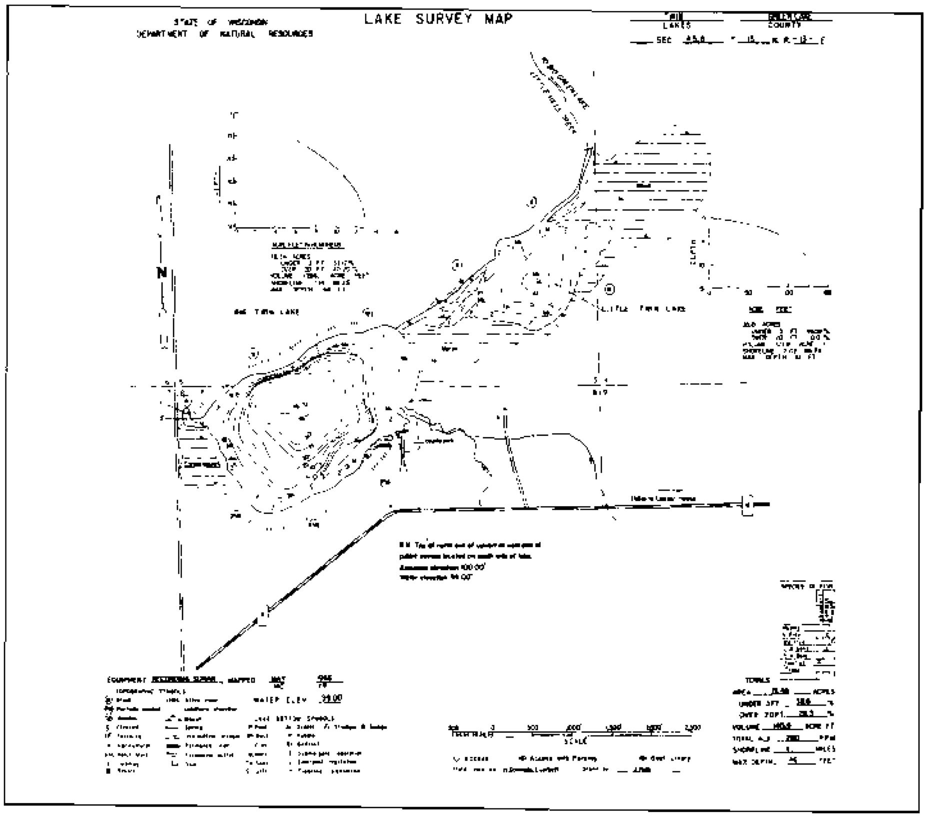
Twin Lakes Comprehensive Survey
Phase I - Progress Report

November 15, 2004



Twin Lakes Association, Inc.
W1941 Twin Lakes Rd.
Markesan, WI 53946

LPL 960

Prepared by:

Brad Roost and Chad Cason
Aquatic Biologists, Inc.
426 N.W. Cumberland St.
Berlin, WI 54923
920-361-4088

Aquatic Biologists, Inc,
Corporate Offices
N4828 Hwy 45 S.
Fond du Lac, WI 54935
800-442-6648

Introduction

Two connected glacial pothole lakes, Big Twin Lake and Little Twin Lake, form the waterbody known as Twin Lakes. Big Twin Lake has a surface area of 78 acres, a maximum depth of 46 feet and an average depth of 17 feet. Little Twin Lake has a surface area of 33 acres, a maximum depth of 10 feet and an average depth of 4 feet. Twin Lakes is located in the rolling hills of east-central Green Lake County, Wisconsin. The surrounding countryside is primarily agricultural land. One unnamed creek drains into Big Twin Lake. The outlet for Twin Lakes, Little Hills Creek, drains from the northeast end of Little Twin Lake and flows into Big Green Lake. The shores of Big Twin Lake are predominantly upland. The north and southwest shorelines are developed with cottages and year-around homes. The shores of Little Twin Lake are predominantly cattail bog. A concrete boat ramp with a wheelchair accessible dock is located on the south shore of Big Twin Lake. Access to Little Twin Lake is through a navigable channel from Big Twin Lake. The wetlands surrounding Twin Lakes provide important habitat for waterfowl and other wildlife. The lakes are also highly prized by local anglers for their quality largemouth bass and bluegill fisheries.

Two exotic plant species, Eurasian watermilfoil (*Myriophyllum spicatum*) and curly leaf pondweed (*Potamogeton crispus*) were found in both lakes in recent years. Faced with increasing threats from invasive exotic plants, the Twin Lakes Association, Inc. retained Aquatic Biologists, Inc. to conduct herbicide treatments for invasive aquatic plants on the lakes. Initial control measures were taken for Eurasian watermilfoil. In 2002 approximately 13 acres of Eurasian watermilfoil were mapped throughout Twin Lakes. The following spring (2003) Eurasian watermilfoil was treated in Little Twin with the herbicide Navigate® (granular 2,4-D). Later in July 2003, a line-transect aquatic plant survey was conducted and confirmed the presence of large amounts of both Eurasian watermilfoil and curly leaf pondweed throughout Twin Lakes. On June 6, 2004, 7.4 acres of Eurasian watermilfoil in Big Twin Lake was treated again with Navigate®. A post treatment survey for Eurasian watermilfoil on June 23, 2004 found excellent treatment success. Eurasian watermilfoil had noticeably declined and only a slight increase in curly leaf pondweed was seen. No treatments for curly-leaf pondweed were performed in 2004. Conducting a pre-treatment aquatic plant survey was a condition of the permit for chemical control of aquatic plants issued by the Wisconsin Department of Natural Resources. This report summarizes the findings of this survey and subsequent treatment.

In recent years, Twin Lakes have also experienced very poor water quality. The lakes have suffered from severe summer algae blooms, poor water clarity, and low dissolved oxygen levels. High levels of nutrients and unusual weather influences have likely contributed to the poor water quality found in Twin Lakes. In order to better understand the role and movement of nutrients throughout Twin Lakes, water chemistry analyses were performed from May to August 2004. Further analyses are scheduled for November 2004 (fall turnover) and January 2005. Preliminary results from these analyses as well as recommendations for future management of Twin Lakes are included in this report.

Methods

Field studies for this project included 1) conducting a submergent plant survey, 2) pre- and post-treatment mapping of the distribution of Eurasian watermilfoil and curly-leaf pondweed, and 3) analyzing several water quality parameters.

Aquatic plant survey

The aquatic plant survey involved plotting a series of 16 transects (8 in each lake basin) that radiated at 45-degree angles from a center point in each basin (Figure 1). GPS coordinates for the starting point of each transect were recorded. Three plots were sampled along each transect: at 2.5, 5, and 10-foot depths in June 2004. At the time of this study, this design covered the maximum extent of rooted vegetation (the littoral zone). Plots were established by estimating a 10-foot diameter circle around the anchored boat. The circular plot was then divided into four quarters with each quarter representing a quadrant. Plants were collected in each quadrant by making tows with a tethered short-toothed rake. A total of 192 quadrants were sampled. From each rake tow, all plants collected were identified to *genus* and to *species* whenever possible. Data collected was used to determine species distribution, relative abundance (percent composition) and percent frequency.

Emergent Plant Survey

An emergent aquatic plant survey was also conducted in June 2004. Sixteen transects of equal distance ran parallel to shore, and were located between the starting points of the submergent plant transects (Figure 1). All emergent and floating-leaf plants observed were identified to *genus* and to *species* whenever possible, and recorded on a data sheet. The relative abundance of each plant species found along a given transect was ranked. The rankings used were:

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

For each transect, data collected was used to determine species composition, percent frequency and relative abundance.

Exotic plant species mapping

Both prior to and following the 2004 herbicide treatment for Eurasian watermilfoil, the extent and location of milfoil beds were determined from surface observations and rake tows. Minimum and maximum depths of beds were noted, and the locations of the beds were drawn on lake contour maps using shoreline features as references (Figure 2). Modified acreage grid analysis was then used to determine the area of each milfoil bed. Similarly, in June 2004, the distribution of curly-leaf pondweed in Little Twin Lake was also mapped (Figure 3).

Figure 1. June 2004 aquatic plant survey transects

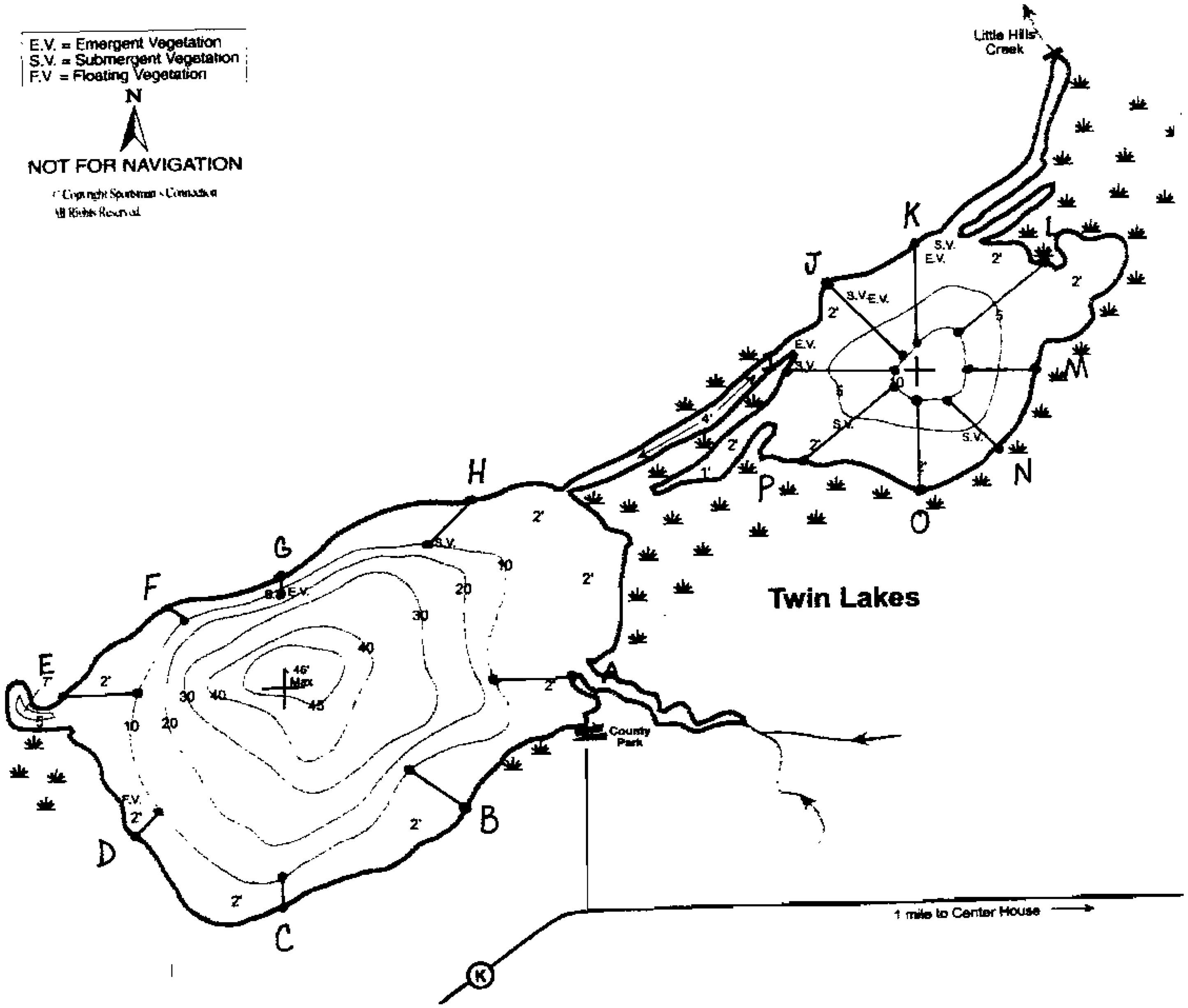


Figure 2. Eurasian watermilfoil beds in Big Twin Lake before and after herbicide treatment on June 6, 2004.

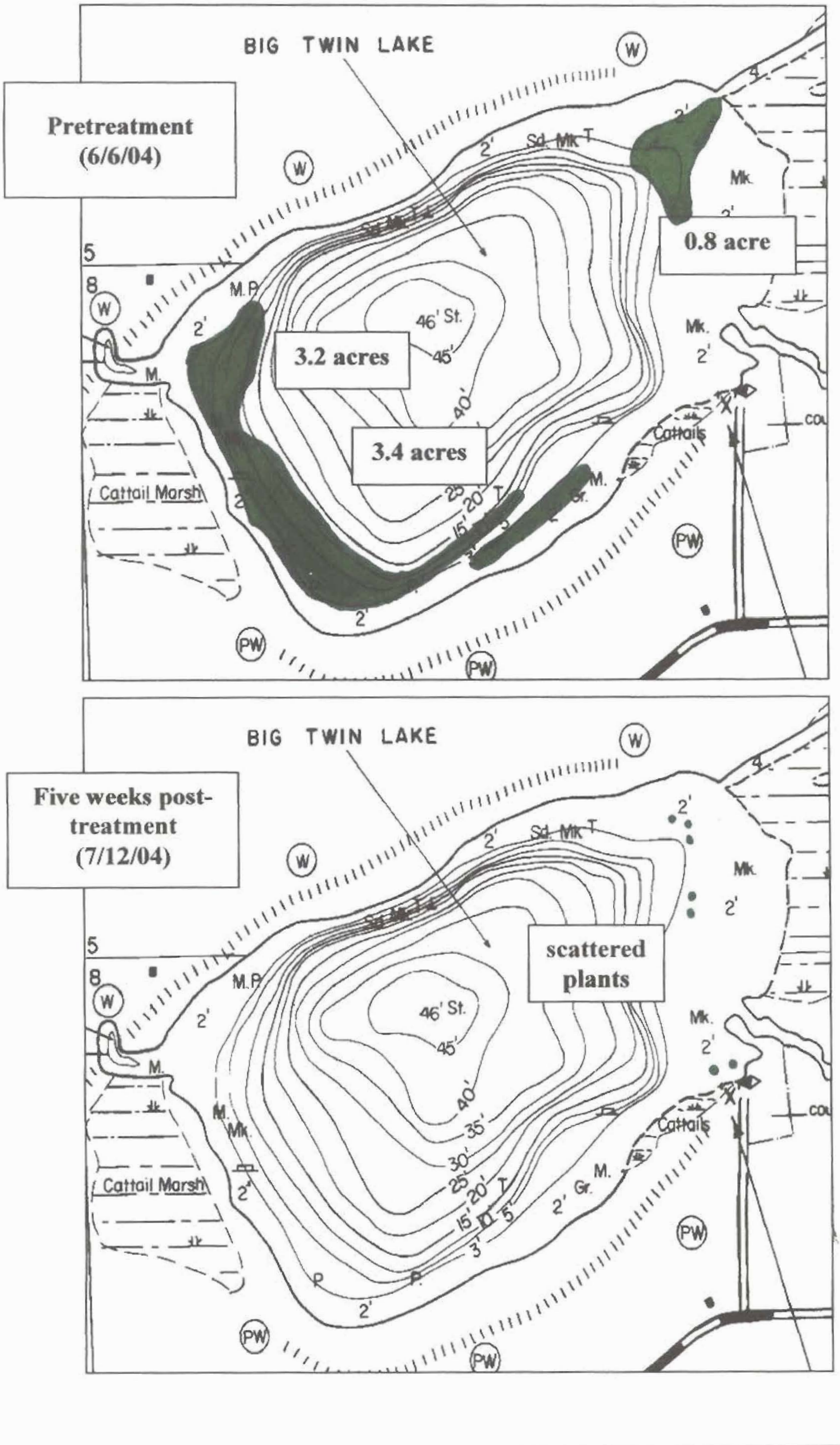
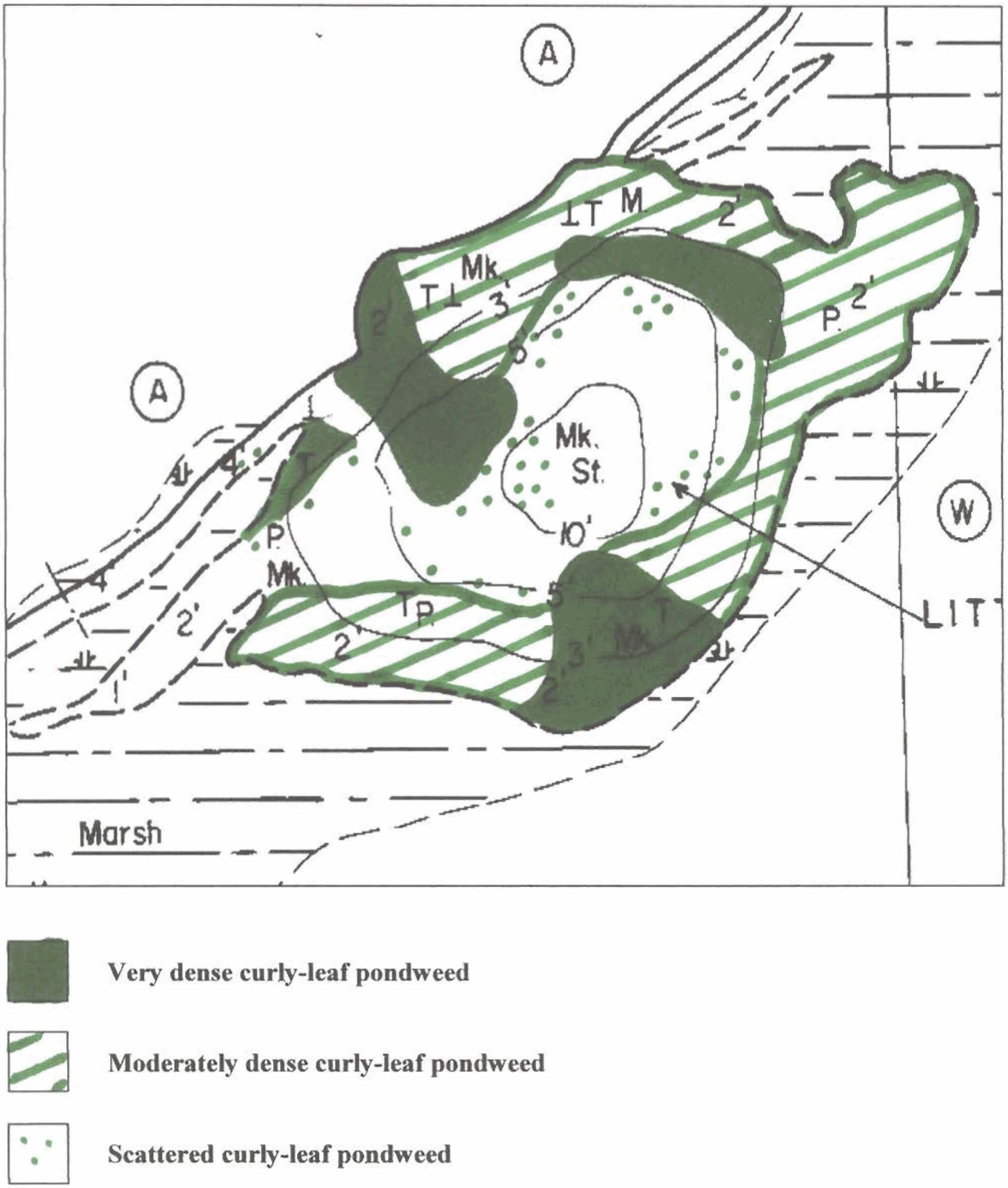


Figure 3. Curly-leaf pondweed beds in Little Twin Lake on June 23, 2004.



Water quality monitoring

Seasonal water quality testing was conducted in May, June, and July of 2004. Samples were collected from the deepest point of each lake basin and from the inlet and outlet locations. Parameters analyzed on site in both lake basins included water transparency (Secchi depth), pH, dissolved oxygen and temperature. pH readings were made using a Hach Kit (titration method). Secchi depths were measured using a standard 8-inch, black and white disc. Dissolved oxygen and temperature profile data were collected with a YSI 55 electronic meter with measurements taken at 2-foot intervals in Big Twin Lake and 1-foot intervals in Little Twin Lake. Water samples were collected at all four sampling locations and sent to the State Lab of Hygiene for analysis. Analyses included total phosphorus, and nitrate and nitrite (as nitrogen). Samples for chlorophyll *a* analysis were also collected in both lake basins and sent for laboratory analysis.

A more thorough or "complete" water chemistry and limnology analysis was conducted in August included:

- pH
- 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

Samples were collected in the same manner as the seasonal samples. However, total phosphorus, dissolved phosphorus, Kjeldahl nitrogen, nitrate + nitrite and ammonia samples were also collected from one foot above the lake bottom in each basin.

Results and Discussion

Aquatic plant community characteristics

A total of 25 species of aquatic plants were recorded during the June 10th submergent and emergent plant surveys of Twin Lakes (Tables 1 and 2, Figure 4). Ten of these were rooted submergent plants, including two exotic species: Eurasian watermilfoil and curly-leaf pondweed, ten were emergent species, three were free-floating plants (duckweeds), and two were colonial or mat-forming algae.

The most abundant species in the submergent plant survey was flatstem pondweed (*Potamogeton zosteriformis*) at 55.2% frequency. The next most abundant species were curly-leaf pondweed, coontail (*Ceratophyllum demersum*) and filamentous algae (*Cladophora, Pithophora, etc.)* The two exotic species, curly-leaf pondweed and Eurasian watermilfoil, were widely distributed around the lakes, having been found at 52.1% and 8.9% of the sample points, respectively. Collectively these two species made up 21% of the aquatic plant community.

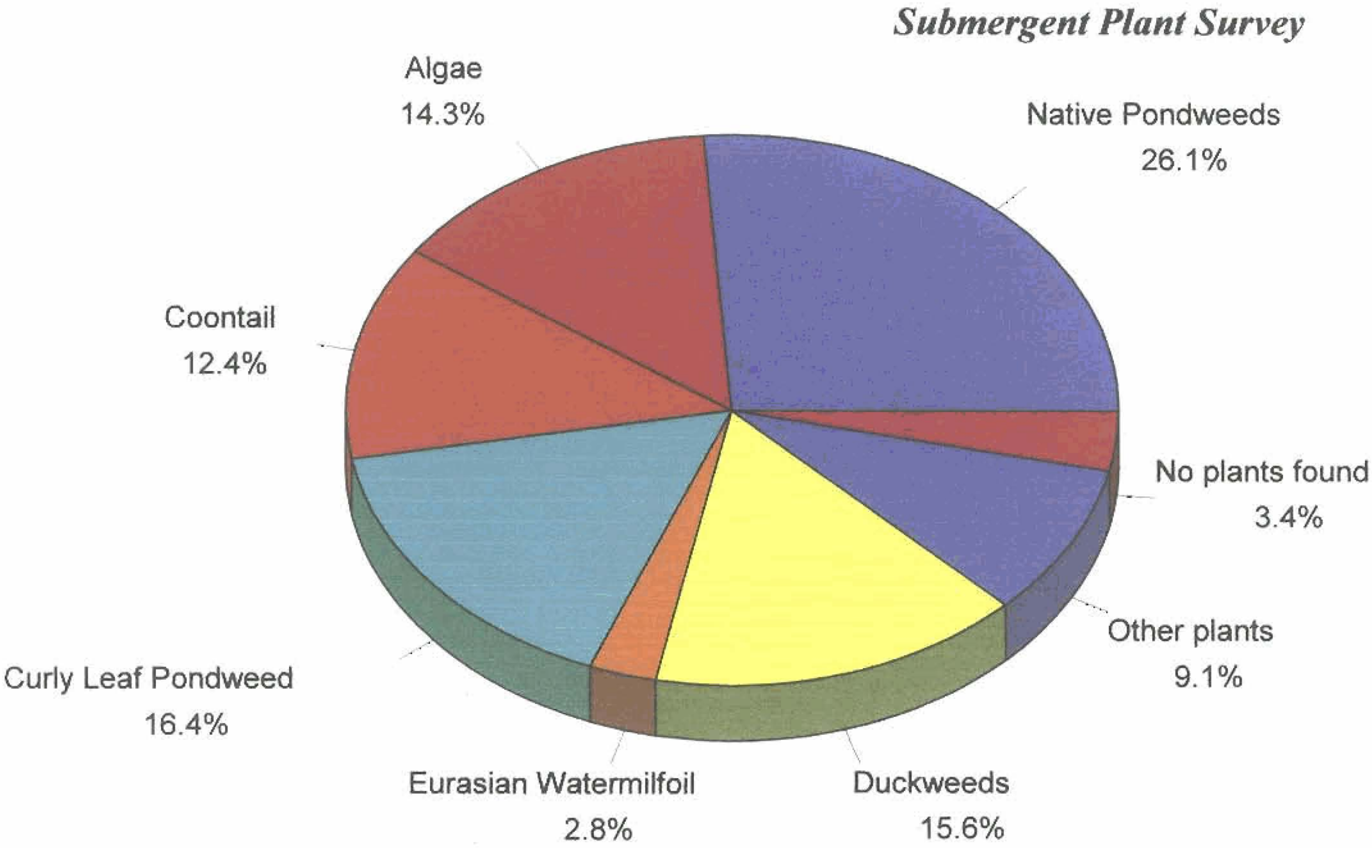
Table 1. Results of the submergent aquatic plant survey conducted on Twin Lakes, June 10, 2004

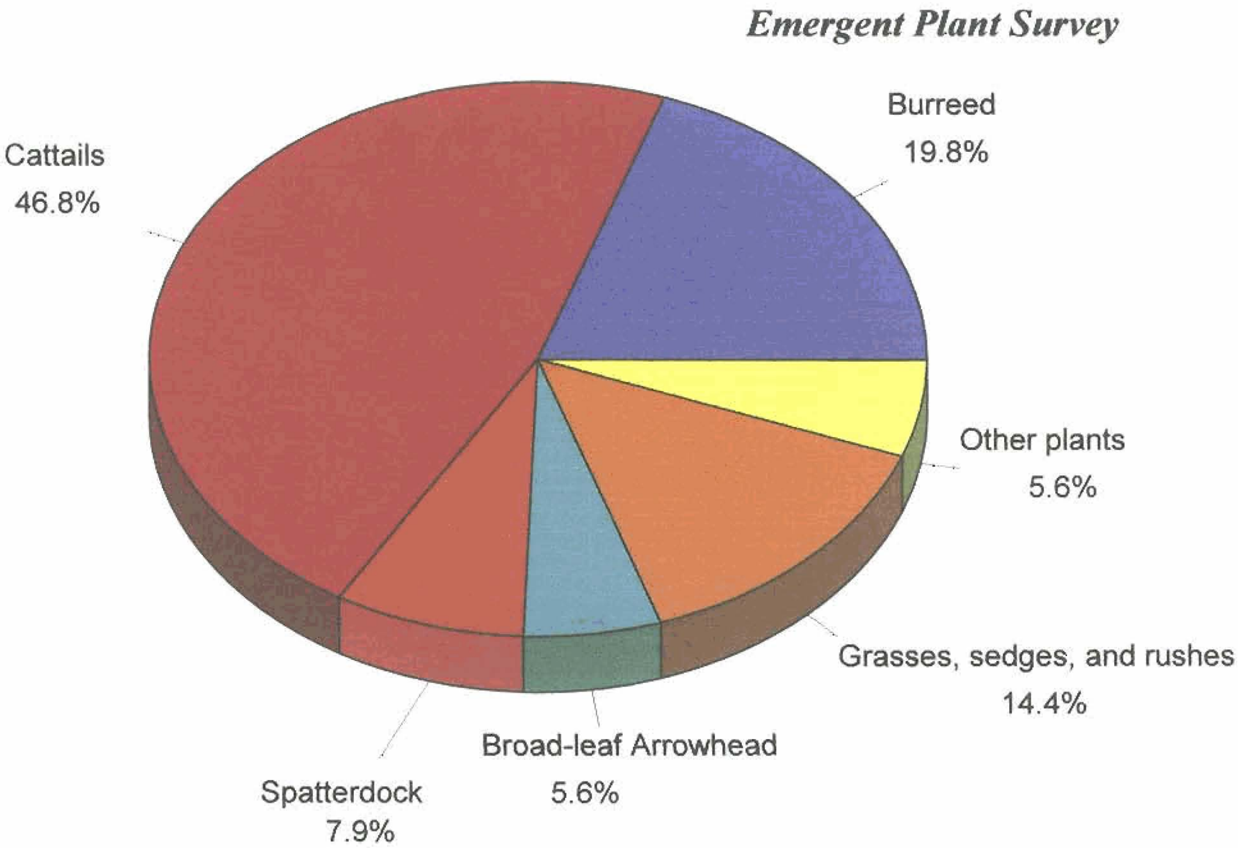
Species common name	scientific name	Frequency	Percent Frequency	Percent Composition
Flatstem Pondweed	*Potamogeton zosteriformis*	*106*	55.2	17.3
Curly Leaf Pondweed	*Potamogeton crispus*	*100*	52.1	16.4
Coontail	*Ceratophyllum demersum*	*76*	39.6	12.4
Filamentous Green Algae	*Cladophora, Pithophora, etc.*	*75*	39.1	12.3
Lesser Duckweed	*Lemna minor*	*53*	27.6	8.7
Northern Water Milfoil	*Myriophyllum sibiricum*	*39*	20.3	6.4
Large Duckweed	*Spirodela polyrhiza*	*36*	18.8	5.9
Sago Pondweed	*Potamogeton pectinatus*	*30*	15.6	4.9
Clasping Leaf Pondweed	*Potamogeton richardsonii*	*24*	12.5	3.9
Eurasian Watermilfoil/hybrid?	*Myriophyllum spicatum*	*17*	8.9	2.8
Musk Grass	*Chara* spp.	*12*	6.3	2.0
Cattails	*Typha* spp.	9	4.7	1.5
Star Duckweed	*Lemna trisulca*	*6*	3.1	1.0
Elodea	*Elodea canadensis*	*5*	2.6	0.8
Common Bur-reed	*Sparganium eurycarpum*	*1*	0.5	0.2
White Water Crowfoot	*Ranunculus longirostris*	*1*	0.5	0.2
No Plants Found		*21*	10.9	3.4
	Total	*611*		*100.0*

Table 2. Results of the emergent aquatic plant survey conducted on Twin Lakes during June 2004.

Species common name	scientific name	Frequency	Percent Frequency	Percent Composition
Cattail	*Typha* spp.	59	92.2	46.8
Common Bur-reed	*Sparganium eurycarpum*	25	39.1	19.8
Spatterdock	*Nuphar variegata*	10	15.6	7.9
Broad-leaf Arrowhead	*Sagittaria latifolia*	7	10.9	5.6
Hardstem Bulrush	*Scirpus acutus*	6	9.4	4.8
Reed Canary Grass	*Phalaris arundinacea*	6	9.4	4.8
Bottlebrush Sedge	*Carex comosa*	4	6.3	3.2
Sweetflag	*Acorus calamus*	4	6.3	3.2
Blue Flag Iris	*Iris versicolor*	2	3.1	1.6
Softstem Bulrush	*Scirpus validus*	2	3.1	1.6
Water Plantain	*Alisma* spp.	1	1.6	0.8
	Total	*126*		*100.0*

Figure 4. Plant community composition for Twin Lakes, June 2004





Data from 2003 and 2004 were compiled and analyzed to determine whether differences between the surveys were statistically significant. Paired t-tests were run on the data using 95% confidence intervals. This comparison of each plant species is given in Tables 3 and 4. A total of 20 submergent species were found between 2003 and 2004. Of these, three species decreased in distribution. These were sago pondweed (*Potamogeton pectinatus*), Eurasian watermilfoil, and coontail (*Ceratophyllum demersum*). The survey on June 23, 2004 confirmed the decrease in Eurasian watermilfoil was due directly to the herbicide treatment. When 2,4-D is applied at the rates used during the 2004 treatment, it is highly selective for Eurasian watermilfoil. Some species, including coontail, are somewhat susceptible to 2,4-D. Their populations may decrease after treatment, but are not impacted in the long-term nearly to the extent that Eurasian watermilfoil is. Often the distribution of plant species will naturally fluctuate. As a result, there may be significant declines from one year to the next. Another likely cause for these declines is the low water clarity that existed in Twin Lakes at the time of the 2004 survey. The turbid water blocked sunlight and inhibited plant growth.

Three native plant species showed significant increases in frequency. They include large duckweed (*Spirodela polyrhiza*), lesser duckweed (*Lemna minor*), and northern milfoil (*Myriophyllum sibericum*). Duckweeds as well as algae typically thrive in stagnant, nutrient-rich waters, and are thus indicators of poor water quality in lakes. Their presence in Twin Lakes suggests excessive nutrient levels. The increase in northern watermilfoil may be due to a number of reasons. However, this plant species, in particular, exhibits wide fluctuations in growth from year to year. The increase in frequency over the past year is likely due to a natural cycle of growth. Although curly leaf pondweed, another invasive exotic species, was found at high levels, it did not appear to have a significant increase in frequency from 2003 to 2004.

The most abundant species in the emergent plant survey were the cattails (*Typha* spp.) at 92.2% frequency. The next most abundant species were common bur-reed (*Sparganium eurycarpum*), spatterdock (*Nuphar variegata*) and broad-leaf arrowhead (*Sagittaria latifolia*).

Water quality analysis

Dissolved Oxygen and Temperature

Dissolved oxygen and temperature data for Big Twin (Table 5) and Little Twin (Table 6) were used to develop profile graphs from May 2004 to August 2004 (Figures 5 - 8). Although the levels of dissolved oxygen at the surface for both lakes generally increased throughout the season, the depth at which oxygen levels dropped off, referred to as the oxycline, became shallower. Below the oxyclines there is insufficient oxygen to support many fish species. The threshold level of oxygen needed for fish such as bass, perch, and sunfish to survive and grow is 5 mg/L. Temperature profiles often present a thermocline, where temperatures drop off as well. As the season progresses, the oxycline and thermocline typically rise in the water column. The profiles shown for Twin Lakes are

Table 3. **Comparison of percent frequency values for submergent aquatic plant surveys conducted on Twin Lakes in 2003 and 2004**

Species **common name**	**scientific name**	**2003 Percent Frequency**	**2004 Percent Frequency**
Flatstem Pondweed	*Potamogeton zosteriformis*	51.6	55.2
Curly Leaf Pondweed	*Potamogeton crispus*	37.5	52.1
Coontail	*Ceratophyllum demersum*	54.7	39.6
Filamentous Green Algae	*Cladophora, Pithophora, etc.*	29.1	39.1
Lesser Duckweed	*Lemna minor*	11.5	27.6
Northern Water Milfoil	*Myriophyllum sibiricum*	2.1	20.3
Large Duckweed	*Spirodela polyrhiza*	3.6	18.8
Sago Pondweed	*Potamogeton pectinatus*	32.8	15.6
Clasping Leaf Pondweed	*Potamogeton richardsonii*	13.0	12.5
Eurasian Watermilfoil/hybrid?	*Myriophyllum spicatum*	23.4	8.9
Musk Grass	*Chara* spp.	7.3	6.3
Cattails	*Typha* spp.	4.7	4.7
Star Duckweed	*Lemna trisulca*	8.3	3.1
Elodea	*Elodea canadensis*	0.0	2.6
Common Bur-reed	*Sparganium eurycarpum*	0.0	0.5
White Water Crowfoot	*Ranunculus longirostris*	0.5	0.5
Spatterdock	*Nuphar variegata*	2.1	0.0
Colonial Bluegreen Algae	*Oscillatoria* spp.	1.0	0.0
Water Stargrass	*Zosterella dubia*	0.5	0.0
Small Pondweed	*Potamogeton pusillus*	0.5	0.0
Bushy Pondweed	*Najas flexilis*	0.5	0.0
No Plants Found		16.7	10.9

Table 4. Analysis of variance between 2003 (top row) and 2004 (*bottom row*) for Twin Lakes submergent plant survey data.

	Transect / Occurences																		stat. sig.	increase/
Species	**A**	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**	**J**	**K**	**L**	**M**	**N**	**O**	**P**	**total**	**t-value***	**difference**	**decrease**
Bushy Pondweed	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	1.00	N	
(Najas flexilis)	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*			
Cattail	0	0	0	0	0	0	3	0	0	0	1	1	0	1	1	2	9	0.00	N	
(Typha spp)	*0*	*0*	*0*	*0*	*0*	*0*	*1*	*0*	*0*	*2*	*1*	*1*	*1*	*2*	*1*	*0*	*9*			
Clasping Leaf Pondweed	1	2	4	2	4	5	3	4	0	0	0	0	0	0	0	0	25	0.17	N	
(Potamogeton richardsonii)	*0*	*1*	*4*	*5*	*6*	*1*	*3*	*4*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*24*			
Common Bur-reed	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-1.00	N	
(Sparganium eurycarpum)	*0*	*0*	*0*	*1*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*1*			
Coontail	7	4	6	7	3	5	8	3	11	9	7	7	6	5	7	9	104	2.22	Y	decrease
(Ceratophyllum demersum)	*1*	*5*	*1*	*10*	*5*	*3*	*1*	*5*	*8*	*6*	*8*	*4*	*5*	*4*	*7*	*3*	*76*			
Curly Leaf Pondweed	8	1	1	2	3	4	0	0	10	5	8	6	7	8	4	5	72	-2.06	N	
(Potamogeton crispus)	*5*	*10*	*2*	*5*	*2*	*7*	*1*	*4*	*10*	*6*	*5*	*10*	*5*	*12*	*4*	*12*	*100*			
Elodea	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-1.46	N	
Elodea canadensis)	*1*	*0*	*1*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*3*	*5*			
Eurasian Watermilfoil	6	1	1	5	2	3	1	0	8	1	4	2	2	2	4	4	46	2.44	Y	decrease
(Myriophyllum spicatum)	*0*	*3*	*0*	*8*	*2*	*0*	*1*	*2*	*0*	*0*	*0*	*1*	*0*	*0*	*0*	*0*	*17*			
Flatstem Pondweed	9	6	7	7	10	11	10	6	6	4	4	2	3	3	7	4	99	-0.63	N	
(Potamogeton zosteriformis)	*2*	*7*	*9*	*11*	*12*	*11*	*9*	*9*	*4*	*2*	*2*	*4*	*4*	*4*	*8*	*8*	*106*			
Green Algae	4	4	4	7	4	0	2	2	8	2	5	4	3	2	3	4	58	-1.14	N	
(Cladophora, Pithophora, etc)	*0*	*4*	*2*	*2*	*0*	*8*	*5*	*4*	*6*	*8*	*8*	*7*	*7*	*5*	*3*	*6*	*75*			
Large Duckweed	0	0	0	0	0	0	0	0	0	2	2	1	0	1	0	1	7	-3.02	Y	increase
(Spirodela polyrhiza)	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*4*	*5*	*4*	*2*	*2*	*5*	*8*	*6*	*36*			
Lesser Duckweed	0	0	0	0	1	0	0	1	5	4	4	3	1	1	1	1	22	-2.99	Y	increase
(Lemna minor)	*0*	*0*	*0*	*0*	*0*	*4*	*4*	*0*	*6*	*8*	*5*	*2*	*4*	*6*	*8*	*6*	*53*			
Musk Grass	2	5	5	2	0	0	0	0	0	0	0	0	0	0	0	0	14	0.70	N	
(Chara spp)	*0*	*4*	*6*	*1*	*0*	*0*	*1*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*12*			
Northern Watermilfoil	0	2	0	0	0	2	0	0	0	0	0	0	0	0	0	0	4	-3.42	Y	increase
(Myriophyllum sibericum)	*0*	*0*	*0*	*6*	*4*	*2*	*2*	*2*	*0*	*2*	*1*	*2*	*1*	*4*	*7*	*6*	*39*			
Sago Pondweed	7	3	5	5	7	9	7	8	1	1	2	0	1	2	3	2	63	3.64	Y	decrease
(Potamogeton pectinatus)	*4*	*0*	*1*	*6*	*6*	*4*	*1*	*4*	*1*	*0*	*0*	*3*	*0*	*0*	*0*	*0*	*30*			
Small Pondweed	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1.00	N	
(Potamogeton pusillus)	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*			
Spadderdock	0	3	0	1	0	0	0	0	0	0	0	0	0	0	0	0	4	1.29	N	
(Nuphar variegata)	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*			

Table 4 (cont.). Analysis of variance between 2003 (top row) and 2004 (*bottom row*) for Twin Lakes submergent plant survey data.

	Transect / Occurences																		stat. sig.
Species	**A**	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**	**J**	**K**	**L**	**M**	**N**	**O**	**P**	**total**	**t-value***	**difference**
Star Duckweed	3	0	0	0	0	0	1	0	0	2	0	3	1	2	2	2	16	1.54	N
(Lemna trisulca)	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*3*	*0*	*1*	*2*	*0*	*0*	*0*	*0*	*0*	*6*		
Water Stargrass	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1.00	N
(Zosterella dubia)	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*		
White Water Crowfoot	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	0.00	N
(Ranunculus longirostris)	*0*	*0*	*0*	*0*	*0*	*1*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*1*		
No Plants Found	1	1	1	1	0	0	1	1	1	0	4	4	4	4	4	3	30	0.90	N
	3	*0*	*2*	*0*	*4*	*0*	*3*	*0*	*1*	*3*	*3*	*0*	*2*	*0*	*0*	*0*	*21*		

*** Paired t-test for two sample means; 95% Confidence limit, df = 15, t = 2.1314**

Table 5. Twin Lakes - Big Twin 2004 dissolved oxygen and temperature profiles.

Depth	May 27, 2004		June 23, 2004		July 19, 2004		August 16, 2004	
(ft)	Temp (C.)	D.O. (mg/l)	Temp (C.)	D.O. (mg/l)	Temp (C.)	D.O. (mg/l)	Temp (C.)	D.O. (mg/l)
0	15.6	8.02	18.8	10.36	23.4	11.64	20.3	13.56
1								
2	15.6	8.13	18.7	10.06	22.9	11.16	20.1	13.47
3								
4	15.6	8.08	18.7	9.87	22.9	11.08	20.0	13.27
5								
6	15.6	7.97	18.7	10.00	22.7	10.95	19.9	13.23
7								
8	14.4	6.31	18.6	10.08	20.7	9.45	19.9	13.17
9								
10	14.3	6.15	17.3	7.92	19.3	8.29	19.9	13.64
11								
12	14.0	5.66	16.1	5.20	17.6	3.47	18.0	7.08
13								
14	13.5	5.02	15.0	2.97	17.6	3.35	17.6	1.33
15								
16	13.4	5.43	14.5	2.67	16.3	0.54	17.0	0.35
17								
18	13.3	5.76	13.6	1.58	15.2	0.26	14.6	0.39
19								
20	12.6	4.57	12.8	0.63	12.8	0.24	13.1	0.22
21								
22	12.2	2.12	12.3	0.48	12.3	0.23	11.8	0.23
23								
24	11.3	0.74	11.7	0.45	11.7	0.23	11.5	0.20
25								
26	10.8	0.34	10.7	0.46	10.9	0.24	11.1	0.21
27								
28	10.4	0.31	10.2	0.46	10.5	0.24	10.5	0.25
29								
30	9.6	0.31	9.7	0.42	10.2	0.23	9.4	0.24
31								
32	9.1	0.31	9.2	0.40	9.7	0.22	8.8	0.23
33								
34	7.6	0.30	8.6	0.42	9.0	0.22	8.3	0.26
35								
36	7.2	0.30	8.3	0.40	8.3	0.22	8.2	0.22
37								
38	7.0	0.28	8.0	0.40	8.0	0.24	7.9	0.14
39								
40	6.9	0.29	7.8	0.40	7.9	0.23		
41								
42	6.8	0.26	7.7	0.39	7.8	0.22		
43								
44	6.8	0.25	7.5	0.38	7.8	0.21		
45								
46	6.8	0.25			7.8	0.21		
47	6.8	0.25						
48					7.8	0.22		
49								
50					7.8	0.20		

Figure 5. Big Twin (Twin Lakes) Dissolved Oxygen Profiles, 2004

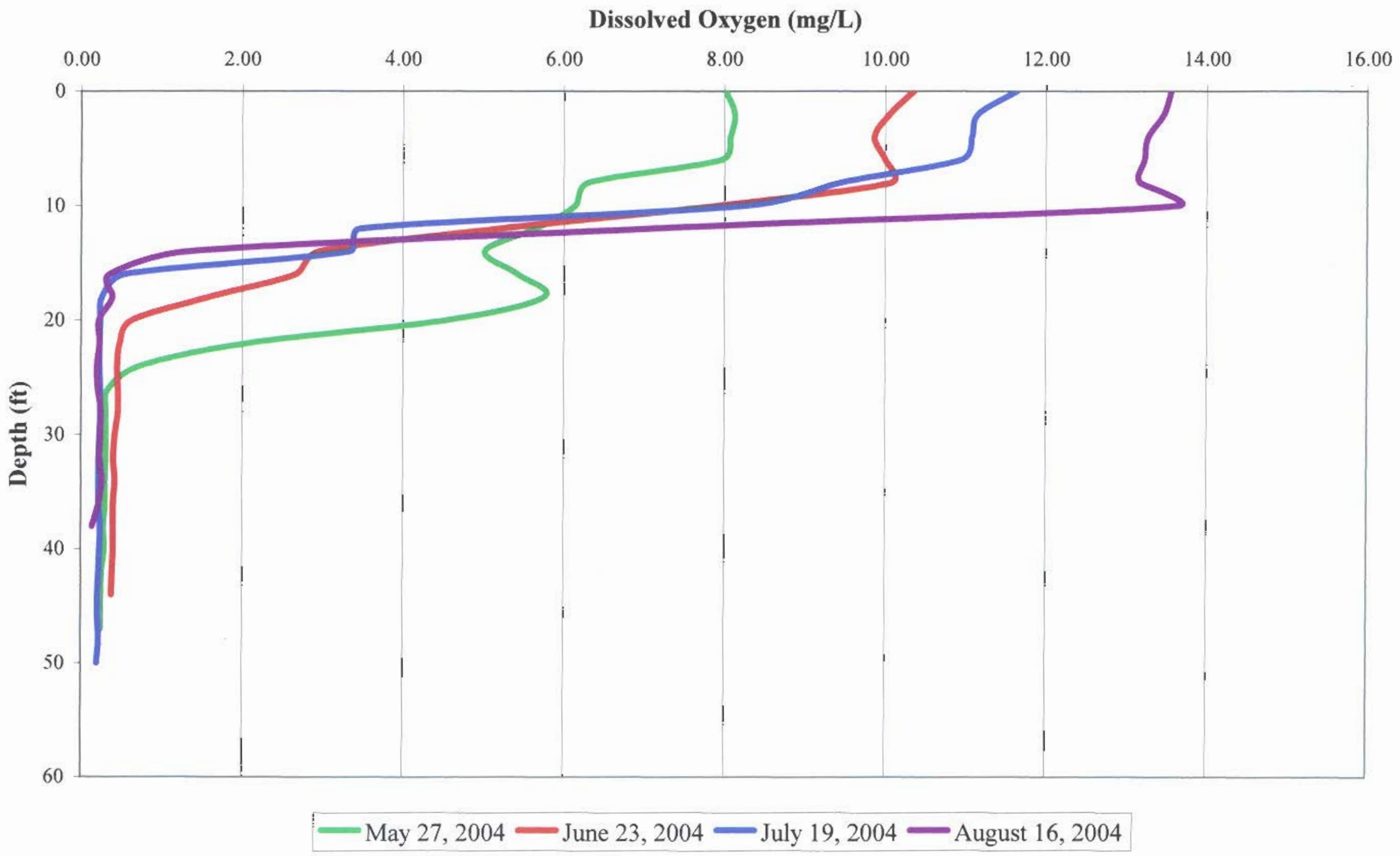


Figure 6. Big Twin (Twin Lakes) Temperature Profiles, 2004

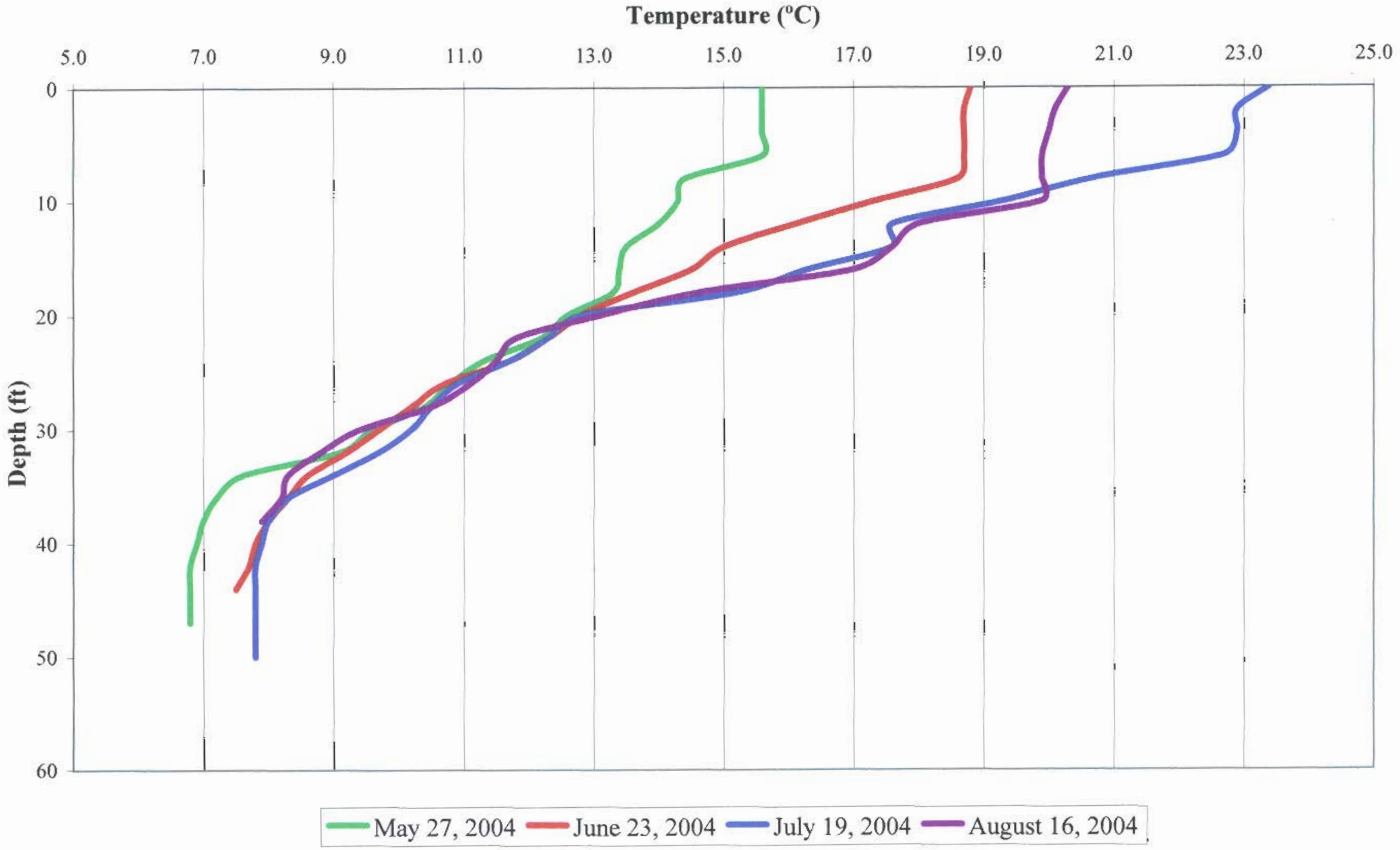


Table 6. Twin Lakes - Little Twin 2004 dissolved oxygen and temperature profiles.

	May 27, 2004		June 23, 2004		July 19, 2004		August 6, 2004	
Depth (ft)	Temp (C.)	D.O. (mg/l)	Temp (C.)	D.O. (mg/l)	Temp (C.)	D.O. (mg/l)	Temp (C.)	D.O. (mg/l)
0	15.1	6.03	23.1	9.61	19.5	7.89	19.9	13.84
1	15.1	6.10	23.2	9.30	19.3	7.66	19.9	12.46
2	15.1	6.08	23.2	9.41	19.2	7.47	19.8	12.81
3	15.1	5.84	23.2	9.52	19.1	7.88	19.8	13.12
4	15.1	5.97	23.3	9.06	19.1	7.19	19.7	12.63
5	15.0	5.63	23.2	9.09	19.1	7.24	19.7	12.12
6	14.9	5.08	23.2	6.98	19.0	7.12	19.1	2.64
7	14.6	3.90	22.6	2.60	18.9	6.46	18.5	1.40
8	14.3	2.78	21.8	1.47	18.7	4.35	18.3	0.57
9	14.2	1.95	20.5	0.37	18.3	1.82	18.3	0.35
10	14.0	1.26	20.1	0.33	16.6	0.60	18.1	0.34
11	13.9	1.01	19.5	0.32	16.0	0.42	18.1	0.38
12	13.8	0.77	18.8	0.24			18.0	0.24
13	13.7	0.36	18.5	0.21				

Figure 7. Little Twin (Twin Lakes) Dissolved Oxygen Profiles, 2004

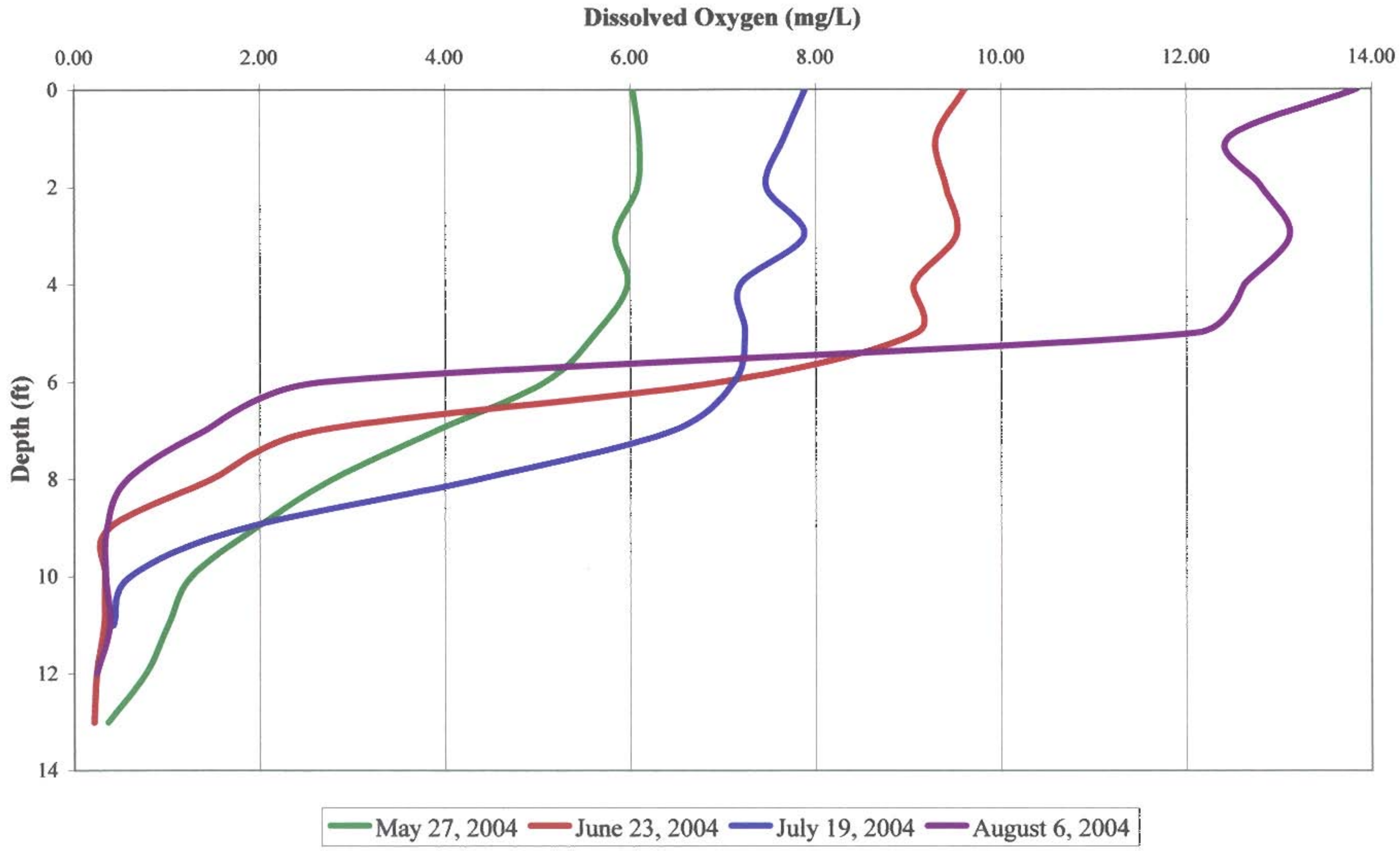
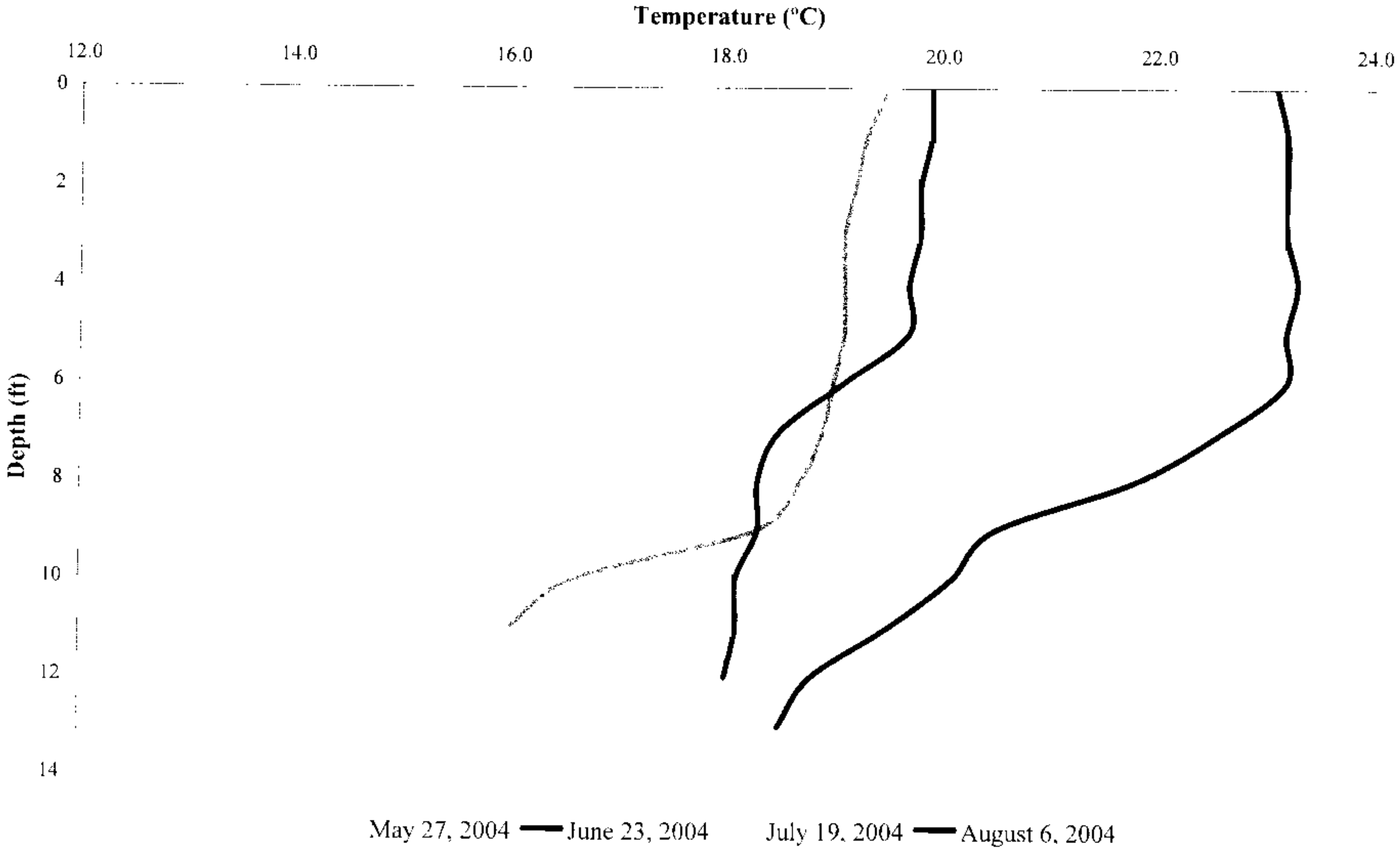


Figure 8. Little Twin (Twin Lakes) Temperature Profiles, 2004



typical of low water quality lakes. By July neither lake had significant amounts of oxygen below 10 ft. This is most significant in Big Twin which reaches depths of approximately 50 ft.

Some discrepancies in the data exist though. To better understand these discrepancies, it is important to first understand the relationship between dissolved oxygen and temperature. As a rule, colder water can hold more oxygen than warmer water. Table 7 illustrates this point.

Table 7. Oxygen solubility in water at different temperatures.

Temperature °C	°F	Oxygen solubility (mg/L)
0	32	15
5	41	13
10	50	11
15	59	10
20	68	9
25	77	8

In the case of Twin Lakes, a number of the profiles do not follow the solubility rules for oxygen and temperature. For these profiles the surface dissolved oxygen levels are higher than solubility levels at the corresponding temperatures. This is likely due to conditions in the lakes producing elevated levels of oxygen. In lakes with high levels of algae, large amounts of oxygen can be produced through photosynthesis. Under sunny conditions in particular, oxygen levels in the lake can rise above those shown in Table 7. This is a condition referred to as supersaturation. These oxygen levels drop then off during the night when photosynthesis ceases and respiration takes over. Through respiration, oxygen is consumed leaving depleted levels in the lake. These wide fluctuations can be particularly stressful to a number of fish species.

Temperature profiles in Little Twin show little change with depth, which is not surprising given its shallowness. Big Twin showed more of a decline in temperature with depth generally dropping to 6-8 °C at the deepest point and reaching over 23°C at the surface in July.

Table 8 gives the seasonal trends in a number of water quality parameters. Table 9. gives the results of the water quality testing from the August sampling event. Both tables should be referenced during the remainder of this section of the report.

pH and Alkalinity

pH is the negative log of the hydrogen ion concentration. It is used to measure the acidity or alkalinity of lakes. Increased photosynthetic activity increases pH. pH levels between 8 and 9 are common in lakes of central Wisconsin. Alkalinity is a measure of the acid

Table 8. Twin Lakes 2004 seasonal water chemistry and Trophic State Index data

May 27, 2004

	Parameter							
Location	pH	Nitrogen (mg/l)	Phosphorus (mg/l)	*Phosphorus TSI*	Chlorophyll (µg/l)	*Chlorophyll TSI*	Secchi (m)	*Secchi TSI*
Inlet	--	11.70	0.132	*74.56*	--	--	--	--
Big Twin	8.5	2.30	0.135	*74.88*	4.33	*44.98*	1.7	*52.56*
Little Twin	8.0	1.42	0.131	*74.45*	2.34	*38.94*	0.9	*60.82*
Outlet	--	1.26	0.098	*70.27*	--	--	--	--

June 23, 2004

	Parameter							
Location	pH	Nitrogen (mg/l)	Phosphorus (mg/l)	*Phosphorus TSI*	Chlorophyll (µg/l)	*Chlorophyll TSI*	Secchi (m)	*Secchi TSI*
Inlet	--	15.30	0.078	*66.97*	--	--	--	--
Big Twin	8.5	5.97	0.076	*66.60*	7.18	*49.94*	2.7	*45.46*
Little Twin	8.25	2.02	0.111	*72.06*	22.1	*60.97*	1.8	*51.30*
Outlet	--	1.31	0.105	*71.26*	--	--	--	--

July 19, 2004

	Parameter							
Location	pH	Nitrogen (mg/l)	Phosphorus (mg/l)	*Phosphorus TSI*	Chlorophyll (µg/l)	*Chlorophyll TSI*	Secchi (m)	*Secchi TSI*
Inlet	--	16.50	0.082	*67.69*	--	--	--	--
Big Twin	8.5	6.28	0.03	*53.20*	20.5	*60.23*	2.4	*47.16*
Little Twin	8.5	1.37	0.066	*64.56*	56.5	*70.18*	1.8	*51.30*
Outlet	--	0.579	0.121	*73.31*	--	--	--	--

Table 8. Twin Lakes 2004 seasonal water chemistry and Trophic State Index data

August 16, 2004

	Parameter							
Location	pH	Nitrogen (mg/l)	Phosphorus (mg/l)	*Phosphorus TSI*	Chlorophyll (µg/l)	*Chlorophyll TSI*	Secchi (m)	*Secchi TSI*
Inlet	--	16.30	0.082	*67.69*	--	--	--	--
Big Twin	8.75	5.00	0.039	*56.98*	35	*65.48*	0.9	*60.82*
Little Twin	8.75	nd	0.233	*82.75*	109	*76.62*	0.5	*71.28*
Outlet	--	0.03	0.199	*80.48*	--	--	--	--

Table 9. "Complete" water quality data collected on Twin Lakes, August 2004.

Parameter	Units	Inlet	Big Twin - surface	Big Twin - bottom	Little Twin - surface	Little Twin - Bottom	Oulet
pH	SU	--	8.65	--	8.41	--	--
Alkalinity	mg/L	--	180	--	199	--	--
Chloride	mg/L	--	29.5	--	28.6	--	--
Conductivity	µMhos/cm	--	495	--	476	--	--
Color	SU	--	10	--	25	--	--
Suspended solids	mg/L	--	8	--	16	--	--
Total dissolved solids	mg/L	--	300	--	286	--	--
Total phosphorus	mg/L	0.082	0.039	0.38	0.233	0.272	0.199
Dissolved (ortho) phosphorus	mg/L		na*	na*	na*	na*	
Total Kjeldahl nitrogen	mg/L	--	5	3.5	2.1	1.44	--
Nitrate + nitrite as N	mg/L	16.3	1.15	1.79	nd*	nd*	0.03
Ammonia as N	mg/L	--	0.019	2.48	0.017	0.114	--
Chlorophyll a	µg/L	--	35	--	109	--	--

* na = not availbale - dissolved phosphorus test were not run as hoped
nd = not detected/ below detection limits

buffering capacity of a lake. It is expressed in mg/L of calcium carbonate. A higher alkalinity value means a higher buffering capacity for a given a lake. Alkalinity values above 25 mg/L are indicative of an aquatic system with very higher buffering capacity. pH values above 8 and alkalinity levels well above 25 mg/L in Twin Lakes reflect not only an increase in productivity but are also indicative of a hard water system able to withstand acidic rain conditions.

Chloride

Chloride is not commonly a concern for lakes in Wisconsin. Naturally occurring concentrations of chloride in central Wisconsin range from approximately 3-10 mg/L. Twin Lakes levels in August were above 28 mg/L. High levels may indicate input from external sources such as septic systems, animal waste, road salt, and potash fertilizers. These elevated levels suggest that nutrients are entering the lake.

Conductivity

Conductivity is the measure of the ions in a body of water by determining how well an electrical current is carried through the water sample. This has a direct correlation to the amount of salts in the water. Conductivity is measured in micromhos per centimeter (μMhos/cm). The recommended value for conductivity in lake samples is below 300 μMhos/cm. Values in Twin Lakes are well above 300 μMhos/cm and indicate higher than normal levels of salts (as also implied by the chloride levels). Again this may indicate high pollutant inputs from external sources.

Color

The color of a lake indicates the type and amount of dissolved organic chemicals present. Measured and reported as standard units, color's main significance is aesthetic. High color values can impair Secchi disc readings. Color values for Twin Lakes in August were 10 and 25. Values below 40 are considered low and have little effect on transparency.

Solids

Total suspended solids (TSS) concentrations indicate the amount of solids suspended in the water, whether mineral (e.g., soil particles) or organic (e.g., algae, plankton). More productive lakes and those with erodeable soils tend to have higher concentrations of suspended solids. High concentrations of particulate matter affect light penetration, recreational values, and habitat quality. Particles also provide attachment places for other pollutants, notably metals and bacteria. Pollution or general human activities usually result in higher TSS concentrations or turbidity.

Dissolved solids are a measure of dissolved organic compounds present in water. The most common sources of dissolved solids are from decomposing plant matter. Water having high concentrations of dissolved solids limits the depth at which photosynthesis can take place. Thus it is an important parameter that can affect lake ecosystems. The high concentrations of dissolved solids found in Twin Lakes likely limit the aquatic plant community.

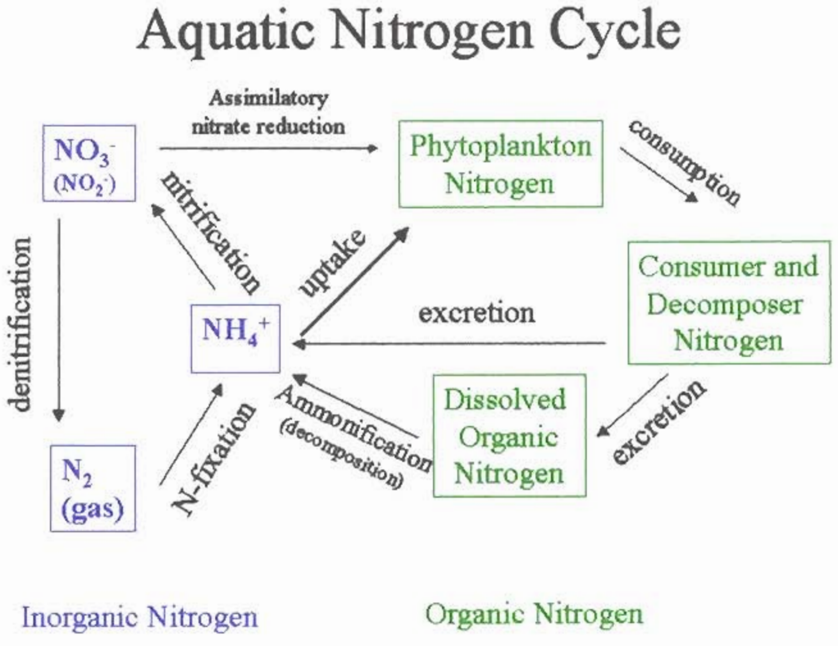
Elevated levels of both suspended and dissolved solids in Twin Lakes are again indicative of external and internal sources of pollutants.

Nitrogen

Large amounts of nitrogen (as nitrates and nitrites) entered Big Twin Lake from the inlet (>10.00 mg/L). Water naturally contains less than 1 mg/L of nitrogen. Higher levels indicate that the water has been contaminated. Although the inlet water is not used for drinking water, the levels of nitrates are still of concern. State and federal laws set a maximum allowable level of nitrate in public drinking water at 10 mg/L. Nitrogen is an important plant fertilizer. But more importantly, it is an indicator that agricultural activities are influencing (polluting) the lake. Common sources of nitrate contamination include fertilizers, animal wastes, septic tanks, municipal sewage treatment systems, and decaying plant debris.

As the water flowed through the Twin Lakes system, the nitrate and nitrite - nitrogen values dropped and the outflow values were consistently less than 1.5 mg/L. Keep in mind, these values are for nitrates (NO_3^-) and nitrites (NO_2^-). The August 2004 nutrient data help shed some light on the fate of the forms of nitrogen in Twin Lakes. Large amounts of nitrogen entered through the inlet. In Big Twin, the values for nitrogen dropped significantly. There are a number of processes at work here. Plants and algae take up some of the nitrogen in what is called uptake or assimilation while some is converted to nitrogen gas (N_2) through denitrification by bacteria (Figure 9). In anaerobic conditions the nitrate and nitrite forms of nitrogen are converted to ammonia (NH_4^+). This is evident by the increase in ammonia – nitrogen in the lake bottom samples for both lake basins. As the water flows into Little Twin Lake there again was a drop in nitrogen concentrations. Finally as the water flows through the large cattail bog adjacent to Little Twin and out Little Hills Creek, the values for nitrogen (nitrate and

Figure 9. Nitrogen cycle found in aquatic systems



nitrite) drops again. By August there was a 99.8% drop in nitrate and nitrite levels between the inlet to the outlet. This is due to the ability of the cattail wetland to filter the surface water and remove nutrients.

Phosphorus

Total phosphorus is one of the most important water quality indicators. Phosphorus levels determine the amount of plant and algae growth in a lake. Phosphorus can come from the watershed (fertilizers, livestock) or to a lesser extent, from groundwater (septic systems). It can also come from within the lake from the bottoms sediments (plants and chemical reactions).

Phosphorus data in Twin Lakes did not follow the same trends as nitrogen. Phosphorus concentrations reached levels as high as 233 μg/l in 2004. Average levels for natural lakes in Wisconsin are 25 μg/l. Values over 50 μg/l are indicative of poor water quality. In June, July, and August concentrations of phosphorus in the water samples collected from the outlet stream was higher than the concentrations in the inlet. Inputs of phosphorus are likely occurring from elsewhere in the watershed. At the same time, in May, June, and August values for phosphorus in Little Twin Lake were higher than the outlet values suggesting the cattail wetland plays a role in removing a portion of the phosphorus from the water as well as nitrogen.

Under anaerobic conditions phosphorus, which is tied up in lake sediments, can be released into the water column. This trend is clearly seen in Big Twin where the concentration of phosphorus at the lake bottom was ten times as high as the concentration at the surface.

Secchi Transparency

Water clarity is often used as a quick and easy test for a lake's overall water quality, especially in relation to the amount of algae present. As the season progressed, the water quality in both lake basins, as estimated by the Secchi transparency, went from fair to very poor. This due to high levels of algae and other particulate matter in the water column. This is often seen as a response to high levels of nutrients entering a lake. Secchi transparency and water quality was consistently lower in Little Twin than in Big Twin.

Chlorophyll *a*

Chlorophyll is the pigment found in all green plants including algae that give them their green color. Chlorophyll *a* is the form of chlorophyll used primarily in lake research. It is the site in plants where photosynthesis occurs. Chlorophyll absorbs sunlight that is used as the energy source to convert carbon dioxide and water to oxygen and sugars. Chlorophyll data is collected because the green pigment is found in algae and can be used to estimate how much phytoplankton (floating algae) there is in the lake. Generally speaking, the more nutrients there are in the water and the warmer the water, the higher the production of algae (chlorophyll).

The trends seen in the transparency data for Twin Lakes are reflected in the Chlorophyll *a* data as well. Chlorophyll *a* concentrations gradually rose in 2004 throughout Twin Lakes and levels measured in Little Twin were higher then those for Big Twin from June to August. This may be due in part to the large beds of curly-leaf pondweed found in Little Twin. Curly-leaf pondweed grows vigorously much earlier in the season than native plants species. By midsummer curly-leaf pondweed dies back and the decomposing plants release large amounts of nutrients into the water column. The first sign of this nutrient release is typically a dramatic increase in chlorophyll *a* concentrations.

Trophic State

Lakes can be categorized by their productivity or trophic state. When productivity is discussed, it is normally a reflection of the amount of plant and animal biomass a lake produces or has the potential to produce. The most significant and often detrimental is large amounts of algae – a result of a high productivity or trophic level in a lake. Lakes can be categorized into three trophic levels:

- oligotrophic - low productivity, high water quality
- mesotrophic - medium productivity and water quality
- eutrophic - high productivity, low water quality

Oligotrophic lakes are typically deep and clear with exposed rock bottoms and limited plant growth. Eutrophic lakes are often shallow and marsh-like, typically having heavy layers of organic silt and abundant plant growth. Mesotrophic lakes are typically deeper than eutrophic lakes with significant plant growth, and areas of exposed sand, gravel or cobble bottom substrates.

A lake's trophic state is a measure of its ability to support living things. Lakes can naturally become more eutrophic with time, however trophic state is more influenced by nutrient inputs than by time. When humans influence the trophic state of a lake the process is called *cultural eutrophication*. Although lakes can naturally evolve from oligotrophic conditions to eutrophic, this process is often highly influenced by human activity. Cultural eutrophication typically results in an accelerated change in trophic state. A sudden influx of available nutrients may cause a rapid change in a lake's ecology. Opportunistic plants such as algae may be able to out-compete macrophytes. The resultant appearance and odor is more typically considered poor water quality.

Total phosphorus, chlorophyll *a* and Secchi depth are often used as trophic state indicators for lakes. Values measured for these parameters can be used to calculate Trophic State Index (TSI) values. The formulas for calculating the TSI values for Secchi disk, chlorophyll *a*, and total phosphorus are as follows:

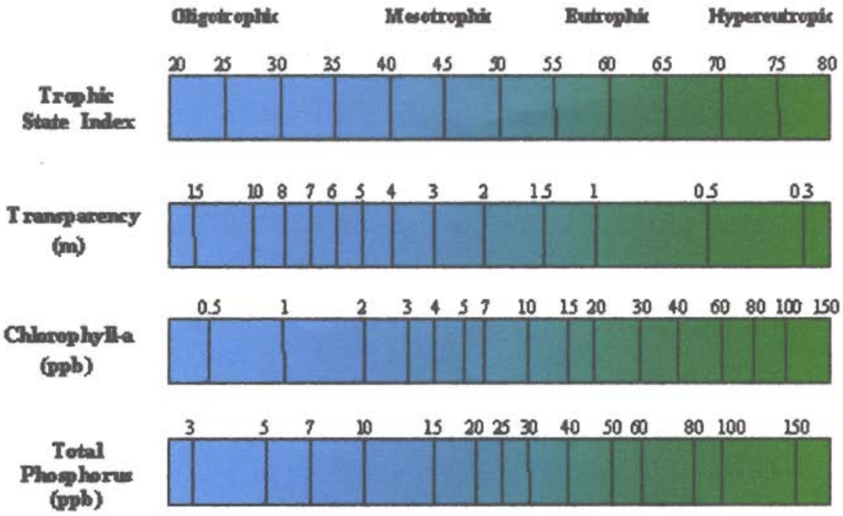
$$\text{TSI} = 60 - 14.41 \ln \text{Secchi disk (meters)}$$

$$\text{TSI} = 9.81 \ln \text{Chlorophyll } a \text{ } (\mu\text{g/L}) + 30.6$$

$$TSI = 14.42 \ln \text{Total phosphorus } (\mu g/L) + 4.15$$

Generally, the higher the TSI calculated for a lake, the more eutrophic it is (Figure 10). Phosphorus is the best estimate of late-season peaks in trophic index values because levels of phosphorus are not as dependent upon seasons/weather as chlorophyll or Secchi transparency are. Often earlier in the spring water temperature are lower and day lengths are shorter. As a result the levels of chlorophyll in the form of algae often have not reached seasonal peaks. There is a strong relationship between phosphorus and chlorophyll *a* concentrations in lakes. As a response to rising levels of phosphorus, chlorophyll *a* levels increase and transparency values decrease. As an example in Twin Lakes, the TSI values for phosphorus (Table 8) were consistently high from May through August while those for transparency and chlorophyll *a* gradually rose through the season. All TSI calculations for August place Twin Lakes well within the boundaries of a eutrophic lake.

Figure 10. Relationship between trophic state in lakes and parameters including water transparency and concentrations of chlorophyll *a* and total phosphorus.



Conclusions and Recommendations

Comprehensive survey

The number one recommendation for Twin Lakes is to continue with the second phase of the comprehensive lake study and complete a management plan. A completed study will provide scientifically based management information, and direction for future management of the lake including application for additional protection and enhancement grants. To this end, Aquatic Biologists, Inc. have been retained by the Twin Lakes Association to apply for a Lake Management Planning Grant through the DNR. This grant application will be submit for the February 1, 2005 deadline. The Twin Lakes Association should expect to budget $2500-$3000 to fund their share of the study.

Aquatic plant management

Eurasian watermilfoil continues to be a serious threat to Twin Lakes. If left to spread and mature, it could potentially shut down lake activities as well as negatively impact the water quality and fishery in Twin lakes. Twin Lakes should be monitored annually for regrowth of milfoil. Lake residents should undertake an active monitoring program for the purpose of identifying and mapping any Eurasian watermilfoil regrowth. Periodic retreatments should be made as needed in subsequent years to maintain Eurasian watermilfoil at or below target levels. The Twin Lakes Association should be able to manage Eurasian watermilfoil at sub-nuisance levels with a minimal annual cost. The Lake association should expect to budget funds and obtain permits annually for spot treatment of milfoil. Even if complete control is reached, Twin Lakes is within an area where numerous lakes are infested with Eurasian watermilfoil. As a result reinfestation is likely.

Although curly-leaf pondweed is generally not as invasive as Eurasian watermilfoil, it may be a bigger problem for Twin Lakes. Curly-leaf pondweed was found in every sample location on Little Twin during the 2004 plant survey. Monitoring should continue and it is recommended that the Twin Lakes Association seriously consider a large scale curly-leaf pondweed treatment. Although treatment could be conducted in 2005, it is probably better to first wait until the management plan is complete.

If native aquatic plants continue to impede navigation on the lake, the Lake Association should seek the required DNR permits and contract with a weed harvesting company to cut navigation lanes in the vegetation. Care should be taken to protect the native aquatic plant community for its value to the fishery and water quality, and for its value in suppressing exotic species.