quality
Dwarf Watermilfoil *(Myriophyllum tenellum)*	Unique among the Watermilfoil family. Leaves are reduced to tiny scales along short unbranched stems. This plant spreads from buried rhizomes and forms a dense grass-like turf along the lakebed.	Provides important habitat for invertebrates and small fish. The dense turf it forms helps stabilize sediments and promotes good water quality.
Elodea *(Elodea canadensis)*	Made up of slender stems with small, lance shaped leaves that attach directly to the stem; leaves are in whorls of 2 or 3 and are more crowded toward the stem tip	Provides cover for fish and is home for many insects that fish feed upon
Flat-stem Pondweed *(Potamogeton zosterformis)*	Emerges from a rhizome which has a strongly flattened stems; leaves are stiff with a prominent mid-vein and many fine parallel veins	Provides cover for fish and is home for many insects which are fed upon by fish
Illinois Pondweed *(Potamogeton illinoensis)*	Stout stems emerge from a thick rhizome; leaves are lance-shaped to oval and often have a sharp tip	Excellent cover for fish and invertebrates; source of food for waterfowl, muskrats, beaver, and deer
Large-Leaf Pondweed *(Potamogeton amplifolius*	Stems are tough and emerge from a ridged black rhizome; leaves are large and broad with many veins; submerged leaves tend to be arched and slightly folded	Offers excellent shelter, shade, and foraging habitat for fish; its nutlets are valued for food by waterfowl
Musk Grass *(Chara spp.)*	A complex algae that resembles a higher plant; its is identified by its pungent, musk-like odor and whorls of toothed branched leaves	Provides shelter for young fish and is associated to black crappie spawning sites; helps stabilize bottom sediments and contributes to better water quality

Table 7 continued.

Pickerel Weed *(Pontederia cordata)*	Glossy, heart shaped leaves that emerge above the water surface; leaf blade made up of many fine, parallel veins; flower spike crowded by many small blue flowers	Home for many insects and fish; food for muskrats and waterfowl; serves as an important shoreline stabilizer against wave action
Stonewort *(Nitella spp.)*	An algae that resembles a vascular plant. Similar in appearance to musk grass, but lacking calcium encrusted and the characteristic musky odor of musk grass.	Provides habitat for a host of invertebrates, and in turn, foraging areas for fish; often grazed upon by waterfowl
Sweet Gale *(Myrica gale)*	A perrenial shrub with wedge-shaped leaves; leaves are toothed and rounded at the tip; resinous dots are visbible on the underside. Leaves have a pungent aroma when crushed	Commonly found in bogs and inundated shores, this plant provides nesting habitat for birds and shelter for mammals.
Water Celery *(Valisneria americana)*	Made up of long ribbon-like leaves that emerge from a cluster; leaves tend to be mostly submersed with only leave tips trailing at water surface	Provides great habitat for fish and is relished by waterfowl, especially the canvasback
Watersheild *(Brasenia schreberi)*	Stems are long and elastic; root stalk attaches to the middle of a single oval leaf; leaves are green on the top and purple on the underside; maroon flowers emerge slightly above the water's surface	Provides shade and cover for fish and invertebrates; consumed by waterfowl
Water Willow *(Justica americana)*	Plants grow along shoreline and trail into water. Woody stems become cork-like underwater. Leaves opposite or in three's. produces purple flowers	An excellent shoreline stabilizer. Provides important nursery areas for fish.
White-Stem Pondweed *(Potamogeton praelongus)*	Long zigzag stems up to 2-3 meters; leaves clasp the stem and are oval shaped with a cupped, boat shaped tip.	Good food producer for waterfowl and furbearers; important habitat for musky and trout
White Water Lily *(Nymphaea odorata)*	Develop round reddish floating pads; large white flowers with yellow stamens float on the water surface	Important cover for fish, especially largemouth bass; food for muskrats, beaver, waterfowl, and moose

4.14 Exotic species

Many of the ecological, aesthetic and recreational values provided by the native aquatic plants found in Loon Lake are threatened by invasive exotic plants. With few natural controls, exotic plants can out compete many native species. This is often detrimental to lake ecosystems. Invasion of exotic aquatic plants has become one of the main problems facing Wisconsin lakes. Lake management groups spend millions of dollars annually toward management of nuisance exotic plants.

The most significant of these exotic invaders has undoubtedly been Eurasian watermilfoil. Eurasian watermilfoil was first introduced into U.S. waters in 1940. It had reached Wisconsin's lakes by 1960. Since then, its expansion has been exponential (Brakken, 2000). Eurasian watermilfoil can be identified by its long, spaghetti-like stems and reddish-tinged, feather-like leaves. It can be easily confused with several of the seven native milfoils. Distinguishing characteristics are the finely divided leaflets that occur in 14-20 pairs (Borman, et.al., 1997). Perhaps its most distinguishing characteristic though, is the plant's ability to form dense, impenetrable beds that grow to the water's surface, inhibiting boating, swimming and fishing.

Eurasian watermilfoil begins growing earlier than native plants, giving it a competitive advantage. The dense surface mats formed by the plant block sunlight and have been found to displace nearly all native submergent plants. Over 200 studies link declines in native plants with increases in Eurasian watermilfoil (Madsen, 2001). Dense growths of Eurasian watermilfoil have been associated with declines in fishery quality, invertebrate abundance and water quality (Pullman, 1993).

Curly-leaf pondweed has been found in the U.S. since at least 1910. A native of Europe, Asia, Africa and Australia, this plant is now found throughout much of U.S. (Baumann, et.al., 2000). Curly-leaf pondweed has oblong leaves that are 2-4 inches long and attach to a flattened stem in an alternate pattern. The most distinguishing characteristics of this plant are the crenellated appearance of the leaves, and the serrated leaf margins. Curly-leaf pondweed is a cold-adapted plant. It can begin growing under the ice while other plants are dormant. By mid-summer when water temperatures reach the upper 70° F range however, the plant begins to die off (Borman, et.al, 1997).

As with Eurasian watermilfoil, curly-leaf pondweeds aggressive early season growth allows it to out compete native species and grow to nuisance levels. Because the plant dies back during the peak of the growing season for other plants though, it is better able to coexist with native species than Eurasian watermilfoil. Perhaps the most significant problem associated with curly-leaf pondweed involves internal nutrient cycling. The die-off and decomposition of the plant during the warmest time of year provides a sudden nutrient release into the water column. This often leads to nuisance algae blooms and poor water quality.

4.15 Eurasian watermilfoil distribution

The distribution of Eurasian watermilfoil found during the survey is shown in **Figure 3**. A total of 87.7 acres were mapped. This is approximately 29% of the lake. Eurasian watermilfoil was most abundant in depths of three to ten feet. The maximum depth of the plant was apparently limited by water clarity. The minimum depth of the plant was likely limited by bottom substrate composition or competition from floating-leaf plants.

Figure 3. 2002 distribution of Eurasian watermilfoil in Loon Lake.
Total area = 87.7 acres.

4.2 Water Quality

The results of the seasonal water monitoring conducted on Loon Lake are shown in **Table 8**. Loon Lake is a clearly phosphorus-limited. Nitrogen and phosphorus parameters were fairly consistent throughout the season, which suggests that watershed influences to the lake were minimal.

Chlorophyll *a*, total phosphorus and Secchi depth are three parameters commonly used to gauge lake water quality. 2002 results from Loon Lake are ranked on water quality indices in **Figures 4,5** and **6**. Loon Lake ranks in the "good" range on the Chlorophyll *a* and total phosphorus indices, but in the "poor" range for Secchi depth. Secchi depth is the standard measure of water clarity. Polluted lakes generally have high levels of suspended sediment or planktonic algae, which reduces water clarity. In Loon Lake however, water clarity is reduced from tannins that color the water. Thus Secchi depth may not be a good water quality indicator for Loon Lake.

Dissolved oxygen and temperature profiles are good indicators of the trophic state, or "age" of a lake. **Tables 9** and **10** show seasonal dissolved oxygen and temperature data collected from Loon Lake during 2002. Data are represented graphically in **Figures 7** and **8.** The dissolved oxygen and temperature profiles found were typical of early stage eutrophic lakes. Thermal stratification was found during June and September. Oxygen stratification occurred on all sample dates. During June and September, oxygen levels would have been stressful to fish below nine feet deep. During the cooler months oxygen levels were generally good above 18 feet deep. The good oxygen profile found during January was not typical of eutrophic lakes. This was probably due to the lack of snow cover on top of the ice sheet. With adequate light penetration, there was little macrophyte die off, and thus below average winter oxygen depletion.

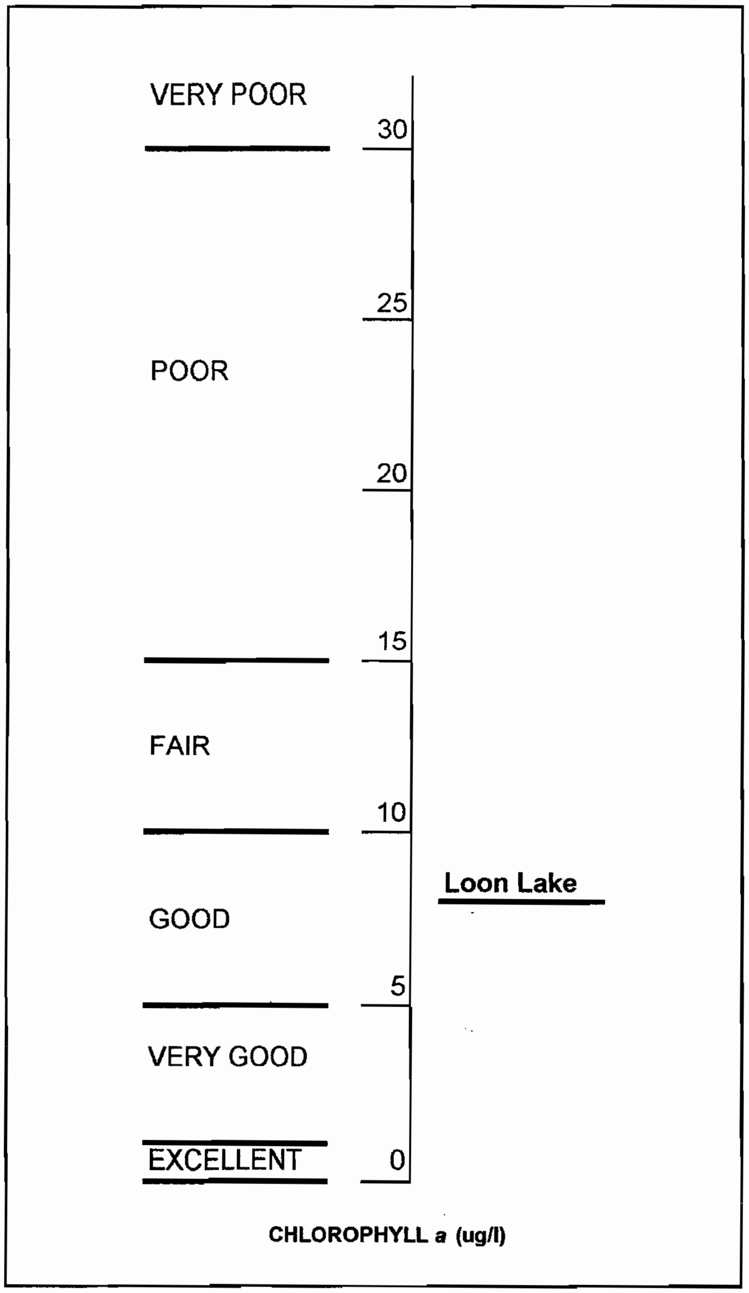
Table 11 compares 2002 results to those from the 1991 survey. These results suggest that water quality had declined in Loon Lake. Nitrogen, phosphorus, chlorophyll and pH values had all increased. These changes are likely to be a by-product of Eurasian watermilfoil infestation. Eurasian watermilfoil invasion typically increases total plant biomass in a lake. This leads to accelerated internal nutrient cycling, and declines in water quality. Water quality often returns to normal following successful Eurasian watermilfoil control programs, however.

Table 8. Loon Lake seasonal water chemistry analysis results.

		Sample Date					
parameter	unit	24-Apr-02	24-Jun-02	2-Sep-02	11-Oct-02	25-Jan-03	Average Value
alkalinity - bottom	mg/l		56				**56**
alkalinity - surface	mg/l		51				**51**
chloride	mg/l		2.7				**2.7**
chlorophyll *a*	ug/l	6.0	0.4	12.0	12.0		**7.6**
color -bottom	s.u.		90				**90**
color - surface	s.u.		80				**80**
conductivity -bottom	um/cm		127				**127**
conductivity -surface	um/cm		118				**118**
dissolved oxygen - bottom	mg/l	0.5	0.3	0.0	0.18	0.42	**0.28**
dissolved oxygen - surface	mg/l	10.1	7.4	6.7	8.7	8.6	**8.30**
ammonia as N - bottom	ug/l		348				**348**
ammonia as N - surface	ug/l		51				**51**
Kjeldahl nitrogen - bottom	ug/l		840				**840**
Kjeldahl nitrogen - surface	ug/l		1000				**1000**
nitrate + nitrite -bottom	ug/l	ND	ND	ND	ND		**ND**
nitrate + nitrite - surface	ug/l	ND	22	ND	ND		**5.5**
total phosphorus - bottom	ug/l	72	24	45	45		**46.5**
total phosphorus - surface	ug/l	21	22	22	22		**21.8**
dissolved phosphorus	ug/l		2				**2**
nitrogen / phosphorus ratio			46 / 1				
pH, field	s.u.	8.5	8.1	8.1	8.2	7.8	**8.1**
pH, lab	s.u.		7.95				**7.95**
Secchi disc depth	ft.	5.0	6.0	5.0	4.9	7.0	**5.6**
temperature - bottom	C	6.7	13.7	17.4	11.9	5	**10.9**
temperature - surface	C	11.2	25.6	23.1	13.6	5.8	**15.9**
total dissolved solids	mg/l		84				**84**
total suspended solids - bottom	mg/l		37				**37**
total suspended solids - surface	mg/l		5				**5**

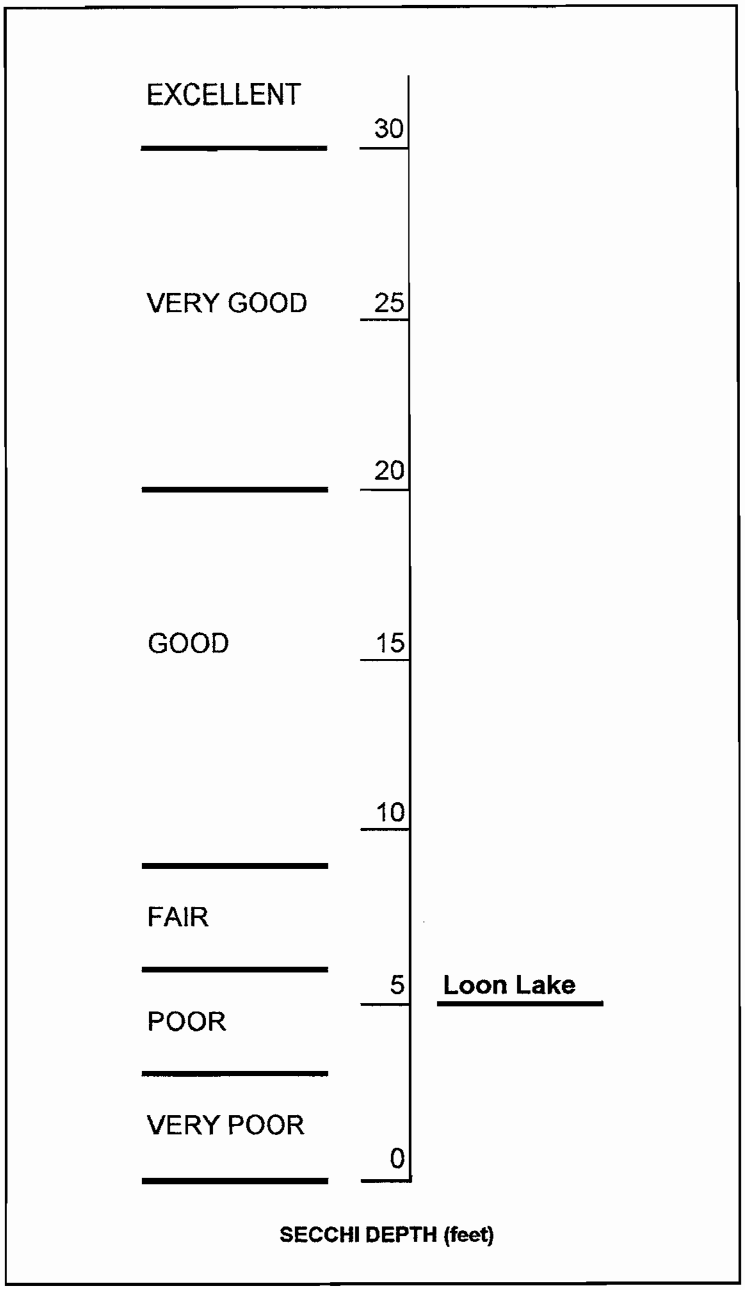
ND = not detected, concentration
below limit of detection

Figure 4. Chlorophyll *a* water quality index.



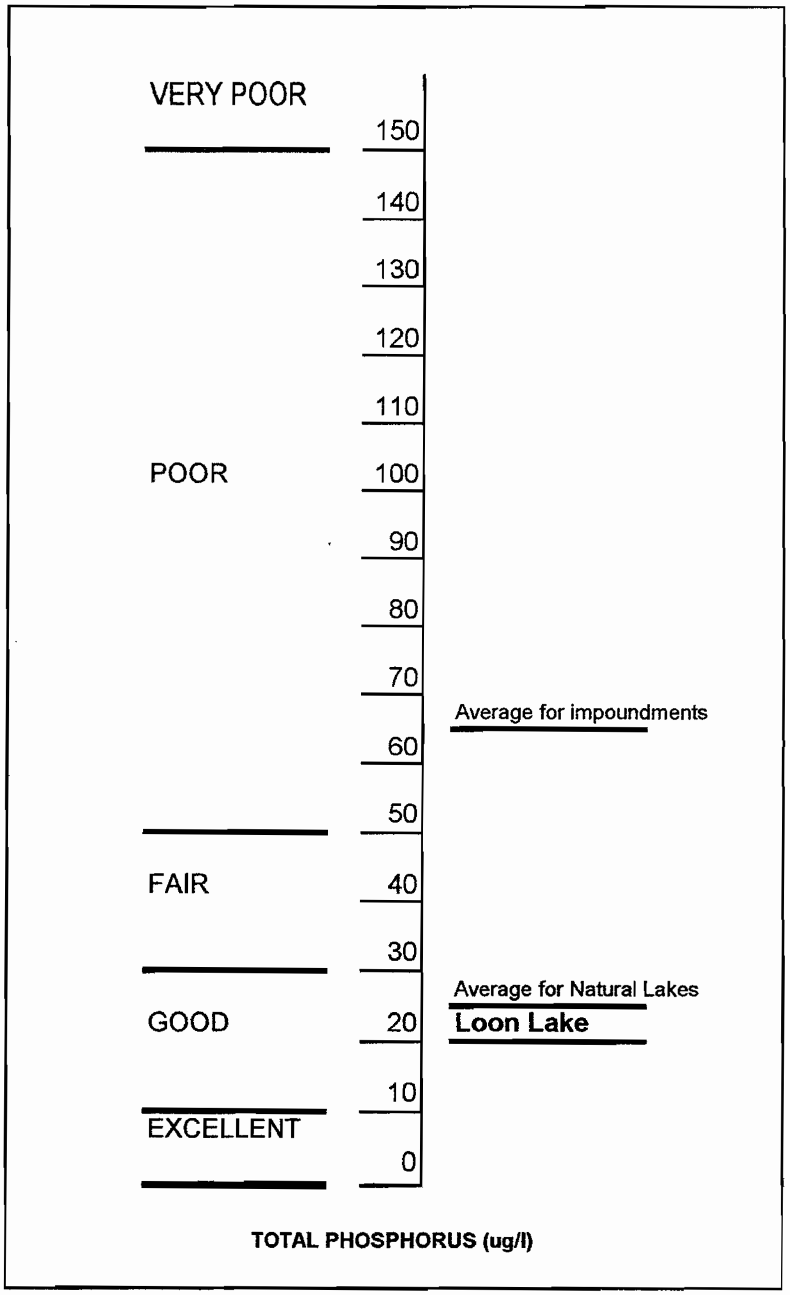
Adapted from Shaw, et. al. (2000).

Figure 5. Secchi disc depth water quality index.



Adapted from Shaw, et. al. (2000).

Figure 6. Total phosphorus water quality index.



Adapted from Shaw, et. al. (2000).

Table 9. Loon Lake 2002 dissolved oxygen profiles.

Depth (ft)	sample date / dissolved oxygen concentration (mg/l)				
	24-Apr-02	24-Jun-02	2-Sep-02	11-Oct-02	25-Jan-03
0	10.1	7.4	6.7	8.7	ice
1	10.1	7.0	6.6	8.5	ice
2	10.1	7.2	6.0	8.1	8.6
3	10.0	7.6	6.5	8.2	8.4
4	10.1	7.0	6.3	8.6	8.8
5	10.1	7.3	6.6	8.4	9.0
6	10.0	5.4	6.0	8.1	9.2
7	9.7	4.7	6.1	8.3	9.0
8	9.8	4.7	6.1	7.8	8.8
9	9.8	4.3	3.4	7.6	7.9
10	9.7	3.2	2.7	7.9	7.1
11	9.6	2.6	1.8	8.0	6.7
12	9.5	1.6	0.7	8.0	6.4
13	9.1	1.1	0.2	7.8	5.9
14	8.6	0.7	0.2	7.7	6.5
15	8.1	0.3	0.2	7.4	6.8
16	8.0	0.3	0.1	7.5	6.5
17	7.3	0.3	0.1	6.8	6.4
18	5.3	0.3	0.1	6.6	5.2
19	4.7	0.3	0.1	6.5	0.4
20	3.1	0.3	0.1	5.2	
21	0.5		0.0	0.3	
22				0.2	

Table 10. Loon Lake 2002 temperature profiles.

Depth (ft)	sample date / temperature (C)				
	24-Apr-02	24-Jun-02	2-Sep-02	11-Oct-02	25-Jan-03
0	11.2	25.6	23.1	13.6	0.0
1	11.1	25.5	23.2	13.7	0.0
2	11.0	25.4	23.2	13.2	5.8
3	10.9	25.3	23.2	13.0	4.7
4	10.9	25.2	23.2	12.8	4.4
5	10.9	24.9	23.2	12.8	4.2
6	10.9	21.7	23.2	12.8	4.2
7	10.9	20.5	23.2	12.7	4.1
8	10.8	19.6	23.2	12.7	4.1
9	10.8	19.1	21.9	12.7	4.1
10	10.8	17.7	21.3	12.7	4.1
11	10.7	16.7	20.8	12.7	4.3
12	10.7	15.3	20.4	12.7	4.4
13	10.2	14.4	19.9	12.7	4.3
14	9.6	13.7	19.6	12.7	4.1
15	8.8	13.3	19.3	12.6	4.2
16	8.5	13.0	18.7	12.6	4.2
17	8.1	12.8	18.6	12.5	4.3
18	7.5	12.7	18.4	12.2	4.3
19	7.1	12.6	17.9	11.8	5.0
20	6.8	13.7	17.6	11.6	
21	6.7		17.4	11.7	
22				11.9	

Figure 7. Loon Lake 2002 dissolved oxygen profiles.

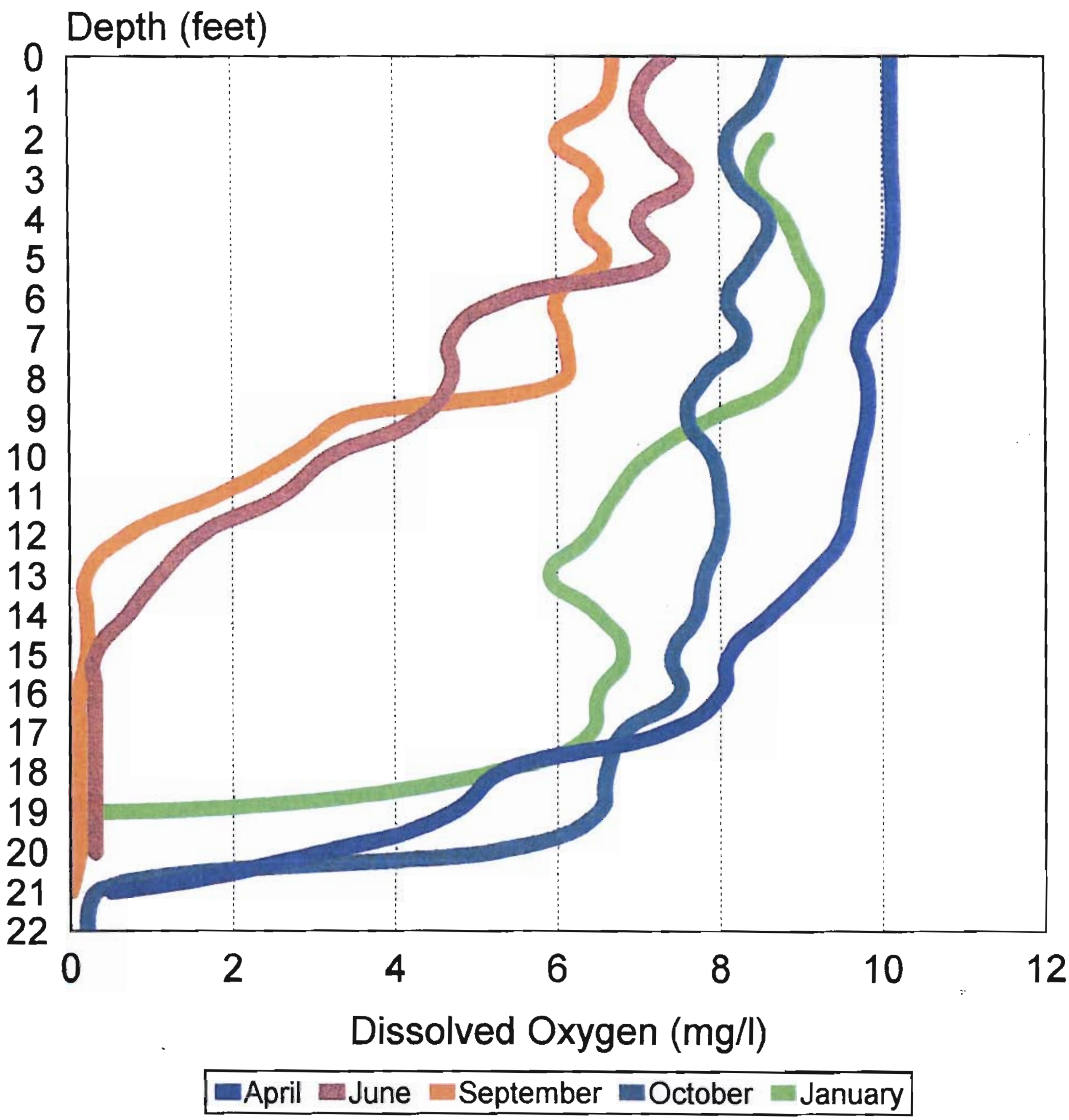


Figure 8. Loon Lake 2002 temperature profiles.

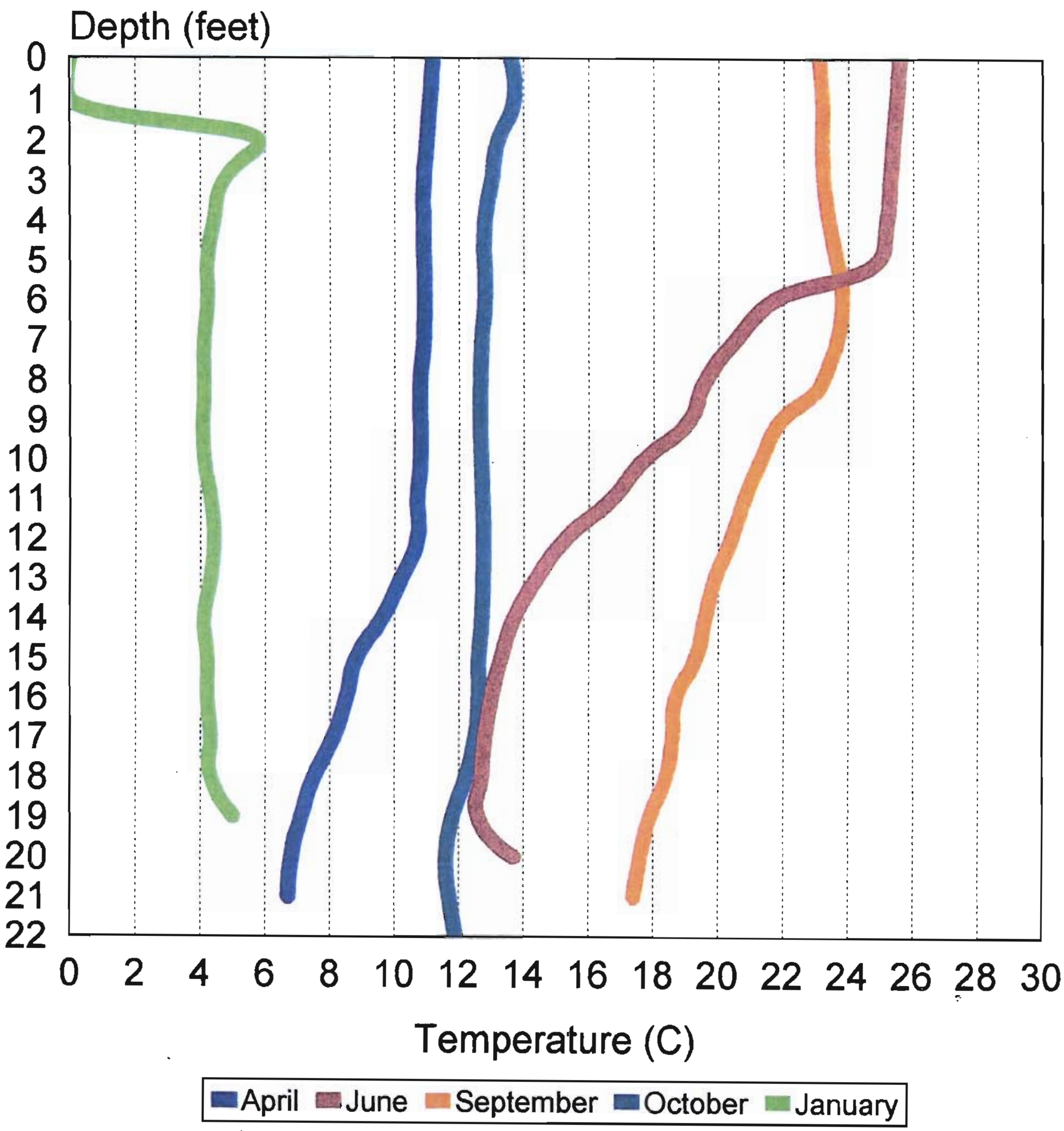


Table 11. A comparison of Loon Lake water quality parameters from 1991 and 2002.

parameter	unit	1991	2002
alkalinity - bottom	mg/l	57	56
alkalinity - surface	mg/l	59	51
chlorophyll *a*	ug/l	5.25	7.61
color - bottom	s.u.	60	90
color - surface	s.u.	50	80
conductivity	um/cm	117	118
dissolved oxygen - bottom	mg/l	3.6	0.5
dissolved oxygen - surface	mg/l	9	8.3
Kjeldahl nitrogen - bottom	ug/l	600	840
Kjeldahl nitrogen - surface	ug/l	700	1000
nitrate + nitrite as N - bottom	ugl	102	ND
nitrate + nitrite as N - surface	ug/l	89	ND
total phosphorus - bottom	ug/l	28	46.5
total phosphorus - surface	ug/l	20.5	21.8
dissolved phosphorus	ug/l	5	2
nitrogen / phosphorus ratio (surface)		38 / 1	46 / 1
pH, field	s.u.	7.46	8.14
secchi disc depth	ft.		5.6
temperature	C	17.3	15.9
total dissolved solids	mg/l	90	84

ND = not detected, concentration below limit of detection

4.3 Milfoil Weevil Studies

4.31 EnviroScience methods and findings

The Loon Lake Management District retained EnviroScience, Inc. to institute a Eurasian watermilfoil control program on Loon Lake that utilized milfoil weevils as a control agent. The stated objective of this program was to achieve a "critical weevil density" of 0.5 weevils / stem. Published research indicated that this density was required to achieve a decline in Eurasian watermilfoil (Newman, et.al. 1996). Eurasian watermilfoil was estimated to occur in approximately 80 acres of Loon Lake at this time.

Prior to stocking 15,000 weevil eggs and larvae in May 2000, EnviroScience conducted a survey of Loon Lake. This survey assessed native weevil densities. Methods involved collecting the tops of two milfoil stems (unspecified lengths) at five evenly spaced intervals along each transect, and counting weevils per stem. It was suspected ,but not clearly stated, that weevil damaged stems, or evidence of weevil life stages, were counted as weevils in this survey. Efforts were also made to collect data on dominant plant species, depth to plant canopy and milfoil density. These surveys were conducted at the four weevil stocking sites, plus an unstocked control site.

The initial survey found a native weevil density of 1.00 weevils / stem, and 255.4 weevils / square meter. This equated to a standing lakewide population of 82.6 million weevils. This finding brings up three pertinent questions:

1. If native weevil densities were twice the "critical density" required to control Eurasian watermilfoil, why was Eurasian watermilfoil at nuisance levels in Loon Lake?
2. If native weevil densities were above target levels, why was stocking necessary?
3. What could be accomplished by stocking 15,000 weevils into an existing population of 82.6 million?

EnviroScience conducted follow-up surveys during August 2000, and in May 2001 prior to stocking an additional 9,500 weevils, and again in August 2001. Answers to the above questions are evident in the results. A steady decline in weevil density was recorded for each stocking site. By August 2001, all sites were well below critical density. Weevil densities declined in the control site as well. Two conclusions can be drawn from this data: 1) Weevil stocking did not result in an increase in weevil density. 2) Weevil population changes were not related to stocking efforts.

Milfoil density had increased by August 2000, but by August 2001 milfoil density had declined sharply. Stem density declines ranged from 62 – 74% in the stocked sites. EnviroScience concluded that this decline in milfoil density was the result of milfoil weevil predation. This may have been an accurate conclusion. However the decline could not be attributed to weevil stocking, as milfoil density declined by 66% in the control site as well. Declines in Eurasian watermilfoil density were not significantly different between the stocked sites and the control site. Declines in Eurasian watermilfoil density however, were apparently short-lived. By June 2002, 87.7 acres of dense Eurasian watermilfoil could be found in Loon Lake.

4.32 Aquatic Biologists weevil studies

The results of the milfoil weevil studies conducted by Aquatic Biologists, Inc on Loon Lake and Lulu Lake during 2002 are shown in **Table 12** and **13**. Despite never having been stocked with weevils, Lulu Lake had more than five times the weevil density of Loon Lake. The rate of stem damage on Lulu Lake was 78.1% - more than twice that found on Loon Lake. Even though Lulu Lake had a higher weevil density and had extensive milfoil stem damage, milfoil density was more than 2.5 times that of Loon Lake.

The characteristics of Eurasian watermilfoil on these two lakes were very different. Milfoil beds on Lulu were extremely dense and grew to the surface. These beds were monotypic, meaning that other species were crowded out. Outwardly, Lulu lake milfoil appeared vibrant and healthy. When plants were disturbed or handled though, they easily broke apart due to the extensive insect boring in the stems. While milfoil beds on Loon Lake were dense enough to be considered a major nuisance to lake users, the beds were not nearly as dense as those found on Lulu Lake. Despite its widespread occurrence in Loon Lake, Eurasian watermilfoil seldom formed monotypic beds. The milfoil beds were often sparse enough to allow native plants to coexist. It was concluded that this growth characteristic was influenced by milfoil weevils.

Lulu Lake and Loon Lake exist in close proximity. They share many of the same physical and chemical characteristics and influences. A major difference between the lakes is their surface area. Loon Lake covers 305 acres, while Lulu Lake covers only 34. Loon Lake has much greater wind fetch and routinely develops significant wave action. In contrast, Lulu Lake rarely develops more than a ripple. It was apparent from handling the brittle Lulu Lake milfoil that significant wave action would greatly change the complexion of the plant beds. Based on this observation, it was concluded that milfoil weevil stem damage *in conjunction with significant wave energy* is required to affect a decline in Eurasian watermilfoil density.

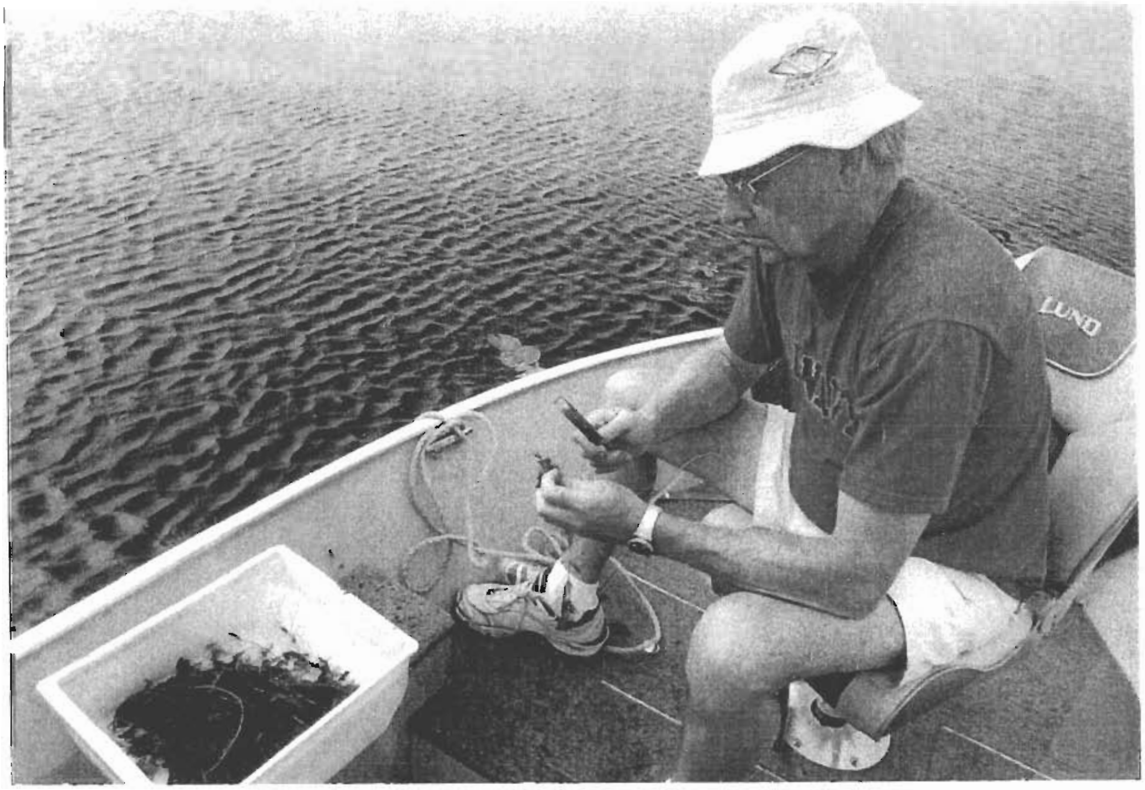
This conclusion was further supported by late season observations of milfoil growth patterns on Loon Lake. By late summer, the narrow milfoil beds found along the steep-dropping west and north shores (see **Figure 3**) had become very sparse. The much wider beds along the south and east shores though, appeared unchanged. These expansive beds were able to absorb much more wave energy and were not as damaged as the narrow beds across the lake.

Table 12. Results of the 2002 milfoil weevil study conducted on Loon Lake.

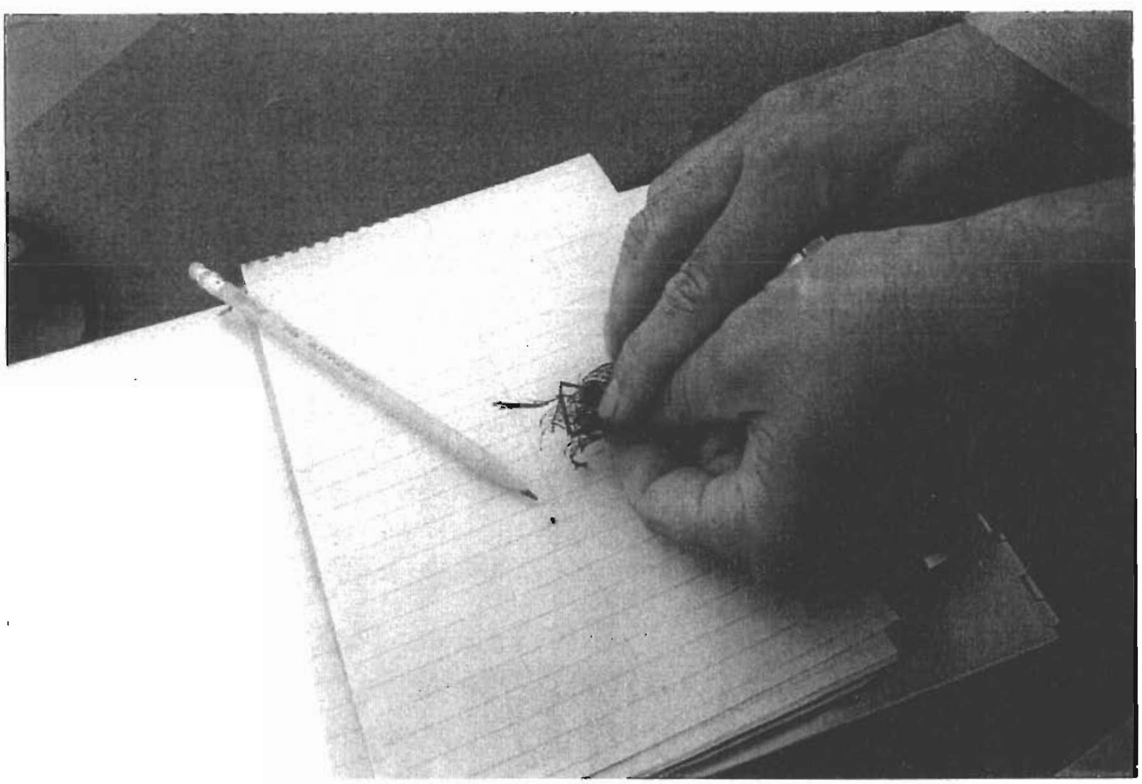
TRANSECT	RESULTS (per square meter)			
	No. of stems	No. of weevils	No. of damaged stems	% damaged stems
A	51	1	20	39.2
B	21	0	9	42.9
C	28	0	9	32.1
D	52	4	44	84.6
E	18	0	9	50.0
F	40	0	18	45.0
G	25	0	10	40.0
H	69	0	8	11.6
I	73	1	7	9.6
J	103	4	45	43.7
K	86	0	19	22.1
L	39	0	15	38.5
AVERAGE	**50.4**	**0.8**	**17.8**	**35.3%**

Table 13. Results of the 2002 milfoil weevil study conducted on Lulu Lake.

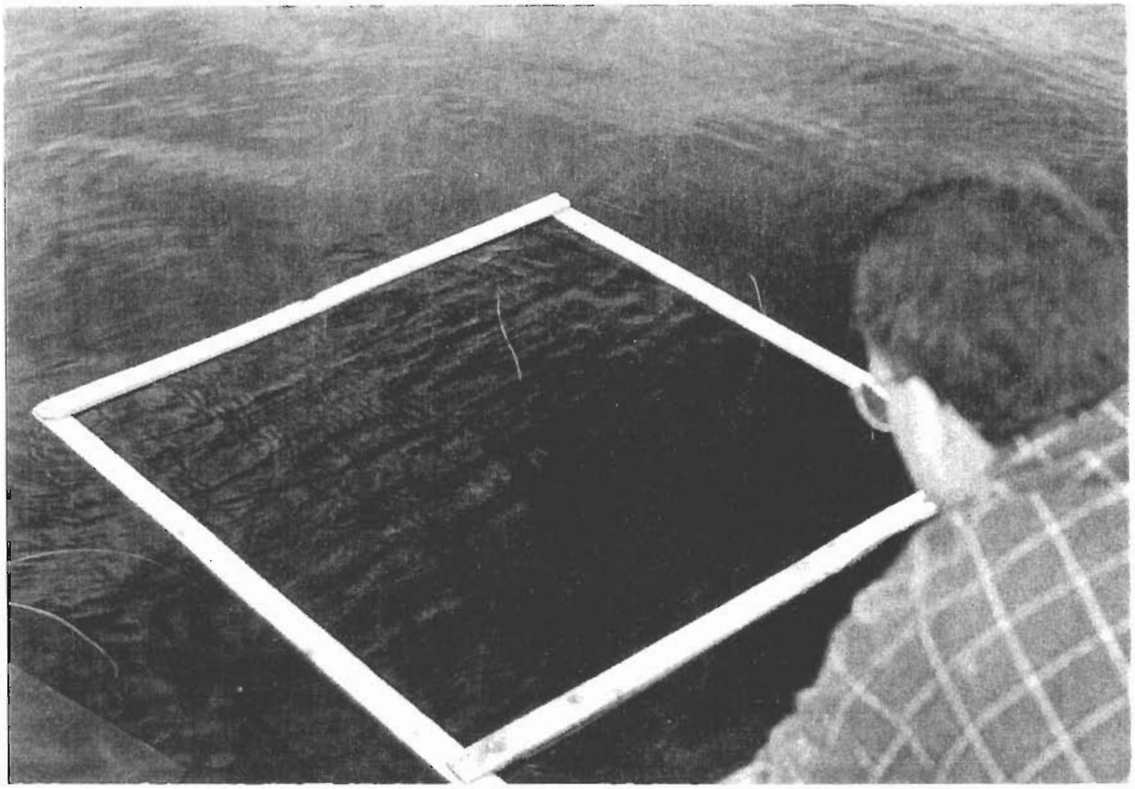
TRANSECT	RESULTS (per square meter)			
	No. of stems	No. of weevils	No. of damaged stems	% damaged stems
N	217	5	184	84.7
NE	154	8	138	89.6
SE	123	6	105	85.4
S	58	0	1	1.7
SW	120	4	93	77.5
NW	89	2	73	82.0
AVERAGE	**126.8**	**4.2**	**99**	**78.1%**



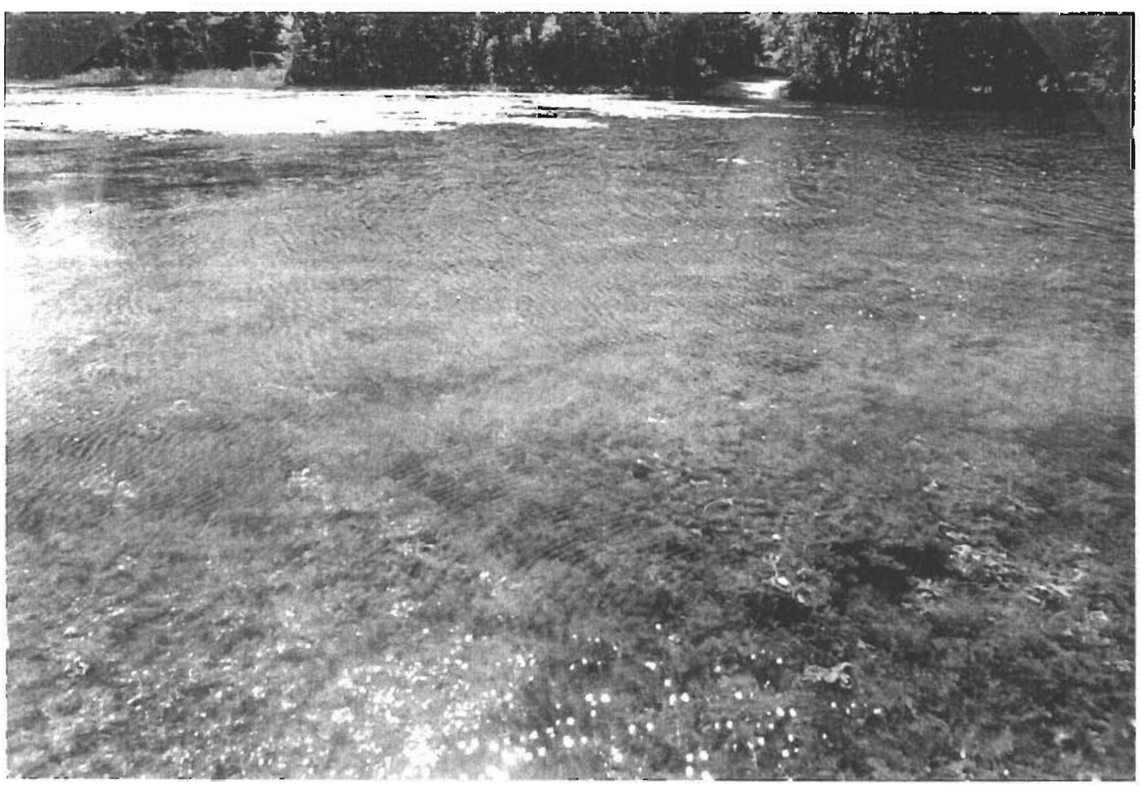
Lloyd Knope assessing milfoil stem damage.



Milfoil weevil (at tip of pencil) found on damaged milfoil stem.



Damian Drewek measuring milfoil stem density on Loon Lake. Note the relative sparseness of the milfoil bed.



In contrast to Loon Lake, milfoil beds on Lulu Lake were extremely dense.

4.33 Literature review

There has been considerable research on the milfoil weevil as a control agent for Eurasian watermilfoil. In 1989 a naturally occurring decline of Eurasian watermilfoil was documented in Brownington Pond in northeastern Vermont. This phenomenon was extensively studied by researchers from Middlebury College, working under contract from the Vermont Department of Environmental Conservation. It was concluded that a native weevil, *Euhrychiopsis lecontei*, was responsible for the decline. This conclusion was further borne out in laboratory experiments. Since this discovery, milfoil weevils have been associated with Eurasian watermilfoil declines in Cayuga Lake in New York (Johnson, et. al., 2000), McCullom Lake in Illinois, Cenaiko Lake in Minnesota (Weinberg, 2002), and Devils Lake, Fish Lake, Whitewater Lake and Lake Wingra in Wisconsin (Jester, et. al., 1997);(Lilie and Helsel, 1997); (Lilie, 2000).

Since the discoveries of naturally occurring milfoil declines associated with milfoil weevils, there has been widespread effort to deliberately control milfoil through augmentation or stocking of weevils. Thus far however, there has been little convincing evidence that *stocked* weevils have produced a decline in Eurasian watermilfoil density. A twelve-lake study called "The Wisconsin Milfoil Weevil Project", (Jester, et. al. 1999) conducted by the University of Wisconsin, Stevens Point in conjunction with the Wisconsin Department of Natural Resources, researched the efficacy of weevil stocking. This report concluded that milfoil weevil densities were not elevated, and that Eurasian watermilfoil was unaffected by weevil stocking in any of the study lakes.

There have been numerous reasons given for the lack of success of weevil stocking as a management option, including calcium carbonate deposits on plants (Jester, et. al. 1999), poor over-wintering habitat (Newman, et, al. 2001), high pH (Kendziorski, 2001) and sunfish predation (Newman, pers. comm.). Perhaps the most compelling reason why weevil stocking has been unsuccessful may be that weevil populations are already at carrying capacity in many lakes. Recent studies indicate that milfoil weevils are widely distributed throughout Wisconsin's lakes (Jester, et. al. 1997).

The relationship between wind energy and the ability of milfoil weevils to affect a decline in Eurasian watermilfoil density, found in the recent studies on Loon and Lulu Lakes, may explain why native weevil populations may have been able to impact Eurasian watermilfoil in some lakes but not others. The four Wisconsin Lakes where natural milfoil declines were observed were all relatively large lakes with significant wind fetch. Devil's Lake has a surface area of 369 acres, Fish Lake has a surface area of 247 acres, Whitewater Lake has a surface area of 640 acres, and Lake Wingra has a surface area of 345 acres. For many Wisconsin Lakes having both nuisance Eurasian watermilfoil growth and native weevil populations, insufficient wind fetch may limit the impact of milfoil weevil stem damage.

4.34 Management implications

Several conclusions can be drawn from the Loon / Lulu Lake studies and the review of available literature:

1. Stocking weevils into an established native population is not likely to result in an increase in weevil density.
2. Weevil density is not necessarily related to milfoil density.
3. Wind fetch may be an important determinant in the ability of milfoil weevils to affect milfoil density.
4. In some lakes, milfoil weevils may reduce the negative ecological impacts of Eurasian watermilfoil.
5. Even in lakes where weevils have significantly affected milfoil density, milfoil may still be perceived as a nuisance to lake users.

The concept of using an indigenous biological vector, such as the milfoil weevil, to control an invasive exotic plant is very appealing to many lake managers and lake users. Milfoil weevil stocking is perceived as a "safe", all-natural alternative to more common control methods, such as herbicide treatments. Unfortunately milfoil stocking has been little more than an expensive disappointment for many lake management organizations. Nonetheless it is evident that milfoil weevils can significantly reduce milfoil density on some lakes. While it should be noted that Eurasian watermilfoil is often still perceived as a nuisance to lake users in lakes where researchers have documented weevil-related declines in the plant (Weinberg, 2002), weevils may be able to substantially reduce the impacts to native plant communities, and therefore help to preserve habitat and water quality in lakes.

Weevil stocking may yet prove to be a useful lake management tool. Its practical application will most certainly have a very limited scope, though. Existing weevil populations, and physical and chemical lake characteristics should be carefully studied and considered before implementing a weevil-stocking program.

4.4 Watershed Assessment

4.41 Boundary delineation and land features

The total watershed drainage area entering Loon Lake was determined to be 8,465 acres (**Figure 9**). 3,135 acres exist in Shawano County. The remaining 5,330 acres exist in Menomonie County. The landscape within the watershed is relatively flat, thus water drains through it very slowly. Water is detained by 21 lakes and numerous wetlands before entering Loon Lake. Land features and uses determined for the watershed are given below.

Land feature	Acreage	% of total
upland forest	5,025	59.4
swamp forest	1,397	16.5
lakes	944	11.2
residential	430	5.0
upland meadow/ pasture /crop field	349	4.1
marsh / shrub carr	320	3.8

4.42 Water imports and exports

Water enters Loon Lake through the Loon Creek Inlet, Lulu Creek, precipitation, surface water percolation from the wetland complex on the west shore, and groundwater seepage. Water leaves Loon Lake through the Loon Creek Outlet and evaporation. Base flow from the Loon Creek Inlet was found to be 34.9 million gallons/day. Base flow from Lulu Creek was found to be 2.4 million gallons/day. Water left Loon Lake via the Loon Creek Outlet at a rate of 67.2 million gallons/day. If we assume that evaporation roughly equals precipitation, then a substantial amount of water, roughly 29.9 milion gallons / day, must enter Loon Lake from surface water percolation from the wetland complex on the west shore and from groundwater seepage.

The 1991 Foth & Van Dyke study reviewed extensive nutrient loading data collected on the inlet creeks and concluded that nutrient imports from the inlet creeks was not a concern. The report speculated that groundwater might be a source of nutrient contamination, however. I likely source for this contamination would be septic systems of lakefront homes. Further investigation was recommended.

Accordingly, groundwater flow patterns were analyzed along the developed shorelines of Loon Lake during 2002 to assess potential for nutrient contamination. Mini-piezometers were installed and monitored at six sites along the developed lakeshore (**Figure 10**). Minor groundwater inflow was recorded at sites P2 and P3. Insignificant groundwater movement was recorded at the remaining four sites. At present, most lakefront homes are connected to sanitary sewer. This includes homes near sites P2 and P3. Homes along the shoreline adjacent to sites P4, P5 and P6 are on private septic systems. Since little groundwater flow occurred at these sites, it was concluded that groundwater contamination from septic systems poses little risk to Loon Lake.

Site	Piezometer reading	Direction of flow
P1	8.7 mm	inflowing
P2	31.8 mm	inflowing
P3	44.5 mm	inflowing
P4	0.0 mm	static
P5	0.0 mm	static
P6	3.2 mm	inflowing

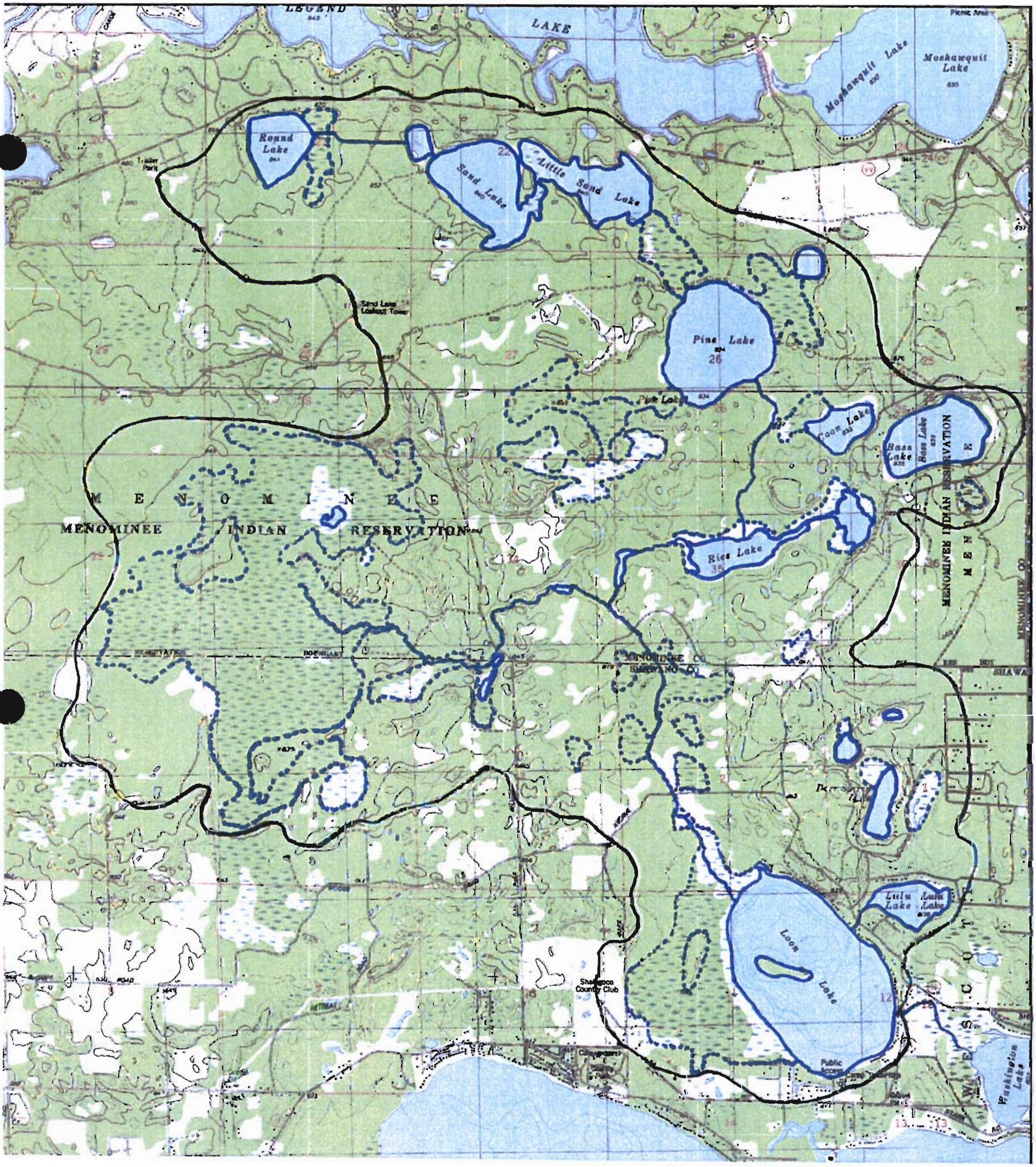
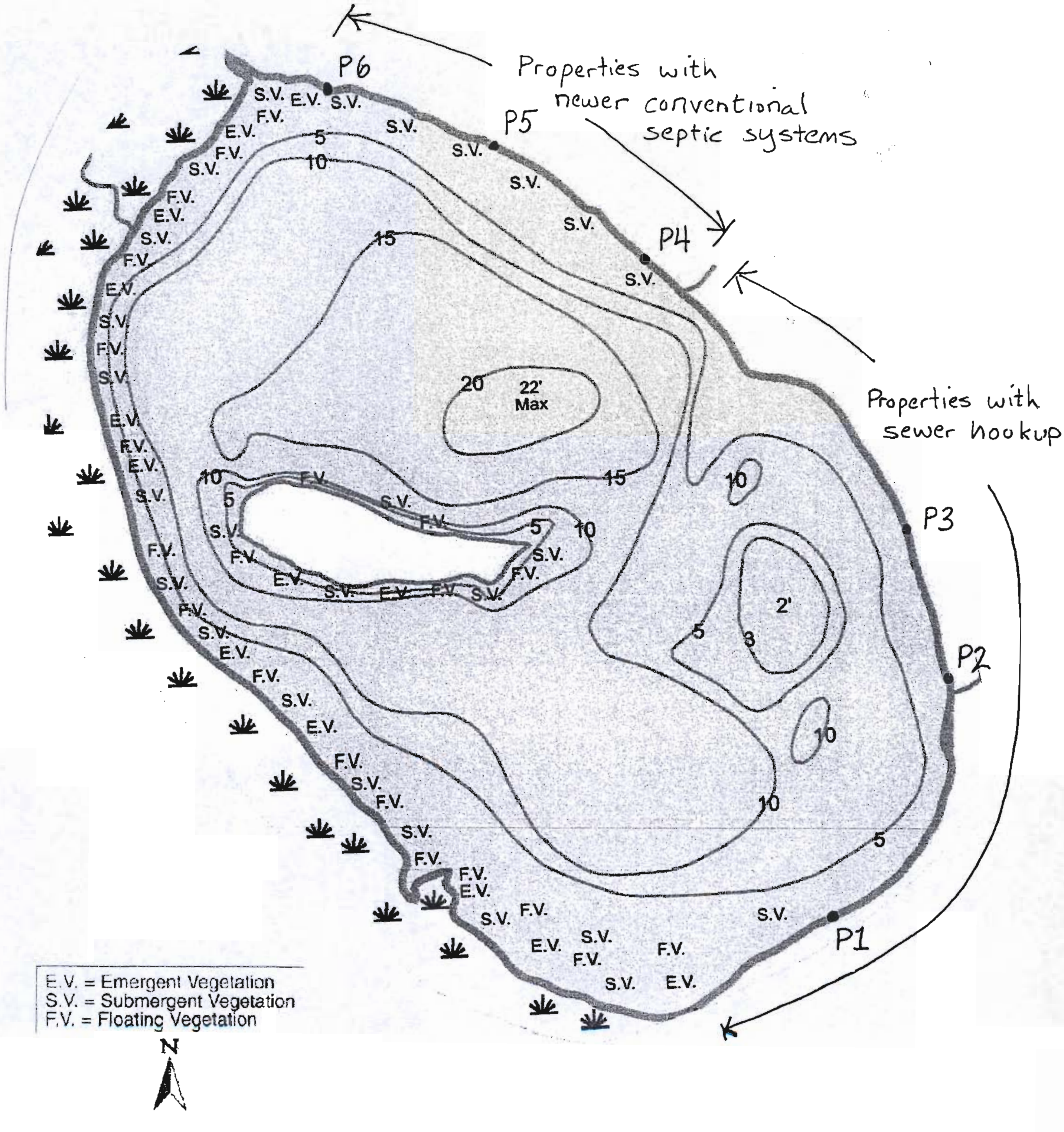


Figure 9. Loon Lake watershed boundary. Total area = 8465 acres.

Figure 10. Loon Lake piezometer locations for groundwater flow analysis.



4.5 Review of Plant Management Options

Eurasian watermilfoil is one of the most prominent problems facing lakes today. Not surprisingly, numerous methods have been employed to control Eurasian watermilfoil. Many common control methods, such as hand pulling and raking, and benthic barriers, are only suitable for small infestations and would be inappropriate for Loon Lake. Biological controls, such as weevil stocking, are also commonly tried. In the case of Loon Lake, this did not prove effective. Several management options that reasonable for large-scale milfoil infestations are presented in the following sections, along with a discussion of their feasibility for Loon Lake.

4.51 Mechanical harvesting

Boat-mounted mechanical weed harvesters have often been employed to control Eurasian watermilfoil. This method is usually used in lakes that have historically used harvesters, and is situations where lake management units have done insufficient planning to receive permits for herbicide use. Mechanical harvest is not a recommended control method for Eurasian watermilfoil, however. Eurasian watermilfoil can reproduce by fragmentation (Borman, et. al. 1997), and the free-floating plant matter left from cutting operations can accelerate dispersal of the plant. Mechanical harvest does offer several distinct advantages, though. Harvested plant matter can be removed from the lake system, eliminating the possibility of low dissolved oxygen due to bacterial decomposition. The possibility of algae blooms due to a sudden nutrient release is also greatly reduced. There are no water use restrictions following mechanical harvest either. A disadvantage of mechanical harvest is that it is not species selective. While cutting does not typically kill plants, there is little evidence to suggest that cutting can induce a shift back to native species. In the process of removing plants, weed harvesters also kill substantial numbers of fish, reptiles, amphibians and invertebrates (Shardt, 1999). Perhaps the greatest drawback of a mechanical harvest program though, is cost. Cost / benefit analysis conducted by the Florida Department of Environmental Protection found that mechanical harvest of nuisance weeds cost over 40 times as much as some herbicide treatments to achieve the same level of control (Shardt, 1999). While other methods may provide some long-term control, mechanical harvesting should be viewed as an annual maintenance program. Given these considerations, employing a mechanical weed harvester to control Eurasian watermilfoil in Loon Lake would be a poor choice.

4.52 Rotovation

The use of rotovators to control Eurasian watermilfoil has been used in the Pacific Northwest but is seldom used in other parts of the country. This technique involves churning bottom sediments with rototiller-like blades to uproot aquatic plants. Rotovators are typically attached to a hydraulic boom that is mounted on a boat. The boat is also equipped with a weed rake or harvester to capture and remove uprooted plant fragments.

Studies have shown that rotovation can produce a high level of milfoil control for up to two years. Eurasian watermilfoil from adjacent uncleared areas then gradually reinvaded the cleared sites (State of Washington, 2001). Rotovation has numerous disadvantages though, including temporary turbidity increase, nutrient and sediment resuspension, impacts to fish and other organisms and high cost. Thus it should not be considered a viable option for Loon Lake.

4.53 Herbicides

Herbicides have been the most widely used and most successful tools for controlling Eurasian watermilfoil. The two herbicide groups most commonly employed are fluridone (Avast®, Sonar®) and 2,4D (Aquacide®, Aquakleen®, Navigate®, Weedar 64®). Fluridone treatments have shown considerable promise for providing both good control and species selectivity for Eurasian watermilfoil (Welling, et al., 1997). Whole-lake Sonar® treatments have been done on several Wisconsin Lakes. While initial results were encouraging (species selectivity, 95-100% initial control), continued monitoring found that desired long-term control was not achieved (Cason, 2002). Because fluridone is a very slow-acting herbicide that requires maintaining specific concentrations for extended periods of time, it may also be less effective on waters such as Loon Lake that have significant flow through.

2,4D herbicides, on the other hand, have been used on hundreds of Wisconsin Lakes with good success. The E.P.A. lists 2,4D as a Class D herbicide, which means that there is no data to support that it is harmful to humans. The E.P.A. product label lists no water use restrictions for swimming or fish consumption following treatment with 2,4D either. 2,4D is a biodegradable organic herbicide that does not persist in the environment in any form. Applied correctly at prescribed rates, 2,4D is highly selective to Eurasian watermilfoil. 2,4D has been used on thousands of lakes throughout North America. To date 2,4D treatments have been the single most effective Eurasian watermilfoil control program. In fact, the number of lakes in Michigan having Eurasian watermilfoil problems has actually declined as a result of 2,4D use (Pullman, 1993).

The greatest disadvantage of 2,4D treatments is that they rarely produce 100% control. As a granular formulation, the product tends to work only where applied. Unnoticed and untreated plants may eventually grow to dense beds if left unchecked. Factors such as pH and plant maturity may also reduce treatment efficacy. Several follow-up treatments, in-season or on subsequent years, may be needed to reduce Eurasian watermilfoil to target levels. While clearly not a cure-all, 2,4D treatments may have the greatest potential to provide effective long-term control of Eurasian watermilfoil in Loon Lake.

5.0 Conclusions and Recommendations

5.1 Milfoil Management Strategies

The ultimate goal of this project was to formulate a strategy for returning Loon Lake as closely as possible to pre- Eurasian water milfoil conditions, and to maintain the lake in that condition for the long term. Results from the comprehensive survey conducted on Loon Lake during 2002 do indeed indicate that Eurasian watermilfoil is the main management concern for the lake. The slight declines in water quality are also likely to be related to the milfoil infestation. A literature review of milfoil management options and an assessment of past management efforts on Loon Lake suggest that 2,4D herbicide treatments will provide the best option for meeting stated goals.

An effective control strategy will aggressively target all identified Eurasian watermilfoil beds in the lake. All milfoil beds should be treated at once early in the season. Milfoil beds should be identified and marked prior to treatment. Treatment accuracy should be facilitated with GPS tracking. Treatment rates should be 100 lbs / acre for maximum selectivity. 30 days after initial treatment, the lake should be re-inspected so that any surviving milfoil can be identified and treated. If more than 10% of the original acreage requires retreatment during this follow-up visit, a second follow-up should be schedule 30 days later. The results of similar projects conducted by Aquatic Biologists, Inc. show that these aggressive treatments are effective in providing substantial long-term control. It is expected that following several seasons of active monitoring and treatment, milfoil can be maintained at sub-nuisance levels for the long term with minimal annual expense.

It is important that the initial large-scale treatment be conducted when milfoil is in its early seasonal growth stages. By conducting treatments early in the season while water temperature are lower, the threats of oxygen depletion from decomposition of dead plant matter are eliminated or greatly reduced. Likewise, the threats of algae blooms fueled by nutrient release are also greatly reduced.

The Loon Lake Management District should implement this Eurasian watermilfoil control program beginning in 2003.

5.2 Contingencies

5.21 Native plant restoration

Applied at a rate of 100lbs. / acre, 2,4D treatments are typically highly selective to Eurasian watermilfoil. Several other plants found in Loon Lake are moderately to slightly susceptible to 2,4D at higher rates. These plants include coontail, bladderwort, water stargrass, watershield and water lilies. The greatest risk to these plants could occur if strong winds occurred after the treatment and elevated concentrations of herbicide in certain areas of the lake. If any native plant species are eliminated from large areas of the lake as a result of treatments, the Lake District should be prepared to re-establish those plants from purchased nursery stock.

5.22 Control of nuisance native plants

Native macrophytes usually respond favorably to successful milfoil control programs. Native plants are quick to recolonize areas of lakebed vacated by milfoil. Occasionally native plants may become very dense following a milfoil control program. This is often a temporary phenomenon, but may persist. If native aquatic plants become dense enough to impair boating, swimming and fishing activities on the lake, and the condition continues for two seasons after Eurasian watermilfoil has been controlled, the Lake District should contract mechanical weed harvesting on the lake. Mechanical weed harvesting will provide nuisance relief, but will not eradicate native species. Thus, the habitat and water quality values of the native plants will be preserved.

5.23 Curly-leaf pondweed

Curly-leaf pondweed, the other exotic plant found is Loon Lake, may also respond positively to successful milfoil control programs. As with some native plants, curly-leaf pondweed may become very dense following control of milfoil. This may also be a temporary phenomenon. However it is more likely to persist, as this species can gain a competitive advantage over native plants. If dense curly-leaf pondweed persists for more than one season after the initial milfoil treatment, the Lake District should implement a control program.

Both mechanical harvesting and herbicide treatments are commonly used to control curly-leaf pondweed. The herbicide most often used is endothol (Aquathol®). While endothol is effective on a broad range of aquatic monocots, at low rates it is highly selective to curly-leaf pondweed. Both mechanical harvesting and herbicide treatments are very effective in providing short-term control. However neither method, as they are commonly applied, tend to provide any long-term control of the plant. Curly-leaf pondweed produces a vegetative reproductive structure in early summer that is called a turion. While herbicides effectively kill the parent plant, the turions are resistant to herbicides. This allows curly-leaf pondweed to regenerate annually.

Recent studies conducted by the Army Corps of Engineers however, have found that conducting treatments of curly-leaf pondweed using Aquathol® when water temperatures are in the 50° F range will kill plants before turions form, thus providing long-term control. These treatments conducted over time were able to significantly reduce curly-leaf pondweed populations (Skogerboe, 2002). These findings may make early season treatments with Aquathol® the tool of choice for controlling curly-leaf pondweed.

5.3 Monitoring

During September 2003, after milfoil treatments have been completed, an aquatic plant survey should be conducted on Loon Lake. This survey should utilize the methods and transects of the 2002 survey. Similar surveys should be conducted during June of 2004 and 2005. Any returning Eurasian watermilfoil should be carefully mapped.

During the 2002 survey Eurasian watermilfoil was found at 63.5% frequency, and was clearly at nuisance levels. Elodea, a dense-growing plant that shares similar habitat preferences to Eurasian watermilfoil, was found at 14.6%. At this frequency, elodea was not considered at nuisance levels in Loon Lake. Therefore reducing Eurasian watermilfoil to less than 15% frequency was established as a realistic and practical goal. A targeted timeframe for achieving this goal is June 2005.

A secondary goal is to restore native aquatic plant communities. Analysis of variance should be conducted on plant survey data to insure that no species have experienced statistically significant declines. Likewise, surveys should indicate that recolonization of the littoral area has occurred. The percent frequency where no plants were found in the 2002 survey was 6.8. A similar percent frequency should be found in subsequent surveys.

The scheduled plant surveys should allow for accurate assessment of program effectiveness, and should provide information needed to fine tune management strategies. If the stated goals of this plan and the expectations of Lake District members have not been met by 2006, three years after program implementation, the Loon Lake Management District should reassess lake conditions, review further management options and update the Lake Management Plan.

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