Lake Nokomis Water Quality Improvement Project:
Implementation of Biomanipulation Study

Summary of 2012 Project Activities
-Third Year-

By: Kelly Dooley

Project Description

Lake Nokomis is a 201 acre lake located in Minneapolis, Minnesota. Water quality in Lake Nokomis is impaired for nutrients, algal abundance and water transparency. Lake analyses and lake modeling scenarios suggest phosphorus from internal sources may be keeping Lake Nokomis reaching acceptable nutrient goals. An estimated reduction of 126 kg of phosphorus in Lake Nokomis would bring the water quality of the lake closer to Minnesota Pollution Control Agency (MPCA) nutrient criteria.

One of the many internal sources that may be contributing to the nutrient impairment in Lake Nokomis is the omnivore, bottom feeding fish populations in Lake Nokomis. The omnivores in Lake Nokomis are bullheads and bluegill sunfish.

Project Objectives

The biomanipulation project would attempt to reduce excessive algal growth in Lake Nokomis caused by elevated phosphorus concentrations by implementing a fish manipulation plan over a 3-year period. The objectives hope to be reached from the fish manipulation would be (1) to reduce the black bullhead population, (2) to increase the game fish (i.e., walleyes) in the lake for the purposes of controlling bluegill sunfish, young black bullheads and yellow perch, (3) observe an increase in native aquatic plants throughout the lake, (4) to reduce an estimated 126 kg of phosphorus from Lake Nokomis, and (5) for Lake Nokomis to meet the MCPA's nutrient criteria.

Project Plan

The fish manipulation plan would involve (1) a fish removal effort targeting adult-sized black bullheads, (2) stocking game fish to control bluegill sunfish and young black bullheads, (3) annual aquatic plant and fish surveys, and (4) sample the lake sediments to access nutrient content (only for the first year).

2012 Project Activities – Third Year

- March 22, 2012 – Minnehaha Creek Watershed District (MCWD) Board of managers authorized funds to carry out the third year of the Biomanipulation project activities. Board of Managers also approved to extend the Biomanipulation Study into a 4th year with no increase in budget. A 4th year of the study will allow for a third walleye stocking event. Only 2 stocking events have occurred by the end of 2012.

- April 2, 2012 – 10,000 Lakes Aquaculture stocked approximately 2,000 walleyes into Lake Nokomis (about 4 lbs/acre). The walleyes yearlings were about 6-8 inches in length.

- There was no rough fish removal conducted this year. The 2011 fish survey found that the black bullhead in Lake Nokomis were at low enough numbers. The MnDNR normal range of black bullheads is 0.7 – 26 fish/net, the survey found 0.1 fish/net.

- August 29, 2012 – Steve McComas, Blue Water Science, conducted a point-intercept aquatic plant survey of Lake Nokomis. About 14 acres of the 201 total acres of the lake has established aquatic plants, three more acres of established plants than in 2011. Coontail and Sago pondweed were the only native submerged plants identified during the survey. The coverage of Coontail increased slightly compared to the past two years. There was no evidence of String pondweed in this year's survey. Eurasian watermilfoil, non-native, was still the dominant aquatic plant found in Lake Nokomis. The aquatic plant survey report is presented as Attachment 1.

- October 11 - 12, 2012 – Steve McComas, Blue Water Science, conducted a fish survey of Lake Nokomis. The objective of the survey was to identify the existing fish conditions, and determine if the fish densities are high enough to contribute to the water quality conditions in the lake. A total of nine fish species were sampled in the survey. The number of fish/net for bluegills sunfish, black crappie, white crappie, pumpkinseed sunfish, and white suckers were within range with the Minnesota Department of Natural Resources (MnDNR) statistics. Black bullheads were not surveyed, most likely due to the project's bullhead removal efforts in the lake. Walleyes were surveyed at 2.8 fish/net, which is above the normal range (0.3 – 1.2 fish/net), most likely due to the stocking efforts of the MnDNR and our efforts from the project. Yellow perch were also above the normal range. Dogfish were below the normal range (See Table 1 – Attachment 2). The bluegill sunfish were the dominate species at 21 fish/net, which is down from 158 fish/net in 2011. The complete fish survey report is presented as Attachment 2.

- October 11-12, 2012 – Carp were surveyed via trapnets in Lake Nokomis at 0.2 fish/net. Electrofishing is one of the best methods for surveying carp, but the equipment needed was unavailable. Therefore, Steve McComas hypothesizes from observations and survey results that the carp population density is most likely at a moderate level. Another method to evaluate carp activity was to assess if the carp from Lake Nokomis have access to Mother Lake and surrounding wetlands. Due to the drought this summer, there was not enough water to evaluate carp activity.

- Steve McComas still plans to review the water quality data for Lake Nokomis which is collected and analyzed by the Minneapolis Parks and Recreation Board (MPRB). The 2012 water quality data for Lake Nokomis will be available from MPRB by early 2013.

Summary

By the end of the third year of the biomanipulation project on Lake Nokomis, two of the five objectives are so far being met. The fish survey shows that the fish removal effort in 2010 and 2011 has reduced the black bullhead population to a level that is manageable by walleyes and other game fish. The walleye population is above normal which indicates that the stocking has worked. As for bluegill sunfish control, the bluegill sunfish population appears to be declining. The stocking of walleyes has enhanced the game fish community to produce enough predatory pressure to control the bluegill sunfish and black bullheads populations in Lake Nokomis. However, the aquatic plants are not reestablishing has quickly as we had hoped. Surveys from Blue Water Science have shown a small increase in the distribution of the native aquatic plants over the past three years. Eurasian watermilfoil is widespread along the near shore of Lake Nokomis and seems to fluctuate in abundance from year to year. The aquatic plants in the lake seem to be limited by 2 factors: poor water clarity and the quick drop-off in lake depth. About half of the lake (approximately 100 acres) is less than 15 feet deep; therefore, if water clarity was to improve in the lake aquatic plants may re-establish. Once established, the aquatic plants could maintain the water clarity of the lake. And there is hope for water clarity improvement in Lake Nokomis. Secchi depth has met or exceeded the MPCA's standards eight times from 1972 to 2011. Also in 2011, total phosphorus and chlorophyll-*a* concentrations met the MCPA's nutrient criteria for the first time since the lake has been monitored. The water quality results for 2012 are still to be reviewed.

Attachment 1

Lake Nokomis, Minneapolis (Google Earth)

Aquatic Plant Survey for Lake Nokomis, Minneapolis, Minnesota, 2012

Survey conducted on: August 29, 2012

Prepared for:
Minnehaha Creek
Watershed District

Prepared by:
Steve McComas
Blue Water Science
St. Paul, MN 55116

November 30, 2012

Aquatic Plant Surveys for Lake Nokomis, Minneapolis, Minnesota, 2012

Summary

Lake Nokomis (MnDNR ID: 27-0019) is a 201 acre lake located in Minneapolis, Minnesota. The coverage of aquatic plants in the August 29, 2012 summer survey was evaluated by conducting a point-intercept aquatic plant survey with 50 meter spacing between points.

In the point-intercept summer survey, native plants were scarce with coontail and sago pondweed being the only native submerged plant species identified. Coontail was observed at ten sites and sago pondweed was found at two sites. The non-native Eurasian watermilfoil was observed at 18 sites (Table S-1 and Figure S-1). Plants grew out to a water depth of 7 feet and estimated plant coverage was 14 acres out of 201 acre lake (7% coverage) (Figure S-2). Coontail showed a slight increase in coverage compared to 2010 and 2011

Table S-1. Summary of the occurrence of plant species for aquatic plant survey for 2010, 2011, and 2012.

	2010 (173 littoral zone sites from 0 - 15 feet) September 9, 2010	**2011** (173 littoral zone sites from 0 - 15 feet deep) July 15, 2011	**2012** (173 littoral zone sites from 0 - 15 feet deep) August 29, 2012
Coontail (*Ceratophyllum demersum*)	3 (2%)	3 (2%)	10 (6%)
Eurasian watermilfoil (*Myriophyllum spicatum*)	21 (12%)	18 (10%)	18 (10%)
Stringy pondweed (*Potamogeton sp*)	--	1 (1%)	--
Sago pondweed (*Stuckenia pectinata*)	--	--	2 (1%)

Figure S-1. Coontail found at a sample site on Lake Nokomis on August 29, 2012.

Aquatic Plant Coverage in Lake Nokomis in 2012

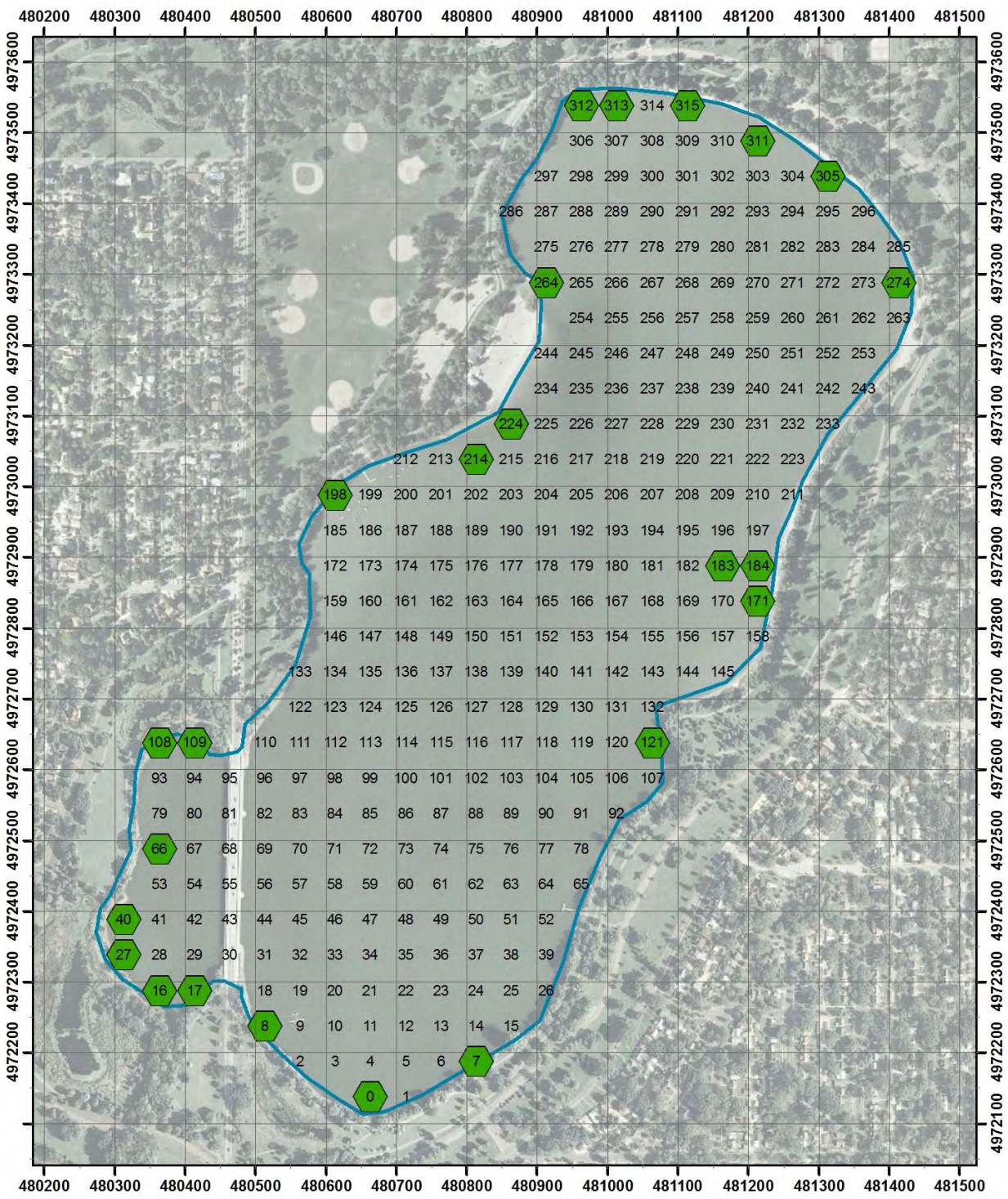

Figure S-2. Aquatic plant coverage of Eurasian watermilfoil, coontail, and sago pondweed for August 29, 2012. Coontail was found at 10 sites, Eurasian watermilfoil was found at 18 sites, and sago pondweed was found at 2 sites.

Lake Nokomis, Minneapolis (ID: 27-0019)

Lake Area: 201 acres (MnDNR)
Littoral Area: 100 acres (MnDNR)
Maximum depth: 33 ft (MnDNR)

Introduction

Previous plant surveys in Lake Nokomis have found sparse aquatic plant growth. However, in the last few years water quality projects have been implemented. If water clarity improves, maybe aquatic plant distribution would increase. The objectives of the 2012 plant evaluation were to conduct an aquatic plant point intercept survey to characterize the existing aquatic plant community of Lake Nokomis and determine if aquatic plants may be increasing in distribution.

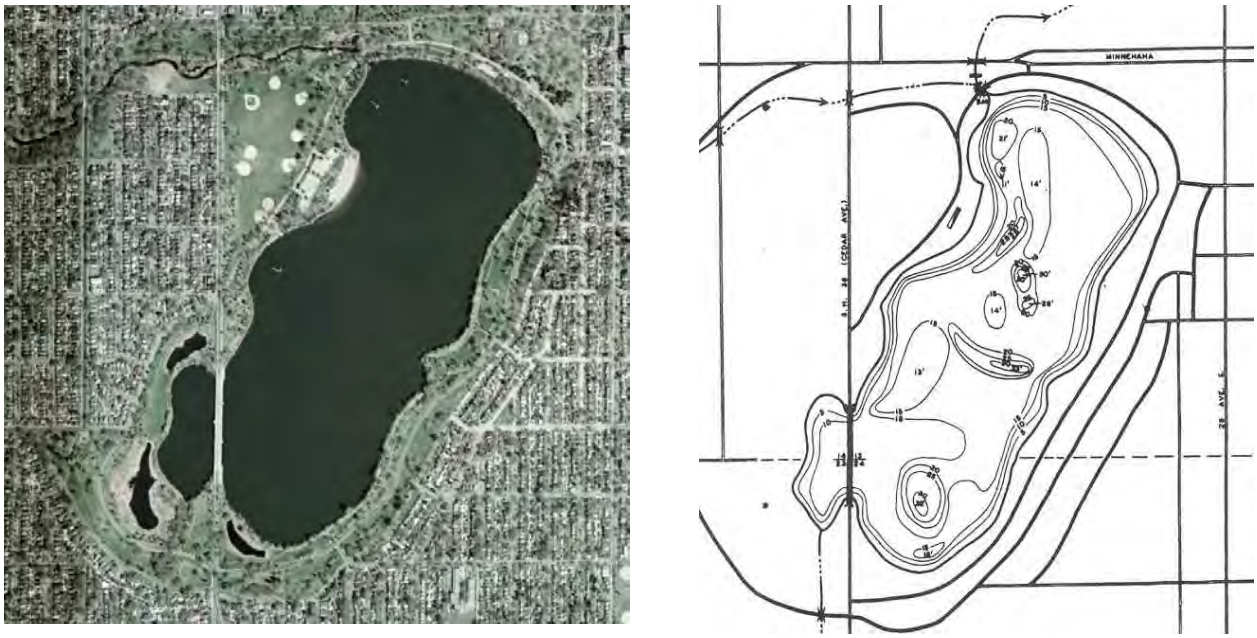

Figure 1. [left] Aerial view of Lake Nokomis, Minneapolis, Minnesota (source: Google Earth). [right] MnDNR contour map.

Methods

Point Intercept Surveys: An aquatic plant survey of Lake Nokomis were conducted by Blue Water Science in 2012. A late season survey was conducted on August 29, 2012. The survey used a point-intercept survey method. A grid map was prepared by Blue Water Science and consisted of a total of 316 points that were distributed throughout the lake (Figure 2). In the littoral area of 0-15 feet deep, there were 173 points. Points were spaced 50 meters apart and each point represented an average of 0.6 acres of lake surface area (201 acres ÷ 316 points = 0.6 ac/pt). GPS coordinates used a UTM WGS84 datum. At each sample point, plants were sampled with a rake sampler. A MnDNR plant density rating was assigned to each plant species on a scale from 1 to 4. A 4.5 or 5 rating indicated matting surface plant growth.

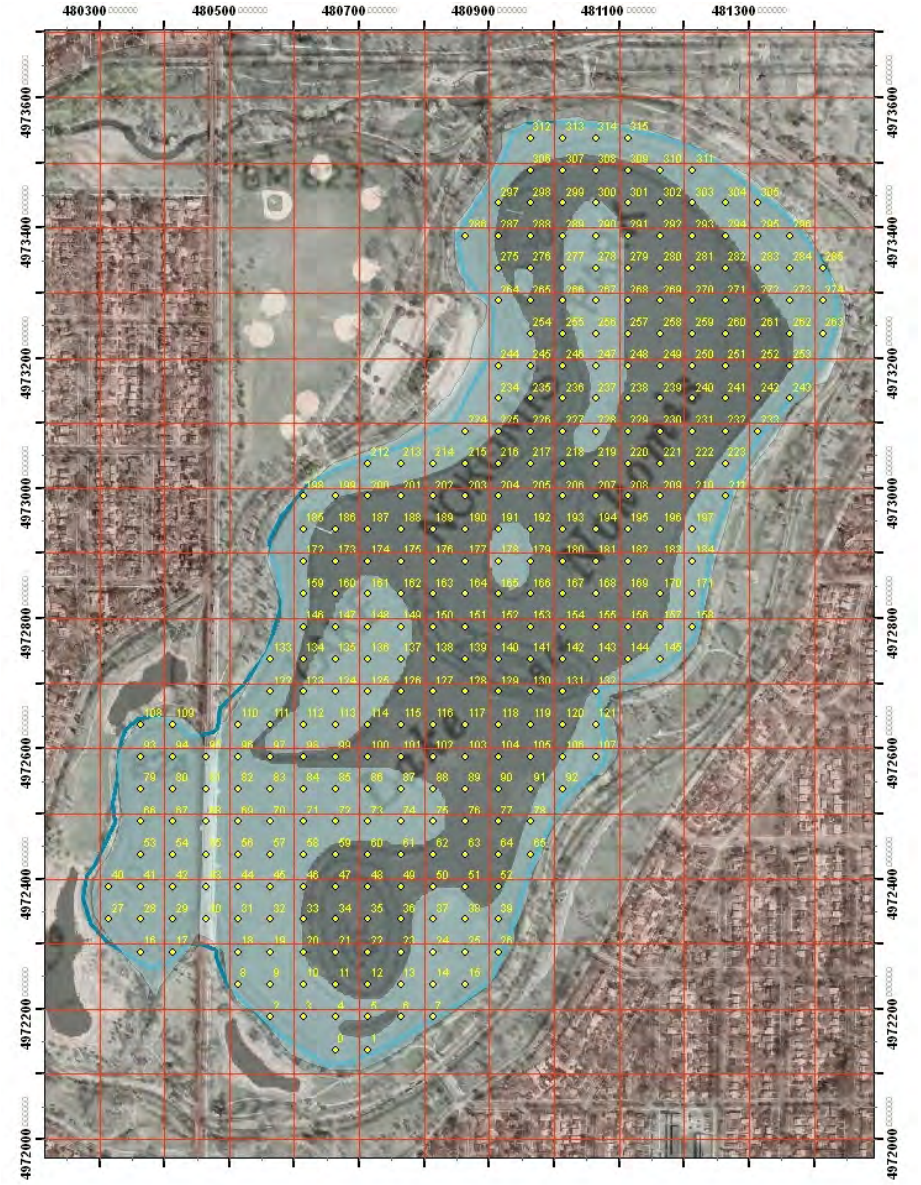

Figure 2. Point locations for the aquatic plant surveys are shown on the lake map with UTM coordinates using the WGS84 datum. The grid consisted of a total of 316 points. This is the same map used in 2010 and 2011. The grey shading represents the littoral area from 0-15 feet deep.

Results of the August 29, 2012 Aquatic Plant Survey

Results of the summer point intercept aquatic plant survey conducted on August 29, 2012 found three submerged aquatic plant species, Eurasian watermilfoil, coontail, and sago pondweed, in Lake Nokomis (Table 1). Results from the plant survey found that plants grew out to depth of 7 feet (Table 2). The location of aquatic plants in Lake Nokomis is shown in Figure 4. The coverage of aquatic plants was estimated at 14 acres out of 201 acres (7% coverage).

Table 1. Summary of the occurrence of plant species for aquatic plant survey for 2012.

	2012 (173 littoral zone sites in water 0 - 15 feet deep) August 29, 2012
Coontail (*Ceratophyllum demersum*)	10 (6%)
Eurasian watermilfoil (*Myriophyllum spicatum*)	18 (10%)
Sago pondweed (*Stuckenia pectinata*)	2 (1%)

Figure 3. Coontail was one of two native plants found in Lake Nokomis in 2012.

Table 2. Aquatic plant densities for sample points. Plant density was assigned based on a scale from 1 - 5 with 5 the densest.

site	depth (ft)	Coontail	EWM	Sago pondweed	NO PLANTS
30	2				1
224	2		2	1	
1	3				1
7	3		1		
108	3	2	1		
109	3	3	1		
132	3				1
198	3	1	2		
171	4		1		
184	4		1		
213	4				1
214	4		1		
263	4				1
296	4				1
305	4		1		
312	4		1		
315	4		2		
2	5				1
8	5	1			
17	5	1			
66	5		1		
121	5		1		
274	5		1		
311	5		1		
313	5		1		
0	6	1	2	1	
16	6	2			
27	6	2	2		
53	6				1
65	6				1
122	6				1
243	6				1
297	6				1
6	7				1
40	7	1			
133	7				1
264	7	1			
3	8				1
197	8				1
26	9				1
78	9				1
93	9				1
199	9				1
285	9				1
286	9				1
314	9				1
29	10				1
79	10				1
146	10				1
172	10				1
211	10				1
212	10				1
18	11				1
31	11				1
92	11				1
107	11				1
110	11				1
145	11				1
185	11				1
275	11				1
15	12				1
144	12				1
159	12				1
223	12				1
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52	13				1
39	14				1
253	14				1
158					1
234					1
244					1

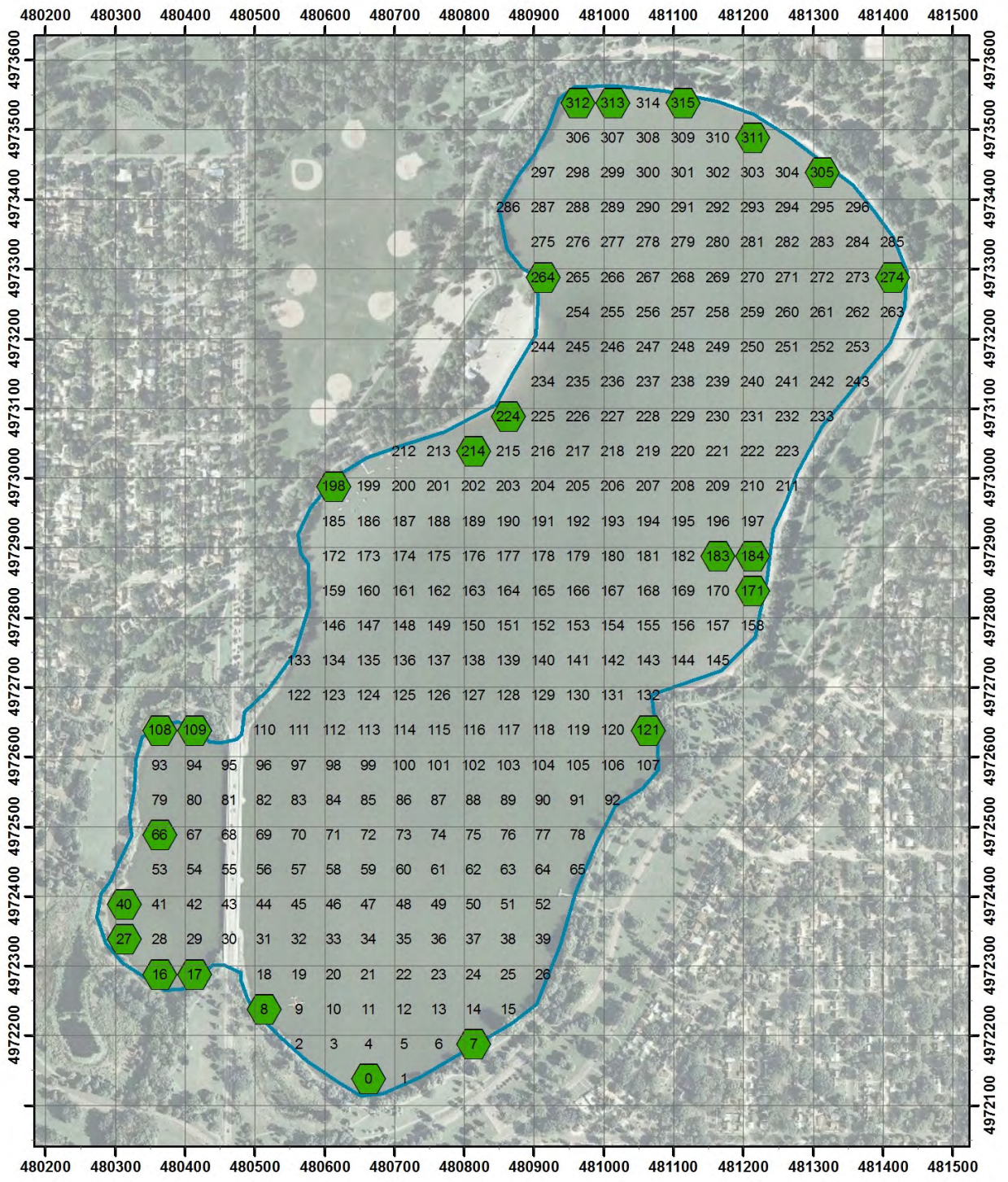
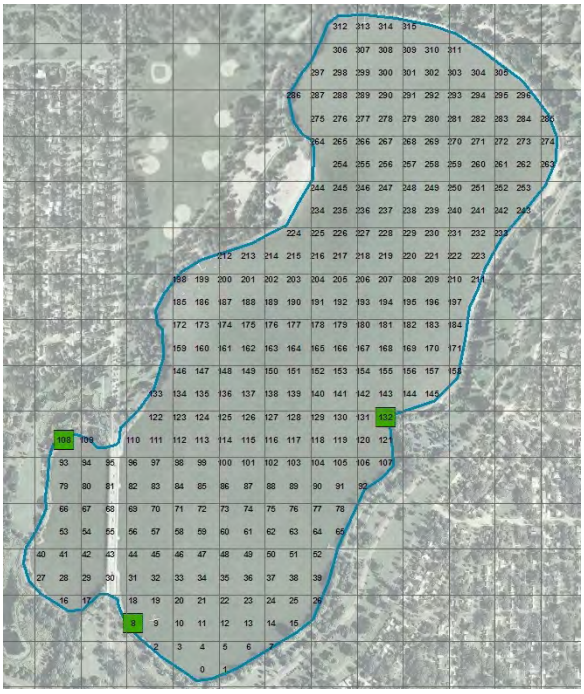


Figure 4. Aquatic plant coverage of Eurasian watermilfoil, coontail, and sago pondweed for August 29, 2012. Coontail was found at 10 sites, Eurasian watermilfoil was found at 18 sites, and sago pondweed was found at 2 sites.

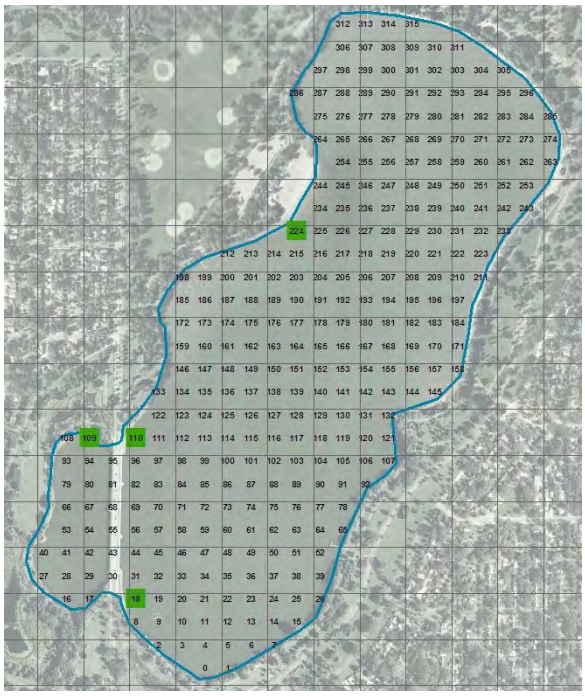
Native Plants in 2010, 2011, and 2012

Native aquatic plants in Lake Nokomis in 2010, 2011, and 2012 have been scarce, with plants observed at three sites in 2010, at four sites in 2011, and at eleven sites in 2012 (Figure 5). Coontail was the dominant native plant found growing out to 7 feet in 2012. Native plants have shown a slight increase in distribution in the last three years.

Native Plants - 2010



Native Plants - 2011



Native Plants - 2012

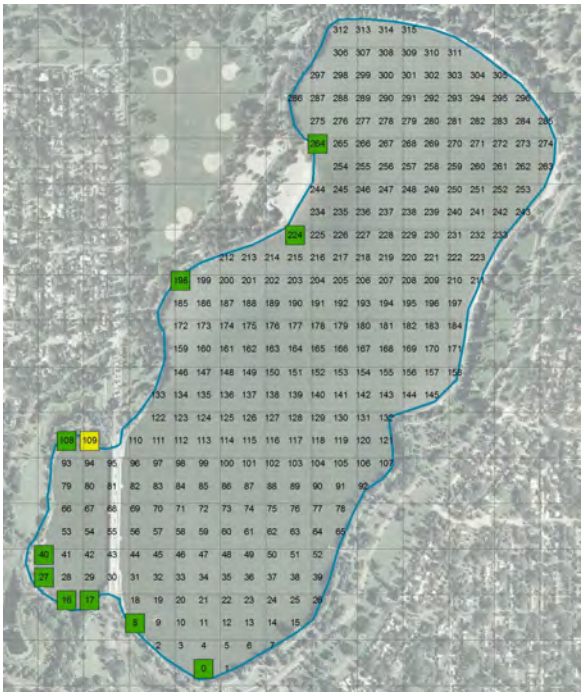
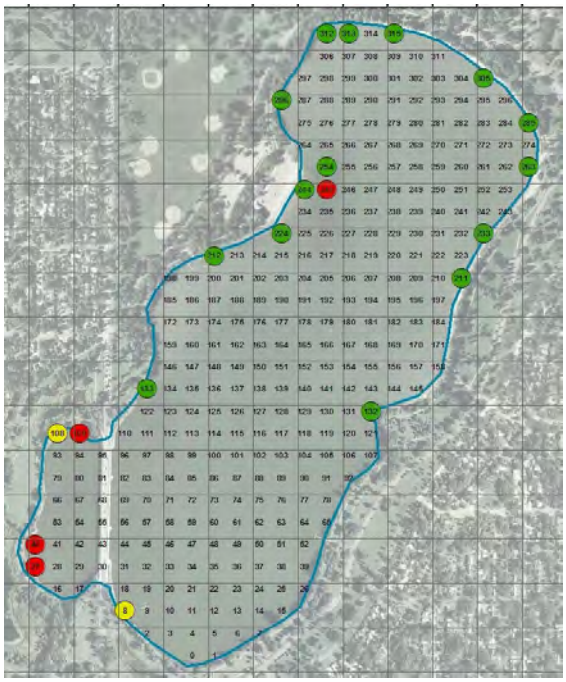


Figure 5. Occurrence of native aquatic plants in Lake Nokomis in 2010, 2011, and 2012. Green squares represent light growth of plants and the yellow square represents moderate growth of plants.

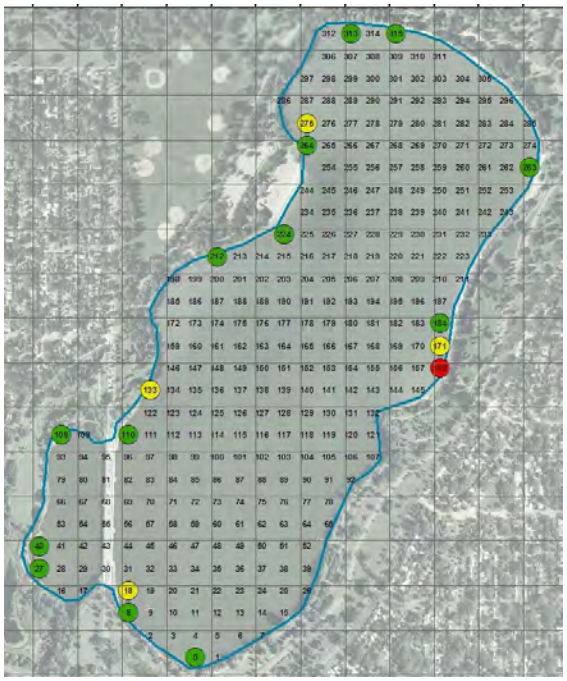
Eurasian Watermilfoil in 2010, 2011, and 2012

Eurasian watermilfoil was the dominant submerged aquatic plant in Lake Nokomis in 2010, 2011, and 2012. Eurasian watermilfoil was first observed in Lake Nokomis in 1995 and it's distribution is fairly widespread around the nearshore area of Lake Nokomis but is stable meaning it is no longer expanding its area of colonization. In 2012, it grew out to a depth of 7 feet and varies in abundance from light to heavy from year to year.

Eurasian Watermilfoil - 2010



Eurasian Watermilfoil - 2011



Eurasian Watermilfoil - 2012

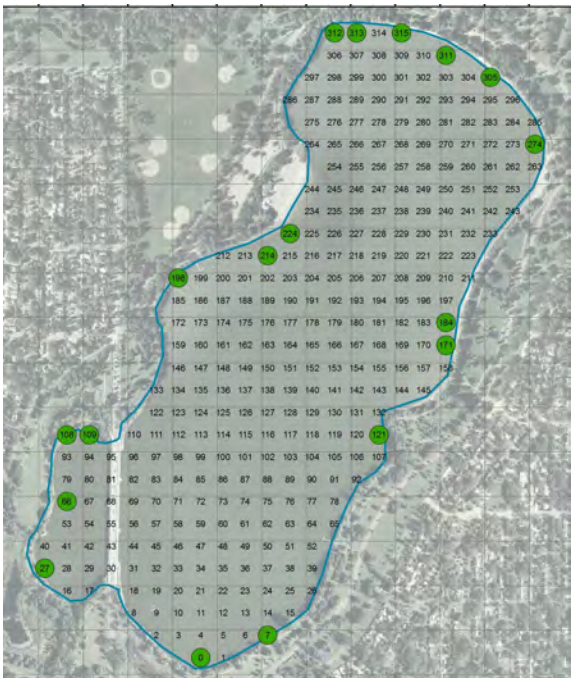


Figure 6. Occurrence of Eurasian watermilfoil in Lake Nokomis in 2010, 2011, and 2012. Green circles = light growth, yellow circles = moderate growth, and red circles = red growth.

Aquatic Plant Distribution in 2008, 2010, 2011, and 2012 and Potential Future Growth in Lake Nokomis

Previous surveys conducted on Lake Nokomis have found a sparse aquatic plant community (Figure 7). It would appear two significant factors are limiting growth. These two factors include poor water clarity and a quick dropoff to a 10-foot depth. Currently, plant growth is restricted to within 10 to 30 meters of the shoreline because the bottom drops off to 10 to 15 feet quickly (within 10 to 30 m of shore). This abrupt dropoff to deeper water limits plant growth. However there are about 100 acres of lake bottom from 0 to 15 feet deep. If clarity could improve to about 8 feet on a consistent basis, aquatic plant distribution might expand to deeper depths. Aquatic plants typically grow to about twice the average Secchi disc depth. Aquatic plant distribution could then sustain good water clarity.

There may have been a slight increase in native plant distribution in 2012.

Table 3. Summary of aquatic plant surveys in 2008, 2010, 2011, and 2012.

	2008 105 nearshore sites September (conducted by the MPRB)		**2010** 173 sites 0-15 feet deep September 9		**2011** 173 sites 0-15 feet deep July 15		**2012** 173 sites 0-15 feet deep August 29	
	Site	% Occur	Site	% Occur	Site	% Occur	Site	% Occur
Coontail	21	20%	3	1%	3	1%	10	5%
Eurasian watermilfoil	64	61%	21	12%	18	10%	18	10%
Curlyleaf pondweed	1	1%	0	0	0	0	0	0
Stringy pondweed	0	0	0	0	1	1%	0	0
Sago pondweed	0	0	0	0	0	0	2	1%

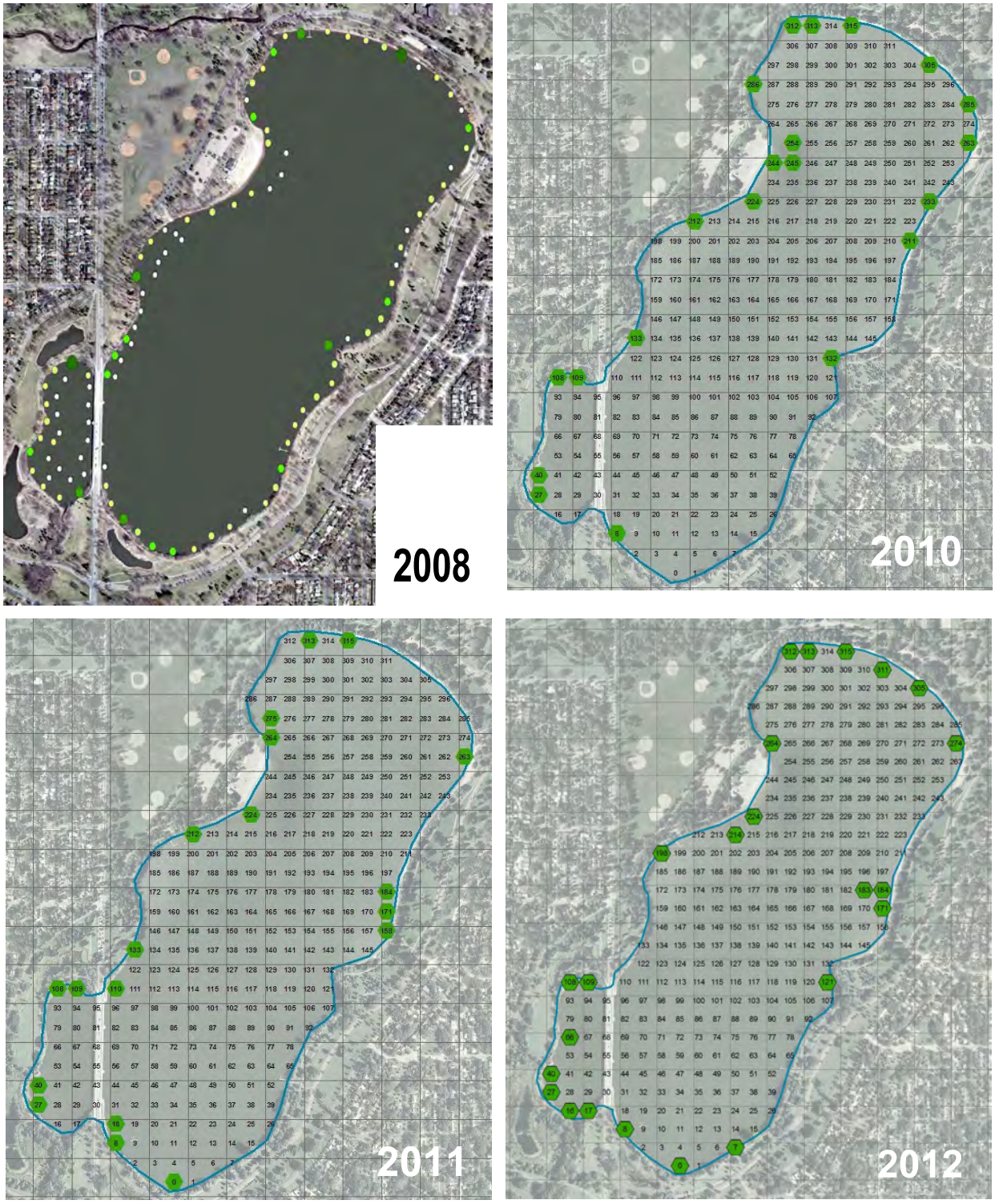


Figure 7. [top-left] Aquatic plant distribution in Lake Nokomis in September 2008 (source: Mpls Park and Rec Board)(all species).
[top-right] Aquatic plant coverage for September 9, 2010 (all species).
[bottom-left] Aquatic plant coverage for July 15, 2011 (all species).
[bottom-right] Aquatic plant coverage for August 29, 2012 (all species).

Potential for Future Curlyleaf Pondweed and Eurasian Watermilfoil Growth in Lake Nokomis

Curlyleaf Pondweed Growth Potential: Lake sediment sampling results from 2010 have been used to predict lake bottom areas that have the potential to support three types of curlyleaf pondweed plant growth: light, moderate, or heavy based on the key sediment parameters of pH, the Fe:Mn ratio, sediment bulk density, and organic matter (McComas, unpublished). Curlyleaf pondweed growth is predicted to produce a combination of low growth and moderate growth (where plants may occasionally top out in a broken canopy) in Lake Nokomis.

Eurasian Watermilfoil Growth Potential: Predicted Eurasian watermilfoil growth based on lake sediment characteristics indicates that mostly low growth is expected with the potential for heavy growth in the south end of the lake. In 2012, actual Eurasian watermilfoil growth in Lake Nokomis was light to moderate. Although heavy growth has been observed in an area on the west side, growth in other areas is predicted to remain light based on lake sediment characteristics.

Potential Curlyleaf Pondweed Growth

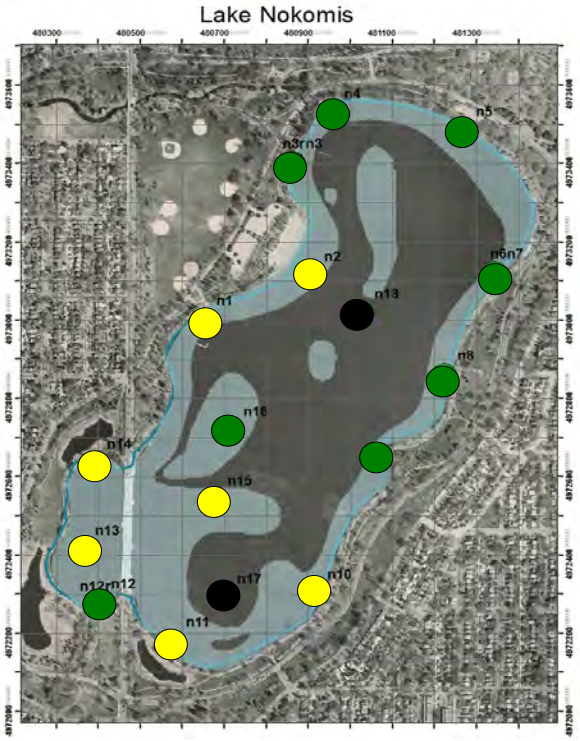


Figure 8. Sediment sample locations are shown with a circle. The circle color indicates the type of curlyleaf pondweed growth predicted to occur at that site. Key: green = light; yellow = moderate; red = heavy. (Two black circles are deep water and there is no plant growth).

Potential Eurasian Watermilfoil Growth

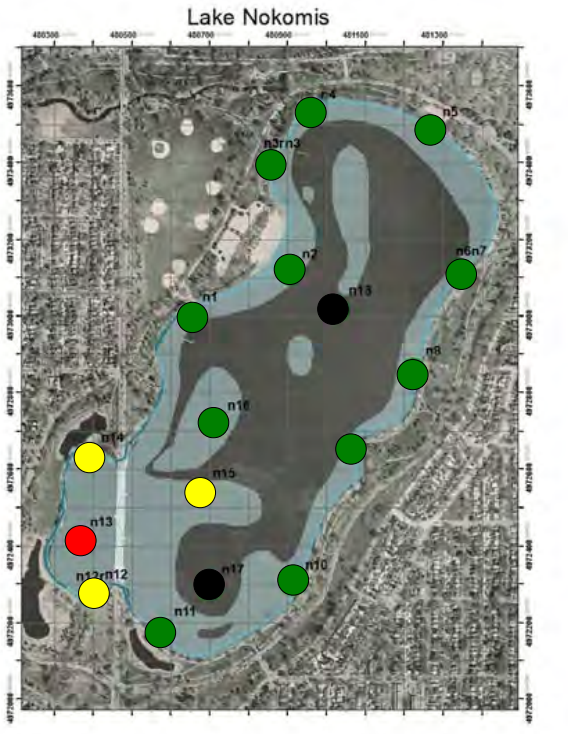


Figure 9. Sediment sample locations are shown with a circle. The circle color indicates the type of Eurasian watermilfoil growth predicted to occur at that site. Key: green = light; yellow = moderate; red = heavy. (Two black circles are in deep water and there is no plant growth).

APPENDIX A

2008 Aquatic plant occurrence from the 2008 plant survey (MPRB)

Notes from a Macrophyte Survey Conducted by the Mpls Parks and Rec Board: MPRB conducts macrophyte surveys in order to determine the extent of aquatic plant beds and species diversity within monitored lakes. In September of 2008, a macrophyte survey was conducted at Lake Nokomis using a modified point-intercept method. The target for data collection was to gather information at 100 data points, or as many as feasible, within the littoral zone at a pre-determined spacing (50m). Ideally, more points would be collected for the best possible statistical analysis. One hundred points were selected as an initial goal so that each data point would represent no more than one percent of the data. Grid spacing was selected based on the size needed to obtain 100 points within the littoral zone of each lake. Macrophytes were collected by rake toss. Plants present were identified and density for each species was estimated and recorded. Data point location was recorded using GPS.

Table A-1. Plant species found in Lake Nokomis and their frequency. 105 points were sampled at Lake Nokomis in 2008. Occurrences do not add up to 105 and percentages do not add up to 100 since some points contained more than one species and in some points plants were absent.

Common Name:	Coontail	Eurasian Watermilfoil	Curly Leaf Pondweed
Scientific Name:	Ceratophyllum demersum	Myriophyllum spicatum	Potamogeton crispus
Number of occurrences	21	64	1
Percent occurrence	20	61	1
Number of Samples	Number Vegetated	Percent Vegetated	Samples containing native macrophytes
105	67	64	21

	Number of Samples	**Percent vegetated**	**Number Vegetated**
< 1 meter	31	90	28
1-2 meters	34	91	31
2-3 meters	22	27	6
>3 meters	17	6	1

(Source: MPRB)

APPENDIX B

2010 Aquatic plant occurrence and densities for sample points (Blue Water Science). Plant density was assigned based on a scale from 1 - 5 with 5 the densest.

site	depth (ft)	Coontail	EWM	NO PLANTS
312	1		1	
224	2		1	
286	2		1	
8	3	2	3	
27	3		4	
40	3		4	
109	3		4	
285	3		0.5	
133	4		2	
212	4		2	
225	4			X
233	4		0.5	
234	4			X
244	4		1	
263	4		1	
315	4		1	
108	4.5	2	3	
313	5		2	
158	7			X
211	7		2	
245	7		4	
254	7		2	
297	7			X
305	7		1	
0	9			X
93	9			X
132	9	1	1	
314	9			X
7	10			X
16	10			X
17	10			X
29	10			X
36	10			X
53	10			X
79	10			X
213	10			X
214	10			X
296	10			X
15	11			X
146	11			X
159	11			X
172	11			X
185	11			X
275	11			X
306	11			X
311	11			X
1	12			X
4	12			X
65	12			X
107	12			X
145	12			X
197	12			X
284	12			X
304	12			X

2011 Aquatic plant occurrence and densities for sample points (Blue Water Science). Plant density was assigned based on a scale from 1 - 5 with 5 the densest.

site	depth (ft)	Coontail	EWM	Stringy pondweed	NO PLANTS
312	1				1
286	2				1
121	5				1
133	5		3.5		
224	5		0.5	0.5	
285	5				1
313	5		0.5		
0	6		0.5		
132	6				1
197	6				1
211	6				1
212	6		2		
263	6		2		
296	6				1
27	7		1		
110	7	1	2		
158	7		4		
184	7		2		
314	7				1
315	7		0.5		
2	8				1
8	8		1		
18	8	2	3		
40	8		2.5		
108	8		0.5		
109	8	1			
171	8		3		
297	8				1
305	8				1
264	9		2		
1	10				1
7	10				1
122	10				1
17	11				1
53	11				1
65	11				1
66	11				1
79	11				1
93	11				1
275	11		3		
4	12				1
15	12				1
16	12				1
41	12				1
92	12				1
107	12				1
145	12				1
223	12				1
233	12				1
304	12				1
306	12				1
311	12				1
39	13				1
146	13				1
214	13				1
78	14				1
253	14				1
274	14				1
284	14				1
26	TD				1
28	TD				1
29	TD				1
36	TD				1
148	TD				1
159	TD				1
172	TD				1
185	TD				1
198	TD				1
199	TD				1
213	TD				1
243	TD				1
244	4				Not Sampled (beach)
234	5				Not Sampled (beach)
225	6				Not Sampled (beach)
245	8				Not Sampled (beach)
254	8				Not Sampled (beach)

Attachment 2

Lake Nokomis Walleyes, October, 2011

Fish Assessment and Project Summaries for Lake Nokomis (ID #27-0019), Hennepin County, Minnesota in 2012

Fish Survey Dates: October 11 - 12, 2012

MnDNR Fish Permit Number: 18362

Prepared for:
Minnehaha Creek Watershed District and MnDNR

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November 30, 2012

Fish Assessment and Project Summaries for Lake Nokomis (ID #27-0019), Hennepin County, Minnesota in 2012

Summary

Lake Nokomis is a 201 acre lake located in Hennepin County, Minnesota. On October 11 and 12, 2012, a fish survey using trapnets was conducted on Lake Nokomis. The objectives of the fish survey were to characterize existing fish conditions and to determine if fish densities were high enough to be contributing to the observed poor water quality in Lake Nokomis.

Results of the 2012 fish survey are shown in Table 1. A total of nine species were sampled. The fish catch was dominated by bluegill sunfish with abundance of other fish species within or close to normal range (based on MnDNR statistics) except for walleyes which are high in abundance.

Bluegill sunfish densities appear to be decreasing and their contribution to poor water quality in Lake Nokomis should be decreasing. It is recommended that a bluegill control program should continue for one more year by stocking walleyes as a predator. Walleyes have the potential to keep both bluegill sunfish and black bullheads under control if walleye abundance remains high.

Table 1. Lake Nokomis trapnet results for the fish survey conducted in October 2012.

Net	Bluegill	Carp	Black Crappie	White Crappie	Dogfish	Pumpkin-seed	Walleye	White Sucker	Yellow Perch
Thursday (10/11)									
subtotal	139	1	46	1	0	4	22	4	16
fish/net	**23**	**0.2**	**7.7**	**0.2**	**0**	**0.7**	**3.7**	**0.7**	**2.7**
Friday (10/12)									
subtotal	92	1	14	0	1	9	9	0	9
fish/net	**18**	**0.2**	**2.8**	**0**	**0.2**	**1.8**	**1.8**	**0**	**1.8**
Total Fish (11 nets)	231	2	60	1	1	13	31	4	25
Fish/ Trapnet	**21**	**0.2**	**5.5**	**0.1**	**0.1**	**1.2**	**2.8**	**0.4**	**2.3**
MnDNR Normal Range*	7.5 - 63	NA	0.7 - 26	1.8 - 21	0.3 - 1	0.7 - 4.2	0.3 - 1.2	0.2 - 1	0.3 - 2

Although fish are suspected as being a water quality factor, many variables are involved. There is basically no correlation to the number of bluegills per trapnet and Secchi disc summer averages (r^2 = 0.07)(Table 2). However, there is also no correlation to rainfall, which is a surrogate for watershed loading as well (r^2= 0.02). The role of fish impacts on water quality is not completely understood in Lake Nokomis.

Table 2. Lake Nokomis fish survey results for bluegill sunfish, carp, and black bullheads for surveys conducted from 1948 through 2012. Water quality parameters in the green boxes represent unimpaired water quality conditions.

	Average Annual Rainfall (inches)	Water Quality			Fish Survey Results					
		Secchi (m)	TP (ppb)	Chl a (ppb)	Bluegill fish/net (trapnet)	Black Crappies fish/net (trapnet)	Carp fish/net (gillnet)	Carp fish/net (trapnet)	Black Bullhead fish/net (gillnet)	Black Bullhead fish/net (trapnet)
1948	17				1	2	0	0.1	0.4	1.0
1958	16				20	83	0.5	0.2	8.0	6.7
1972	24	1.2			1	12	0	0	1.0	2.0
1973	21									
1974	19									
1975	35				1	11	2.0	0.3	1.3	0.6
1976	17									
1977	35	0.9 (6.29)			21	16	2.7	0.6	10	3.4
1978	30									
1979	31									
1980	22	0.9								
1981	28	1.0 (6.23)								
1982	30				23	98	0.3	2	1.7	13
1983	39									
1984	37	0.9								
1985	32									
1986	37									
1987	32	1.8 (6.24)			75	28	0.3	0	14	12
1988	19	0.8								
1989	23	0.9								
1990	33	0.7								
1991	37	0.6			1	5		0		26
1992	30	0.9			115	133	0.5	0.4	14	6.0
1993	32	1.5								
1994	30	1.2								
1995	26	1.4								
1996	26	1.1			94	293	0.2	0.2	2.8	7.8
1997	34	1.6								
1998	33	1.4	59	26						
1999	31	1.5	64	47						
2000	32	1.3	59	33						
2001	34	1.3	76	39	54	23	0	0	5.5	1.6
2002	38	1.7								
2003	23	1.7	43	20						
2004	27	1.1	83	28						
2005	33	1.2	57		27	2	1.0	0	56	1.3
2006	28	1.0	67	36						
2007	24	1.1	56	29	183	5.8	0.3	0.1	28	2.6
2008	22	1.2	44	12	474	14		0		5.7
2009	25	1.0	60	25						
2010	33	1.2	47	22	188		0.5	0	2.3	0.8
2011	28	1.4	36	14	158	14		0		0.1
2012		1.2			21	5.5		0.2		0

Conclusions and Recommendations

Currently, the walleye abundance (based on fish per trapnet) is above average. Also, the average length of the bluegill population has increased since 2008. Not only does that make for good recreational fishing, but maybe bluegill food habits have changed from a benthic (bottom) feeding mode to a more open water mode. This could benefit water quality. The carp population in Lake Nokomis is probably at a moderate level and is not directly limiting aquatic plant growth. However, maybe the combined effects of carp and the high abundance of bluegill sunfish could play a role in the poor mid-summer water transparency, which in turn, could limit plant distribution.

In the last few years, plant growth is documented out to about 10 feet of water depth. It is estimated that the lake area from 0 - 10 feet is only about 20 acres (BWS estimate), but the lake area from 0 - 15 feet covers an area of 100 acres (MnDNR). If a summer average clarity increases to 7 or 8 feet, than plant growth could become established out to 15 feet of water depth and the lake could sustain long-term good water quality with the help of the aquatic plant community. Currently, the average Secchi disc transparency is about 5-feet. To sustain good water quality in Lake Nokomis (1.4 m transparency, 40 ppb of TP, and 14 ppb of chlorophyll), continuing predation pressure by walleyes on black bullheads and bluegill sunfish would be beneficial.

Maintaining a broad distribution of aquatic plant growth coupled with a balanced fish population could produce unimpaired water quality conditions for the long term in Lake Nokomis.

Sequence of Events for Nokomis Projects

1. Stock walleyes in 2013 to serve as a predator species for bluegill control. This should not interfere with the tiger muskie stocking program.

2. Conduct a seedbank growth project for sediments collected between 10-15 feet of water depth to see if there are viable native aquatic plant seeds or propagules (summer of 2013).

3. Conduct annual aquatic plant surveys to track distribution, diversity, and depth of colonization of plants.

4. Conduct annual fish surveys to track the fish community, especially for walleye and bluegill abundance.

5. If water quality does not meet unimpaired status, a potential project to consider would be a carp removal option. Carp do not appear to be a major factor at this time, but electrofishing or winter seining could confirm this. If a winter seining effort produced less than 10,000 pounds (50 pounds/ac), seining could be discontinued.

6. Two to three years after completion of walleye stocking, if water quality does not meet unimpaired status, another potential project to consider, somewhat extreme, is to conduct a 5-foot lake draw down for 1 to 3 years to stimulate aquatic plant growth.

Introduction

Lake Nokomis is a 201-acre lake, located in Hennepin County, Minnesota.

In October of 2012, the Minnehaha Creek Watershed District contracted for a fish survey with Blue Water Science with a permit number 18362 granted from the MnDNR. The objectives were to characterize the fish community and to determine if fish were contributing to the poor water quality or lack of submerged aquatic plants that have been observed in Lake Nokomis.

Methods

Six standard trapnets were used over two nights to survey fish in Lake Nokomis. The trapnet was a MnDNR-style with a 4 x 6 feet square frame with two funnel mouth openings and 50-feet lead. Net mesh size was ½ inch (bar length). Six standard trap nets were set on Wednesday afternoon October 10, 2012. Six nets were fished for the following 2 days (October 11, 12). Trapnet locations are shown in Figure 1 and pictures of a typical trapnet are shown in Figure 2.

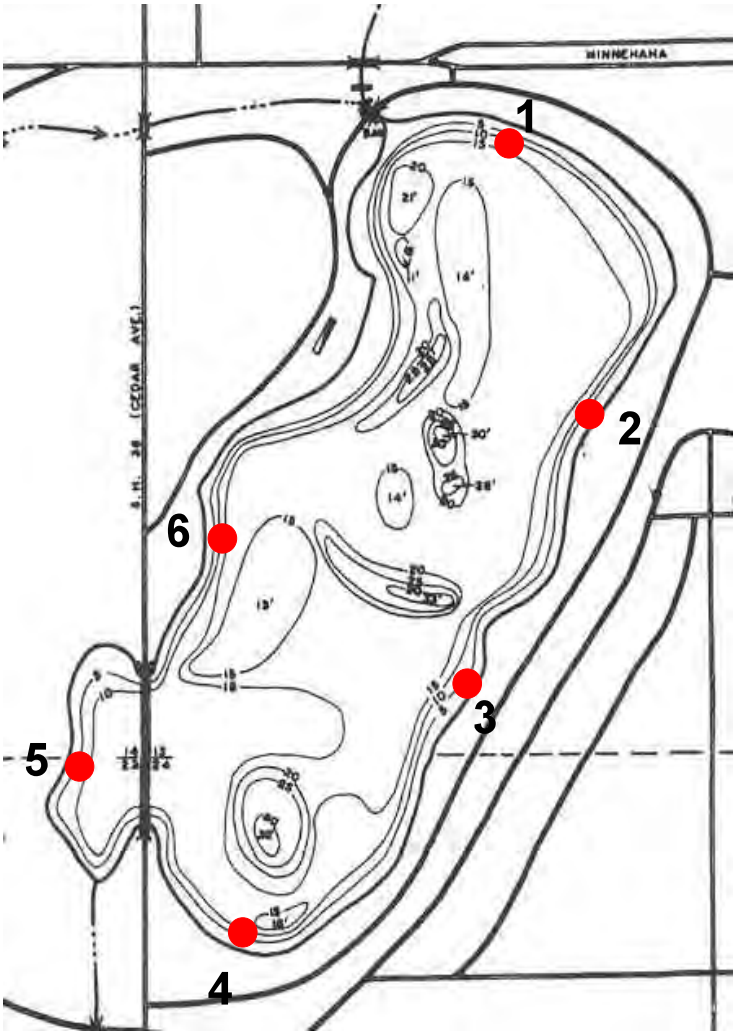

Figure 1. Map of trapnet sets.

Figure 2. [top] A trapnet is a live fish trap. Fish run into the 50-foot lead net and follow it back through a series of hoops with funnel mouths. Fish end up in the back hoop.
[middle] A handheld net is used to remove the fish from the back of the trapnet.
[bottom] Fish are transferred to tubs, then they are counted and measured.

Results

A total of nine fish species were sampled in Lake Nokomis on October 11-12, 2012. The fish catch was dominated by bluegill sunfish. The number of bluegill sunfish caught per net was moderate with the average haul of 21 per net (Table 1). This is within the normal range of 8-63 bluegills per lift for a lake like Lake Nokomis.

Crappies and pumpkinseed sunfish were found in low numbers and were within the normal range for lakes of the Lake Nokomis type, as defined by the MnDNR.

Two carp were sampled in this fish survey. Carp are present in Lake Nokomis but at low densities.

Walleyes were sampled with an above average abundance (Table 1).

Table 1. Lake Nokomis trapnet results for the fish survey conducted in October 2012.

Net	Bluegill	Carp	Black Crappie	White Crappie	Dogfish	Pumpkin-seed	Walleye	White Sucker	Yellow Perch
Thursday (10/11)									
1	11		2				2		1
2	10	1	1				7	3	10
3	8		5			2	2		1
4	8		5	1		1	4	1	1
5	5		16				3		
6	97		17			1	4		3
subtotal	139	1	46	1	0	4	22	4	16
fish/net	**23**	**0.2**	**7.7**	**0.2**	**0**	**0.7**	**3.7**	**0.7**	**2.7**
Friday (10/12)									
2	10				1	3	1		6
3	32		2			5	2		1
4	18		3				3		1
5	11		9			1	2		1
6	21	1					1		
subtotal	92	1	14	0	1	9	9	0	9
fish/net	**18**	**0.2**	**2.8**	**0**	**0.2**	**1.8**	**1.8**	**0**	**1.8**
Total Fish (11 nets)	231	2	60	1	1	13	31	4	25
Fish/ Trapnet	**21**	**0.2**	**5.5**	**0.1**	**0.1**	**1.2**	**2.8**	**0.4**	**2.3**
MnDNR Normal Range*	7.5 - 63	NA	0.7 - 26	1.8 - 21	0.3 - 1	0.7 - 4.2	0.3 - 1.2	0.2 - 1	0.3 - 2

Length Frequencies: Fish lengths are shown in Table 2. All the fish sampled in this survey were measured. Approximately 33% of the bluegill catch were 6 inches or greater. Walleyes have been stocked in Lake Nokomis for a number of years. Walleyes, with lengths up to 24 inches, represented several year classes. The population of walleyes may be strong enough to keep bluegills and black bullheads under control.

Table 2. Length frequency of fish species (as total length) for the Lake Nokomis fish survey in 2012 (number in parentheses are number of measured fish).

Size Range (in)	Bluegill (n=231)	Carp (n=2)	Black Crappie (n=60)	White Crappie (n=1)	Dogfish (n=1)	Pumpkin-seed (n=13)	Walleye (n=31)	White Sucker (n=4)	Yellow Perch (n=25)
<3.0									
3	2								
3.5	9					1			
4	24					4			
4.5	56					3			
5	45								1
5.5	19								
6	25		1			5			8
6.5	28		2				2		8
7	21		18						5
7.5	2		22	1			1		2
8			15						1
8.5									
9			1				1		
9.5							1		
10							1		
10.5							1		
11			1						
11.5							5		
12							5		
12.5							2		
13									
13.5							1		
14							1		
14.5								1	
15								1	
15.5									
16									
16.5									
17									
17.5									
18							1	2	
18.5							1		
19							3		
19.5									
20							1		
20.5							1		
21		1							
21.5							1		
22									
22.5									
23		1					1		
23.5									
24							1		
24.5									
25									
25.5					1				
26									

Representative Fish Species from Lake Nokomis in 2012

Figure 3. Top left: Bluegill sunfish.
Top right: carp
Middle left: Crappies. The white crappie (top fish) was the only 6one sampled. The crappie on the bottom is a black crappie.
Middle right: Bowfin (Dogfish).
Bottom left: Walleye.
Bottom right: Yellow perch.

Summary of Past Fish Surveys

Trapnet Results: There have been 17 trapnet fish surveys from 1948 - 2012. The number of species has ranged from a low of 7 in 1972 and 2011 to a high of 15 in 1996. In 2012, walleyes were the dominant piscivore. Largemouth bass haven't been sampled since 2001 and northern pike haven't been sampled since 1982. Tiger muskies are probably present, but in low numbers and have not been sampled since 2005. Bluegills were at an all time high in 2008 but have decreased in abundance since then. Crappies have also been found at high levels in the past, especially in 1996 and in 1992 (Table 3).

Table 3. Lake Nokomis trapnet results for fish surveys conducted from 1948 - 2005 and 2010 - 2012. The 2008, 2011, and 2012 surveys were conducted by Blue Water Science, all other surveys were conducted by the MnDNR.

	1948 May 5	1958 May 19	1972 July 1	1975 Aug 5	1977 June 29	1982 June 25	1987 June 24	1991 May 2	1992 June 22	1996 June 24	2001 July 19	2005 July 18	2007 July 16	2008 July 10 (BWS)	2010 July 17	2011 Oct 11 (BWS)	2012 Oct 11 (BWS)	% occur for 17 surveys
Bluegill	0.9	20	1	0.4	21	23	75	0.4	115	94	54	27	183	474	188	158	21	100%
Black Bullhead	1	6.7	2	0.6	3.4	13	12	26	6	7.8	1.6	1.3	2.6	5.7	0.8	0.1		94%
Black Crappie	1.6	83	12	11	16	98	28	5	133	293	23	2	5.8	14	4.9	14	5.5	100%
Bowfin						0.3	0.3					0.2	0.1				0.1	29%
Brown Bullhead				0.1		0.3												12%
Carp	0.08	0.2		0.3	0.6	2			0.4	0.2			0.1				0.2	53%
Golden Shiner		0.5			0.4	0.1	0.3	0.1	5.1	4.3	0.9	0.2		0.08				59%
Goldfish											0.1							6%
Green Sunfish		0.3					1.8	0.1		1.4	2.4	0.1						35%
Hybrid Sunfish		0.3		0.3	0.6	1.9	2.3		1.1	0.2	4.4	0.9	0.6	0.2	1.0			71%
Large-mouth Bass	0.3	0.3					1.3			0.1	0.1							29%
Northern Pike			0.1	0.1	0.3	0.3												24%
Pumpkin-seed		16			0.7	4	7	0.7	13	2.2	3.8	0.6	4.5	3.3	0.4	1.3	1.2	82%
Tiger Muskie										0.2	0.1	0.1						18%
Walleye						0.9	0.3	3	3.1	2	0.4	1.2	0.3	0.5	0.7	3.8	2.8	71%
White Crappie			8.9							1.6					0.4		0.1	24%
White Sucker	0.08	0.1	0.6	0.2	1	4.5		1.3	2.3	1.3	0.4	2.1		0.5	0.1	1.0	0.4	88%
Yellow Bullhead	0.08					0.5	0.8	0.6	0.3	0.3	0.1		0.1					47%
Yellow Perch	0.08	1.7	12	2	2.7	4.3	15	5	15	21	6.8	3.8	0.4	0.5	1.0	1.5	2.3	100%
Number of fish species	8	11	7	9	10	14	12	10	11	15	14	12	10	9	9	7	9	

Gillnet Results: There have been 13 gillnet fish surveys from 1948 - 2010. The number of species has ranged from 6 to 14 (Table 4). Black crappies and bluegill sunfish were the most abundant species sampled in 2010 and walleyes were the most abundant piscivore sampled with tiger muskies, northern pike, and largemouth bass present as well. Black bullhead numbers have declined since their peak which was recorded in 2005. Yellow perch abundance has fluctuated over the years with a low abundance found in 2010. Carp abundance was down in 2010 compared to the recorded catch of 2.33 fish/set in 2005.

Table 4. Lake Nokomis gillnet results for fish surveys conducted from 1948 though 2010. All surveys were conducted by the MnDNR.

	1948 *May 5*	1958 *May 19*	1972 *July 1*	1975 Aug 5	1977 *June 29*	1982 *June 25*	1987 *June 24*	1992 *June 22*	1996 *June 24*	2001 *July 19*	2005 *July 18*	2007 July 16	2010 July 17	% occur for 13 surveys
Black bullhead	0.4	8.0	1.0	1.3	10.0	1.7	14.3	14.0	2.8	5.5	130.3	28.3	2.3	100%
Black crappie	49.0	28.7	15.0	22.7	11.0	15.3	22.0	36.5	6.2	23.2	3.7	10.8	22.8	100%
Bluegill	1.8	5.5					1.0	2.5		2.0	3.2	38.8	19.2	62%
Bowfin				0.25	0.33									15%
Brown bullhead											0.33			8%
Carp		0.5		2.0	2.7	0.33	0.33	0.5	0.17		2.33	0.33	0.5	77%
Golden shiner	2.8	21.3		0.33				0.5	0.17	1.0	1.0	1.3	6.3	69%
Green sunfish						0.33				0.17				15%
Hybrid sunfish	0.2										0.33	0.50		23%
Large-mouth bass											0.33		0.17	15%
Northern pike	0.2	1.2	10	2.0	6.3	2.7	3.0		1.3				0.17	69%
Pumkin-seed		3.7			0.33					0.67	2.0	2.5		38%
Tiger musky							0.33	1.5	1.3	0.67	0.33	1.2	1.0	54%
Walleye						4.0	8.7	16.0	4.3	5.3	5.0	5.2	5.8	62%
White crappie			18							0.17			0.17	23%
White sucker	6.6	2.0	3.0	1.3	1.0	5.7	6.7	0.5	3.8	2.5	5.7	2.5	1.3	100%
Yellow bullhead										0.17	0.33			15%
Yellow perch	117	201	448	76.3	56.0	18.7	145	89.5	170	157	91.5	46.5	7.0	100%
Number of fish species	8	9	6	8	8	8	9	9	9	12	14	11	12	

Comparing Bluegill Lengths from 2008, 2011, and 2012

The bluegill population structure may be changing in Lake Nokomis. In 2012, 33% of the bluegills were 6-inches or larger while in 2011, 88% of the bluegills were 6-inches or longer (Figure 5). In addition the number of bluegills caught per trapnet decreased from 2008 to 2012. Maybe predation on the smaller bluegills reduced the number of bluegills.

Figure 4. Left: Bluegill sunfish in 2011 were larger than in 2008 (pumpkinseed is shown on the measuring board, bluegills are in the tub).
Right: Bluegill sunfish in 2012 were smaller than 2011.

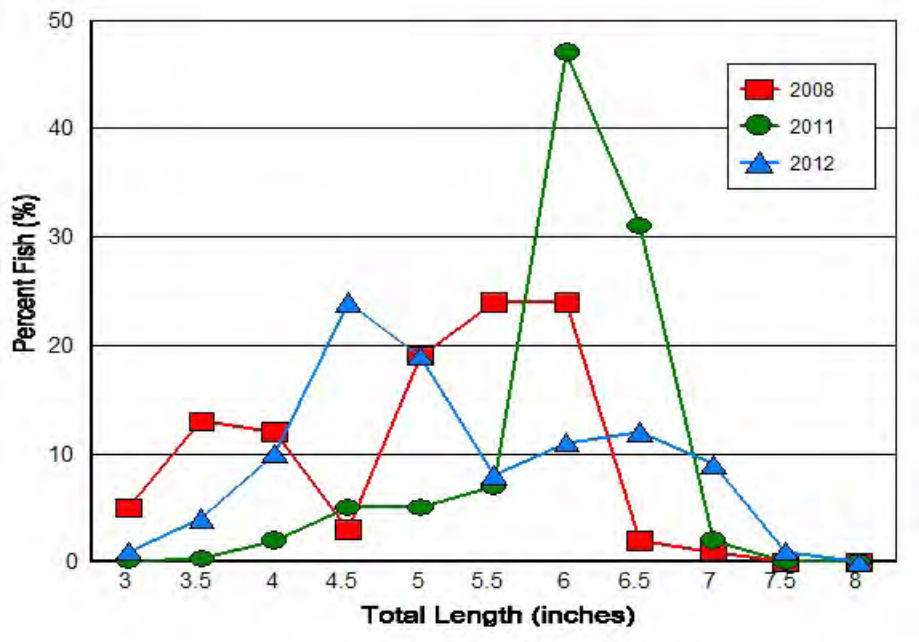

Figure 5. Bluegill sunfish length frequency comparison from 2008 to 2011 to 2012.

Lake Nokomis Fish Removal Projects in 2010 and 2011

Black Bullhead Removal in 2010 and 2011: Black bullhead removal was conducted by Westerberg Commercial Fishing in 2010 and 2011 and involved Brad Westerberg and Jeff Riedemann.

On April 10, 2010, hoopnets were set with a total of 10 net sets with four pockets per set for a total of 40 pockets. Then, on April 15, 2010, nets were emptied and a total of 2,400 pounds of bullheads were removed (rounded to nearest 100 pounds). There were five days of net sets with an average removal of 480 pounds/day or 48 pounds per net/day. Nets were then reset and on April 22, 2010, nets were emptied and removed from the lake. A total of 1,200 pounds of bullheads were removed (rounded to nearest 100 pounds). There were seven days of net sets with an average removal of 171 pounds/day or 17 pounds/net/day. For a total of 12 days of net sets, the total poundage of black bullheads removed in April of 2010 was 3,600 pounds (Table 5).

Table 5. Summary of bullhead removal for 2010 and 2011.

	2010	2011
Total pounds removed:	3,660	750
Pounds/ac removed:	17.6 lbs/ac	3.6 lbs/ac
Pounds removed per net per day:	30 pounds/net/day (10 nets, 12 days = 120 net-days)	4.5 pounds/net/day (12 nets, 14 days = 168 net days)
Average length	9.5 inches (n=17)	9.6 inches (n=10)

Figure 6. [left] Commercial fishermen and their equipment in 2010.
[right] Sample of black bullheads that were removed from Lake Nokomis using hoopnets in 2010.

On April 23, 2011, twelve hoopnets were set in the same general areas as in 2010 (Figure 7). They were emptied on April 29 and a total of 300 pounds were removed. Nets were reset and emptied 8 days later on May 7 and 450 pounds of bullheads were removed. For 14 days of net sets, an average of 54 pounds/day of bullheads were caught with a total of 750 pounds of black bullheads (Table 5). This is a relatively low poundage of fish removed in 2011.

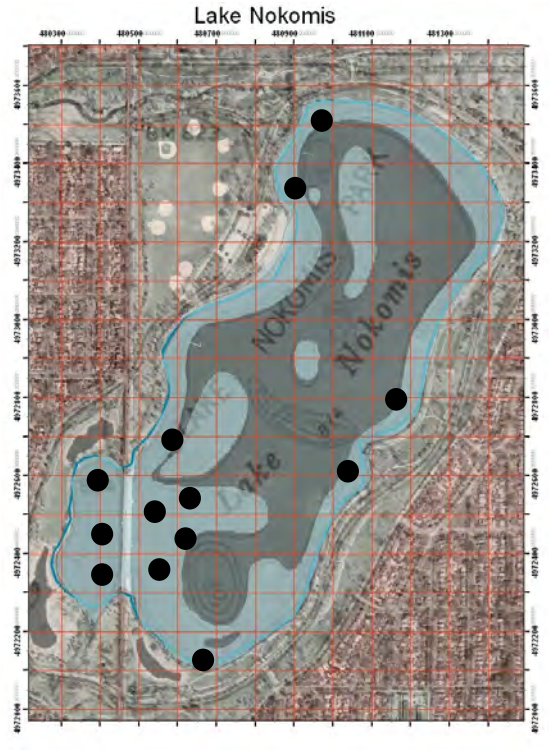

Figure 7. Hoopnet placement in 2010 for bullhead removal.

Figure 8. [left] Commercial fishermen pulling in nets in Lake Nokomis on April 29, 2011. [right] Several goldfish were also captured with the bullhead removal effort in 2011.

Carp Removal in 2010: As a result of an early summer rainfall, the water level in Minnehaha Creek rose until it went over a weir separating Lake Nokomis from the creek. Carp either swam out of Lake Nokomis toward the inflowing creek water or swam into Lake Nokomis from the creek. When water levels went down carp were trapped in a shallow pool behind the weir. A high concentration of carp consumed the oxygen in the pool and died (Figure 9). It appears the carp were swimming out of Lake Nokomis, toward the creek.

It was estimated between 1,600 to 2,000 pounds of carp were removed from this pool, about 10 pounds of carp per acre from Lake Nokomis.

Figure 9. After a rainstorm, carp were trapped in this pool between a sandbar (left) and a weir (right). It appears carp came from Lake Nokomis and did not get into the creek.

Lake Nokomis Walleye Stocking in 2012

On April 2, 2012, approximately 2,000 walleye yearlings ranging in size from 6 to 8 inches were stocked in Lake Nokomis. Total weight of the stocked fish was about 200 pounds (10 fish to a pound). The fish came from a private supplier, 10,000 Lakes Aquaculture (Osakis, MN) and the stocking was sponsored by the Minnehaha Creek Watershed District.

From 2007 - 2012, there have been over 2,023 pounds of walleye stocked into Lake Nokomis which is about 10.1 pounds per lake acre.

Table 6. Fish stocked by species from 2002-2012.

Year	Species	Size	Number	Pounds
2012	Walleye*	yearlings	2,000	200
2011 (Oct 10)	Walleye	fingerlings	9,376	468 (est)
2011 (Apr 25)	Walleye*	yearlings	2,000	400
2010	Tiger Muskellunge*	fingerlings	200	58.6
2009	Tiger Muskellunge*	fingerlings	200	28.6
	Tiger Muskellunge*	fingerlings	258	75.9
	Walleye	fingerlings	7,718	299.9
2007	Walleye	yearlings	610	412.1
	Walleye	yearlings	130	41.8
	Walleye	fingerlings	63	6.0
	Walleye	adults	156	195.0
2006	Tiger Muskellunge*	fingerlings	300	89.8
2005	Walleye	fingerlings	4,266	195.1
2003	Walleye	fingerlings	7,873	215.2
2002	Tiger Muskellunge	fingerlings	300	60.0

* indicates privately stocked fish. Private stocking includes fish purchased by the DNR for stocking and fish purchased and stocked by private citizens and sporting groups.

Figure 10. [left] In the April stocking, over-wintered walleyes stocked into Lake Nokomis were 6-8 inches in length.
[right] An example of a walleye that was stocked in Lake Nokomis in 2012.

Discussion: Fish, Aquatic Plants, and Water Quality

Predation Pressure May Help Control Abundance of Small Fish: Lake Nokomis offers good fishing opportunities based on the sizes of bluegills and walleyes found in this survey. The existing fish community in Lake Nokomis may have enough piscivore pressure to prevent the development of stunted sunfish and bullhead populations in the future. Using the chart in Figure 11 and converting walleye length to mouth gape, it is apparent that the walleye lengths in Lake Nokomis, when converted to gape widths, should exert some degree of predation pressure and possibly prevent stunted bluegill (typical around 4-inches) or black bullhead populations. This type of fish community structure is a benefit for fishing and for water quality.

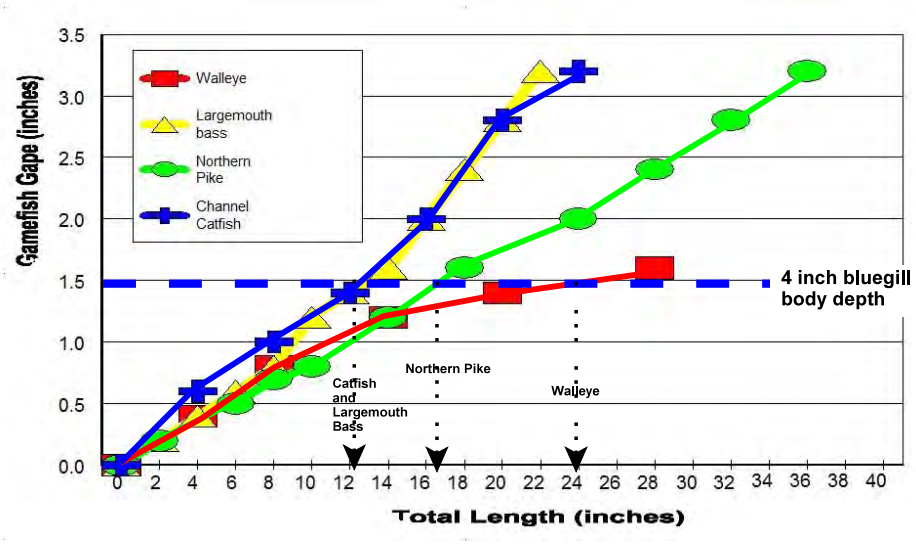

Figure 11. Gamefish gape increases as a function of it's total length. The gape determines the size of the prey fish that can be swallowed. For example, a 4-inch bluegill has a body depth of 1.5 inches. To ingest a 4-inch bluegill it would take a 12-inch bass that has a gape of 1.5 inches. There are walleyes in Lake Nokomis that should be able to ingest 4-inch bluegills or smaller.

Figure 12. The walleye community appears to be well established in Lake Nokomis. Here are two walleyes with a mouth gape that should control young bluegills and bullheads.

Aquatic Plant Conditions and Potential Impacts from Fish: Lack of aquatic plants in a lake can be an indicator of excessive numbers of bottom feeding fish. Bottom feeding fish, such as carp, can uproot plants in their search for food. Initially, the scarcity of submerged aquatic plants in Lake Nokomis (Figure 13) was attributed to excessive numbers of bottom feeding fish. But the lack of aquatic plants in Lake Nokomis may be related to other factors.

Figure 13. Submerged plants are scarce in Lake Nokomis. A plant survey was conducted by Blue Water Science in August 2012. Three aquatic plant species were found: coontail (native), Eurasian watermilfoil (non-native, and sago pondweed (native). Coontail was the dominant native plant.

A modified point intercept survey was conducted by the Minneapolis Park and Recreation Board in September of 2008 and regular point-intercept surveys were conducted in 2010 - 2012 by Blue Water Science. A map of aquatic plant distribution is shown in Figure 14. Plants were restricted to nearshore areas around the perimeter of Lake Nokomis. Plants did not grow in water deeper than 7 feet in 2012.

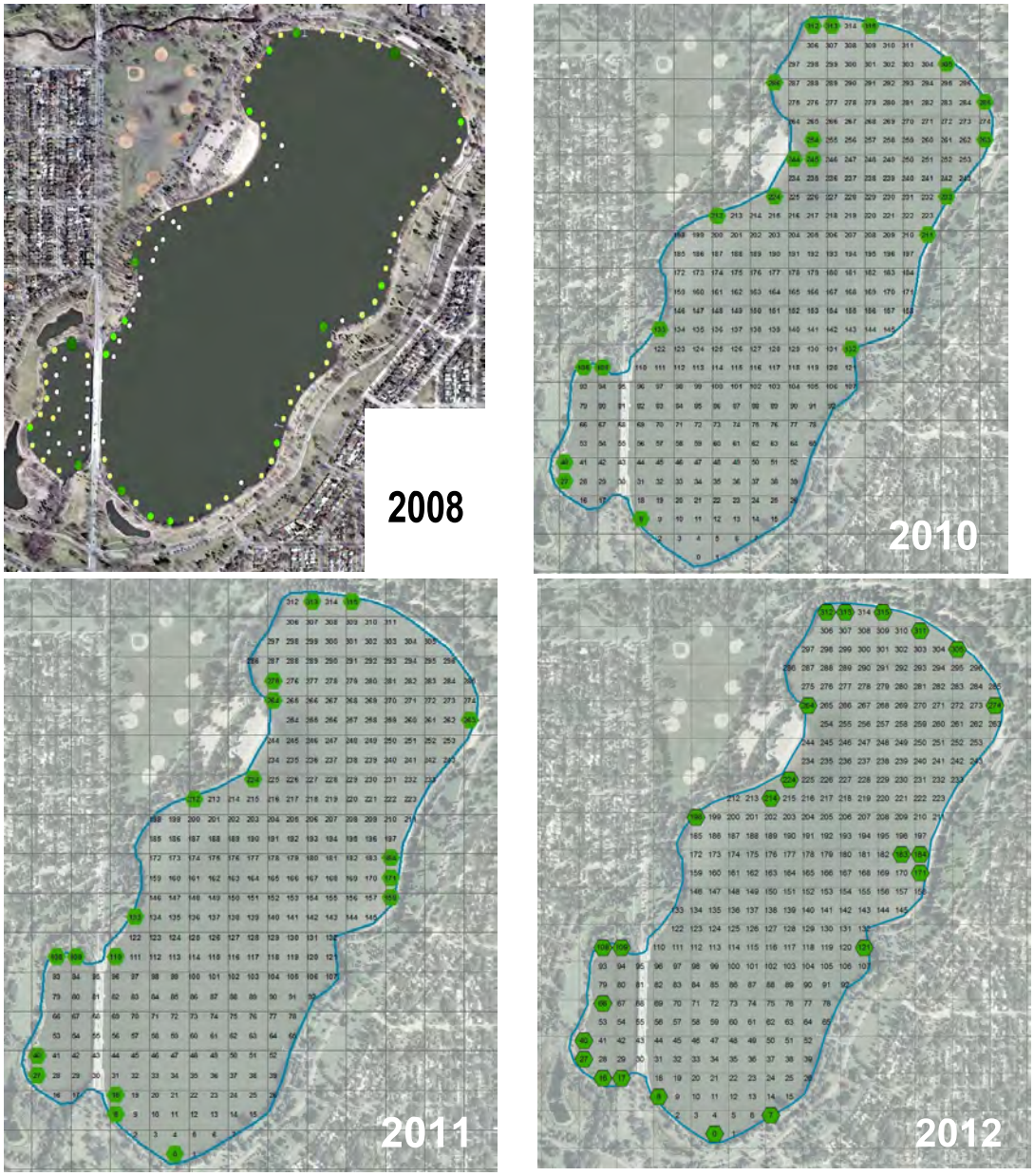

Figure 14. [top-left] Aquatic plant distribution in Lake Nokomis in September 2008 (source: MPLS Park and Rec Board).
[top-right] Aquatic plant coverage for September 9, 2010.
[bottom -left] Aquatic plant coverage for July 15, 2011.
[bottom-right] Aquatic plant coverage for August 29, 2012.

Aquatic plants have been sparse and found with a low diversity in Lake Nokomis for some time. A summary of aquatic plant surveys from 1982 - 2012 is shown in Table 8. In the most recent survey of 2012 plants did not grow deeper than 7 feet of water. Aquatic plants were estimated to cover about 16 acres of lake area, based on an assessment by Blue Water Science in July 2008. Although this is only 7% lake area, the bathymetry of the lake is a factor. Water depth drops off relatively quickly after the 10-foot depth. Plants are not growing deeper than 11-feet because they are probably light limited and limited plant growth is not likely due to fish impacts.

For Lake Nokomis, it is estimated that the lake area between 0 to 10 feet is about 20 acres and that plants occupy about 16 acres. This is only 4 acres less than what might be expected based on the water clarity. If fish are having an impact it is an indirect impact, that is, their indirect impact comes from contributing nutrients to produce algae blooms which produce mid-summer transparencies around 1 meter or less. Then aquatic plants are light-limited. A rule of thumb is plants grow to about twice the depth of mid-summer Secchi readings. Plants would not be expected to grow much deeper than about 9 feet in Lake Nokomis. It does not appear that fish are directly uprooting plants and limiting their growth from that mechanism.

Table 7. Aquatic plant species observed in Lake Nokomis. Eurasian watermilfoil was first observed in Lake Nokomis in 1995.

	1982 June 23 - 25 (MnDNR)	1992* June 22 - 25 (MnDNR)	2008 September % Occur (105 points) (MPRB)	2010 September % Occur (173 points) (BWS)	2011 July 15 % Occur (173 points) (BWS)	2012 August 29 % Occur (173 points) (BWS)
Cattail		Present		Present	Present	Present
Hardstem bulrush		Present		Present	Present	Present
Sedge	Present					
Narrowleaf pondweed	Common	Present				
Sago pondweed	Common	Occasional				1%
Curlyleaf pondweed	Common	Occasional	1%			
Water stargrass	Present					
Coontail			20%	1%	1%	6%
Eurasian watermilfoil			61%	12%	10%	10%
Floatingleaf pondweed			Present			
Stringy pondweed					1%	

* plants observed only along the north and northeast shore.

Annual Rainfall, Fish Abundance, and Lake Nokomis Water Quality: In the recent past, bluegill sunfish have been abundant in Lake Nokomis with densities higher than regional averages. Gamefish, such as walleyes, are important because they would serve as a population control on panfish. Without this control, bluegill numbers could become even greater.

At the present density, bluegills may be contributing to elevated phosphorus concentrations in Lake Nokomis. How do panfish cause poor water quality? Bluegills deplete zooplankton in the water column, and at a high bluegill density, will feed in the bottom sediments as well. The bottom feeding results in resuspension of lake sediments, but there is another impact. Bluegills ingest sediment along with food particles, and excrete most of the sediment which is high in phosphorus. This is another way phosphorus gets into the water column. At high bluegill densities, their bottom feeding impact is similar to the impact of bottom feeding carp.

Stomach content analysis of bluegills in other lakes with high bluegill densities have showed insect parts along with bottom detrital material and confirms that bluegills are feeding off the bottom (McComas, unpublished). The result is an elevated phosphorus concentration in the lake resulting in abundant algae growth combined with the suspension of bottom lake sediments that together produce poor water clarity.

Theoretical phosphorus loading from bluegill sunfish is shown in Table 8.

Table 8. Bluegill phosphorus excretion rates (from Schaus et al 1997) are 1.0 to 2.3 µg/g/hr for unfed fish and 1.2 to 5.7 µg/g/hr for fish that were fed. For Lake Nokomis a rate of 3.0 µg/g/hr was used (72 µg/g/day). Therefore, 72 µg x 454 g/pound = 33 mg-P/pound of fish/day. Assume 300 pounds of fish/ac, 300 pounds/ac x 33 mg-P = 9,900 mg = 9.9 g/ac/day. For 201 acre Lake Nokomis: 201 ac x 9.9 g/ac/day = 1,990 g/day = 726 kg/yr.

Bluegill Sunfish (pound/ac)	Theoretical Bluegill Phosphorus Loading (in kg/yr) for Lake Nokomis (201 acres)
0	0
50	123
100	246
150	369
200	492
250	614
300	726
350	860
400	983

The potential phosphorus loading from bluegill sunfish is high enough at 726 kg/yr to impact Lake Nokomis water quality. However, the potential p-loading from bluegills needs to be put into context. There may be less than 300 lbs of bluegills/lake acre and they are not feeding all 365 days of the year. Also, the biggest phosphorus impact would come from fish feeding in the lake sediments and excreting "new" phosphorus compared to feeding in the water column and "recycling" water column phosphorus. At this time, it is unknown how much time bluegills feed in the water column verses in the sediments.

Although fish are suspected as being a water quality factor, many variables are involved. There is basically no correlation to the number of bluegills per trapnet and Secchi disc summer averages ($r^2 = 0.07$)(Table 9). However, there is also no correlation to rainfall, which is a surrogate for watershed loading as well ($r^2 = 0.02$). The role of fish impacts on water quality is not completely understood in Lake Nokomis. At this time, it is not known if the improved water quality observed in 2011 will be sustained or if it is temporary.

Table 9. Lake Nokomis fish survey results for bluegill sunfish, carp, and black bullheads for surveys conducted from 1948 through 2012. Water quality parameters in the green boxes represent unimpaired water quality conditions.

	Average Annual Rainfall (inches)	Water Quality			Fish Survey Results					
		Secchi (m)	TP (ppb)	Chl a (ppb)	Bluegill fish/net (trapnet)	Black Crappies fish/net (trapnet)	Carp fish/net (gillnet)	Carp fish/net (trapnet)	Black Bullhead fish/net (gillnet)	Black Bullhead fish/net (trapnet)
1948	17				1	2	0	0.1	0.4	1.0
1958	16				20	83	0.5	0.2	8.0	6.7
1972	24	1.2			1	12	0	0	1.0	2.0
1973	21									
1974	19									
1975	35				1	11	2.0	0.3	1.3	0.6
1976	17									
1977	35	0.9 (6.29)			21	16	2.7	0.6	10	3.4
1978	30									
1979	31									
1980	22	0.9								
1981	28	1.0 (6.23)								
1982	30				23	98	0.3	2	1.7	13
1983	39									
1984	37	0.9								
1985	32									
1986	37									
1987	32	1.8 (6.24)			75	28	0.3	0	14	12
1988	19	0.8								
1989	23	0.9								
1990	33	0.7								
1991	37	0.6			1	5		0		26
1992	30	0.9			115	133	0.5	0.4	14	6.0
1993	32	1.5								
1994	30	1.2								
1995	26	1.4								
1996	26	1.1			94	293	0.2	0.2	2.8	7.8
1997	34	1.6								
1998	33	1.4	59	26						
1999	31	1.5	64	47						
2000	32	1.3	59	33						
2001	34	1.3	76	39	54	23	0	0	5.5	1.6
2002	38	1.7								
2003	23	1.7	43	20						
2004	27	1.1	83	28						
2005	33	1.2	57		27	2	1.0	0	56	1.3
2006	28	1.0	67	36						
2007	24	1.1	56	29	183	5.8	0.3	0.1	28	2.6
2008	22	1.2	44	12	474	14		0		5.7
2009	25	1.0	60	25						
2010	33	1.2	47	22	188		0.5	0	2.3	0.8
2011	28	1.4	36	14	158	14		0		0.1
2012		1.2								

Conclusions and Recommendations

Currently, the walleye abundance (based on fish per trapnet) is above average. Also, the average length of the bluegill population has increased since 2008. Not only does that make for good recreational fishing, but maybe bluegill food habits have changed from a benthic (bottom) feeding mode to a more open water mode. This could benefit water quality. The carp population in Lake Nokomis is probably at a moderate level and is not directly limiting aquatic plant growth. However, maybe the combined effects of carp and the high abundance of bluegill sunfish could play a role in the poor mid-summer water transparency, which in turn, could limit plant distribution.

Currently, plant growth is documented out to about 10 feet of water depth. It is estimated that the lake area from 0 - 10 feet is only about 20 acres (BWS estimate), but the lake area from 0 - 15 feet covers an area of 100 acres (MnDNR). If a summer average clarity increases to 7 or 8 feet, than plant growth could become established out to 15 feet of water depth and the lake could sustain long-term good water quality with the help of the aquatic plant community. Currently, the average Secchi disc transparency is about 5-feet. To sustain good water quality in Lake Nokomis (1.4 m transparency, 40 ppb of TP, and 14 ppb of chlorophyll), continuing predation pressure by walleyes on black bullheads and bluegill sunfish would be beneficial.

Maintaining a broad distribution of aquatic plant growth coupled with a balanced fish population could produce unimpaired water quality conditions for the long term in Lake Nokomis.

Sequence of Events for Nokomis Projects

1. Stock walleyes in 2013 to serve as a predator species for bluegill control. This should not interfere with the tiger muskie stocking program.

2. Conduct a seedbank growth project for sediments collected between 10-15 feet of water depth to see if there are viable native aquatic plant seeds or propagules (summer of 2013).

3. Conduct annual aquatic plant surveys to track distribution, diversity, and depth of colonization of plants.

4. Conduct annual fish surveys to track the fish community, especially for walleye and bluegill abundance.

5. If water quality does not meet unimpaired status, carp removal could be an option. Carp do not appear to be a major factor at this time, but seining could confirm this. If a winter seining effort produced less than 10,000 pounds (50 pounds/ac), seining could be discontinued.

6. Two to three years after completion of walleye stocking, if water quality does not meet unimpaired status, a somewhat extreme measure to consider is to conduct a 5-foot lake draw down for 1 to 3 years to stimulate aquatic plant growth.

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Appendix A

Minnesota DNR Fish Permit

From: Steve McComas [mailto:mccomas@pclink.com]
Sent: Tuesday, October 09, 2012 4:03 PM
To: Daryl Ellison ; Greg Salo
Cc: Eric Fieldseth; Kelly Dooley; Pilger, Debra L.; Rachael Crabb
Subject: Fish survey on Lake Nokomis, Hennepin County

Hello all,

Blue Water Science will be conducting a fish survey in Lake Nokomis (27-0019), Hennepin County, starting on Wednesday, October 10, 2012. We will set 6 standard fyke nets on Wednesday in the lake. The nets will be monitored daily and all fish will be weighed, measured, and returned to the lake. The nets will be removed from the lake on Friday, October 12, 2012. The fish survey is sponsored by the Minnehaha Creek Watershed District with the objectives to characterize the existing fish community structure and assess potential impacts of fish on water quality.

This survey is being conducted under the permit number 18362

Cordially,

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BLUE WATER SCIENCE
550 South Snelling Avenue
St. Paul, MN 55116
651 690 9602
mccomas@pclink.com

APPENDIX B

Lake Sediment Conditions and Potential Impacts from Fish

Estimating a carp population and its biomass in a lake is difficult. A standard technique is to use trapnet results from fish surveys and compare to regional averages to determine a high or low carp population. This approach is helpful, but there is still uncertainty involved. An additional technique is to look for signs of carp activity in a lake.

At low to moderate carp densities, carp will feed in aquatic plant beds where high quality macro-invertebrates are present. At low densities, some plants are uprooted but many are still intact. Carp are not a problem in these situations and do not significantly contribute to water quality problems. However, at high carp densities, after plant bed feeding is exhausted, carp go to open sand and mud flat areas to feed. The food quality of macro-invertebrates is lower in these areas, and is a secondary feeding area.

When feeding in lake sediments, carp create small bowl-like depressions in the sediments, much like what is shown in Figure B1. These depressions can be seen in shallow water and indicate a high density of carp are present in a lake.

In July of 2008, a shoreline “carp indicator” survey was conducted in Lake Nokomis. No bowl-like depressions were observed in Lake Nokomis in the course of the survey. Although carp are observed in Lake Nokomis, their population may be low to moderate.

Figure B1. These are bowl-like depressions caused by carp feeding. These depressions were observed in aquaria with carp at the Blue Water Science labs and were similar to what has been observed in lakes with high density of carp. These bowl-like depressions were not observed in Lake Nokomis.

Fish Impacts on Water Quality in Other Lakes: For centuries (going back to Chinese fish farmer reports), it's been known fish have impacts on water quality. In Minnesota, as early as 1916, carp were being seined out of lakes because of their deleterious effect on aquatic plants and water clarity (McComas 2003a).

More recently, experiments in eutrophic Swedish lakes showed dense fish populations of planktivorous and benthivorous fish resulted in high concentrations of chlorophyll, blooms of blue-green algae and low transparency (Andersson et al 1978).

A variety of fish species can cause adverse water quality impacts, and a summary of fish species that can impact water quality is shown in Table B-1.

Table B-1. List of fish that have been documented to cause poor water clarity.

Species	Situation	Reference
Carp	Adverse water quality and plant impacts have been known for some time.	Lamarra 1975; Zambrano et al 2001; Parkos et al 2003
Black bullheads	Eagle Lake, Cottonwood County, cleared up after a rotenone treatment	McComas, unpublished
Smallmouth buffalo	Mesocosm experiments found smallmouth buffalo enhanced turbidity, algae, nitrogen, and phosphorus.	Shormann and Cotner 1997
Crucian carp	Fish density: 1,960 lb/ac (in mesocosm) produces a lot of algae.	Andersson et al 1978
Gizzard shad	Nutrient excretion by bottom-feeding fish, in this case gizzard shad, produces nutrients for algae growth. Fish density was 370 lbs per acre.	Schaus et al 1997
Bream and roach	Fish density: 800 lb/ac (in mesocosm) produces a lot of algae.	Andersson et al 1978
Young of year walleye	Larval walleye (9 mm TL) stocked at 50 fish/m^3 produced lower clarity and more algae than ponds stocked at 10 fish/m^3.	Qin and Culver 1995
Mosquitoe fish	Water quality improves dramatically when a fungal infection kills more than 80% of the *Gambusia* (Mosquitoe Fish).	Nagdali and Gupta 2002
Fathead minnows	Ponds with fathead minnows had poorer water clarity and fewer aquatic plants than fishless ponds.	Zimmer et al 2001
Bluegill sunfish	High density of over 1,400 bluegill sunfish per trapnet was correlated with poor clarity and no submerged aquatic plants in Pond 213.	McComas, 2003b
Bluegill sunfish and black bullheads	High density of bluegill sunfish (465/lift) and black bullheads (97/lift) were suspected of causing poor water quality in Lee Lake.	McComas, 2004
Bluegill sunfish	High density of bluegill sunfish of 193 bluegills/net and 50 black bullheads/net were suspected of causing poor water quality in Alimagnet Lake.	McComas, 2005