

Changes in the Aquatic Plant Community and  
the Long-term Impact of Winter Drawdown on  
Eurasian Watermilfoil and the Native Plant  
Community

of

Mallalieu Lake

St. Croix County, Wisconsin

1991-2001

submitted  
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## Executive Summary

Lake Mallalieu is a eutrophic lake with poor water clarity and quality. Filamentous algae was abundant, especially at depths less than 5 feet. Aquatic macrophytes occur at low densities in a disturbance tolerant community of average diversity and below average quality.

A winter drawdown was conducted on Lake Mallalieu during 1998-99 to repair the dam. The water level was left down over the winter to control dense growth of Eurasian watermilfoil in the east basin. Due to delays in the repair, Lake Mallalieu remained down 6 feet for the entire winter instead of the approved 3-foot drawdown. During the summer of 1999, immediately after the 6ft drawdown:

- 1) no Eurasian watermilfoil was found,
- 2) curly-leaf pondweed was decreased 85-94%,
- 3) the number of species, species diversity, coverage of aquatic vegetation and quality of the aquatic plant community were decreased,
- 4) disturbance tolerance was increased.

Between 1999 and 2001, the aquatic plant community recovered to some extent.

- 1) The coverage and density of aquatic vegetation increased.
- 2) Beds of white water lilies partially recovered.

Management to improve the aquatic macrophyte community should focus on

- 1) improving water quality by expanding the buffer of natural shoreline and protecting wetlands in the watershed,
- 2) protecting and increasing beds of emergent vegetation for habitat,
- 3) monitoring for any reoccurrence of Eurasian watermilfoil,
- 4) limiting control of aquatic submergent vegetation to occasions when vegetation is truly at nuisance levels and prevents use of the lake,
- 5) conducting winter drawdowns only if Eurasian watermilfoil returns and becomes invasive
- 6) conducting winter drawdowns at depths less than 6ft.

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**Changes in the Aquatic Plant Community and  
The Long-term Impact of Winter Drawdown on  
Eurasian Watermilfoil and the Native Plant Community  
Lake Mallalieu, St. Croix County  
1991-2001**

**I. INTRODUCTION**

Studies of the aquatic macrophytes (plants) in Lake Mallalieu were conducted during July 1998, July 1999 and June 2001 by Water Resources staff of the West Central Region - Department of Natural Resources (DNR).

A plant survey had been conducted in August 1991 by Barr Engineering of Minneapolis (Barr 1992).

The present study was conducted to assess the long-term impacts to the native plant community and the Eurasian milfoil of a winter drawdown (1998-99).

The present study will also provide information for fish habitat improvement, protection of sensitive wildlife areas, aquatic plant management, and water resource regulations. The data that it provides will be compared to past and future plant inventories to analyze any changes occurring in the aquatic community.

A study of the diversity, density, and distribution of aquatic plants is an essential component of understanding a lake due to the important ecological role of aquatic vegetation and the ability of the vegetation to characterize the water quality (Dennison et al. 1993).

**Ecological Role:** All other life in the lake depends on the plant life (including algae) - the beginning of the food chain. Aquatic plants provide food and shelter for fish, wildlife, and the invertebrates that in turn provide food for larger animals and fish. Plants improve water quality, protect shorelines and lake bottoms, add to the aesthetic quality of the lake, and impact recreation.

**Characterize Water Quality:** Aquatic plants serve as indicators of water quality because of their sensitivity to water quality parameters, such as water clarity and nutrient levels (Dennison et al. 1993).

**Background and History**

Lake Mallalieu is a 270-acre impoundment on the Willow River in St. Croix County, Wisconsin. Its maximum depth is 17 feet at the dam and the mean depth is 5 feet.

The first dam that formed Lake Mallalieu was built for a sawmill operation in 1848; hydroelectric facilities were added in 1886. The dam washed out during a storm in 1933 and was rebuilt over a

two years period.

The first recorded complaints of algae blooms in Lake Mallalieu were in 1946; the first recorded complaints concerning excess plant growth were in 1949, when letters were sent to the DNR requesting help in "destroying" the weeds. The first permit approved for chemical control of aquatic plants in Lake Mallalieu using arsenic compounds was issued in 1961. This led to a series of arsenic treatments (Table 1).

**Table 1. Chemical Treatments for Aquatic Plant Control.**

	Arsenic	Endothall	Diquat	2,4 -D	Silvex
1961	2860#				
1962	660#				
No treatment					
1964	1800#				
1965	1200#				
1966	720#	3.6 #	12 gal.		5 #
1998		4 gal.	2 gal.	73 oz.	
2000				22 oz.	
Totals	7240#		14 gal.	95 oz.	5 #

The total of pounds of arsenic applied to Lake Mallalieu during the 1960's was 7240 pounds, predominantly in the littoral zone and the shallow northeast end of the lake. Arsenic does not break down and will remain in the sediment; a 1979 sediment study in Lake Mallalieu recorded arsenic in the sediments, at concentrations varying from 17.4-34.4ppm. Arsenic and Silvex (2,4,5-TP) were later found to be detrimental, so are no longer approved for aquatic application. Arsenic and Silvex are broad-spectrum herbicides, therefore, they are not selective and would kill any plant to which they were applied. Other broad-spectrum chemicals have been used in Lake Mallalieu: endothall and diquat (Table 1).

There is no record of chemical treatments between 1966 and 1998, but some property owners admitted to using unpermitted herbicides, when other residents made complaints. The types and amounts are unknown and so cannot be included in the table.

There have been numerous drawdowns on Lake Mallalieu, including a 7-foot drawdown in 1983 for dam repairs and a 6-foot drawdown in 1998-99.

In 1974, long-time residents of the Hudson area expressed concern about the *lack of plant growth* in Lake Mallalieu. DNR

investigations confirmed that aquatic plant growth was sparse. Frequent drawdowns, past chemical treatments and carp were thought to be the reason for the lack of plant growth. The condition of sparse plant growth would make it easier for an invasive species to begin colonizing Lake Mallalieu.

During the late 1980's, several lakeshore residents became ill; water testing found extremely high levels of fecal coliform in Lake Mallalieu. A sanitary survey was conducted in 1989 and found 36 failed and 17 failing septic systems; some septic systems were discharging directly to the lake. These failed and failing septic systems would have been an additional nutrient source to the lake; sanitary sewers were installed in 1990-91.

The lake was drawn down six feet in the fall of 1998 to repair the dam. The water was left down over the winter in an attempt to control the Eurasian watermilfoil that had densely colonized the shallow east basin. The intention was to bring the lake up to 3 feet below normal level after the repairs were finished and leave the lake down 3 feet over the winter. However, there was a problem with the gates freezing, so the lake was left down 6 feet over the winter.

The Lake Mallalieu Association received a grant in 1997 to develop a lake management plan. The Lake Management Plan was completed in 2001.

Part of the lake management process involved a resident survey conducted in the autumn of 1998. Results of the survey indicated that:

- 1) The number one use of Lake Mallalieu is "peace and tranquillity", followed closely by "observing..."
- 2) Canoes are the most frequently owned watercraft.
- 3) The number one aspect of the lake that residents most enjoy is the natural beauty and the one aspect least enjoyed is jet ski use.
- 4) The majority of the residents would like to restrict jet ski use (Fussell et. al. 1998).
- 5) The aspect of Lake Mallalieu that residents most want to see improved is water quality.
- 6) Most felt that there were too many weeds, everywhere in the lake.
- 7) The majority of residents feel that fishing is average in Lake Mallalieu.

## II. METHODS

### Field Methods

The 1998, 1999 and 2001 study design was based primarily on the rake-sampling method developed by Jessen and Lound (1962). Twenty-three transects were placed along the shoreline, perpendicular to the shoreline (Figure 1). The transects were placed in the same location that Barr Engineering had sampled in their 1991 study. These transects were used for all subsequent surveys. Although Barr Engineering did not take samples in each depth zone of the transect, there will be an attempt to compare the Barr Engineering study to the DNR studies in 1998-2001.

One sampling site was randomly located in each depth zone (0-1.5ft., 1.5-5ft., 5-10ft., and 10-20ft.) along each transect. Using a long-handled, steel thatching-rake, four rake samples were taken at each sampling site. The four samples were taken from each quarter of a 6-foot diameter quadrat. The aquatic plant species that were present on each rake sample were recorded. The species recorded included macrophytes (vascular plants), and a few macrophytic algae, such as *Nitella* and *Chara* that have a plant-like growth form. Each species was given a density rating (0-5) based on the number of rake samples on which it was present at each sampling site. A rating of 1, 2, 3, or 4 indicates that a species was present on 1, 2, 3, or 4 rake samples; a rating of 5 indicates that it was abundantly present on all rake samples at that sampling site.

Occurrence of filamentous algae was recorded. Visual inspection and periodic samples were taken between transect lines in order to record the presence of any species that did not occur at the sampling sites.

Specimens of all plant species present were collected and saved in a cooler for later preparation of voucher specimens. Nomenclature was according to Gleason and Cronquist (1991). The sediment type at each sampling site was also recorded.

The type of shoreline cover was recorded at each transect. A section of shoreline, 50 feet on either side of the transect intercept with the shore and 30 feet back from the shore, was evaluated. The percentage of each cover type within this 100' x 30' rectangle was visually estimated.

### Data Analysis

Data from each survey (August 1991, July 1998, July 1999, July 2001) were analyzed separately and compared. The percent frequency of each species was calculated (number of sampling sites at which it occurred / total number of sampling sites) (Appendix I- IV). Relative frequency was calculated based on the number of occurrences of a species relative to total occurrence of all species (Appendix I- IV).

The mean density was calculated for each species (sum of a species' density ratings / number of sampling sites) (Appendix V-VIII). Relative density was calculated based on a species density relative to total plant densities. A "mean density where present" was calculated for each species (sum of a species' density ratings / number of sampling sites at which the species occurred) (Appendix V-VIII). The relative frequency and relative density was summed to obtain a Dominance Value (Appendix IX-XII). Simpson's Diversity Index was calculated (Appendix I-IV).

### III. RESULTS

#### PHYSICAL DATA

Many physical parameters impact the macrophyte community. Water quality (nutrient levels, algal levels, clarity, pH, hardness) can influence the macrophyte community as the macrophyte community can in turn modify these parameters. Lake morphology, sediment composition and shore land use also effect the macrophyte community.

**Water Quality** - The trophic state of a lake is an indication of its water quality. Phosphorus concentration, chlorophyll concentration, and water clarity data are collected to determine the trophic state.

Oligotrophic lakes are low in nutrients and support limited plant growth and smaller fish populations.

Eutrophic lakes are high in nutrients and therefore support a large biomass.

Mesotrophic lakes have intermediate levels of nutrients and biomass.

#### **Nutrients**

Phosphorus is a limiting nutrient in many Wisconsin lakes and is measured as an indication of the nutrient level in a lake.

Increases in phosphorus in a lake can feed algae blooms and, occasionally, excess plant growth.

**2001 summer phosphorus in Lake Mallalieu was 89 ug/l.,** indicating eutrophic status (Table 2).

**Table 2. Trophic Status**

	Quality Index	Phosphorus ug/l	Chlorophyll ug/l	Secchi Disc ft.
Oligotrophic	Excellent	<1	<1	> 19
	Very Good	1-10	1-5	8-19
Mesotrophic	Good	10-30	5-10	6-8
	Fair	30-50	10-15	5-6
Eutrophic	Poor	50-150	15-30	3-4
Hypereutrophic	Very Poor	>150	>30	>3
Lake Mallalieu	Poor	89	39	3.28

After Lillie & Mason (1983) & Shaw et. al. (1993)

Although phosphorus is a limiting nutrient in most Wisconsin lakes, about 10% of Wisconsin lakes are considered nitrogen limited. Nitrogen limitation results when the ratio of nitrogen:phosphorus is less than 10:1 (Shaw et. al. 1993). The nitrogen in Lake Mallalieu was measured at 720ug/l. This is a



nitrogen:phosphorus ratio in Lake Mallalieu is 8:1, which means that nitrogen can be limiting and inputs of nitrogen can feed algae and plant growth.

### **Algae**

Measuring the concentration of chlorophyll in lake water gives an indication of algae concentrations. Algae are natural and essential in lakes, but high algae levels can increase the turbidity, reducing the light available for plant growth.

**2001 summer chlorophyll in Lake Mallalieu was 39 ug/l.,** indicating hypereutrophic status (Table 2).

### **Water Clarity**

Water clarity is a critical factor for aquatic plants. When plants receive less than 1 - 2% of the surface illumination, they can not survive. Water clarity is reduced by turbidity (suspended materials such as algae cells and silt) and dissolved organic chemicals that color the water. Water clarity is measured with a Secchi disc that measures the combined effect of turbidity and color.

**Secchi disc clarity in 2001 was 3.28 ft.,** indicating eutrophic status and poor water clarity (Table 2).

Secchi disc readings can be used to calculate a predicted maximum rooting depth for plants in the lake (Dunst 1982).

**Based on the 2001 Secchi disc water clarity, the predicted maximum rooting depth in Lake Mallalieu would be 6.7 ft.**

The combination of nutrient and algae concentration and water clarity place Lake Mallalieu in the eutrophic class. This trophic state would support abundant plant growth and frequent algae blooms.

### **pH**

The pH of a lake indicates the acidity or alkalinity of the water; a pH of 7.0 indicates neutral water.

**2001 summer pH in Lake Mallalieu was 8.5.**

Higher pH values can result from the photosynthetic activity of plants and algae and would favor plants adapted to slightly alkaline conditions.

### **Hardness**

The alkalinity as measured by mg of CaCO<sub>3</sub>/l indicates the hardness of the water.

**The 2001 hardness in Lake Mallalieu was 144 mg CaCO<sub>3</sub>/l.**

Hardness values between 121 and 180 mg CaCO<sub>3</sub>/l indicate hard water; hard water favors plant growth in lakes.

### Sediment Composition

Silt, a soft, low-density sediment, was the predominant sediment in Lake Mallalieu (Table 3), especially in the east basin. The frequency of occurrence of silt sediments increased with increasing depth.

Sand and rock, hard, high-density sediments were commonly recorded: sand in the 0-10 ft depth zone and rock in the 1.5-20 ft depth zone (Table 3). Other hard, high-density sediments were commonly found. Sand/rock mixtures were predominant in the 0-1.5 ft depth zone, mainly in the narrow, west basin of the lake.

**Table 3. Sediment Composition**

		0-1.5ft.	1.5-5ft.	5-10ft.	10-20ft.	Overall
<b>Hard Sediments</b>	Sand	22%	26%	24%		21%
	Rock	17%	22%	18%	25%	20%
	Sand/Rock	35%	17%	6%		18%
<b>Mixed Sediments</b>	Sand/Silt	17%	17%	11%		14%
<b>Soft Sediments</b>	Silt	4%	13%	41%	75%	24%
	Silt/Muck	4%	4%			3%

There are slight differences in the sediments recorded at the sample sites in 1998, 1999 and 2001 (Table 4).

Sand sediments and silt sediments have decreased slightly. Mixtures of sand and silt have increased, as have rock sediments (Table 4).

As the lake was drawn down, there could have been a mixing of the two sediments and a movement of softer, finer sediments into the deeper parts of the lake. This migration of fine sediments may have exposed more rock base.

**Table 4. 1998-2001 Sediment Composition**

		1998	1999	2001
<b>Hard Sediments</b>	Sand	38%	25%	21%
	Rock	12%	18%	20%
	Sand/Rock	16%	22%	18%
<b>Mixed Sediments</b>	Sand/Silt	5%	11%	14%
<b>Soft Sediments</b>	Silt	30%	21%	24%
	Silt/Muck		1%	3%

**SHORELINE LAND USE** - Land use can strongly impact the aquatic plant community and, therefore, the entire lake community. Practices on shore can directly impact the plant community through increased sedimentation from erosion, increased nutrients from fertilizer run-off and soil erosion and increased toxics from farmland and urban run-off.

Cultivated lawn was the most frequently encountered shoreline cover at the transects and had the highest mean coverage in 2001 (Table 5). Lawn occurred at nearly half the sites and covered more than 1/3 of the shoreline. Wooded cover, shrubs, native herbaceous, rip-rap and hard structures were also commonly encountered in 2001 (Table 5).

**Table 5. Shoreline Land Use**

Cover Type		Frequency of Occurrences at Transects			% of Coverage		
		1998	1999	2001	1998	1999	2001
Natural Shoreline	Wooded	70%	64%	39%	40%	38%	23%
	Shrub	61%	59%	39%	18%	25%	17%
	Native Herbaceous	35%	23%	43%	8%	8%	9%
Disturbed Shoreline	Cultivated Lawn	52%	27%	48%	27%	16%	35%
	Paved Surface	13%	9%	13%	5%	4%	6%
	Rip-Rap	13%	23%	39%	1%	5%	4%
	Eroded Soil		13%	17%		3%	2%
	Hard Structures	4%	4%	22%	1%		3%

Based on the shoreline at the sample sites, the occurrence of natural shoreline (wooded, shrub, native herbaceous) decreased from 87% of the sites in 1998 to 78% of the sites in 2001, with wooded cover and shrub cover decreasing the most. The area of the shoreline covered by natural shoreline decreased from 66% in 1998 to 49% in 2001 (Table 5).

Conversely, the occurrence of disturbed shoreline (cultivated lawn, paved surfaces, rip-rap and hard structures) increased from 61% of the sites in 1998 to 74% in 2001. The area of the shoreline covered by disturbed shoreline increased from 34% in 1998 to 50% in 2001.

The coverage of wooded shoreline has decreased the most at the expense of increases in cultivated lawn, rip-rap and hard structures (Table 5).

**MACROPHYTE DATA**  
**SPECIES PRESENT**

Twenty-seven species were found in Lake Mallalieu during the 1991, 1998, 1999 and 2001 aquatic plant surveys. Of the 24 species, 7 were emergent species, 4 were a floating-leaf species and 16 were submergent species (Table 6).

No endangered or threatened species were found.

Three non-native species were found:

*Lythrum salicaria*

*Myriophyllum spicatum*

*Potamogeton crispus*

**Table 6. Lake Mallalieu Aquatic Plant Species**

<u>Scientific Name</u>	<u>Common Name</u>	<u>I. D. Code</u>
<u>Emergent Species</u>		
1) <i>Asclepias incarnata</i> L.	swamp milkweed	ascin
2) <i>Calamagrostis canadensis</i> (Michx.)	bluejoint	calca
3) <i>Carex</i> sp.	sedge	carsp
4) <i>Impatiens capensis</i> Meerb.	Orange jeweleweed	impca
5) <i>Lycopus virginicus</i> L.	water-horehound	lycvi
6) <i>Lythrum salicaria</i> L.	purple loosestrife	lytsa
7) <i>Typha latifolia</i> L.	common cattail	typla
<u>Floating-leaf Species</u>		
8) <i>Lemna minor</i> L.	small duckweed	lemmi
9) <i>Nymphaea odorata</i> Aiton.	white water lily	nymod
10) <i>Spirodela polyrrhiza</i> (L.) Schleiden.	greater duckweed	spipo
11) <i>Wolffia columbiana</i> Karsten.	common watermeal	wolco
<u>Submergent Species</u>		
12) <i>Ceratophyllum demersum</i> L.	coontail	cerde
13) <i>Elodea canadensis</i> Michx.	common water-weed	eloca
14) <i>Myriophyllum sibiricum</i> Komarov.	common watermilfoil	myrsi
15) <i>Myriophyllum spicatum</i> L.	Eurasian watermilfoil	myrsp
16) <i>Najas flexilis</i> (Willd.) R. & S.	northern water-nymph	najfl
17) <i>Potamogeton crispus</i> L.	curly-leaf pondweed	potcr
18) <i>Potamogeton illinoensis</i> Morong.	Illinois pondweed	potil
19) <i>Potamogeton natans</i> L.	floating-leaf pondweed	potna
20) <i>Potamogeton nodosus</i> Poiret.	long-leaf pondweed	potno
21) <i>Potamogeton pectinatus</i> L.	sago pondweed	potpe
22) <i>Potamogeton pusillus</i> L.	slender pondweed	potpu
23) <i>Potamogeton zosteriformis</i> Fern.	flat-stem pondweed	potzo
24) <i>Ranunculus longirostris</i> Godron.	white water crowfoot	ranlo
25) <i>Vallisneria americana</i> L.	water celery	valam
26) <i>Zannichellia palustris</i> L.	horned pondweed	zanpa
27) <i>Zosterella dubia</i> (Jacq.) Small.	water stargrass	zosdu

**FREQUENCY OF OCCURRENCE**

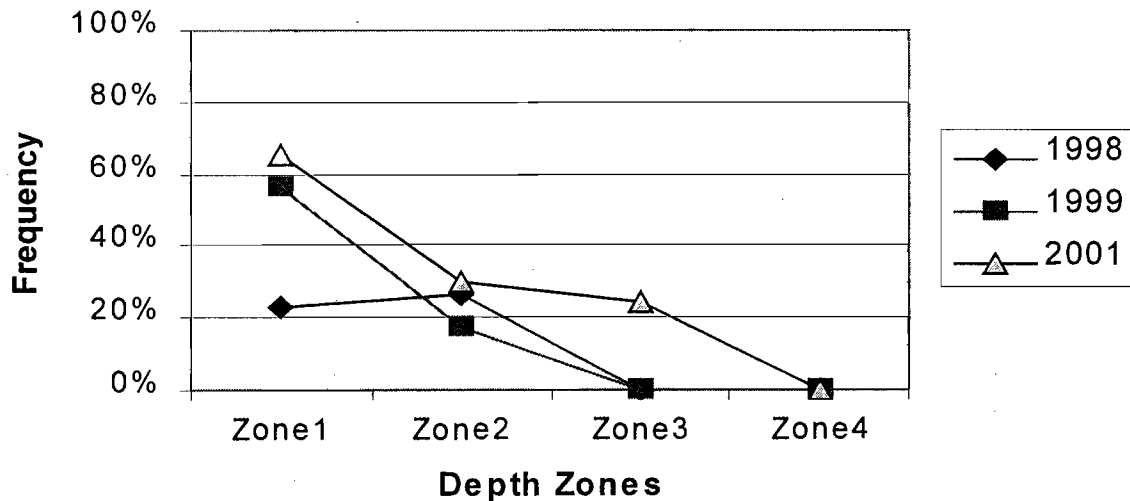
The species with the highest frequency of occurrence in 1991 was *Myriophyllum spicatum* (36%) and in 1998 was *Ceratophyllum demersum* (30%) (Table 7). Neither of these species were found in 1999. The most frequent species in 1999 and 2001 was *Nymphaea odorata*, although even it occurred at lower frequencies than previously (Table 7).

**Table 7. Frequency of aquatic plant species in Lake Mallalieu.**

Species	1991	1998	1999	2001
<i>Ceratophyllum demersum</i>	18%	30%		7%
<i>Elodea canadensis</i>	5%	20%	1%	
<i>Myriophyllum spicatum</i>	36%	17%		
<i>Nymphaea odorata</i>		23%	10%	21%
<i>Zosterella dubia</i>	10%	25%		

The occurrence of filamentous algae was not recorded in the 1991 study, but occurred at:  
 17% of the sample sites in 1998  
 24% of the sample sites in 1999  
 36% of the sample sites in 2001

The overall increase in filamentous algae was the result of a nearly three-fold increase in filamentous algae in the shallow zone in 1999 and an increase of algae in the 5-10 ft. depth zone in 2001 (Figure 1). Filamentous algae occurs more frequently in the shallower depth zones (Figure 1).



**Figure 1. Occurrence of filamentous algae in Lake Mallalieu.**

### DENSITY

*Myriophyllum spicatum* was the species with the highest mean density (0.98 on a scale of 4) in 1991 and *Ceratophyllum demersum* was the species with the highest mean density (0.66 on a scale of 4) in 1998 (Table 8). Neither species was found at the sample sites in 1999. *Nymphaea odorata* was the species with the highest mean density in 1999 and 2001, although its density was lower in than in previous surveys (Table 8).

**Table 8. Density of plant species in Lake Mallalieu, 1991-2001.**

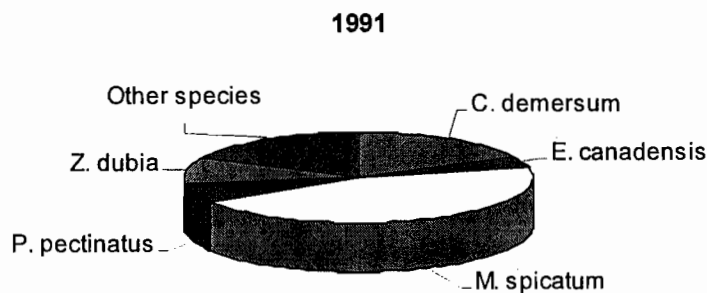
Species	1991	1998	1999	2001
<i>Ceratophyllum demersum</i>	0.33	<b>0.66</b>		0.07
<i>Elodea canadensis</i>	0.05	0.44	0.01	
<i>Myriophyllum spicatum</i>	<b>0.90</b>	0.25		
<i>Nymphaea odorata</i>		0.39	<b>0.17</b>	<b>0.30</b>
<i>Zosterella dubia</i>	0.18	0.47		

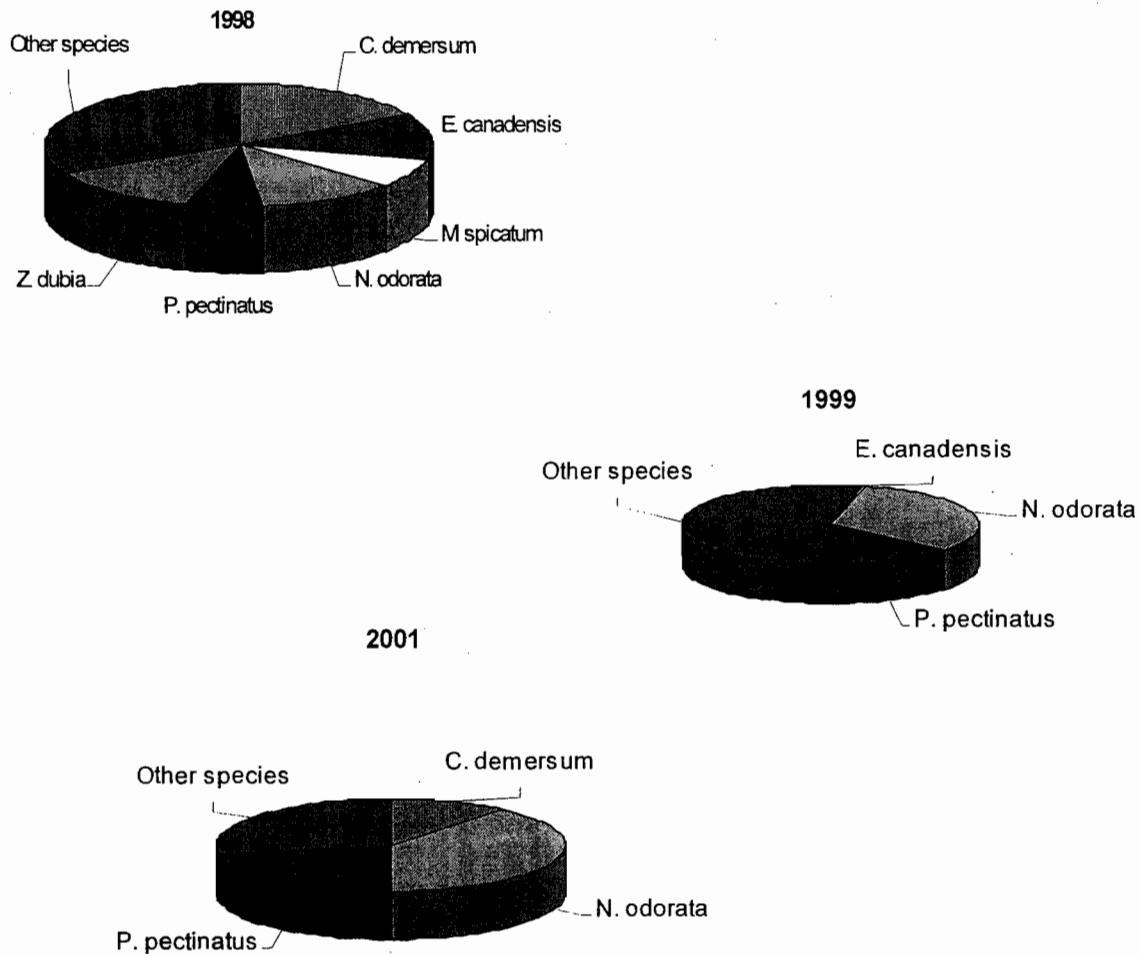
### DOMINANCE

Combining relative frequency and relative density into a Dominance Value indicates the dominance of species within the macrophyte community (Appendix IX-XII). Based on the Dominance Value, *Myriophyllum spicatum* and was the dominant species within the macrophyte community in 1991 (Figure 2).

*Ceratophyllum demersum* was the dominant species in 1998, with *Elodea canadensis*, *Nymphaea odorata* and *Zosterella dubia* as sub-dominants (Figure 2).

Both *Myriophyllum spicatum* and *Ceratophyllum demersum* disappeared in 1999. *Nymphaea odorata* became the dominant species in 1999 and 2001 with *Potamogeton pectinatus* as the sub-dominant species (Figure 2).





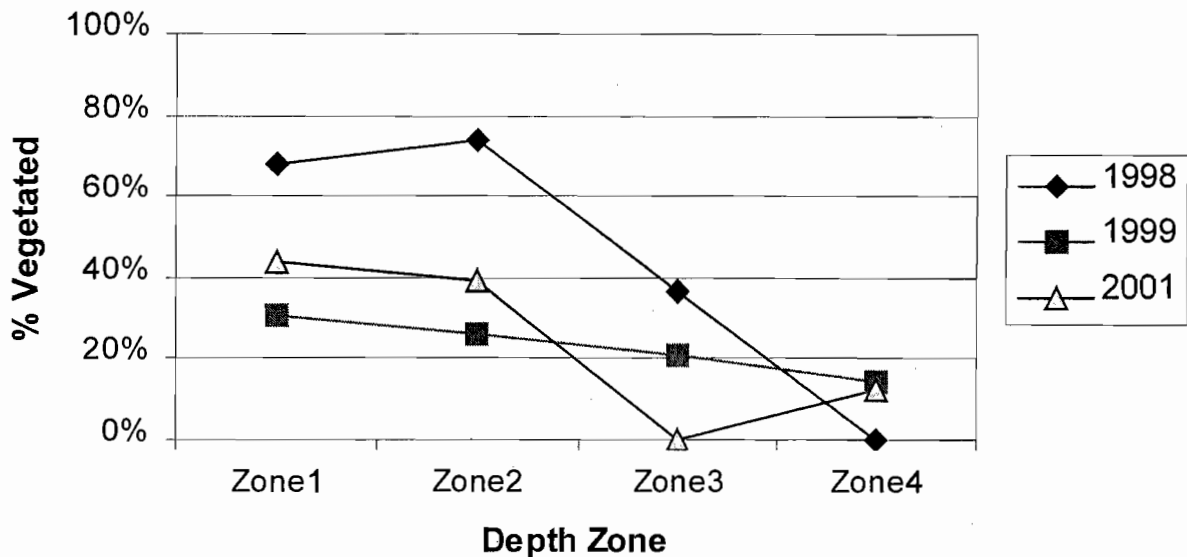
**Figure 2. Dominance within the macrophyte community, of the most prevalent plants, based on Dominance Value, 1991-2001.**

**DISTRIBUTION**

The highest percent of vegetated sites has been in the 0-5 ft. depth zone and the year with the highest percent of vegetated sites was 1998 (Figure 3).

The percent of vegetated sites decreased in 1999. Since 1999, the percentage of vegetated sites has increased slightly, except in the 5-10 ft. depth zone (Figure 3).





**Figure 3. Percent of sites with rooted vegetation, by depth zone and year.**

In 1999 and 2001, aquatic plant growth, including the dominant species, *Nymphaea odorata*, was found mainly in the east end of the lake. Aquatic vegetation was found at a few other sparsely scattered sites around the lake.

The 0-5ft depth zones supported the greatest total occurrence and density of aquatic plants (Figure 4, 5). The highest total occurrence and total density of aquatic plants was in 1998. The total occurrence and density of plant growth decreased dramatically in 1999 and recovered only slightly in 2001 (Figure 4, 5).

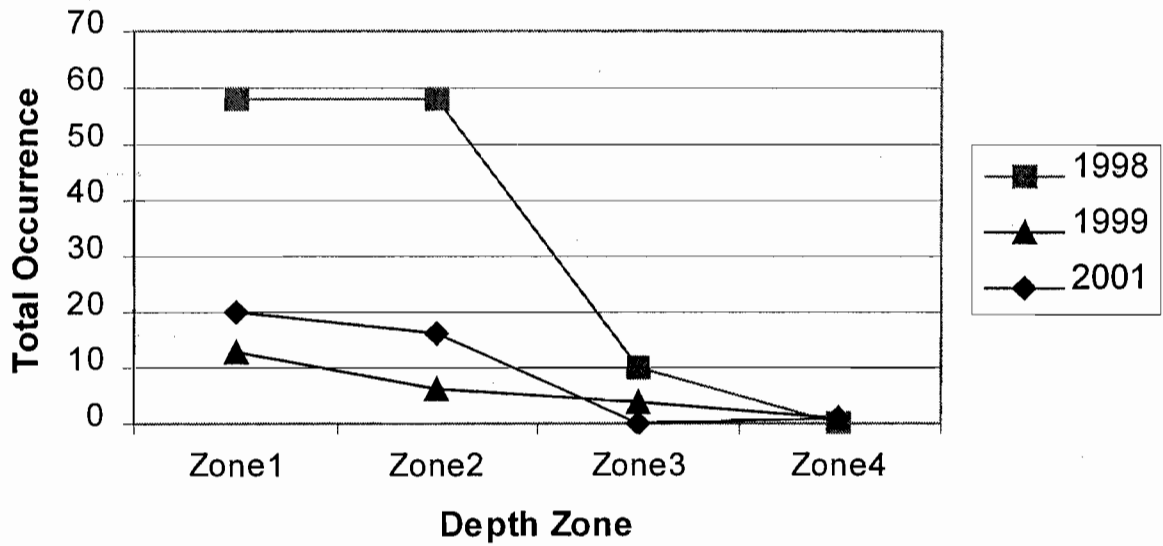


Figure 4. Total occurrence of plants by depth zone.

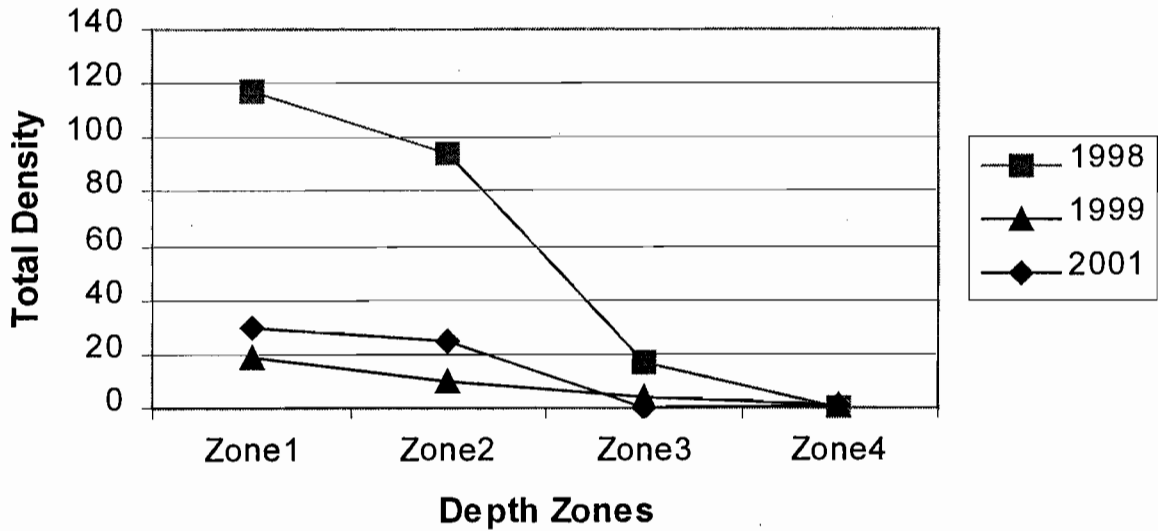


Figure 5. Total density of plants by depth zone.

The greatest number of species per site has been in the 0-5 ft. depth zone (Figure 6). The greatest number of species per sample site was recorded in 1998, followed by a dramatic decrease in 1999 and a very slight recovery in 2001 (Figure 6).

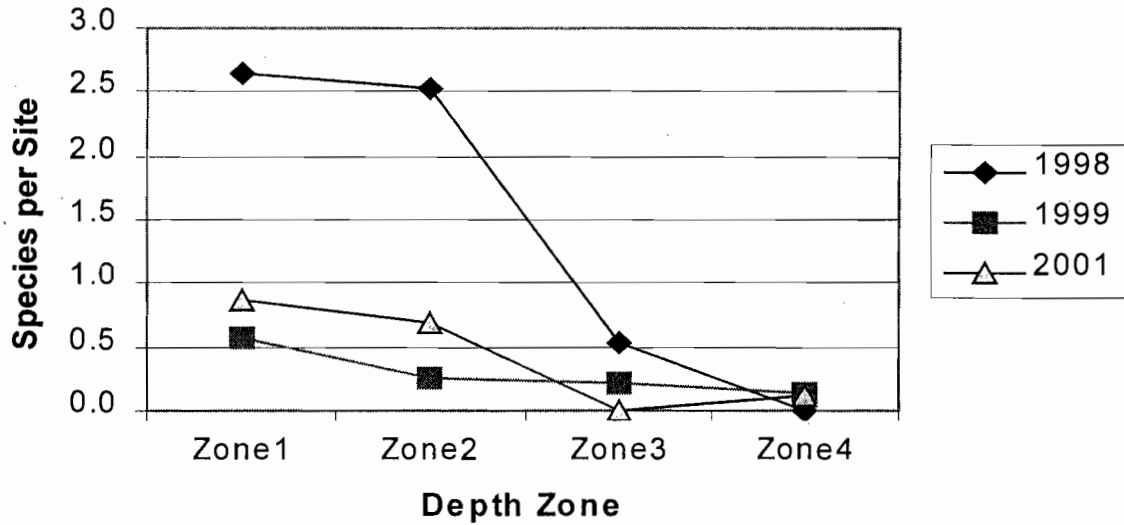


Figure 6. Mean number of macrophyte species per site, by depth zone.

The frequencies and densities of individual species varied with depth zone and sampling year. *Myriophyllum spicatum* grew at its highest frequency and density in 1991 and in the 1.5-5ft depth zone (Figure 7, 8). *M. spicatum* declined in 1998, disappeared in 1999 and did not occur at the transects in 2001. However, *M. spicatum* was found at two other sites in 2001; a few plants were found in the shallow bay west of transect #23 and a plant was found in the northeast end where the Willow River enters the impoundment. Both areas were pulled.

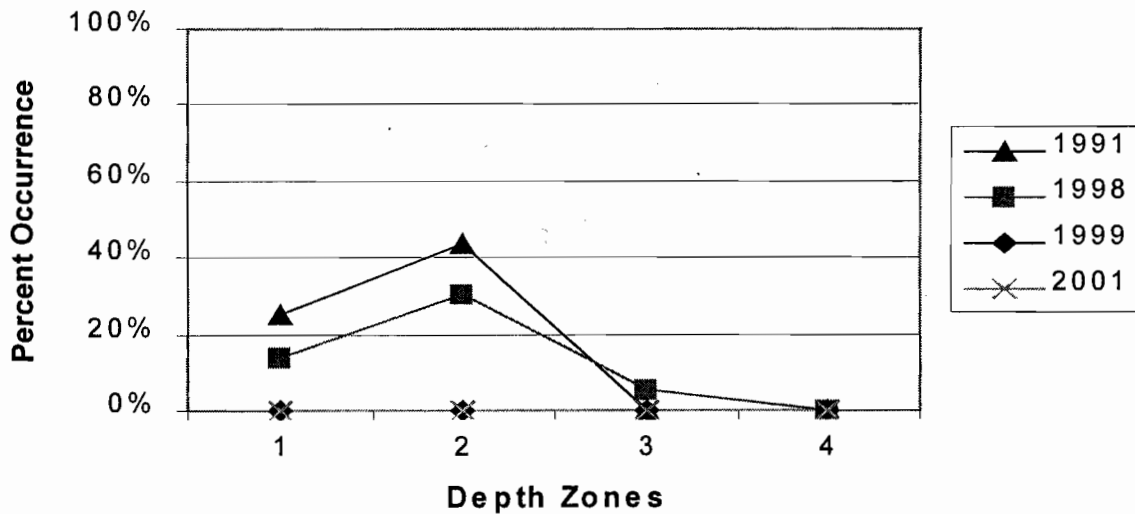


Figure 7. Frequency of *Myriophyllum spicatum* by depth zone.

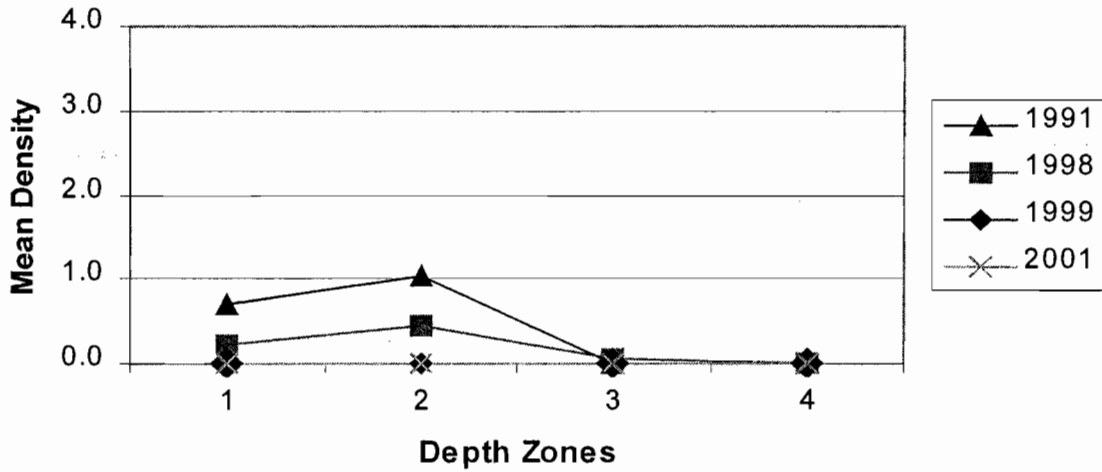


Figure 8. Density of *Myriophyllum spicatum* by depth zone.

*Ceratophyllum demersum* was found at its highest frequency in the 1.5-5ft depth zone (Figure 9). However, its density was more evenly distributed (Figure 10). *C. demersum* occurred at its highest frequency and density in 1998 and was the dominant species in the 1.5-10 ft depth zone. *C. demersum* disappeared in 1999 and recovered slightly by 2001 (Figure 9, 10).

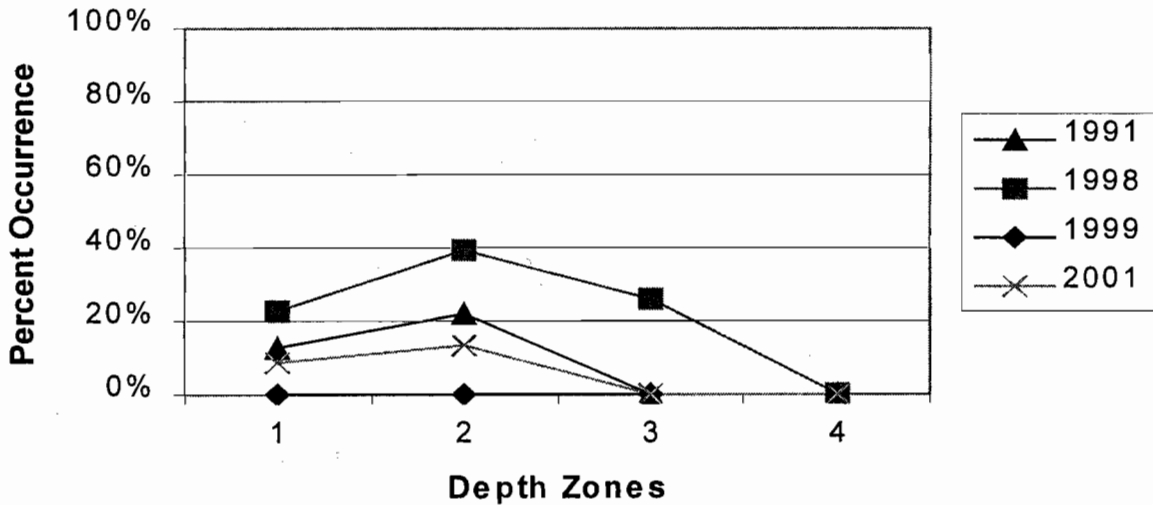


Figure 9. Frequency of *Ceratophyllum demersum* by depth zone.

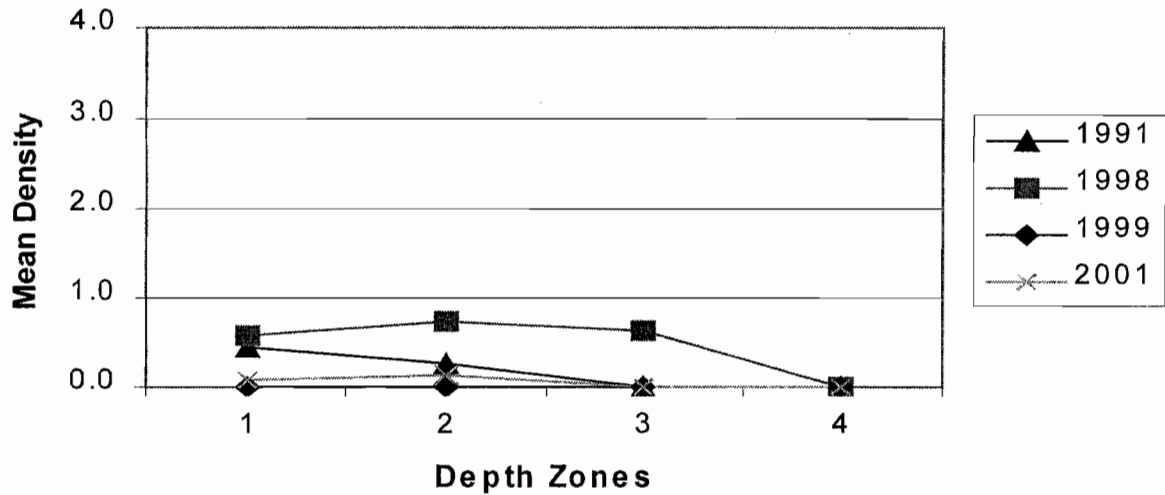


Figure 10. Density of *Ceratophyllum demersum* by depth zone.

*Nymphaea odorata* occurred at its highest frequency and density in the 1.5-5 ft. depth zone (Figure 11, 12). *N. odorata* was at its highest frequency and density in Lake Mallalieu in 1998, declined in 1999 and increased in the 0-1.5 ft. depth zone in 2001 (Figure 11, 12). *N. odorata* was the dominant species in the 1.5-10 ft. depth zone in 1999 and in all depth zones in 2001.

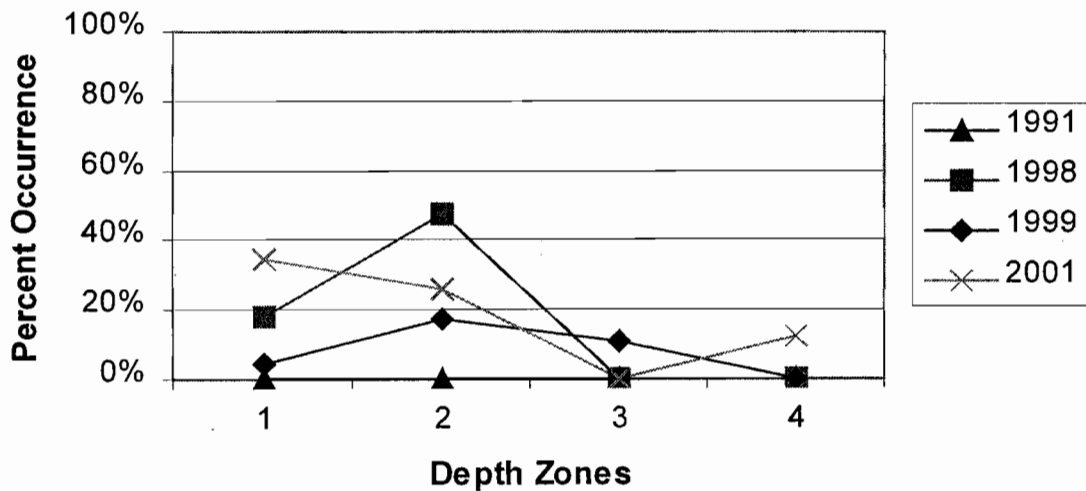


Figure 11. Frequency of *Nymphaea odorata* by depth zone.

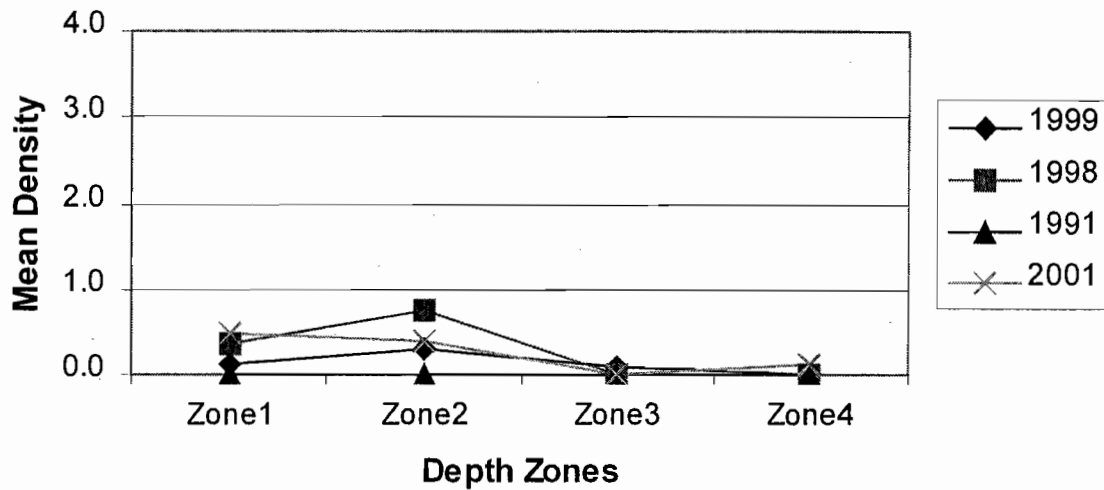


Figure 12. Density of *Nymphaea odorata* by depth zone.

**SEDIMENT INFLUENCE** - Many plants depend on the sediment in which they are rooted for their nutrients. The richness or sterility of the sediment will determine the type and abundance of macrophyte species that can survive in a location.

The availability of mineral nutrients for growth is highest in sediments of intermediate density, such as silt (Barko and Smart 1986). Highly organic muck sediments are low-density sediments; sand, gravel and rock are high-density sediments. Sand sediments and silt sediments both occurred frequently in Lake Mallalieu and supported moderate growth of vegetation (Table 9).

Rock sediments supported no vegetation in 1999 and moderate growth in 2001.

Mixed silt and sand sediment supported moderate growth of vegetation in 1999 and high amounts of vegetation in 2001. However, silt and sand mixtures did not occur frequently (Table 9).

Organic muck sediments had the highest level of vegetation, but occurred at few sites.

**Table 9. Sediment Influence**

		1999		2001	
		Percent of sites	Percent vegetated	Percent of sites	Percent vegetated
<b>Hard Sediments</b>	Sand	25%	22%	21%	33%
	Rock	18%	0%	20%	15%
	Sand/Gravel/Rock	22%	25%	18%	8%
<b>Mixed Sediments</b>	Sand/Silt	11%	38%	14%	60%
<b>Soft Sediments</b>	Silt	21%	33%	24%	24%
	Silt/Muck	1%	100%	3%	100%

**THE AQUATIC PLANT COMMUNITY**

Many measures and indices can be used to characterize a plant community and determine changes in the community. Several indices suggest that changes have occurred in the plant community of Lake Mallalieu.

The number of species at the sampling sites has decreased nearly 70% since 1998. Also decreased since 1998 is the percent of the littoral zone that is vegetated by more than 50%, the percent occurrence of free-floating species and the percent occurrence of submergent species by 64% (Table 10).

**Table 10. Changes in the Lake Mallalieu Macrophyte Community**

	1998	1999	2001	Change 1998-99	Change 1999-01	Change 1998-01	Maximum Change	%Change 1998-01
<b>Number of Species</b>	23	11	7	-12	-4	-16	16	-69.6%
<b>Maximum Rooting Depth</b>	7.0	11.0	10.0	4	-1	3	4	42.9%
<b>% of Littoral Zone Vegetated</b>	61%	25%	28%	-0.4	0.0	-0.3	0.4	-54.1%
<b>%Sites/Emergents</b>	2%	1%		0.0	0.0	0.0	0.0	-100.0%
<b>%Sites/Free-floating</b>	33%		7%	-0.3	0.1	-0.3	0.3	-78.8%
<b>%Sites/Submergents</b>	50%	15%	18%	-0.4	0.0	-0.3	0.4	-64.0%
<b>%Sites/Floating-leaf</b>	22%	10%	21%	-0.1	0.1	0.0	0.1	-4.5%
<b>Simpson's Diversity Index</b>	0.91	0.85	0.76	-0.06	-0.09	-0.15	0.15	-16.5%
<b>Floristic Quality</b>	19.96	12.33	12.09	-7.63	-0.24	-7.87	7.87	-39.4%

Simpson's Diversity Index decreased from 0.91 (very good) in 1998, to average diversities of 0.85 in 1999 and 0.76 in 2001. An index of 1.0 would mean that each plant in the lake would be a different species (the most diversity achievable).

The Floristic Quality (a measure of a plant community's closeness to an undisturbed condition, discussed later in this document) decreased 39% from 1998 to 2001.

The maximum rooting depth has increased. Floating-leaf vegetation decreased between 1998 and 1999, but recovered in 2001 (Table 10).

The Aquatic Macrophyte Community Index (AMCI) was developed by Weber et. al. (1995) to quantify the quality of an aquatic macrophyte community. Values between 0 and 10 are given for each of six categories that measure the health of the aquatic plant community. The highest value for this index is 60 (Table 11). Lake Mallalieu was slightly below the average (40) for lakes in Wisconsin in 1998 with an Index of 38. The quality of the aquatic macrophyte community, as measured by the AMCI, in Lake Mallalieu has been declining since 1998, to a below average value of 27 in 2001 (Table 11).

**Table 11. Lake Mallalieu Aquatic Macrophyte Community Index**

Category	1998	1999	2001
Maximum Rooting Depth	4	6	6
% Littoral Zone Vegetated	10	6	6
Simpson's Diversity	10	9	8
# of Species	6	3	1
% Submersed Species	8	6	6
% Sensitive Species	0	0	0
Totals	38	30	27



The decline in the quality as measured by AMCI has been due to decreased colonization of the littoral zone by aquatic plants, decreased colonization of submerged plant growth and declining numbers of species and species diversity.

The Coefficient of Community Similarity is a measure of the percent similarity between two communities. Coefficients less than 0.75 indicate that the two communities are considered significantly different, in that they are only 75% similar.

The coefficients for Lake Mallalieu indicate that the 1998 and 1999 aquatic plant communities were significantly different (Table 12), only 36% similar. The change between 1999 and 2001 was still significant, but not as great; the 1999 and 2001 aquatic plant communities were 61% similar. Some of the change between 1999 and 2001, however, may be changes related to recovery of the plant community. The coefficient for the 1998 and 2001 communities suggest this. The 1998 and 2001 communities are significantly different, but being 44% similar, are more similar than the 1998 and 1999 (36% similar) (Table 12).

**Table 12. Coefficients of Community Similarity**

Coefficient of Similarity		Percent Similar
1998-99	0.356	36%
1999-01	0.61	61%
1998-01	0.441	44%

Aquatic plant communities change because the frequency and density of the plant species in the community change. Many species disappeared between 1998 and 1999: 3 emergent species, the three duckweed species and 7 submergent species (Appendix XIII).

In 2001, two of the species, *Ceratophyllum demersum* and *Potamogeton nodosus*, returned. However, 4 other emergent species and 2 other submergent species disappeared.

In addition to the species that disappeared, *Potamogeton crispus* decreased most in frequency of occurrence and density (85% and 94% decrease). *Potamogeton nodosus* and *Ceratophyllum demersum* also decreased substantially in frequency and density (71-89% decreases). There was no species in 2001 that had a greater frequency and/or density than in 1998.

Nichols (1998) recently outlined a method for evaluating the closeness of an aquatic plant community to an undisturbed condition using Coefficients of Conservatism.

A Coefficient of Conservatism (C) is an assigned value, 0-10, the probability that a species will occur in a relatively undisturbed habitat. The Average Coefficient of Conservatism ( $\bar{C}$ ) is the mean of the coefficient of conservatism for each species found in a lake and measures the disturbance tolerance of a plant community.

Floristic quality (I), calculated from the coefficients, is a measure of plant community's closeness to an undisturbed condition.

When Nichols applied this metric to a sample of 554 lakes throughout Wisconsin, the Average Coefficient of Conservatism for all Wisconsin lakes ranged from a low of 2.0 (most tolerant of disturbance) to a high of 9.5 (least disturbance tolerant). The lowest Floristic Quality was 3.0 (farthest from an undisturbed condition) and the high was 44.6 (closest to an undisturbed condition) (Table 13).

Lake Mallalieu is located in the North Central Hardwood Forest Region (NCHF) and was compared to lakes in that region and in the state.

**Table 13. Floristic Quality and Coefficient of Conservatism of Lake Mallalieu, Compared to Wisconsin Lakes and Region Lakes.**

	( $\bar{C}$ ) Average Coefficient of Conservatism	(I) Floristic Quality
Wisconsin Lakes	5.5, 6.0, 6.9*	16.9, 22.2, 27.5*
NCHF	5.2, 5.6, 5.8*	17.0, 20.9, 24.4*
Lake Mallalieu, 1998-2001		
1998	4.58	19.96
1999	4.11	12.33
2001	4.57	12.09

\* upper limit of lower quartile, mean, lower limit of upper quartile

The Average Coefficient of Conservatism for Lake Mallalieu aquatic plant species has been in the lowest quartile for all Wisconsin lakes and lakes in the North Central Hardwood Region (Table 13). This suggests that the plant community in Lake Mallalieu is among those lakes most tolerant of disturbance, probably the result of being subjected to disturbance.

The Floristic Quality of the plant community in Lake Mallalieu has been slightly more variable. The Floristic Quality was below

the mean of Wisconsin lakes and Northern Central Hardwood lakes in 1998 (Table 13). In 1999 and 2001 the Floristic Quality was in the lower quartile of both Wisconsin lakes and Northern Lakes (Table 13). This indicates that the plant community in Lake Mallalieu was below average in its closeness to an undisturbed condition in 1998, but in 1999 and 2001 was within the quartile of lakes farthest from an undisturbed condition.

Disturbances can be of many types:

- 1) Direct disturbances to the plant beds result from boat traffic, plant harvesting, chemical treatments, water level manipulations and the placement of docks and other structures, etc.
- 2) Indirect disturbances can be the result of factors that impact water clarity and thus stress species that are more sensitive: resuspension of sediments, sedimentation from erosion, increased algae growth due to nutrient inputs.
- 3) Biological disturbances include the introduction of a non-native or invasive plant species, grazing from an increased population of aquatic herbivores, destruction of plant beds by the fish population, etc.

## **V. DISCUSSION**

### **Background**

Based on nutrient and algae concentrations and water clarity, Lake Mallalieu is a eutrophic lake with poor water clarity and poor water quality.

In Lake Mallalieu, the eutrophic status, hard water and shallow depths and gradual-sloped littoral zone in the east portion would favor plant growth.

Conversely, plant growth in Lake Mallalieu would be limited by the poor water clarity, the predominance of hard, high-density sediments within the photic zone and the steep littoral zone in the west portion of the lake. The sediment types that support the most plant growth in Lake Mallalieu occur at lower frequencies and are more predominant in the deeper zones, where light is limiting.

The Lake Mallalieu aquatic plant in 2001 was a disturbance tolerant community of below average quality and average species diversity. White water lily, *Nymphaea odorata*, was the dominant species. Aquatic plant growth is sparse (28%) of the littoral zone, occurring mainly in the east basin and in scattered locations up to a maximum depth of 10 feet. The most abundant plant growth occurred in the 0-5ft-depth zone. The maximum rooting depth is greater than predicted rooting depth based on water clarity. This is likely due to better water clarity in the spring when aquatic plant growth begins, before the algae blooms reduce light availability.

### **Impacts**

#### **Shoreline Impacts**

The aquatic community in Lake Mallalieu appears to be losing its protecting shoreline buffer zone.

Since 1998, the occurrence and mean coverage of natural shoreline (wooded, shrub and native herbaceous growth) on Lake Mallalieu has decreased and the occurrence and coverage of disturbed shoreline has increased. In 2001, some form of disturbed shoreline occurred at 74% of the sites and covered 50% of the shoreline. One type of disturbed shoreline, cultivated lawn was found at nearly half the sites and covered more than one-third of the shoreline.

There are several reasons for concerns about non-natural shorelines. Cultivated lawn increases the run-off of fertilizers and pesticides into the lake. Reducing lawn fertilizers is important because it appears that nitrogen is limited in Lake Mallalieu and the addition of either nitrogen or phosphorus can feed algae blooms.

Bare and eroded soil directly effect sedimentation. These areas along the shore indicate that soil is already eroding into the

lake. The soil carries nutrients into the lake and impacts near shore habitat by covering it with sediment.

Rip-rap does not provide a good buffer to prevent run-off and nutrient enrichment. Hard surfaces and structures also increase run-off. In addition, rip-rap and hard structures at the shore are detrimental to the aesthetics of the lake.

#### **Chemical treatments**

In the past, treatments with herbicides were conducted to control aquatic plant growth. Non-selective herbicides (those that kill all plants species) such as diquat and endothall have been used in Lake Mallalieu and may have been conducted with the wrong approach, a stated desire to "destroy weeds". By non-selectively killing all species, the lake could be likened to a plowed field, vulnerable to the colonization of aggressive species, such as Eurasian watermilfoil. By the 1970's, there were complaints about too few plants in Lake Mallalieu. Eurasian watermilfoil did invade the lake and was the dominant species in 1991. Another non-native species, curly-leaf pondweed, also colonized Lake Mallalieu.

Silvex and arsenic were also used in the past, but were found to be detrimental, so are no longer approved. Arsenic does not breakdown and is still in the sediments of Lake Mallalieu.

#### **Impacts of the 1998-99 Winter Drawdown**

In the past, frequent drawdowns were used to control plant growth. A drawdown, 6 feet, was conducted in the winter 1998-99 to control Eurasian watermilfoil. The aquatic plant community in Lake Mallalieu underwent a dramatic change after the drawdown.

The coefficients of community similarity indicate that the aquatic plant community in 1998 was only 36% similar to the aquatic plant community in 1999, a significant difference. The total occurrence and density of aquatic plant growth, the percent of vegetated sites and the number of species per site were lowest in 1999, declining dramatically after the drawdown.

Positive changes after the drawdown:

- 1) The two non-native species have been impacted; *Myriophyllum spicatum* appeared to have disappeared and *Potamogeton crispus* declined 85-94%.
- 2) The maximum rooting depth increased. This may be due to consolidation of the sediment during drying the produced a more solid rooting base.
- 3) The dominant species changed from coontail, *Ceratophyllum demersum*, to a species with more habitat value, white water lily, *Nymphaea odorata*.

Negative changes after the drawdown:

- 1) The number of aquatic plant species occurring in Lake

Mallalieu decreased 70%. Thirteen species disappeared, including the 1998 dominant species, *Ceratophyllum demersum*.

- 2) This loss of species has resulted in a decrease in the diversity index, from very good, to average.
- 3) The percent of the littoral zone that is vegetated dropped to 25%, a 50% decrease.
- 4) The percentage of sites with submergent vegetation decreased to 15%, a 64% decrease.
- 5) The occurrence of filamentous algae increased. When plant growth is reduced, nutrients are available for increased algae growth.
- 6) The quality of aquatic plant community, as measured by the AMCI decreased from near average in 1998 (38 on a scale of 60), to below average in 2001 (27 on a scale of 60).
- 7) The Floristic Quality Index (FQI) decreased 39%, placing Lake Mallalieu among the group of lakes in Wisconsin and the North Central Hardwood Region farthest from an undisturbed condition.

#### **Long-term Changes**

The 2001 plant study indicated that the aquatic plant community was still in a state of change. Even though some recovery from the 1998-99 winter drawdown was seen in the plant community, most plant growth was still confined to the east end of the lake.

The Coefficient of Community Similarity suggested that the aquatic plant community may be returning somewhat to the pre-drawdown condition. The pre-drawdown, 1998 plant community was more similar to the 2001 plant community (44%) than it was to the post drawdown, 1999 community (36%).

Changes from 1999-2001 suggesting recovery are:

- 1) A slight increase in percent of vegetation in the littoral zone.
- 2) A slight increase in the percent occurrence of submergent species.
- 3) An increase in the total occurrence and density of plant growth.
- 4) An increase in the number of species per site.
- 5) The recovery of white water lily, *Nymphaea odorata*.

Continued negative changes were:

- 1) Continued decline in number of species (4 more species disappeared) and species diversity.
- 2) Continued decline in the quality of the plant community as measured by the AMCI.
- 3) Continued increase in the occurrence of filamentous algae

## **VI. CONCLUSIONS**

### **Benefits of Aquatic Plants**

A healthy aquatic plant community plays a vital role within the lake community. This is due to the role plants play in

- 1) improving water quality
- 2) providing valuable resources for fish and wildlife
- 3) resisting invasions of non-native species and
- 4) checking excessive growth of tolerant species that could crowd out more sensitive species and therefore reduce diversity.

### Improving Water Quality

Plant communities improve water quality in many ways: they trap nutrients, debris, and pollutants entering a water body; they absorb and break down some pollutants; they reduce erosion by damping wave action and stabilizing shorelines and lake bottoms; they remove nutrients that would otherwise be available for algae blooms (Engel 1985).

### Providing Resources for Fish and Wildlife

Aquatic plant communities provide important fishery and wildlife resources. Plants (including algae) start the food chain that supports many levels of wildlife, and at the same time produce oxygen needed by animals. Plants are used as food, cover and nesting/spawning sites by a variety of wildlife and fish.

Compared to non-vegetated lake bottoms, plant beds support larger, more diverse invertebrate populations that in turn will support larger and more diverse fish and wildlife populations (Engel 1985). Mixed stands of plants support 3-8 times as many invertebrates and fish as monocultural stands because diversity in the plant community creates more microhabitats for the preferences of more species (Engel 1990).

Plant beds of moderate density support adequate numbers of small fish without restricting the movement of predatory fish (Engel 1990). Cover within the littoral zone should be about 25-85% to support a healthy fishery. The plant growth in Lake Mallalieu in 2001 provided 28% cover within the littoral zone, only 18% cover of submerged plant growth. This amount of plant growth is at the lower limits and may be barely adequate for providing cover for most fish.

### **Lake Mallalieu**

Lake Mallalieu is a eutrophic lake with poor water clarity and quality. Filamentous algae was abundant, especially in the 0-5 ft. depth zone and periodic planktonic algae blooms occur.

### **Aquatic Plant Community**

The slope of the littoral zone, water depths and sediments differ in the east and west portions of the lake. More favorable conditions for plant growth in occur in the east portion of Lake Mallalieu and less favorable conditions in the west portion.

The quality of the aquatic plant community in Lake Mallalieu is below average for Wisconsin lakes and is characterized by average diversity, disturbance tolerant vegetation and low density of plant growth.

#### **MANAGEMENT RECOMMENDATIONS**

##### **I. Improve the water quality in Lake Mallalieu through efforts in the lake and in the watershed.**

- 1) Disturbed shoreline increased between 1999 and 2001. Preserve the natural buffer zones of native vegetation around the lake to protect water quality and wildlife habitat.
- 2) Currently, half of the shoreline on Lake Mallalieu is classified as "disturbed"; restore shoreline around the lake to natural vegetation.
- 3) Protect wetlands around the lake to preserve habitat and maintain the wetland functions that help maintain water levels and water clarity in Lake Mallalieu.
- 4) Cooperate with educational programs in the community regarding nutrient and pesticide management.
- 5) Cooperate with efforts to reduce erosion and run-off in the watershed.

##### **II. Encourage the colonization of emergent vegetation.**

- 1) The amount of emergent vegetation in Lake Mallalieu is very low.
- 2) The lack of emergent vegetation may limit fish populations that depend on emergent plants for spawning sites.
- 3) Wildlife use emergent vegetation as cover and nesting.
- 4) Emergent vegetation protects the shorelines from erosion much better than rip-rap. The occurrence of rip-rap has increased since 1999.
- 5) Emergent species should be planted and any emergents currently colonizing the lake should be protected.

##### **III. Protect native submergent vegetation in the lake.**

- 1) Concentrate on educational efforts to the lake residents that stress the importance of the aquatic plant community to Lake Mallalieu. A survey of residents conducted in 1999 indicated that most felt there were too many aquatic plants, but the residents may not realize the importance of the aquatic plant community to address other concerns expressed in the survey.
  - a) Water quality was the one aspect that the majority of the residents most want to see improved. A healthy aquatic plant community can help improve and maintain water quality.
  - b) The majority of residents stated that fishing was only average. Plant communities provide the habitat for the fish community; the current colonization of vegetation is barely adequate in its coverage for fish



habitat.

- c) Peace and tranquillity; observing wildlife were the two uses listed most often by Lake Mallalieu residents. The plant community provides habitat for the wildlife and adds to the aesthetic quality of the lake.
- d) The majority of residents want to restrict jet ski use. A lake free of weeds is the biggest invitation to jet ski and other high speed use of a lake.

2) With the importance of aquatic vegetation in mind, the second step is to ensure that the vegetation is actually causing a nuisance before attempting removal and that the control is carefully considered before conducted.

- a) The frequent drawdowns and non-selective chemical treatments conducted in the past "to destroy weeds" likely stressed the native plant community.
- b) The non-selective control of aquatic plants may have made it easier for non-native species to colonize the lake.
- c) There are no records that indicate when the non-natives, curly-leaf pondweed and Eurasian watermilfoil, were introduced to Lake Mallalieu, but it is likely that it was during the period of frequent drawdowns and broad-spectrum chemical treatments.

3) If aquatic plant control is needed, explore alternate methods of aquatic plant control, harvesting or a less severe winter drawdown in order to limit chemical treatments.

- a) Chemical treatments other than selective methods merely knock down plant growth but do not truly kill the plants.
- b) Chemical treatments leave the plant material in the lake to decompose. This decomposition has two major impacts. It releases nutrients that feed algae blooms and the bacteria use dissolved oxygen needed by fish.
- c) Chemical treatments may result in concerns in the future about ecological side effects of herbicide. This is illustrated by the previous use of arsenic. At the time arsenic was applied, these compounds were considered safe.

#### **IV. Eurasian Watermilfoil Monitoring.**

Lake residents should form monitoring teams that will look for new colonies of Eurasian water milfoil and remove them as soon as possible.

Eurasian watermilfoil disappeared after the 1998-99 winter drawdown. By the 2001, there were two colonies that reappeared and were pulled by the survey staff. Eurasian watermilfoil could recolonize Lake Mallalieu; milfoil could be reintroduced into the lake through boat trailers or could float down from upstream.

If the reinfestation of Eurasian milfoil becomes widespread again, Mallalieu Lake should experiment with less severe drawdowns to control milfoil.

#### V. Winter Drawdown

- 1) If it is decided to conduct another winter drawdown, conduct a 3-foot drawdown to determine if there is less damage to the native plant community.
- 2) The benefits of the 6-foot winter drawdown was the
  - a) elimination of the invasive, Eurasian watermilfoil
  - b) an 85-94% decrease of the non-native curly-leaf pondweed
  - c) an increase in the maximum rooting depth
- 3) The negative impacts to the native aquatic plant community the summer after the drawdown were the dramatic decrease in number of species, species diversity, colonization of aquatic vegetation and colonization of submergents; a decrease in the quality (AMCIndex) of the plant community, a decreased Floristic Quality (indicates increased disturbance).
- 4) There has been some recovery in the plant community two years after the drawdown. From 1999 to 2001, there was a slight increase in percent of vegetation and submergent vegetation; an increase in the total occurrence and density of plant growth; recovery of white water lily, *Nymphaea odorata*.

Lake Mallalieu's beauty and proximity to an urban area makes it an important resource that deserves protection. Efforts to improve and protect the water quality and wildlife habitat in the lake are worth the effort.

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