MINNEHAHA CREEK WATERSHED DISTRICT
QUALITY OF WATER QUALITY OF LIFE

Lake Nokomis Water Quality Improvement Project: Biomanipulation Update

Background

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. One of the many internal sources that may be contributing to the nutrient impairment is the omnivorous, bottom feeding fish populations – black bullheads and bluegill sunfish. An estimated reduction of 126 kg of phosphorus in Lake Nokomis via fish community manipulation would bring the water quality of the lake closer to Minnesota Pollution Control Agency's (MPCA) nutrient criteria.

Summary of Biomanipulation Project

Project Objectives

From 2010-2013, the biomanipulation project attempted to re-balance the fish community over the 4-year period. By re-balancing the fish community in Lake Nokomis, the following was expected to occur:

1. Increase walleye population
2. Reduced black bullhead and blue gill populations
3. Observe an increase in native aquatic plants
4. Reduce an estimated 126 kg of phosphorus
5. Water quality parameters meet the MPCA's nutrient criteria

Project Summary

At the end of 2013, the biomanipulation project resulted in achieving the first three objectives: an increase in the walleye population and in number of native aquatic plants species, and a reduction in the black bullhead and bluegill populations. Positive changes in the water quality of natural systems, such as Lake Nokomis, often are observed after the timeframe of the project.

Update

Post project monitoring in Lake Nokomis began in 2014 and will occur through the fall of 2016. The monitoring of the water quality and the fish, aquatic plants, and plankton communities in Lake Nokomis are shared among Minnehaha Creek Watershed District, Minneapolis Parks and Recreation Board (MPRB) and the consultant, Blue Water Science.

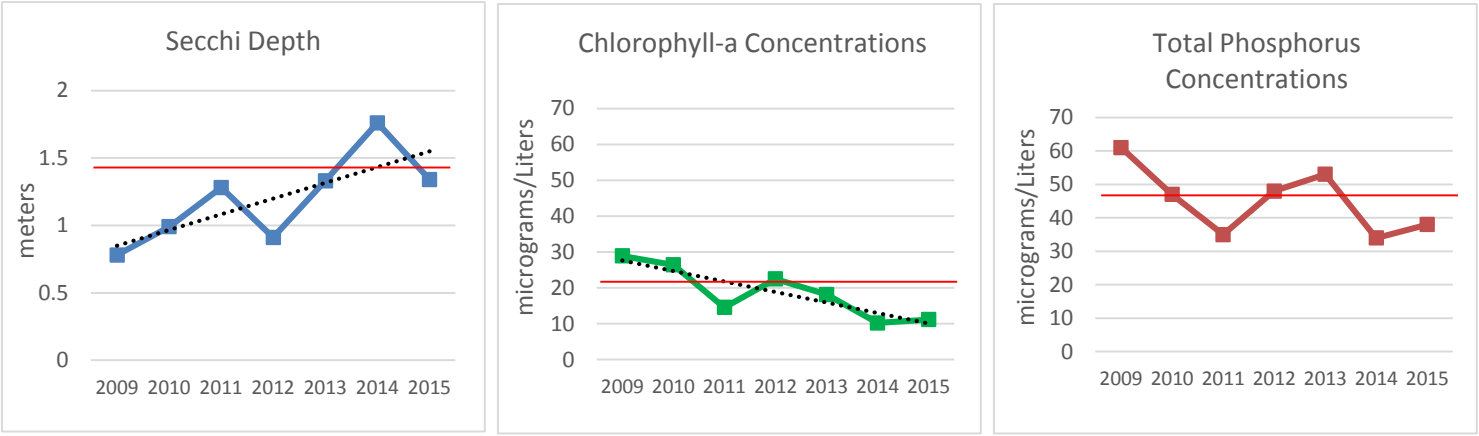
Post-Project Summary: 2015

- Water quality of Lake Nokomis was monitored from June-September 2015 (MPRB) (Graph 1)
    - Two of the three parameters met the standards in 2015
    - Second year in a row that chlorophyll and total phosphorus concentrations met the standards
    - *Preliminary Statistic Results:* Secchi depth and chlorophyll-a concentrations were found to have significantly improved in Lake Nokomis, since the beginning of the biomanipulation project (Graph 1). Note: 8-10 years of consecutive data are recommended for conducting trend analysis.

- Aquatic plant survey conducted on August 3, 2015 (Blue Water Science's Report - Attachment 1)
    - 8 species of aquatic plants were identified; 6 of the 8 were native plants
    - Estimated aquatic plant coverage was up to 29 acres, about double the coverage compared to the coverage in 2010
    - Aquatic plants grew out to depths of 11 feet, one foot deeper than in 2014

- Fish survey conducted on October 20-22, 2015 (Blue Water Science's Report - Attachment 2)
    - 12 fish species were sampled
    - Black crappies dominated the catch, and were above the range recommended by the DNR
    - Bluegill sunfish were slightly higher in 2015 compared to 2014, but not significantly higher; in fact, the population has been declining in the last few years
    - Declining blue gill population has created a niche for the black crappies
    - Continued predation by the walleye and yellow perch is needed to keep the blue gills and black crappie populations in check
    - Stocking walleye in Lake Nokomis is recommended

Graph 1. Lake Nokomis water quality means (Red line indicates standard)



Secchi: $\alpha < 0.05$; P-value = 0.035; positive trend CHLA: $\alpha < 0.05$; P-value = 0.035; negative trend TP: $\alpha < 0.05$; P-value = 0.368; No trend

Note: 2010: Start of the Biomanipulation Project; 2014: Start of Post-Project monitoring

Additional Activities: 2015

- Three settling ponds adjacent to Lake Nokomis were monitored from May-September 2015: (MCWD). The range of total phosphorus concentrations for the three ponds was 120 µg/L to 800 µg/L.

- Possible pathways that carp travel to and from Lake Nokomis were scouted this summer by Blue Water Science (Attachment 3). Five possible pathways were discovered. Two of the five pathways were rated a high probability of being used as carp transport. Solomon wetland south of Lake Nokomis and Taft Lake are the two pathways. Since 2015 was not a high water year, the results are not conclusive.

- August 2015: Justine Koch, Research Fellow for the Six Mile Creek Subwatershed Carp Assessment, conducted a snap-shot carp survey on Lake Nokomis (Table 1)
    - Results are preliminary, since a snap-shot survey was conducted
    - Results of 2015 were comparable to the 2014 results
    - A one-year-old carp was captured in 2015, so some level of recruitment is occurring in Lake Nokomis or in connected waters

Table 1. Results from the snap-shot carp survey on Lake Nokomis

Year	Estimated # of Carp	Estimated Biomass (kg/ha)
Ecological Limit		100
2014	8,421	298
2015	10,908	373

Note: Carp biomass above ~100 kg/ha has been found to cause ecological damage in shallow lakes (Bajer et al. 2009)

- MPRB submitted a grant proposal to Legislative-Citizen Commission on Minnesota Resources (LCCMR) in May 2015 to request funds to conduct invasive carp applied research in Lake Nokomis Subwatershed.

- MPRB and MCWD staff presented the grant proposal at the LCCMR grant committee in October 2015. The LCCMR grant committee will recommend the legislature to fund the invasive carp applied research in Lake Nokomis Subwatershed.

Work In-Progress:

- MPRB collects and analyzes the plankton data in Lake Nokomis. The analysis of the plankton data is underway.

- The revised manuscript on the Lake Nokomis biomanipulation project is planned to be resubmitted to a peer-to-peer scientific journal. The authors decided that additional data is needed to address the comments from the journal's review committee. The data will be collected by the fall of 2016.

Attachment 1

Swimming Beach at Lake Nokomis, Minneapolis, on August 3, 2015

Aquatic Plant Survey for Lake Nokomis, Minneapolis, Minnesota, 2015

Survey conducted on: August 3, 2015

Prepared for:
Minnehaha Creek Watershed District

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

November 2015

Aquatic Plant Surveys for Lake Nokomis, Minneapolis, Minnesota, 2015

Summary

Lake Nokomis (MnDNR ID: 27-0019) is a 201 acre lake located in Minneapolis, Minnesota. The coverage of aquatic plants in 2015 was evaluated by conducting a late season point-intercept aquatic plant surveys with 50 meter spacing between points.

In the late summer point-intercept survey on August 3, 2015, eight species of submerged aquatic plants were found in August, 2015. The most abundant was Eurasian watermilfoil followed by coontail. The non-native Eurasian watermilfoil was observed at 32 sites (Table S1). Plants grew out to a water depth of 11 feet and estimated plant coverage was 29 acres out of 201 acre lake (14% coverage)(Figure S2).

The distribution of aquatic plants in Lake Nokomis appears to be increasing (Table S2 and Figure S3). Aquatic plant coverage has more than doubled since 2010 (Table S2). The number of aquatic plant species has also increased (Table S2).

Figure S1. Aquatic plants from August 3, 2015. Stringy pondweed [left] at a density of a "1". Coontail and elodea [right] on a sample rake at densities of "2" and "1" respectfully.

Aquatic Plant Coverage in Lake Nokomis in 2015

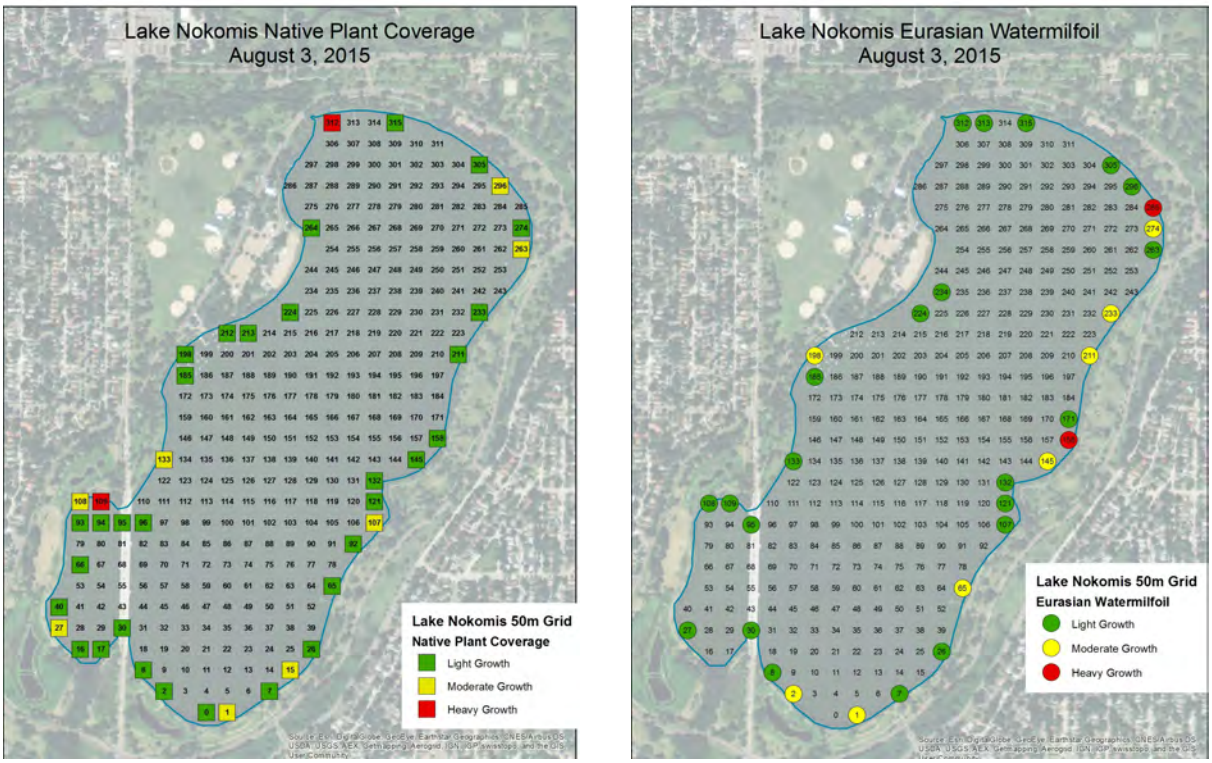


Figure S2. [left] Native submerged aquatic plant coverage in Lake Nokomis on August 3, 2015. [right] Eurasian watermilfoil coverage in Lake Nokomis on August 3, 2015. Key: Green = light growth, yellow = moderate growth, and red = heavy growth.

Table S1. Late season aquatic plant occurrences.

	August 3, 2015 sites present
Coontail	23
Elodea	19
Eurasian watermilfoil	32
Naiads	6
Curlyleaf pondweed	3
Floatingleaf pondweed	4
Stringy pondweed	12
Sago pondweed	5
Number of Species	8

Table S2. Summary of aquatic plant surveys in 2008, 2010 through 2015. Sample sites within the littoral zone were 173 sites.

	2008 105 nearshore sites - Sept (conducted by the MPRB)		**2010** 173 sites 0-15 ft deep Sept 9		**2011** 173 sites 0-15 ft deep July 15		**2012** 173 sites 0-15 ft deep August 29		**2013** 173 sites 0-15 ft deep July 18		**2014** 173 sites 0-15 ft deep June 20		**2014** 173 sites 0-15 ft deep August 20		**2015** 173 sites 0-15 ft deep August 3	
	Sites	% Occur	Sites	% Occur	Sites	% Occur	Sites	% Occur	Sites	% Occur	Sites	% Occur	Sites	% Occur	Sites	% Occur
Chara	0	0	0	0	0	0	0	0	1	1%	0	0	1	1%	0	0
Coontail	21	20%	3	1%	3	1%	10	5%	11	6%	11	6%	21	12%	23	13%
Elodea	0	0	0	0	0	0	0	0	1	1%	3	2%	9	5%	19	11%
Eurasian watermilfoil	64	61%	21	12%	18	10%	18	10%	33	19%	15	9%	43	25%	32	18%
Naiads	0	0	0	0	0	0	0	0	0	0	0	0	3	2%	6	3%
Cabbage	0	0	0	0	0	0	0	0	0	0	0	0	1	1%	0	0
Curlyleaf pondweed	1	1%	0	0	0	0	0	0	2	1%	1	1%	4	2%	3	2%
Floatingleaf	0	0	0	0	0	0	0	0	0	0	1	1%	2	1%	4	2%
Stringy pondweed	0	0	0	0	1	1%	0	0	7	4%	1	1%	16	9%	12	7%
Sago pondweed	0	0	0	0	0	0	2	1%	6	4%	0	0	5	3%	5	3%
Whitestem pondweed	0	0	0	0	0	0	0	0	1	1%	0	0	0	0	0	0
% occurrence (all species)	--	--	--	12%	--	11%	--	14%	--	21%	--	--	--	29%	--	26%
Number of Species	3	--	2	--	3	--	3	--	8	--	6	--	10	--	8	--
Plant Coverage (ac)	--		13		12		15		22		--		32		29	

Aquatic Plant Coverage (all species): 2008 - 2015

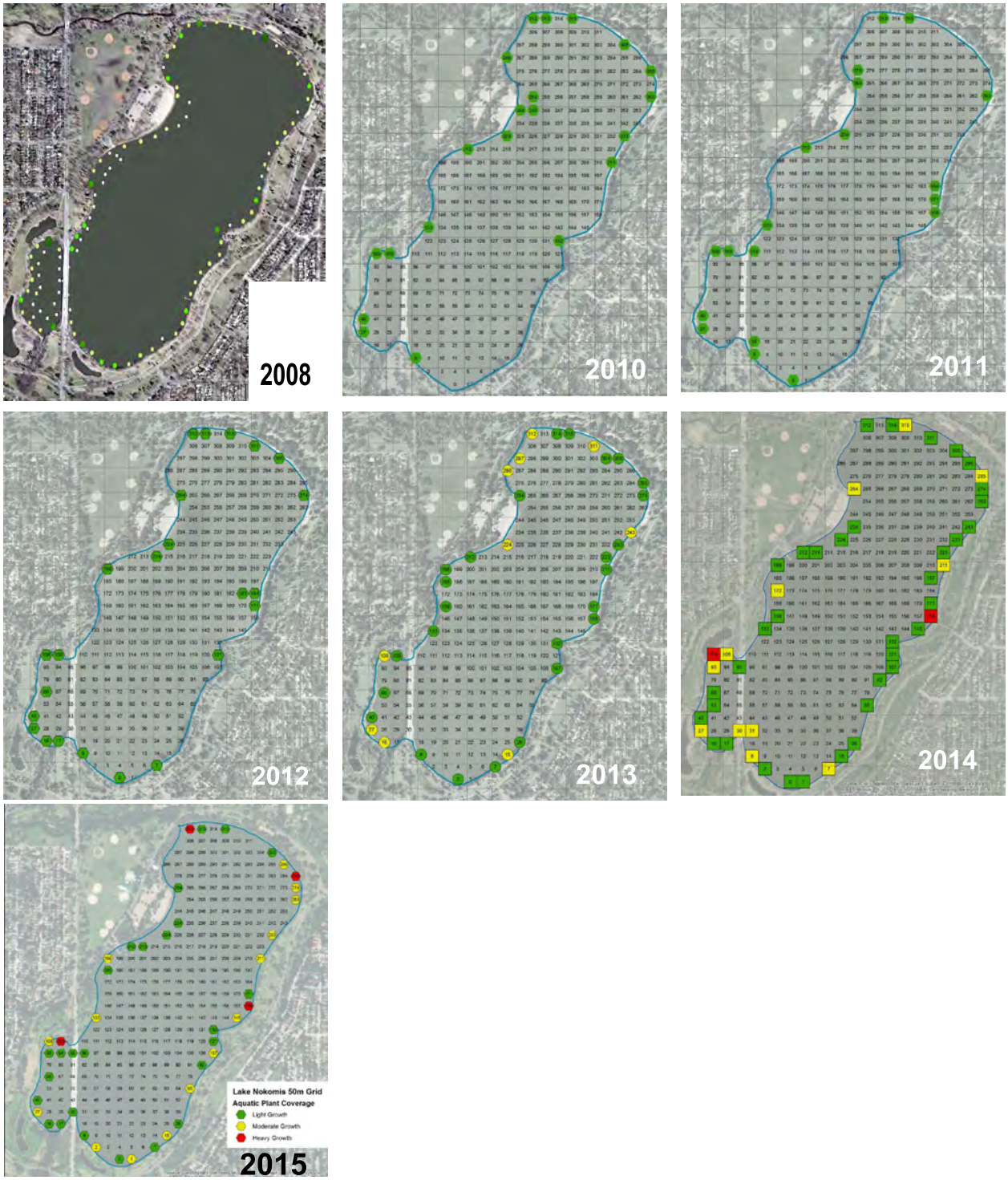


Figure S3. Aquatic plant distribution in Lake Nokomis in 2008 and 2010-2015.

Aquatic Plant Survey for Lake Nokomis, Minneapolis, Minnesota, 2015

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 and as water clarity improves, aquatic plant distribution should increase. The objectives of the 2015 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.

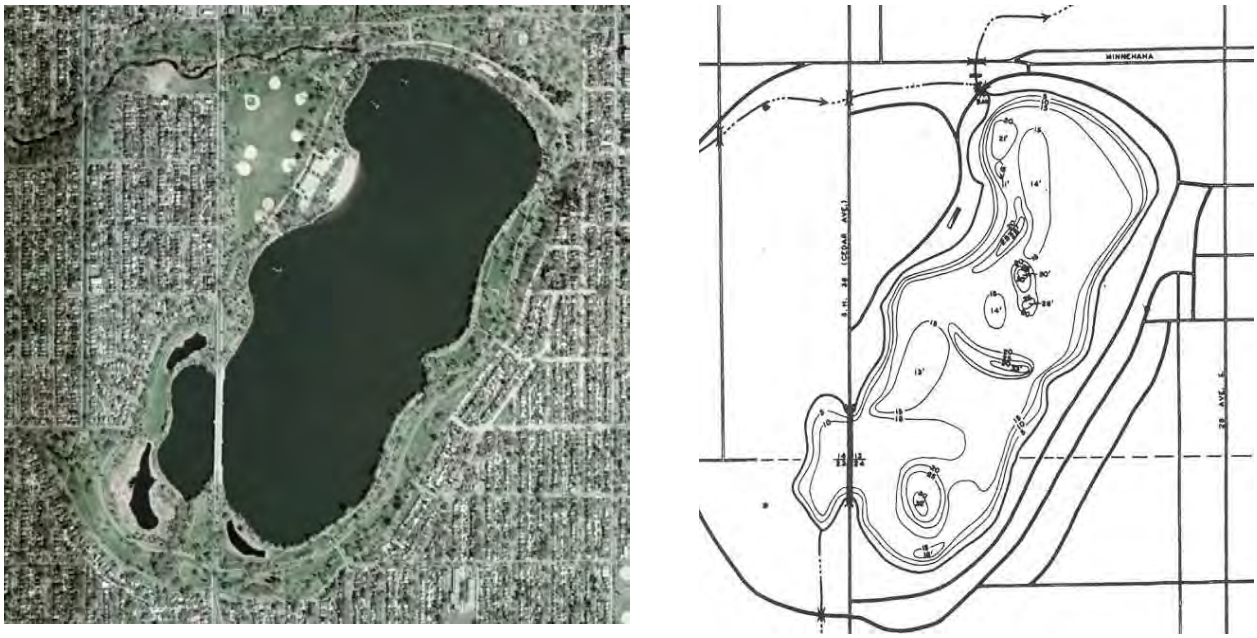


Figure 1. [left] Aerial view of Lake Nokomis, Minneapolis, Minnesota (source: Google Earth). [right] MnDNR contour map.

Methods

Point Intercept Surveys: An aquatic plant survey of Lake Nokomis was conducted by Blue Water Science on August 3, 2015. 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.

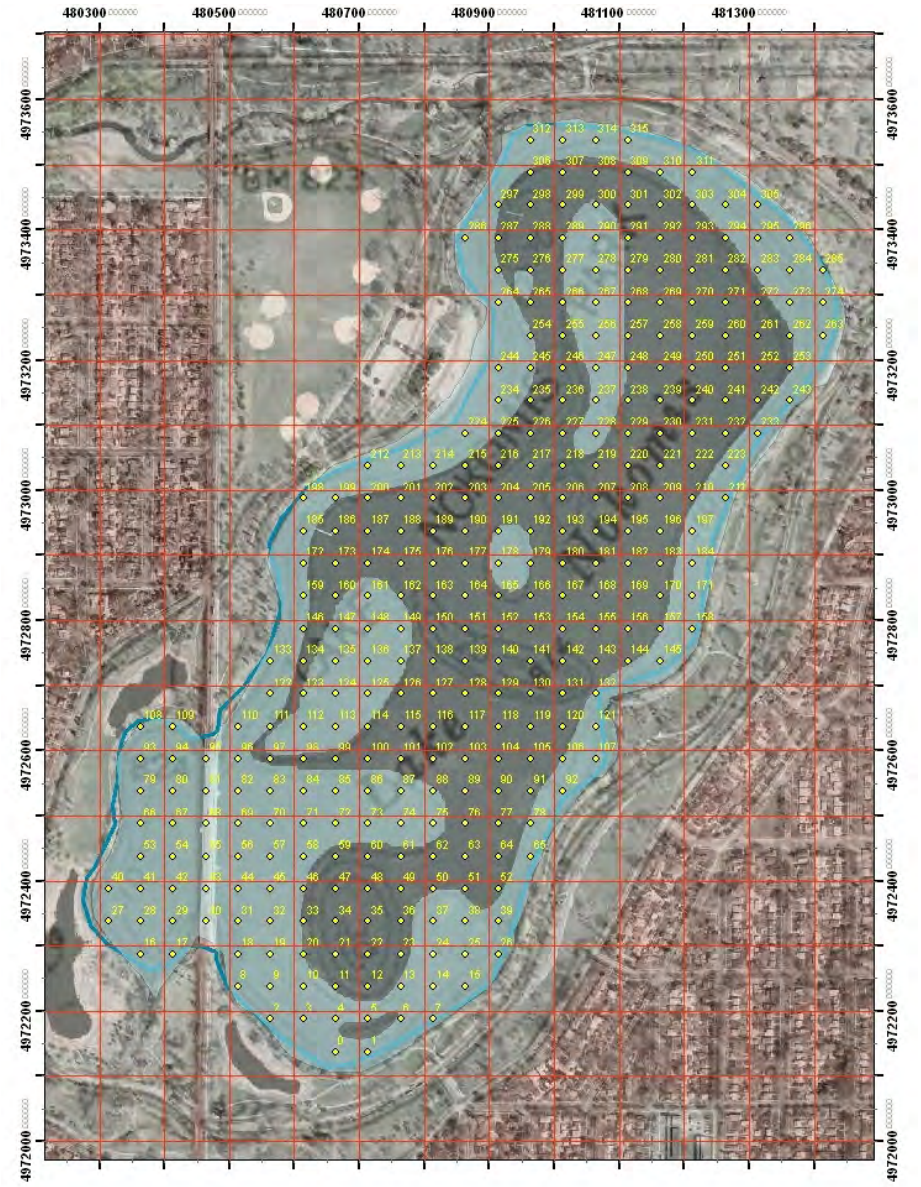


Figure 2. Point locations for the aquatic plant surveys are shown on the lake map with UTM coordinates using the WGS84 datum. The grid consisted of a total of 316 points. This is the same map used in 2010 through 2015. The grey shading represents the littoral area from 0-15 feet deep.

Results of the August 3, 2015 Aquatic Plant Survey

Results of the late summer point intercept aquatic plant survey conducted on August 3, 2015 found 8 submerged aquatic plant species in Lake Nokomis (Table 1). Results from the plant survey found that plants grew out to depth of 11 feet (Table 2). The location of aquatic plants in Lake Nokomis is shown in Figure 4. The coverage of aquatic plants was estimated at 29 acres out of 201 acres (14% coverage).

Table 1. Summary of aquatic plant survey conducted on August 3, 2015. Sample sites within the littoral zone were 173 sites.

	2015 173 sites 0-15 ft deep August 3	
	Sites	% Occur
Coontail	23	13%
Elodea	19	11%
Eurasian watermilfoil	32	18%
Naiads	6	3%
Curlyleaf pondweed	3	2%
Floatingleaf pondweed	4	2%
Stringy pondweed	12	7%
Sago pondweed	5	3%
Number of Species	8	--
Plant Coverage (ac)	29	

Figure 3. A sample rake with aquatic plants found in Lake Nokomis on August 3, 2015.

Table 2. Aquatic plant densities for the August 3, 2015 sample points. Plant density was assigned based on a scale from 1 - 5 with 5 the densest.

Site	Depth (ft)	Coontail	CLP	Elodea	EWM	Floatingleaf	Naiad	Sago	Stringy	No plants
0	11	1								
1	5	1		1	3		3		1	
2	5		1	1	3					
7	4	1		2	2				1	
8	6			1	1				1	
15	6			1		1	3			
16	11	2								
17	8	1								
18	14									1
26	7	1		1	1				1	
27	7	3			2					
29	13									1
30	4			2	1					
31	14									1
39	14									1
40	11	1								
53	14									1
62	16									1
65	6	1		1	3					
66	10	1								
79	13									1
92	7								2	
93	10	1								
94	12			1						
95	9	1		2	2					
96	9			2						
107	7	3		1	1				1	
108	5	3			1					
109	7	4			1					
110	14									1
121	9				2		1			
122	15									1
132	5				2		2		1	
133	5	3		1	1		1		1	
145	6			1	3					
146	11									1
148	5	2			3					
158	4				4			1		
159	15									1
171	6				2					
179	14									1
184	7									1
185	8	2	1	1	2					
197	16									1
199	15									1
211	4				3			1		
212	10	2		1						
213	9								1	
223	13									1
224	6				1				1	

Table 2. Aquatic plant densities for the August 3, 2015 sample points. Plant density was assigned based on a scale from 1 - 5 with 5 the densest.

Site	Depth (ft)	Coontail	CLP	Elodea	EWM	Floatingleaf	Naiad	Sago	Stringy	No plants
233	6				3	1		1		
234	6		1		2					
243	9									1
263	6			3	2			1	2	
264	11	1								
274	6			1	3	1			1	
285	4				4					
286	12									1
296	6	3			1			1		
297	16									1
305	7			1	2	1	1			
311	14									1
312	5	4			1					
313	9				1					
314	10									1
315	7	1			1					
Average		1.9	1.0	1.3	2.0	1.0	1.8	1.0	1.2	
occurrence		23	3	19	32	4	6	5	12	21
% occurrence (based on 173 sample sites)		13%	2%	11%	18%	2%	3%	3%	7%	

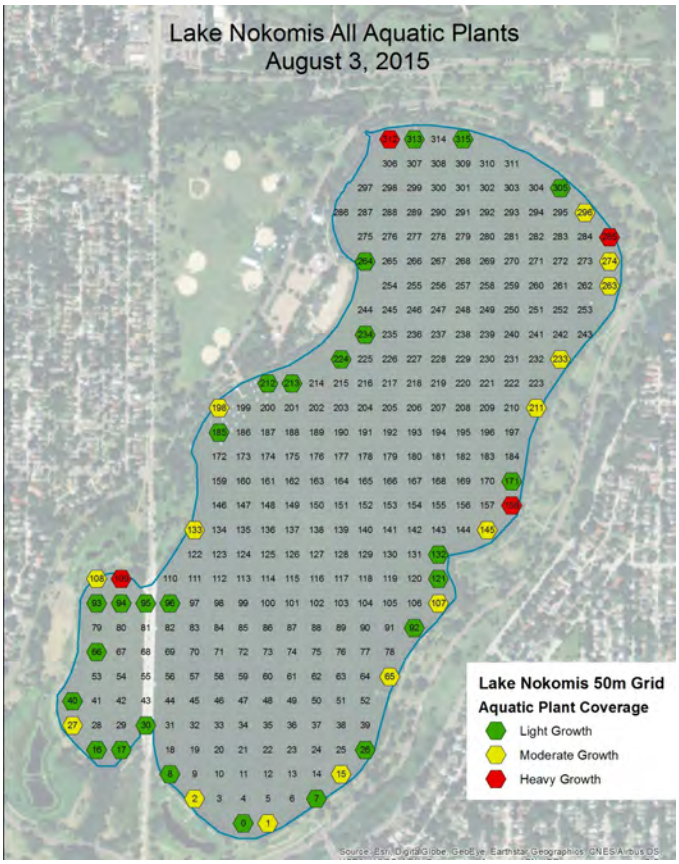


Figure 4. Aquatic plant coverage for August 3, 2015. Key: Green = light growth, yellow = moderate growth, and red = heavy growth.

Native Plants in 2010 through 2015

Native aquatic plants in Lake Nokomis in 2010 through 2015 have been increasing, with plants observed at 3 sites in 2010, at 4 sites in 2011, at 11 sites in 2012, 23 sites in 2013, 37 sites in 2014, and 41 sites in 2015 (Figure 5). Coontail was the dominant native plant found growing out to 11 feet in 2015. Native plants have shown an increase in distribution since 2010.

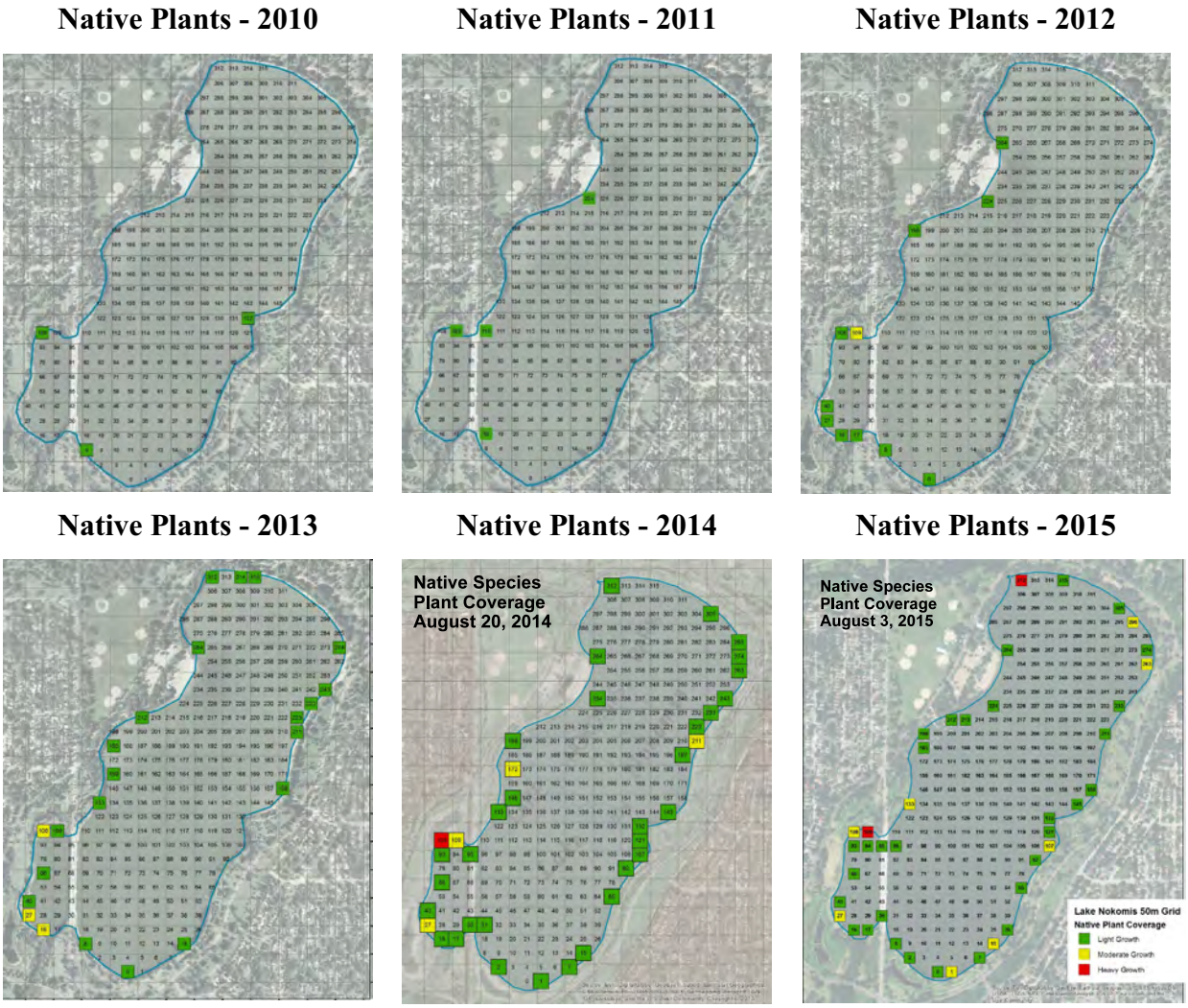


Figure 5. Occurrence of native aquatic plants in Lake Nokomis in 2010 through 2015. Green squares represent light growth of plants, yellow square represents moderate growth of plants, and red squares represents heavy growth of plants.

Eurasian Watermilfoil in 2010 through 2015

Eurasian watermilfoil was the dominant submerged aquatic plant in Lake Nokomis in 2010 through 2015. 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.

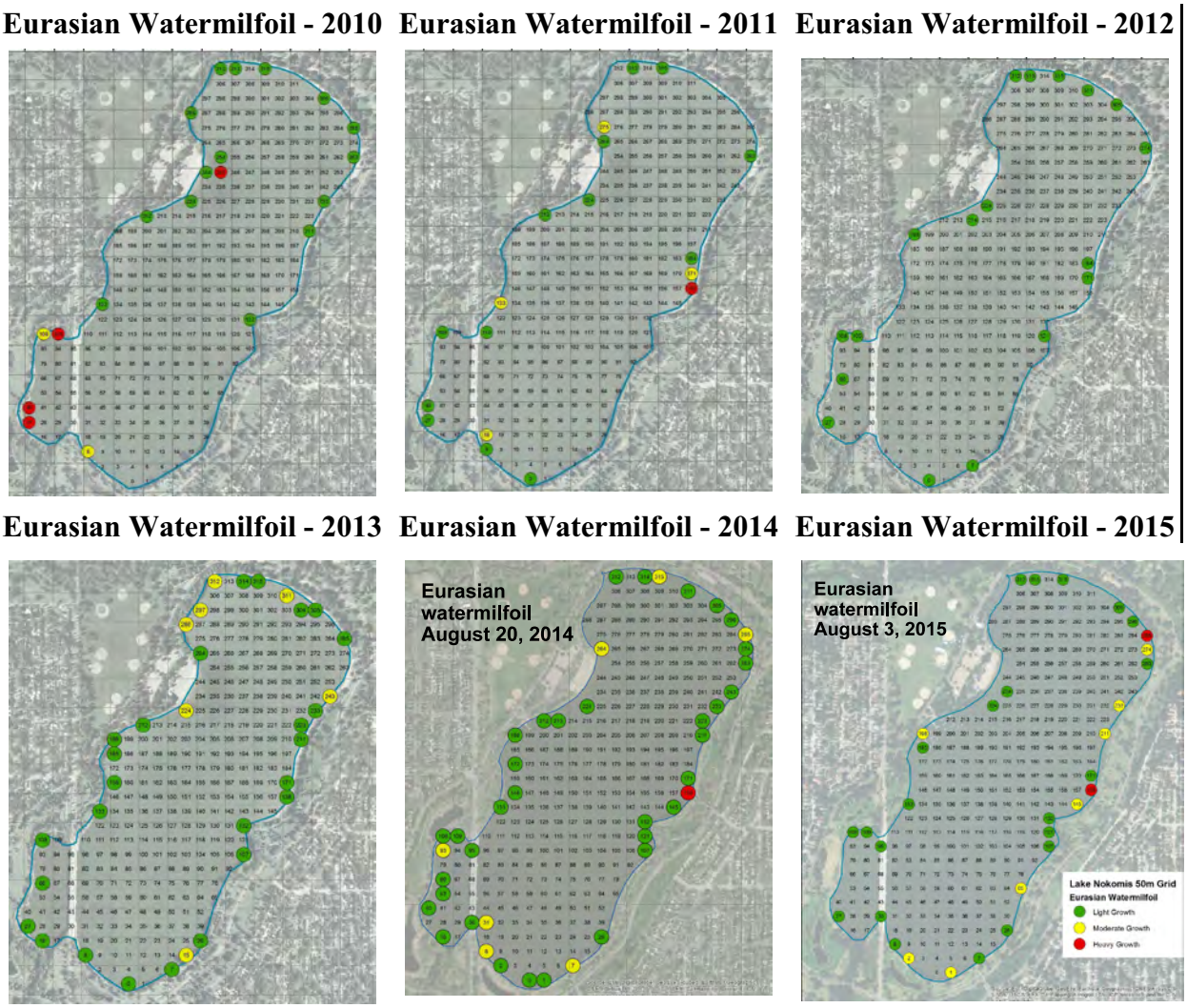


Figure 6. Occurrence of Eurasian watermilfoil in Lake Nokomis in 2010 through 2015. Green circles = light growth, yellow circles = moderate growth, and red circles = red growth.

Aquatic Plant Distribution in 2008, 2010 through 2015 and Potential Future Growth in Lake Nokomis

Previous surveys conducted on Lake Nokomis have found a sparse aquatic plant community (Figure 8). 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.

Since 2010, there has been an increase in aquatic plant distribution.

Table 3. Summary of aquatic plant surveys in 2008, 2010 through 2015. Sample sites within the littoral zone were 173 sites.

	2008 105 nearshore sites - Sept (conducted by the MPRB)		**2010** 173 sites 0-15 ft deep Sept 9		**2011** 173 sites 0-15 ft deep July 15		**2012** 173 sites 0-15 ft deep August 29		**2013** 173 sites 0-15 ft deep July 18		**2014** 173 sites 0-15 ft deep June 20		**2014** 173 sites 0-15 ft deep August 20		**2015** 173 sites 0-15 ft deep August 3	
	Sites	% Occur	Sites	% Occur	Sites	% Occur	Sites	% Occur	Sites	% Occur	Sites	% Occur	Sites	% Occur	Sites	% Occur
Chara	0	0	0	0	0	0	0	0	1	1%	0	0	1	1%	0	0
Coontail	21	20%	3	1%	3	1%	10	5%	11	6%	11	6%	21	12%	23	13%
Elodea	0	0	0	0	0	0	0	0	1	1%	3	2%	9	5%	19	11%
Eurasian watermilfoil	64	61%	21	12%	18	10%	18	10%	33	19%	15	9%	43	25%	32	18%
Naiads	0	0	0	0	0	0	0	0	0	0	0	0	3	2%	6	3%
Cabbage	0	0	0	0	0	0	0	0	0	0	0	0	1	1%	0	0
Curlyleaf pondweed	1	1%	0	0	0	0	0	0	2	1%	1	1%	4	2%	3	2%
Floatingleaf	0	0	0	0	0	0	0	0	0	0	1	1%	2	1%	4	2%
Stringy pondweed	0	0	0	0	1	1%	0	0	7	4%	1	1%	16	9%	12	7%
Sago pondweed	0	0	0	0	0	0	2	1%	6	4%	0	0	5	3%	5	3%
Whitestem pondweed	0	0	0	0	0	0	0	0	1	1%	0	0	0	0	0	0
Number of Species	3	--	2	--	3	--	3	--	8	--	6	--	10	--	8	--
Plant Coverage (ac)	--		13		12		15		22		--		32		29	

Aquatic Plant Coverage (all species): 2008 - 2015

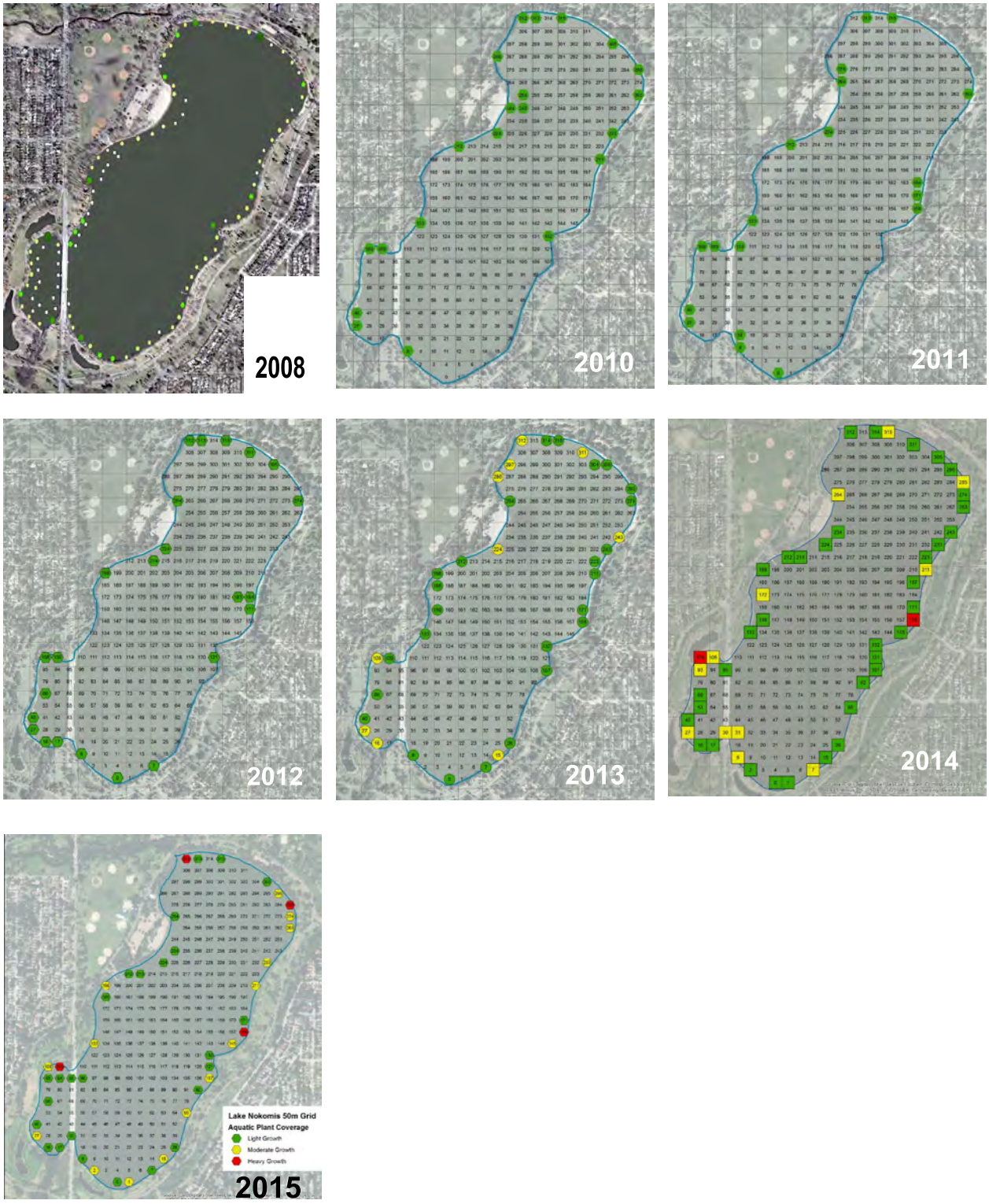


Figure 7. [top-left] September 2008 (source: Mpls Park and Rec Board)(all species). [top-middle] September 9, 2010 (plant growth to 9 feet). [top-right] July 15, 2011 (plant growth to 11 feet–1 site, otherwise growth was out to 9 feet). [middle-left] August 29, 2012 (plant growth to 7 feet). [middle-middle] July 18, 2013 (plant growth to 9 feet). [middle-right] August 20, 2014 (plant growth to 10 feet). [bottom-left] August 3, 2015 (plant growth to 12 feet).

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 light 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 light growth is expected with the potential for heavy growth in the south end of the lake. In past surveys, actual Eurasian watermilfoil growth in Lake Nokomis has been 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

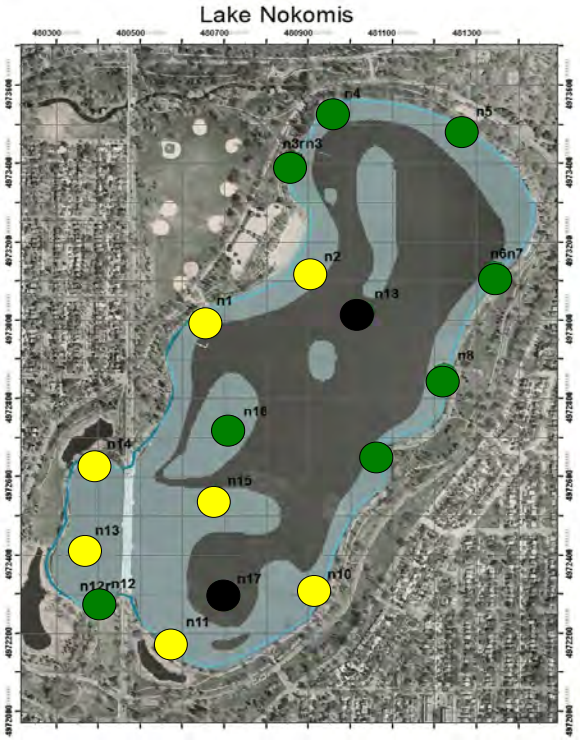


Figure 8. Sediment sample locations are shown with a circle. The circle color indicates the type of curlyleaf pondweed growth predicted to occur at that site. Key: green = light; yellow = moderate; red = heavy. (Two black circles are deep water and there is no plant growth).

Potential Eurasian Watermilfoil Growth

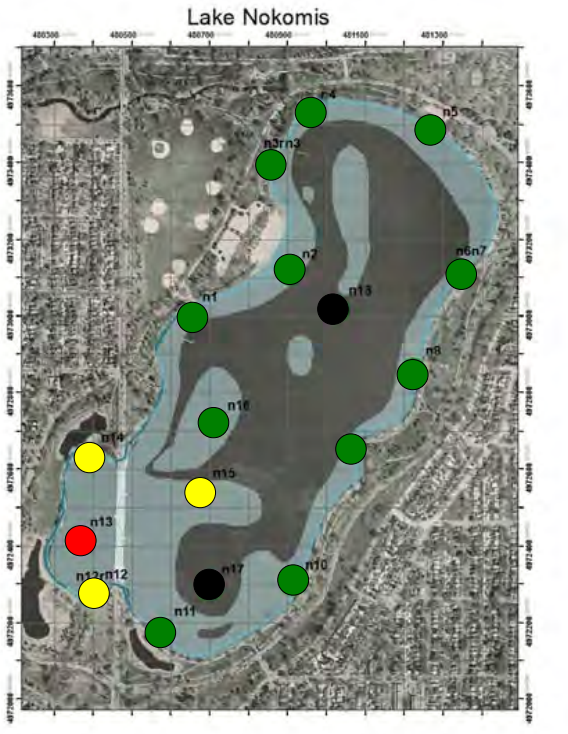


Figure 9. Sediment sample locations are shown with a circle. The circle color indicates the type of Eurasian watermilfoil growth predicted to occur at that site. Key: green = light; yellow = moderate; red = heavy. (Two black circles are in deep water and there is no plant growth).

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)

2012 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	Sago	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
233	12				1
287	12				1
52	13				1
39	14				1
253	14				1
158					1
234					1
244					1

2013 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)	Chara	Coontail	CLP	Elodea	EWM	Sago	Stringy	White-stem	NO PLANTS
1	3									1
132	4					1				
184	4									1
213	4									1
214	4									1
225	4									1
305	4					1				
312	4		1			3				
396	4									1
7	5					1				
26	5					1				
108	5		3			1				
121	5									1
133	5					1	1			
159	5		2			1				
198	5					1				
211	5					1		1		
212	5		1			1				
223	5			1		2	1			
233	5					1	1			
264	5	1				1		1		
274	5							1		
311	5					3				
314	5					2	1			
315	5					1	1			
15	6		1			3		1		
40	6			1				1	1	
53	6									1
66	6		1		1	1				
107	6					2				
243	6					3		1		
286	6					3				
297	6					3				
0	7					2		1		
8	7		1			1				
27	7		3			1				
158	7					1	1			
185	7		1			1				
224	7					3				
145	8									1
171	8					1				
197	8									1
304	8					1				
16	9		3			1				
109	9		1							
285	9					1				
17	10									1
146	10									1
254	10									1
2	11									1
92	11									1
110	11									1
122	11									1
199	12									1
245	12									1
52	13									1
172	13									1
275	13									
39	14									1
65	14									1
78	14									1
134										1
147										1
183										1
215										1
265										1
298										1
308										1

June 20, 2014: Aquatic plant occurrences and densities for the sample points. Plant density was assigned based on a scale from 1 - 5 with 5 the densest.

Site	Depth (ft)	Cabbage	Chara	Coontail	CLP	Elodea	EWM	Floating-leaf	Naiad	Sago	Stringy	No Plants
1	4				1		1		1	1	1	
7	4			1		1	3			1		
30	4	3		1		1	1					
31	4						3		1			
93	4			2			3		1			
95	4			1		2	1					
108	4			4			1				1	
132	4						1				2	
158	4						4					
211	4			1			1	3		1	1	
264	4			2			3			2		
8	5						3					
16	5						2				1	
65	5										2	
66	5			1		1	1					
145	5						2			1	1	
146	5			1		1	2					
224	5						2					
234	5										1	
243	5		1				2					
244	5											1
263	5						1				1	
272	5						1				2	
285	5			1			3					
172	6			3			2					
198	6			2			2					
223	6						2				1	
233	6						1				1	
296	6						1					
305	6						1				1	
312	6			1			1					
315	6				1		3					
0	7						1					
2	7			2			1					
15	7					1					1	
26	7						2					
109	7			3		1	1					
121	7			1			1					
213	7				1		1					
27	8			3		1						
92	8										1	
133	8			1			1					
171	8						1					
184	8											1
197	8							1				
212	8						1					
314	8						1					
40	9			1	1	2	1					
107	9			1			1				1	
297	9											1
311	9						1					
17	10			2								
53	10						1					
286	10											1
78	11											1
79	11											1
122	11											1
185	11											1
6	12											1
18	13											1
29	13											1
39	13											1
110	13											1
3	14											1
64	15											1
143	15											1
144	15											1
199	15											1
295	15											1
304	15											1
313	15											1
52	16											1
159	16											1
253	16											1

August 20, 2014: Aquatic plant occurrences and densities for the sample points. Plant density was assigned based on a scale from 1 - 5 with 5 the densest.

Site	Depth (ft)	Cabbage	Chara	Coontail	CLP	Elodea	EWM	Floating-leaf	Naiad	Sago	Stringy	No Plants
1	4				1		1		1	1	1	
7	4			1		1	3			1		
30	4	3		1		1	1					
31	4						3		1			
93	4			2			3		1			
95	4			1		2	1					
108	4			4			1				1	
132	4						1				2	
158	4						4					
211	4			1			1	3		1	1	
264	4			2			3			2		
8	5						3					
16	5						2				1	
65	5										2	
66	5			1		1	1					
145	5						2			1	1	
146	5			1		1	2					
224	5						2					
234	5										1	
243	5		1				2					
244	5											1
263	5						1				1	
272	5						1				2	
285	5			1			3					
172	6			3			2					
198	6			2			2					
223	6						2				1	
233	6						1				1	
296	6						1					
305	6						1				1	
312	6			1			1					
315	6				1		3					
0	7						1					
2	7			2			1					
15	7					1					1	
26	7						2					
109	7			3		1	1					
121	7			1			1					
213	7				1		1					
27	8			3		1						
92	8										1	
133	8			1			1					
171	8						1					
184	8											1
197	8							1				
212	8						1					
314	8						1					
40	9			1	1	2	1					
107	9			1			1				1	
297	9											1
311	9						1					
17	10			2								
53	10						1					
286	10											1
78	11											1
79	11											1
122	11											1
185	11											1
6	12											1
18	13											1
29	13											1
39	13											1
110	13											1
3	14											1
64	15											1
143	15											1
144	15											1
199	15											1
295	15											1
304	15											1
313	15											1
52	16											1
159	16											1
253	16											1

August 3, 2015: Aquatic plant occurrences and densities for the sample points. Plant density was assigned based on a scale from 1 - 5 with 5 the densest.

Site	Depth (ft)	Coontail	CLP	Elodea	EWM	Floatingleaf	Naiad	Sago	Stringy	No plants
7	4	1		2	2				1	
30	4			2	1					
158	4				4			1		
211	4				3			1		
285	4				4					
1	5	1		1	3		3		1	
2	5		1	1	3					
108	5	3			1					
132	5				2		2		1	
133	5	3		1	1		1		1	
148	5	2			3					
312	5	4			1					
8	6			1	1				1	
15	6			1		1	3			
65	6	1		1	3					
145	6			1	3					
171	6				2					
224	6				1				1	
233	6				3	1		1		
234	6		1		2					
263	6			3	2			1	2	
274	6			1	3	1			1	
296	6	3			1			1		
26	7	1		1	1				1	
27	7	3			2					
92	7								2	
107	7	3		1	1				1	
109	7	4			1					
184	7									1
305	7			1	2	1	1			
315	7	1			1					
17	8	1								
185	8	2	1	1	2					
95	9	1		2	2					
96	9			2						
121	9				2		1			
213	9								1	
243	9									1
313	9				1					
66	10	1								
93	10	1								
212	10	2		1						
314	10									1
0	11	1								
16	11	2								
40	11	1								
146	11									1
264	11	1								
94	12			1						
286	12									1
29	13									1
79	13									1
223	13									1
18	14									1
31	14									1
39	14									1
53	14									1
110	14									1
179	14									1
311	14									1
122	15									1
159	15									1
199	15									1
62	16									1
197	16									1
297	16									1

Attachment 2

Walleyes from Lake Nokomis, October 2014

Fish Survey for Lake Nokomis (ID #27-0019), Minneapolis, Minnesota in 2015

Trapnet Fish Survey Dates: October 20-22, 2015

MnDNR Fish Permit Number: 20691

Prepared for:
Minnehaha Creek Watershed District and MnDNR

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

November 24, 2015

Fish Survey for Lake Nokomis (ID #27-0019), Minneapolis, Minnesota in 2015

Summary

Lake Nokomis is a 201 acre lake located in Hennepin County, Minnesota. On October 20-22, 2015, 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 2015 fish survey along with other trapnet surveys going back to 1948 are shown in Table S1. A total of 12 species were sampled in 2015. The fish catch was dominated by bluegill sunfish and the abundance of other fish species were within or close to normal range for fish of similar lakes (based on MnDNR statistics). Several fish species have increased in density in the last couple of years including black crappies and yellow perch (Figure S1).

Bluegill sunfish densities appear to be decreasing compared to the higher densities from 2007 to 2011 and their contribution to poor water quality in Lake Nokomis should be decreasing. It is recommended that a bluegill control program should continue using stocked walleyes as the primary predator. Walleyes have the potential to keep both bluegill sunfish and black bullheads under control if walleye abundance remains high.

Figure S1. Yellow perch were caught at an average rate of 11/net.

Table S1. Lake Nokomis trapnet results for fish surveys conducted from 1948 - 2005 and 2010 - 2015. The 2008, 2011 through 2015 surveys were conducted by Blue Water Science, all other surveys were conducted by the MnDNR. Data shown is fish per net.

	1948 May 5	1958 May 19	1972 July 1	1975 Aug 5	1977 Jun 29	1982 Jun 25	1987 Jun 24	1991 May 2	1992 Jun 22	1996 Jun 24	2001 July 19
Black Bullhead	1	6.7	2	0.6	3.4	13	12	26	6	7.8	1.6
Black Crappie	1.6	83	12	11	16	98	28	5	133	293	23
Bluegill	0.9	20	1	0.4	21	23	75	0.4	115	94	54
Bowfin						0.3	0.3				
Brown Bullhead				0.1		0.3					
Carp	0.08	0.2		0.3	0.6	2			0.4	0.2	
Golden Shiner		0.5			0.4	0.1	0.3	0.1	5.1	4.3	0.9
Goldfish											0.1
Green Sunfish		0.3					1.8	0.1		1.4	2.4
Hybrid Sunfish		0.3		0.3	0.6	1.9	2.3		1.1	0.2	4.4
Largemouth Bass	0.3	0.3					1.3			0.1	0.1
Northern Pike			0.1	0.1	0.3	0.3					
Pumpkinseed		16			0.7	4	7	0.7	13	2.2	3.8
Tiger Muskie										0.2	0.1
Walleye						0.9	0.3	3	3.1	2	0.4
White Crappie			8.9							1.6	
White Sucker	0.08	0.1	0.6	0.2	1	4.5		1.3	2.3	1.3	0.4
Yellow Bullhead	0.08					0.5	0.8	0.6	0.3	0.3	0.1
Yellow Perch	0.08	1.7	12	2	2.7	4.3	15	5	15	21	6.8
Number of fish species	8	11	7	9	10	14	12	10	11	15	14

	2005 July 18	2007 July 16	2008 July 10 (BWS)	2010 July 17	2011 Oct 11 (BWS)	2012 Oct 11 (BWS)	2013 Jun 29 (BWS)	2014 Oct 1 (BWS)	2015 Oct 20 (BWS)	% occur for all surveys
Black Bullhead	1.3	2.6	5.7	0.8	0.1		0.5	0.2	0.1	95%
Black Crappie	2	5.8	14	4.9	14	5.5	26	24	77	100%
Bluegill	27	183	474	188	158	21	46	64	71	100%
Bowfin	0.2	0.1				0.1		0.1	0.3	35%
Brown Bullhead										10%
Carp		0.1				0.2	0.1	0.1		55%
Golden Shiner	0.2		0.08				0.1	0.3	0.3	65%
Goldfish										5%
Green Sunfish	0.1									30%
Hybrid Sunfish	0.9	0.6	0.2	1.0				0.2	0.3	70%
Largemouth Bass							0.1	0.2	0.3	40%
Northern Pike										20%
Pumpkinseed	0.6	4.5	3.3	0.4	1.3	1.2	0.7	5.2	4.8	85%
Tiger Muskie	0.1									15%
Walleye	1.2	0.3	0.5	0.7	3.8	2.8	0.4	3.3	2.3	75%
White Crappie				0.4		0.1				20%
White Sucker	2.1		0.5	0.1	1.0	0.4	0.4	0.3	0.1	90%
Yellow Bullhead		0.1						0.2	0.1	50%
Yellow Perch	3.8	0.4	0.5	1.0	1.5	2.3	0.3	23	11	100%
Number of fish species	12	10	9	9	7	9	10	13	12	

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)(based on data in Table S2). 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 an evolving issue in Lake Nokomis.

Table S2. Lake Nokomis fish survey results for bluegill sunfish, carp, and black bullheads for surveys conducted from 1948 through 2014. Water quality parameters in the green boxes represent unimpaired water quality conditions.

	Average	Water Quality (May-Sept)			Fish Survey Results for Benthivores and Planktivores						Zooplankton (May-Sept)	
	Annual Rainfall (inches)	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)	Copepods + Cladocerans (#/l)	Cladorcerans (#/l)
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							330	151
2004	27	1.1	83	28							263	51
2005	33	1.2	57		27	2	1.0	0	56	1.3	372	77
2006	28	1.0	67	36							148	53
2007	24	1.1	56	29	183	6	0.3	0.1	28	2.6	171	49
2008	22	1.1	44	12	474	14		0		5.7	123	52
2009	25	1.0	60	25							271	44
2010	33	1.2	47	22	188		0.5	0	2.3	0.8	89	18
2011	28	1.4	36	14	158	14		0		0.1	191	41
2012	30	1.2	46	21	21	6		0.2		0	219	69
2013	34	1.3	53	18	46	26		0.1		0.5	214	58
2014	36	1.8**	34**	10**	64	24		0.1		0.2		
2015	20*	1.3**	38**	11**	71	77				0.1		

*Precipitation through July for Hennepin County.
**June-September average

Conclusions and Recommendations

Even with significant walleye stocking, the walleye abundance (based on fish per trapnet) fluctuates in Lake Nokomis. However, since 2011, walleye abundance has been above average (except for 2013) compared to previous surveys going back to 1948. In addition, the abundance of bluegill sunfish and black bullheads are lower in number compared to 2008 which was one of the lake management objectives. With a less dense population maybe bluegill food habits will change from a benthic (bottom) feeding mode to a more open water mode. This could benefit water quality. The carp population in Lake Nokomis appears to be at a moderate level based on an electrofishing survey conducted by the University of Minnesota in the summer of 2014 and 2015. The combined effects of external loading, carp activities, and the relative abundance of bluegill sunfish could play a role in producing moderately poor 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, 50 ppb of TP, and 14 ppb of chlorophyll), continuing predation pressure by walleyes on black bullheads and bluegill sunfish would be beneficial. A carp management program is also in progress.

It is theorized that 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.

Ongoing Recommended Lake Projects

1. Evaluate the performance of key stormwater wetlands and ponds that are tributary to Lake Nokomis.

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

3. Conduct an annual fish survey in Lake Nokomis to track the fish community, especially for walleye and bluegill abundance.

4. Conduct trapnet surveys is tributary ponds and lakes to characterize carp status as well as other fish species.

5. The connection between Mother Lake (lake to the south of Lake Nokomis) and Lake Nokomis as a source of carp to Lake Nokomis should be investigated.

6. If water quality does not consistently meet unimpaired status, a potential project is a carp removal option. Electrofishing in 2014 and 2015, conducted by the University of Minnesota, found carp at an estimated 200 pounds or more per acre. In the next couple of years winter seining for carp removal should be considered. Annual seining should be continued annually until less than 10,000 pounds/winter are netted.

Fish Survey for Lake Nokomis (ID #27-0019), Minneapolis, Minnesota in 2015

Introduction

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

In October of 2015, the Minnehaha Creek Watershed District contracted for a fish survey with Blue Water Science with a permit number 20691 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 Tuesday morning on October 20, 2015. Six nets were fished for the following 2 days (October 21, 22). Trapnet locations are shown in Figure 1 and pictures of a typical trapnet are shown in Figure 2.

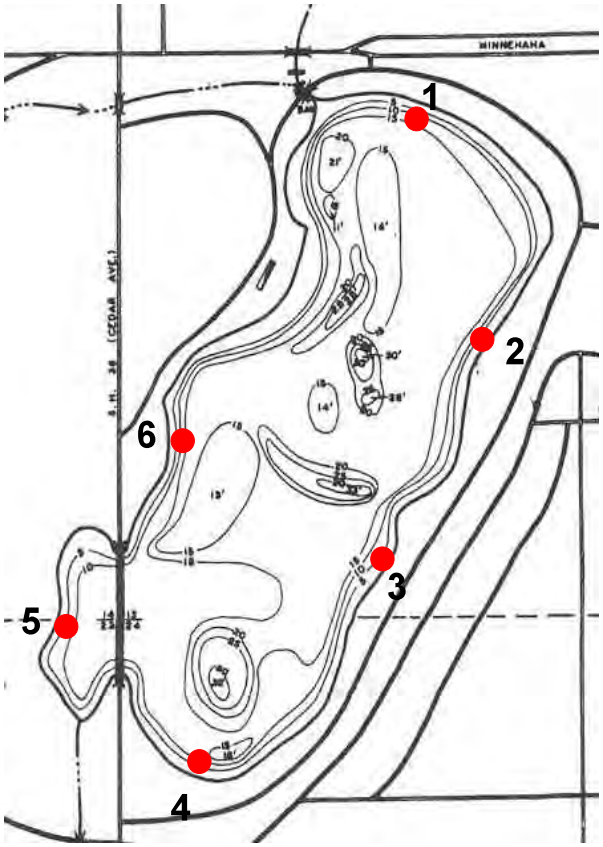


Figure 1. Map of trapnet sets for 2015.

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

Fish Trapnet Survey on October 21-22, 2015: A total of 12 fish species were sampled in Lake Nokomis on October 21-22, 2015. The fish catch was dominated by black crappies. The number of black crappies caught per net was high with the average haul of 77 per net (Table 1). This is above the normal range of 2-21 black crappies per lift for a lake like Lake Nokomis.

Bluegill sunfish were found in high numbers and were above the normal range for lakes of the Lake Nokomis type, as defined by the MnDNR.

Walleyes were sampled with a high average abundance (Table 1).

Table 1. Lake Nokomis trapnet results for the fish survey conducted in October 21-22, 2015.

	Fish Captured (October 21-22, 2015)												Total Catch	2015 Fish per Net (n=12)	Normal Range (MnDNR)
	Net 1		Net 2		Net 3		Net 4		Net 5		Net 6				
	Day 1	Day 2	Day 1	Day 2	Day 1	Day 2	Day 1	Day 2	Day 1	Day 2	Day 1	Day 2			
Black bullhead (*Ameiurus melas*)									1				1	0.1	0.7 - 25.7
Black crappies (*Pomoxis nigromaculatus*)	7	3	46	9	19	38	133	141	418	75	25	15	929	77.4	1.8 - 21.2
Bluegill sunfish (*Lepomis macrochirus*)	1		14	7	18	21	243	195	203	46	72	33	853	71.1	7.5 - 62.5
Bowfin (*Amia calva*)		1							1	1			3	0.3	NA
Golden shiner (*Notemigonus crysoleucas*)	3												3	0.3	NA
Hybrid sunfish (*Lepomis sp*)									1	2			3	0.3	NA
Largemouth bass (*Micropterus salmoides*)			1						1		1		3	0.3	NA
Pumpkinseed (*Lepomis gibbosus*)							2	3	33	19	1		58	4.8	0.7 - 4.2
Walleye (*Sander vitreus*)	4		2	2	1	1	1		5		10	1	27	2.3	0.3 - 1.2
White sucker (*Catostomus commersonii*)									1				1	0.1	0.2 - 1.0
Yellow bullhead (*Ameiurus natalis*)									1				1	0.1	NA
Yellow perch (*Perca flavescens*)	10	32	3	2	17	23	3	6	12	11	9	4	132	11.0	0.3 - 1.7
TOTAL FISH	25	36	66	20	55	83	382	345	677	154	118	53	2,014	168	
Black crappies - YOY (*Pomoxis nigromaculatus*)	2					1			8	5			16	1.3	
Bluegill sunfish - YOY (*Lepomis macrochirus*)	12	14			1	1	2		121	26			177	14.8	

Figure 3. Three largemouth bass were sampled in 2015. A spawning population is present, but numbers are low.

Length Frequencies: Fish lengths are shown in Table 2. In 2015, approximately 75% of the bluegill catch were 6 inches or greater. Walleyes have been stocked in Lake Nokomis for a number of years and walleyes, with lengths up to 23 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 on October 21-22, 2015 (number in parentheses are number of measured fish). Bluegills less than 3 inches were considered young-of-the-year and were not included in the statistics.

Length (inches)	Black bullhead (n=1)	Black crappie (n=343)	Bluegill sunfish (n=291)	Bowfin (n=3)	Golden shiner (n=3)	Hybrid sunfish (n=3)	Large-mouth bass (n=2)	Pumpkin-seed (n=58)	Walleye (n=27)	White sucker (n=1)	Yellow bullhead (n=1)	Yellow perch (n=132)
<3		16	186									
3.5			1		1		1					2
4			4		2			7				
4.5			12					9				
5			9			1	1	26				
5.5		1	46			2		14				1
6		32	128					2				23
6.5		126	46									54
7		147	34									45
7.5		20	8									6
8	1	11	3									1
8.5		5										
9		1										
9.5									1			
10									3			
10.5												
11									5			
11.5												
12									1		1	
12.5												
13												
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17									2			
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18									2	1		
18.5												
19									1			
19.5												
20									5			
20.5									1			
21									3			
21.5									2			
22												
22.5									1			
23												
23.5												
24				1								
24.5												
25				1								
25.5				1								
26												
26.5												
27												
Total measured	*1*	*343*	*291*	*3*	*3*	*3*	*2*	*58*	*27*	*1*	*1*	*132*

Representative Fish Species from Lake Nokomis in 2015

Figure 4. Top-left: Black bullhead. Top-middle: Black crappie. Top-right: Bluegill sunfish. Middle-top-left: Carp. Middle-top-middle: Dogfish (bowfin). Middle-top-right: Golden shiner Middle-bottom-left: Largemouth bass. Middle-bottom-middle: Pumpkinseed sunfish. Middle-bottom-right: Walleye. Bottom-left: White sucker. Bottom-middle: Yellow bullhead. Bottom-right: Yellow perch.

Summary of Past Fish Surveys

Trapnet Results: There have been 20 trapnet fish surveys from 1948 - 2015. The number of species has ranged from a low of 7 in 1972 and 2011 to a high of 15 in 1996. In 2015, walleyes were the dominant piscivore. Three largemouth bass were sampled in 2015 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). Black bullhead numbers have been less than 1 per trapnet since 2010.

Figure 5. [top] Walleyes captured in one trapnet on October 21, 2015 in Lake Nokomis. [middle] Walleye sampled in Lake Nokomis. [bottom] Walleye mouth gape in 2015.

Table 3. Lake Nokomis trapnet results for fish surveys conducted from 1948 - 2005 and 2010 - 2015. The 2008, 2011 through 2015 surveys were conducted by Blue Water Science, all other surveys were conducted by the MnDNR. Data shown is fish per net.

	1948 May 5	1958 May 19	1972 July 1	1975 Aug 5	1977 Jun 29	1982 Jun 25	1987 Jun 24	1991 May 2	1992 Jun 22	1996 Jun 24	2001 July 19
Black Bullhead	1	6.7	2	0.6	3.4	13	12	26	6	7.8	1.6
Black Crappie	1.6	83	12	11	16	98	28	5	133	293	23
Bluegill	0.9	20	1	0.4	21	23	75	0.4	115	94	54
Bowfin						0.3	0.3				
Brown Bullhead				0.1		0.3					
Carp	0.08	0.2		0.3	0.6	2			0.4	0.2	
Golden Shiner		0.5			0.4	0.1	0.3	0.1	5.1	4.3	0.9
Goldfish											0.1
Green Sunfish		0.3					1.8	0.1		1.4	2.4
Hybrid Sunfish		0.3		0.3	0.6	1.9	2.3		1.1	0.2	4.4
Largemouth Bass	0.3	0.3					1.3			0.1	0.1
Northern Pike			0.1	0.1	0.3	0.3					
Pumpkinseed		16			0.7	4	7	0.7	13	2.2	3.8
Tiger Muskie										0.2	0.1
Walleye						0.9	0.3	3	3.1	2	0.4
White Crappie			8.9							1.6	
White Sucker	0.08	0.1	0.6	0.2	1	4.5		1.3	2.3	1.3	0.4
Yellow Bullhead	0.08					0.5	0.8	0.6	0.3	0.3	0.1
Yellow Perch	0.08	1.7	12	2	2.7	4.3	15	5	15	21	6.8
Number of fish species	8	11	7	9	10	14	12	10	11	15	14

	2005 July 18	2007 July 16	2008 July 10 (BWS)	2010 July 17	2011 Oct 11 (BWS)	2012 Oct 11 (BWS)	2013 Jun 29 (BWS)	2014 Oct 1 (BWS)	2015 Oct 20 (BWS)	% occur for all surveys
Black Bullhead	1.3	2.6	5.7	0.8	0.1		0.5	0.2	0.1	95%
Black Crappie	2	5.8	14	4.9	14	5.5	26	24	77	100%
Bluegill	27	183	474	188	158	21	46	64	71	100%
Bowfin	0.2	0.1				0.1		0.1	0.3	35%
Brown Bullhead										10%
Carp		0.1				0.2	0.1	0.1		55%
Golden Shiner	0.2		0.08				0.1	0.3	0.3	65%
Goldfish										5%
Green Sunfish	0.1									30%
Hybrid Sunfish	0.9	0.6	0.2	1.0				0.2	0.3	70%
Largemouth Bass							0.1	0.2	0.3	40%
Northern Pike										20%
Pumpkinseed	0.6	4.5	3.3	0.4	1.3	1.2	0.7	5.2	4.8	85%
Tiger Muskie	0.1									15%
Walleye	1.2	0.3	0.5	0.7	3.8	2.8	0.4	3.3	2.3	75%
White Crappie				0.4		0.1				20%
White Sucker	2.1		0.5	0.1	1.0	0.4	0.4	0.3	0.1	90%
Yellow Bullhead		0.1						0.2	0.1	50%
Yellow Perch	3.8	0.4	0.5	1.0	1.5	2.3	0.3	23	11	100%
Number of fish species	12	10	9	9	7	9	10	13	12	

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 and 2011 through 2015: The bluegill population structure may be changing in Lake Nokomis. In 2015, 75% of the bluegills were 6-inches or larger. In 2008, less than 10% of the bluegills were greater than 6-inches (Figures 6 and 7).

Figure 6. Bluegill sunfish in 2015.

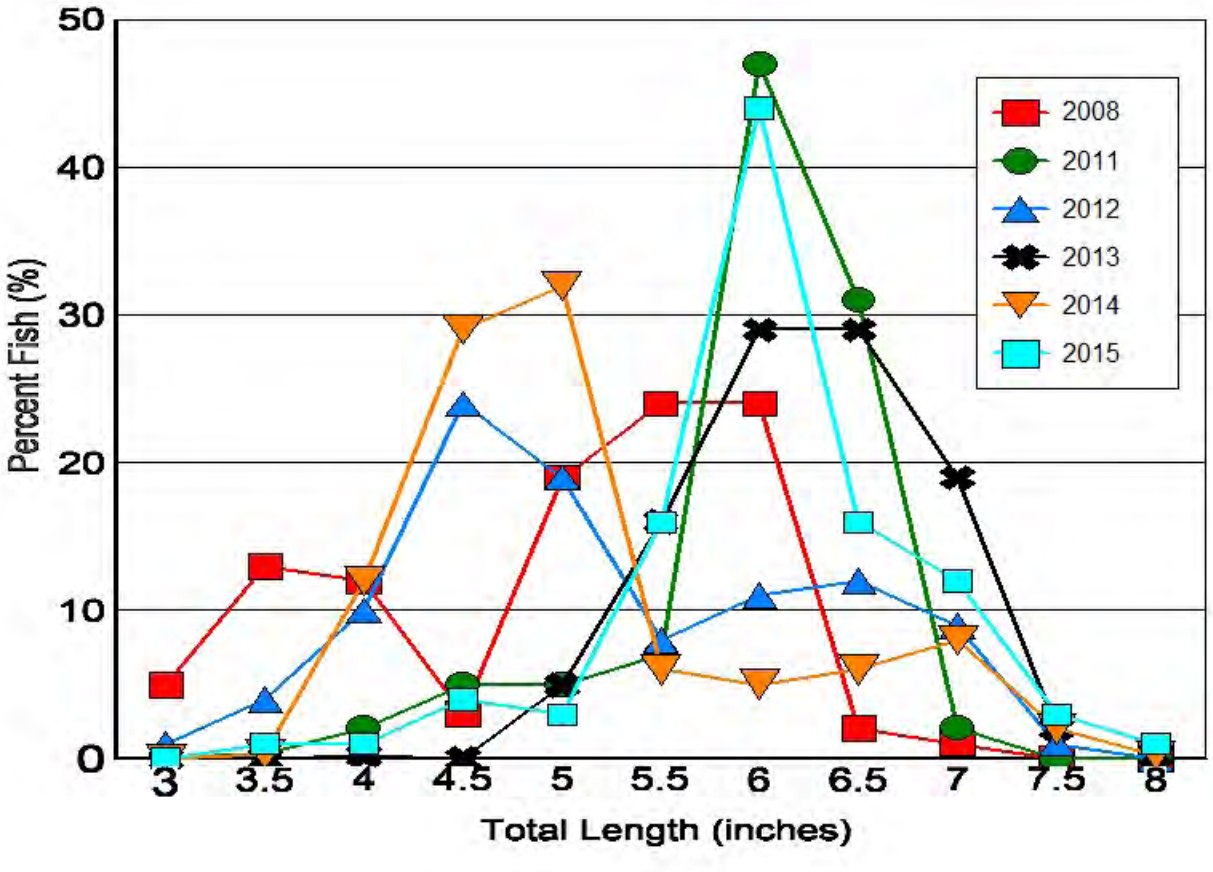

Figure 7. Bluegill sunfish length frequency comparison from 2008 to 2011 through 2015.

Comparing Walleye Lengths from 2008 and 2011 through 2015: Trapnet results since 2011 have been sampling walleyes over 20 inches in most years. Walleyes at these lengths have the potential to prey on panfish such as bluegills. Fishing pressure may also impact size structure of the walleye population. Ongoing stocking helps maintain a strong predator population.

Table 5. Walleye length frequencies for trapnet fish surveys from 2008 - 2015.

Length (inches)	2008 (12 nets)	2010 - MnDNR (11 nets)	2011 (12 nets)	2012 (12 nets)	2013 (12 nets)	2014 (12 nets)	2015 (12 nets)
3							
4							
5							
6				2			
7		3		1		1	
8						11	
9	1	1	3	2	2	2	4
10	1		7	2	1	1	5
11	2		6	5		3	
12			3	7			1
13			1	1	1		
14	1			1			
15	1					4	
16						6	
17		1					2
18		1	4	2		5	2
19		1	1	3		4	1
20		1	1	2	1		5
21			3	1			4
22			5			2	2
23			5	1			1
24			3	1			
25			2				
26			1				
Total	6	8	45	31	5	39	27
number/net	0.5	0.7	3.8	2.8	0.4	3.3	2.3

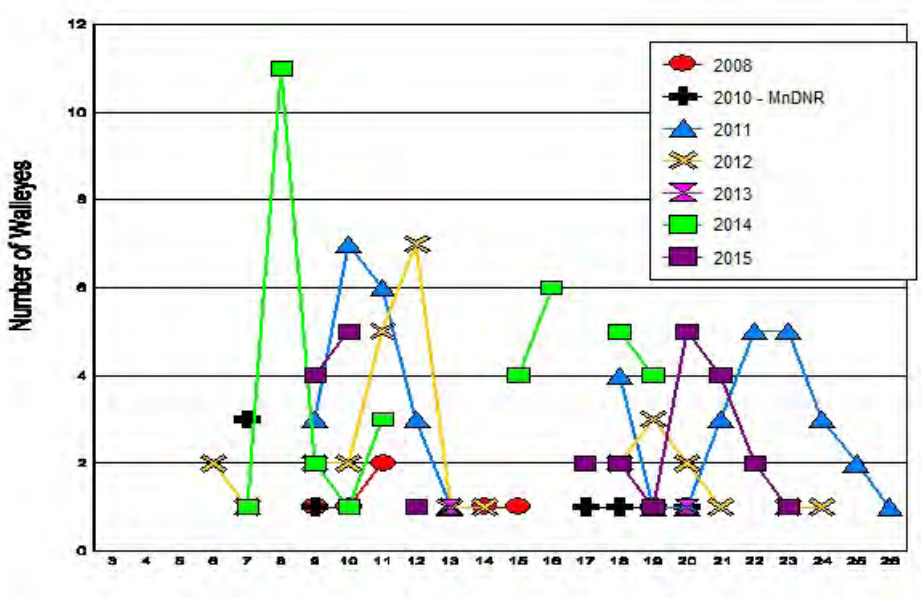

Figure 8. Walleye lengths found in the trapnet fish surveys from 2008 - 2015.

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 (Figure 9).

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 6).

Table 6. 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 9. [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 10). 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 6). This is a relatively low poundage of fish removed in 2011.

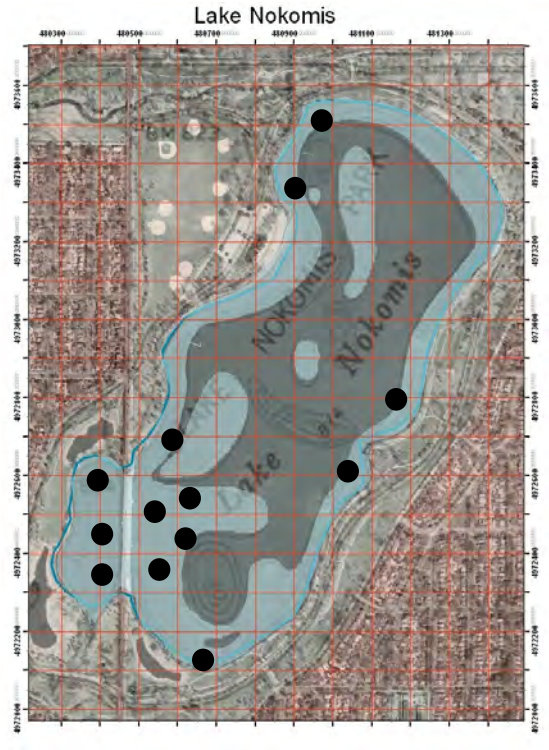

Figure 10. Hoopnet placement in 2010 for bullhead removal.

Figure 11. [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 in 2010, 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 12). 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 12. 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 and Muskie Stocking in from 2002 - 2015

Lake Nokomis is managed for walleyes and muskies and these species have been stocked over the years. In the last walleye stocking on October 22, 2015, approximately 350 walleye yearlings ranging in size from 9 to 12 inches were stocked in Lake Nokomis. Total weight of the stocked fish was about 300 pounds (1.2 fish to a pound).

A summary of walleye and muskie stocking from 2002 - 2015 is shown in Table 7. Approximately 3,247 pounds of walleye have been stocked into Lake Nokomis which is about 16.2 pounds per lake acre or about 1.2 pounds per acre per year. When the other piscivore species, the muskie, is included the total stocked piscivores is 3,663 pounds or 1.4 pounds of piscivores per acre per year.

Table 7. Fish stocked by species from 2002-2015.

Year	Species	Size	Number	Pounds
2015 (Oct 22)	Walleye	yearlings	350	300
2014	Tiger muskellunge	fingerlings	200	41.2
2013 (Oct 23)	Walleye*	fingerlings	2,000	240
2013 (Oct 21)	Walleye	fingerlings	7,518	259
2013 (Oct 18)	Walleye	fingerlings	958	62
2012 (Apr)	Walleye*	yearlings	2,000	286
2012	Tiger muskellunge	fingerlings	200	61.4
2011 (Oct 10)	Walleye	fingerlings	9,376	335
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 13. [left] In the October stocking, yearling walleyes stocked into Lake Nokomis were 9-12 inches in length. [right] Stocking was conducted by netting the fish out of the tanker and placing the net full of fish into the water.

Discussion: Plants, Fish, and Water Clarity

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, bullheads, or high densities of bluegill sunfish can uproot plants in their search for food. At the beginning of the project, there was a scarcity of submerged aquatic plants in Lake Nokomis but native plants, such as coontail, have started to increase (Figure 14). The lack of plants (Figure 15) has been attributed to excessive numbers of bottom feeding fish but two other factors may be involved: bathymetry of the lake and light-limited conditions.

Figure 14. Coontail is increasing in Lake Nokomis but submerged plants are still scarce. Plant surveys have been conducted by Blue Water Science from 2010 - 2015. Although several native plant species have been observed, the dominant plant has been the non-native Eurasian watermilfoil.

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 - 2015 by Blue Water Science. A map of aquatic plant distribution is shown in Figure 15.

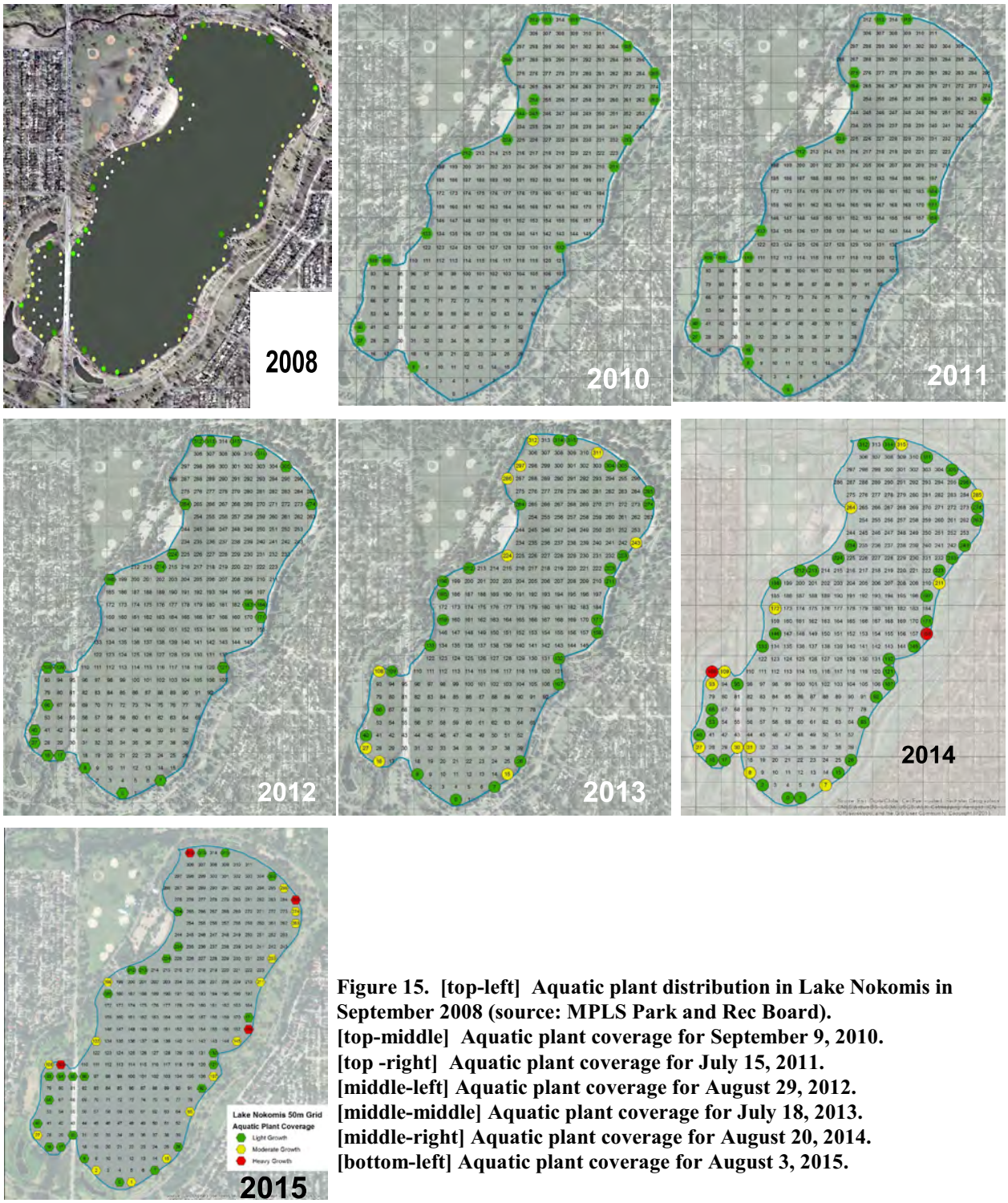

Figure 15. [top-left] Aquatic plant distribution in Lake Nokomis in September 2008 (source: MPLS Park and Rec Board). [top-middle] Aquatic plant coverage for September 9, 2010. [top -right] Aquatic plant coverage for July 15, 2011. [middle-left] Aquatic plant coverage for August 29, 2012. [middle-middle] Aquatic plant coverage for July 18, 2013. [middle-right] Aquatic plant coverage for August 20, 2014. [bottom-left] Aquatic plant coverage for August 3, 2015.

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 - 2015 is shown in Table 8. Plants were restricted to nearshore areas around the perimeter of Lake Nokomis. The depth of water that plants grew out to was between 7 to 9 feet deep from 2010-2015. In 2011, there was one site that plants grew in 11 feet of water.

Although plant colonization has been a low percentage of the lake area (around 10% in 2015), 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 rather than impacted by bottom feeding fish.

For Lake Nokomis, it is estimated that the lake area between 0 to 10 feet is about 25 acres and that plants occupy about 16 acres. Aquatic plants were estimated to cover about 13 acres of lake area, based on the 2010 survey and increased to about 32 acres in 2014. With the reduction of bottom feeding fish rooting in the sediments in the lake, the aquatic plants should have increased. If fish are having an impact, it is an indirect impact. Instead of up-rooting the plants, the fish are contributing nutrients into the open water. The excess nutrients produce algae blooms that lead to mid-summer transparencies around 1 meter or less, which create light-limited conditions for aquatic plants. A rule of thumb is plants grow to about twice the depth of mid-summer Secchi readings, therefore plants in Lake Nokomis would not be expected to grow much deeper than about 9 feet. It appears from the survey data that fish are not directly uprooting plants, rather creating light-limited conditions in Lake Nokomis.

Table 8. Summary of aquatic plant surveys in 2008, 2010 through 2015. Sample sites within the littoral zone were 173 sites.

	1982 June 23-25 (MnDNR)	1992* June 22-25 (MnDNR)	**2008** 105 nearshore sites - Sept (conducted by the MPRB)		**2010** 173 sites 0-15 ft deep Sept 9		**2011** 173 sites 0-15 ft deep July 15		**2012** 173 sites 0-15 ft deep August 29		**2013** 173 sites 0-15 ft deep July 18		**2014** 173 sites 0-15 ft deep June 20		**2014** 173 sites 0-15 ft deep August 20		**2015** 173 sites 0-15 ft deep August 3	
			Sites	% Occur	Sites	% Occur	Sites	% Occur	Sites	% Occur	Sites	% Occur	Sites	% Occur	Sites	% Occur	Sites	% Occur
Chara			0	0	0	0	0	0	0	0	1	1%	0	0	1	1%	0	0
Coontail			21	20%	3	1%	3	1%	10	5%	11	6%	11	6%	21	12%	23	13%
Elodea			0	0	0	0	0	0	0	0	1	1%	3	2%	9	5%	19	11%
Eurasian watermilfoil			64	61%	21	12%	18	10%	18	10%	33	19%	15	9%	43	25%	32	18%
Naiads			0	0	0	0	0	0	0	0	0	0	0	0	3	2%	6	3%
Cabbage			0	0	0	0	0	0	0	0	0	0	0	0	1	1%	0	0
Curlyleaf pondweed	common	occasional	1	1%	0	0	0	0	0	0	2	1%	1	1%	4	2%	3	2%
Floatingleaf			0	0	0	0	0	0	0	0	0	0	1	1%	2	1%	4	2%
Stringy pondweed			0	0	0	0	1	1%	0	0	7	4%	1	1%	16	9%	12	7%
Narrowleaf pondweed	common	present	0	0	0		0	0	0	0	0	0	0	0	0	0	0	0
Sago pondweed	common	present	0	0	0	0	0	0	2	1%	6	4%	0	0	5	3%	5	3%
Water stargrass	present		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Whitestem pondweed			0	0	0	0	0	0	0	0	1	1%	0	0	0	0	0	0
Number of Species			3	--	2	--	3	--	3	--	8	--	6	--	10	--	8	--
Plant Coverage (ac)			--		13		12		15		22		--		32		29	

* plants observed only along the north and northeast shore.

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 16 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 (Figure 16). This type of fish community structure is a benefit for fishing and for water quality. However, trapnetting results in 2012 and 2013 show a decrease in catch rate and in size distribution of walleyes (Table 8 and Figure 16). Fishing pressure may have an impact on the walleye population by reducing the numbers and the size. However, walleye numbers rebounded in 2014 (Table 8 and Figure 16).

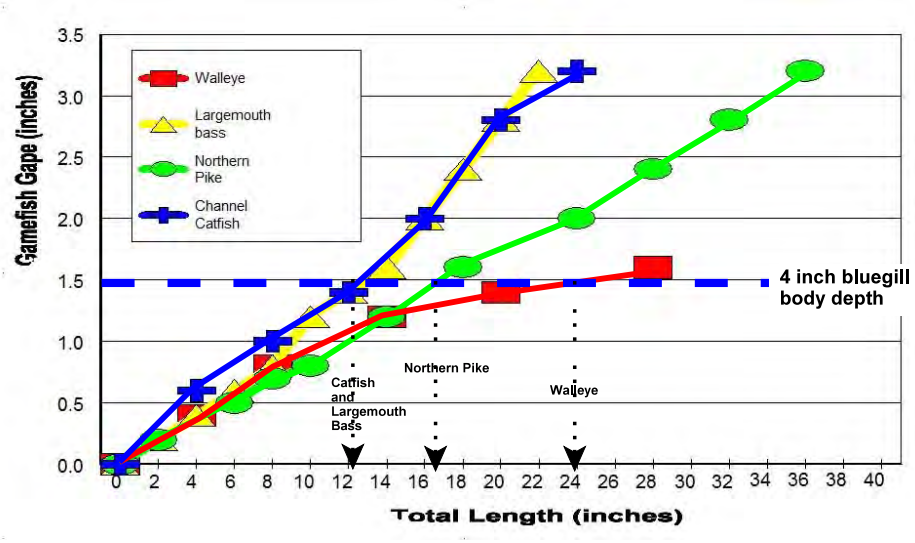

Figure 16. Gamefish gape increases as a function of it's total length. The gape determines the size of the prey fish that can be swallowed. For example, a 4-inch bluegill has a body depth of 1.5 inches. To ingest a 4-inch bluegill it would take a 12-inch bass that has a gape of 1.5 inches. There are walleyes in Lake Nokomis that should be able to ingest 4-inch bluegills or smaller.

Figure 17. 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.

Conclusions and Recommendations

The walleye abundance (based on fish per trapnet) fluctuates in Lake Nokomis. In 2014, walleye abundance was the second highest (at 3.3 walleyes/trapnet) since 1948. In addition, the abundance of bluegill sunfish and black bullheads are lower in number compared to 2008 which was one of the lake management objectives. With a less dense population maybe bluegill food habits will change from a benthic (bottom) feeding mode to a more open water mode. This could benefit water quality. The carp population in Lake Nokomis appears to be at a moderate level based on an electrofishing survey conducted by the University of Minnesota in the summer of 2014. The combined effects of external loading, carp activities, and the relative abundance of bluegill sunfish could play a role in the producing moderately poor 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, 50 ppb of TP, and 14 ppb of chlorophyll), continuing predation pressure by walleyes on black bullheads and bluegill sunfish would be beneficial.

It is theorized that 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.

Ongoing Recommended Lake Projects

1. Evaluate the performance of key stormwater wetlands and ponds that are tributary to Lake Nokomis.

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

3. Conduct an annual fish survey in Lake Nokomis to track the fish community, especially for walleye and bluegill abundance.

4. Conduct trapnet surveys is tributary ponds and lakes to characterize carp status as well as other fish species.

5. The connection between Mother Lake (lake to the south of Lake Nokomis) and Lake Nokomis as a source of carp to Lake Nokomis should be investigated.

6. If water quality does not consistently meet unimpaired status, a potential project is a carp removal option. Electrofishing in 2014, conducted by the University of Minnesota, found carp at an estimated 200 pounds or more per acre. In the next couple of years winter seining for carp removal should be considered. Annual seining should be continued annually until less than 10,000 pounds/winter are netted.

References

Andersson, G., H. Berggren, G. Cranberg, and C. Glenn. 1978. Effects of planktivorous and benthivorous fish on organisms and water chemistry in eutrophic lakes. Hydrobiologia 59:9-15.

Brabrand, A., B.A. Faafeng, and J.P.M. Nilssen. 1990. Relative importance of phosphorus supply to phytoplankton production: fish excretion versus external loading. Canadian Journal of Fisheries and Aquatic Sciences 47:364-372.

Lamarra, V.A., Jr. 1975. Digestive activities of carp as a major contributor to the nutrient loading of lakes. Verh. Int. Ver. Limn. 19:2461-2468.

McComas, S.R. 2003a. Lake and pond management guidebook. CRC Press, Boca Raton, FL.

McComas, S.R. 2003b. Fish survey of Pond 213P, Apple Valley, Minnesota. Prepared for the City of Apple Valley, Minnesota.

McComas, S.R. 2004. Fish survey of Lee Lake, Lakeville, Minnesota in 2004. Prepared for the City of Lakeville, Minnesota.

McComas, S.R. 2005. Fish survey of Alimagnet Lake, Apple Valley and Burnsville, Minnesota in 2005. Prepared for the Cities of Apple Valley and Burnsville.

Nagdali, S.S. and P.K. Gupta. 2002. Impact of mass mortality of a mosquito fish, *Gambusia affinis* on the ecology of a fresh water eutrophic lake (Lake Naini Tal, India). Hydrobiologia 468:45-51.

Parkos III, J.J., V.J. Santucci, Jr, and D.H. Wahl. 2003. Effects of adult common carp (*Cyprinus carpio*) on multiple trophic levels in shallow mesocosms. Canadian Journal of Fisheries and Aquatic Sciences 60:182-192.

Qin, J. and D.A. Culver. 1995. Effect of young-of-the-year walleye (*Percidae: Strizostedion vitreum*) on plankton dynamics and water quality in ponds. Hydrobiologia 297:217-227.

Schaus, M.H., M..J. Vanni, T.E. Wissing, M.T. Bremigan, J.E. Garvey, and R.A. Stein. 1997. Nitrogen and phosphorus excretion by detritivorous gizzard shad in a reservoir ecosystem. Limnology and Oceanography 42:1386-1397.

Shapiro, J., B. Forsberg, V. Lamarra, G. Lindmark, M. Lynch, and G. Zoto. 1982. Experiments and experiences in biomanipulation. Studies of biological ways to reduce algal abundance and eliminate blue-greens. Interim Report, Limnological Research Center University of Minnesota 19. Rep. EPA-600/3-82-096, Corvallis Environmental Research Laboratory, Oregon.

Shormann, D.E. and J.B. Cotner. 1997. The effects of benthivorous smallmouth buffalo (*Ictiobus bulalus*) on water quality and nutrient cycling in a shallow flood plain lake. Lake and Reservoir Management 13:270-278.

Zambrano, L., M. Scheffer, and M. Martinez-Ramos. 2001. Catastrophic response of lakes to benthivorous fish introduction. Oikos 94:344-350.

Zimmer, K.D., M.A. Hanson, M.G. Butler, W.G. Duffy. 2001. Influences of fathead minnows and aquatic macrophytes on nutrient partitioning and ecosystem structure in two prairie wetlands. Arch. Hydrobiologia. 150:411-433.

Appendix A

Minnesota DNR Fish Permit

From: Steve McComas [mailto:mccomas@pclink.com]
Sent: Friday, October 16, 2015 10:54 AM
To: 'Ellison, Daryl G (DNR)'; Capt. Jason Peterson
Cc: Kelly Dooley; Yvette Christianson; Eric Fieldseth; Rachael Crabb
Subject: Fish survey notification for Lake Nokomis

Hello all,

Blue Water Science will be conducting a fish survey in Lake Nokomis (MN ID 27--001900), Hennepin County, starting on Tuesday, October 20, 2015. We will set 6 standard fyke nets in the lake. The nets will be monitored daily on Wednesday and Thursday and all fish will be weighed and measured and returned to the lake. The nets will be removed from the lake on Thursday, October 22. The fish surveys are sponsored by the Minnehaha Creek Watershed District and the Minneapolis Parks and Recreation Board with the objectives of characterizing the existing fish community structure and assessing potential impacts of fish on water quality.

This survey is being conducted under the permit number: 20691.

Thank you,

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

APPENDIX B

2008: Length frequency of fish species (as total length) for the Lake Nokomis fish survey (number in parentheses are number of measured fish).

Size Range (in)	Bluegill (n=360)	Black Bullhead (n=59)	Black Crappie (n=165)	Golden Shiner (n=2)	Hybrid Sunfish (n=2)	Pumpkin-seed (n=32)	Walleye (n=6)	White Sucker (n=6)	Yellow Perch (n=5)
<3.0	1		2						
3	17								
3.5	47		1			2			
4	43		5		1	2			
4.5	9	1	8			8			1
5	60		26		1	14			
5.5	87		5			3			
6	87		9			2			2
6.5	8		13			1			
7	1		46	2					1
7.5			22						
8		2	12						
8.5			9						
9		33	3						1
9.5		16	2				1		
10		7	1				1		
10.5									
11							2		
11.5			1						
12									
13									
14							1		
15							1	1	
16								2	
17									
18								1	
19								2	
20									
21									
22									
23									
24									
25									
26									

2011: Length frequency of fish species (as total length) for the Lake Nokomis fish survey (number in parentheses are number of measured fish). Red shading indicates young-of-the-year fish.

Size Range (in)	Bluegill (n=668)	Black Bullhead (n=1)	Black Crappie (n=166)	Pumpkinseed (n=16)	Walleye (n=184)	White Sucker (n=6)	Yellow Perch (n=18)
<3.0	410						
3	0.1 (1)						
3.5	0.3 (2)						
4	2 (14)			25 (4)	1		
4.5	5 (31)			6 (1)	52		
5	5 (34)			31 (5)	73		28 (5)
5.5	7 (49)		4 (7)	31 (5)	11		33 (6)
6	47 (314)		24 (39)	6 (1)	2		28 (5)
6.5	31 (209)		32 (53)				6 (1)
7	2 (14)		7 (11)				6 (1)
7.5			20 (33)				
8			12 (20)				
8.5			1 (1)				
9							
9.5					7 (3)		
10		1	1 (1)		7 (3)		
10.5					9 (4)		
11			1		13 (6)		
11.5							
12					4 (2)		
12.5					2 (1)		
13						17 (1)	
13.5					2 (1)		
14							
14.5							
15							
15.5							
16							
16.5						17 (1)	
17							
17.5						17 (1)	
18					2 (1)	50 (3)	
18.5					7 (3)		
19					2 (1)		
19.5							
20					2 (1)		
20.5							
21					2 (1)		
21.5					4 (2)		
22					7 (3)		
22.5					4 (2)		
23					4 (2)		
23.5					7 (3)		
24					4 (2)		
24.5					2 (1)		
25					4 (2)		
25.5							
26					2 (1)		

2012: Length frequency of fish species (as total length) for the Lake Nokomis fish survey (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									

2013: Length frequency of fish species (as total length) for the Lake Nokomis fish survey (number in parentheses are number of measured fish).

Size Range (in)	Black bullhead (n-6)	Bluegill (n=550)	Carp (n=1)	Black crappie (n=315)	Largemouth bass (n=1)	Pumpkin-seed (n=8)	Shiner (n=1)	Walleye (n=5)	White sucker (n=5)	Yellow perch (n=3)
<3.0		1								
3					1					
3.5						1	1			
4		1								
4.5										
5		29				2				
5.5		87				5				
6		157		3						1
6.5		162		9						
7		102		84						1
7.5		10		105						1
8	1	1		102						
8.5				11						
9				1						
9.5	1							2		
10								1		
10.5										
11	2									
11.5	1									
12										
12.5										
13	1							1		
13.5										
14										
14.5										
15										
15.5										
16										
16.5										
17									3	
17.5										
18									2	
18.5										
19										
19.5										
20								1		
20.5										
21										
21.5										
22										
22.5										
23										
23.5										
24										
24.5										
25										
25.5										
26			1							

2014: Length frequency of fish species (as total length) for the Lake Nokomis fish survey on October 2-3, 2014 (number in parentheses are number of measured fish).

Length (inches)	Black bullhead (n=2)	Black crappie (n=289)	Bluegill sunfish (n=650)	Carp (n=1)	Dogfish (n=1)	Golden shiner (n=4)	Hybrid sunfish (n=2)	Large-mouth bass (n=2)	Pumpkin-seed (n=62)	Walleye (n=39)	White sucker (n=4)	Yellow bullhead (n=2)	Yellow perch (n=280)
<3			52										
3.5			2						2				
4			77						17				
4.5			190						30				
5		6	208				1	1	4				19
5.5		59	38			1		1	3				51
6		143	31			1	1		6				126
6.5		27	42			2							40
7		10	50							1			23
7.5		11	11							3			6
8		18	1							8			8
8.5	1	11								1			5
9		1								1		1	
9.5		3											2
10										1			
10.5													
11	1									3			
11.5													
12													
12.5												1	
13													
13.5													
14													
14.5										1			
15										3			
15.5										2			
16										4	2		
16.5													
17											1		
17.5										4			
18										1	1		
18.5										4			
19													
19.5													
20													
20.5													
21													
21.5										1			
22										1			
22.5													
23													
23.5													
24													
24.5													
25													
25.5													
26					1								
26.5													
27				1									

Attachment 3

Pathways of Carp Recruitment in Lake Nokomis

By Steve McComas, Blue Water Science, November 30, 2015

SUMMARY

Carp are present in Lake Nokomis (Table 1) and could have a density sufficient to adversely impact lake water quality. A question to address is where do they come from?

Table 1. Electrofishing survey conducted by the University of Minnesota.

	2014 (September 1)	2015 (July 14)
Carp captured/hour	21.3	27.8
Average length (mm)	600 mm (average 23.6 inches)	585
Average weight (kg)	2.87 (averaging 6. pounds)	2.78 kg
Estimated population of whole lake	8,421	10,908
Estimated biomass	298 kg/ha	373 kg/ha
Estimated population (fish/ac)	42 fish/ac	55 fish/ac

A list of five possible carp pathways into Lake Nokomis and the potential contribution from each pathway is summarized below:

1. Carp have come into Lake Nokomis from Minnehaha Creek during high water events (rare occurrence).
2. Carp spawn in adjacent lagoons and the lagoons serve as a nursery and a refuge (low probability).
3. Carp population may be successfully spawning in Lake Nokomis with some recruitment (slight impact).
4. Carp run out of Nokomis and spawn in the Soloman wetland (need more information).
5. Carp population in Taft Lake uses Mother and Legion as refuges for rearing fish and then migrate into Lake Nokomis (high probability, need to know the magnitude of the immigration).

The source of carp in Lake Nokomis are most likely derived from modest spawning success in Lake Nokomis (Pathway 3), the ability of carp to leave Lake Nokomis and spawn in the Soloman Wetland, and then return to Lake Nokomis (Pathway 4) and the potential for carp from Taft Lake to exploit spawning refuges in Legion and Mother Lakes and then migrate from Taft Lake into Lake Nokomis (Pathway 5). These 3 potential pathways need more work to determine their potential contributions to the carp population of Lake Nokomis.

Potential Sources and Pathways of Carp Populating Lake Nokomis

1. Carp come into Nokomis from Minnehaha Creek during high water events.
With high water in Minnehaha Creek, fish including carp could enter Lake Nokomis. In recent years, high water in Minnehaha Creek would overtop the Lake Nokomis outlet barrier (Figure 1). In 2011, carp were trapped in a pool between the dam and a rock bar (Figure 2). In 2014, there was high water in Minnehaha Creek and carp were observed in the pool next to the dam (Figure 3). The rebuilt dam is likely to limit future immigration from Minnehaha Creek into Lake Nokomis except in instances of flood conditions (Figure 4).

Conclusion: Not a major source of carp to Lake Nokomis but possible immigration during high water.

Figure 1. Sand bags were placed on top of the dam to hold back water from entering Lake Nokomis.

Figure 2. Carp were pooling up in the water next to the dam before entering Lake Nokomis

Figure 3. Carp schooling up behind the dam at Lake Nokomis in June 2014.

Figure 4. Rebuilt outlet of Lake Nokomis.

2. Carp spawn in adjacent lagoons and the lagoons serve as a refuge.
Carp were observed in the lagoons when they were first constructed in 2001 (Figure 5). In 2001 they moved into the lagoons before all the screens and grates were in place.

However, since inlet and outlet grates have been in place, the potential for adult cap to migrate into the lagoons is low. The grate lagoon outlet to Lake Nokomis should prevent adult carp movement into or out of the lagoons (Figure 6). In addition, seining with 20-foot long seine conducted in all three lagoons did not capture any fish (Figure 7 and 8). Wintertime dissolved oxygen monitoring by the MCWD shows low DO in all three lagoons. The lagoons may be fishless.

Conclusion: Adult carp movement into the lagoons to spawn and then exit back to the lake is unlikely. Lagoons do not appear to be a carp refuge.

Figure 5. Steve McComas, Blue Water Science, holding a carp captured from seining the lagoons in 2001.

Figure 6. Lagoon outlet to Lake Nokomis has a gated inflow/outflow.

Figure 7. Lagoon seining in 2015 did not sample any fish.

Figure 8. Multiple seining attempts in all 3 lagoons resulted in no fish. The lagoons may winterkill and not support fish.

3. Carp population is spawning in Lake Nokomis.
There is a significant carp population in Nokomis based on electrofishing results and population estimates (Table 1). It is possible carp are successfully spawning in Lake Nokomis and that may be sustaining the population. However, electrofishing in Lake Nokomis in 2014 and 2015 found only one juvenile carp. If spawning was occurring in Lake Nokomis, the predictions are it would not be very successful due to the predator population that is present. Electrofishing results seem to support that.

Conclusions: There is likely carp spawning occurring in Lake Nokomis. However, it would not appear to be responsible for producing large annual year classes of young carp or for generating the high population that is present. There is most likely an additional source of carp to Lake Nokomis.

Figure 9. Young of the year carp from a Rice Lake, Maple Grove fish survey in 2014 following a lake drawdown and a fish winterkill from the previous winter. Without predation pressure from other fish, carp spawning and recruitment success is enhanced.

Figure 10. Tub of bluegills and crappies from a Lake Nokomis fish survey in 2015. Panfish may eat a majority of carp eggs and other predators may prey on carp fry to limit carp recruitment in Lake Nokomis.

4. Carp run out of Nokomis and spawn in the Soloman wetland.
Lake Nokomis has a major inflow at the south end of the Lake Nokomis which drains subwatersheds to the south. The inflowing stream has enough volume in some seasons to allow fish movement by way of the stream, but not at all times of the year. Pictures of the inflowing stream conditions are shown in Figure 11.

Conclusions: Carp from Lake Nokomis may leave Lake Nokomis and spawn in the Soloman Wetland, located downstream from the Taft outlet. At this time, carp have not been observed leaving Lake Nokomis and young carp have not been observed in the wetland which could serve as a spawning refuge. More work needs to be conducted in this system.

Figure 11. Stream conditions flowing into Lake Nokomis.
[top-left] Low flow on April 9, 2015. [top-right] Higher flow on July 8, 2015.
[middle-left] Stream conditions on July 8, 2015. [middle-right] Same stream on October 20, 2015.
[bottom-left] Soloman Wetland outlet to Lake Nokomis stream on October 20, 2015.
[bottom-right] Soloman Wetland on November 6, 2015.

5. Carp population in Taft Lake uses Mother and Legion Lakes as refuges and then migrate into Taft Lake and into Lake Nokomis.
It was noticed fish were present in a small, shallow pond at the outlet of Taft Lake. It is possible, carp could use this area as a refuge an migrate into Lake Nokomis when they were more mature. This pond was seined with a 20-foot long seine on November 8. Results found no carp.

Conclusion: This may be an important source of carp to Lake Nokomis. More work is needed to determine the magnitude of the carp contribution to Lake Nokomis from this system.

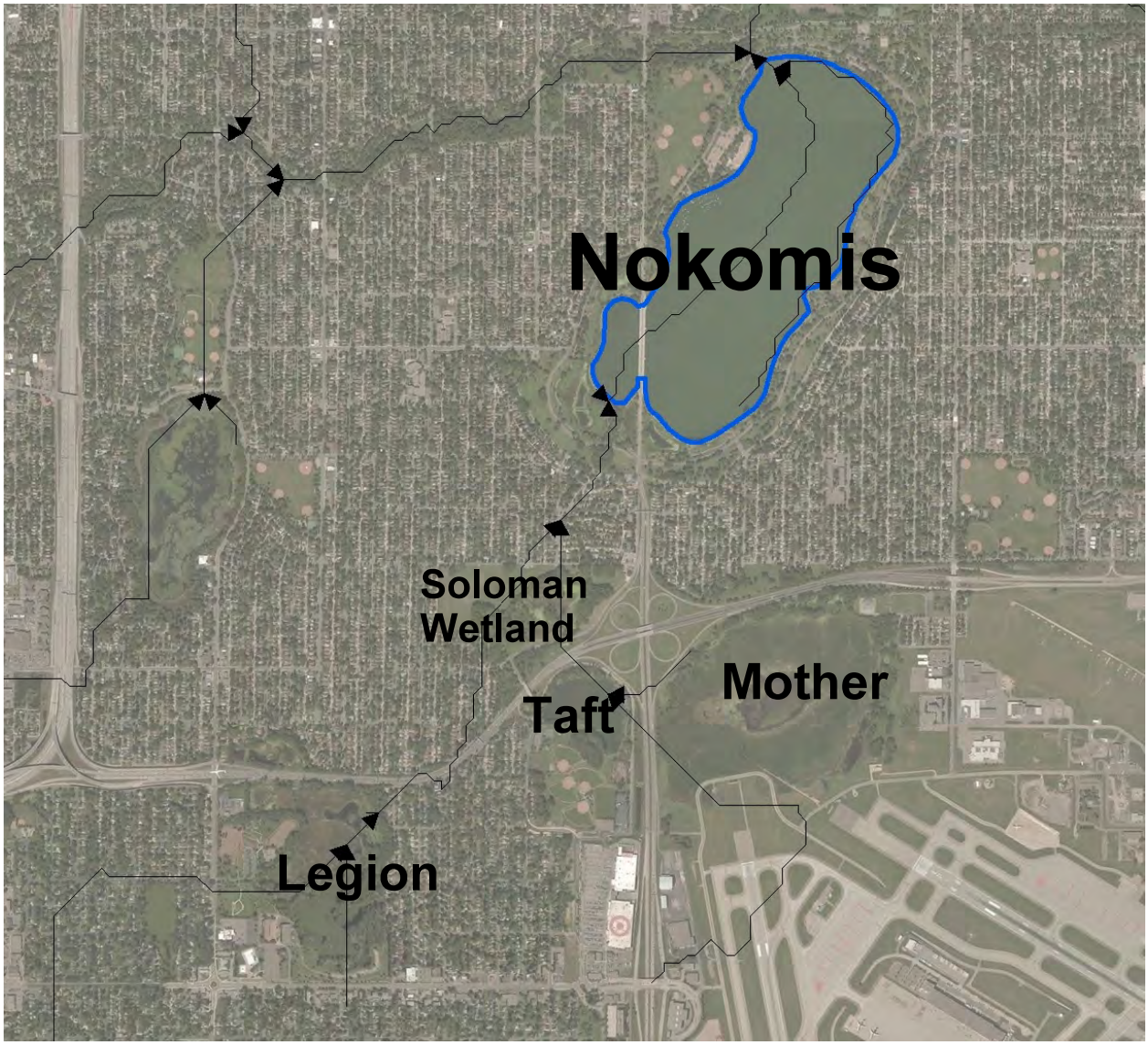

Figure 12. Legion and Mother Lakes drain into Taft Lake. The outlet from Taft Lake flows north, under Hwy 62 and into Soloman Wetland. The outlet from the Soloman Wetland flows by an underground culvert and daylights at Edgewater Road. Then there is an open channel into Lake Nokomis.

Figure 13. [top-left] Taft Lake and outflow into a small outlet pool. This pool held a high density of young fish (see Figure 11).
[top-right] Inflow from Mother Lake into Taft Lake.
[middle-left] Outflow from Legion Lake.
[middle-right] Inflow from Legion Lake into Taft Lake.
[bottom-left] Flow from Taft Lake into Soloman Wetland is through this culvert.
[bottom-right] The outflow from the Soloman Wetland goes into this buried culvert and daylights into Nokomis Creek which flows into Lake Nokomis.

Fish in the Taft Subwatershed: Carp are documented in Taft Lake based on the MnDNR fish survey from 2012 (Table 2). Also numerous young bluegill sunfish and largemouth bass were sampled by seining in the outlet pool from Taft Lake (Figure 14). No young carp were found in these samples. However, it is possible that carp could migrate from Taft Lake into Lake Nokomis.

Table 2. MnDNR fish survey for Taft Lake. Fish Sampled for the 2012 Survey Year.

Species	Gear Used	Number of fish per net		Average Fish Weight (lbs)	Normal Range (lbs)
		Caught	Normal Range		
Black Bullhead	Trap net	26.50	1.3 - 26.0	0.14	0.2 - 0.5
	Gill net	88.00	5.2 - 56.2	0.17	0.2 - 0.5
Black Crappie	Trap net	0.67	1.8 - 18.1	0.16	0.2 - 0.3
	Gill net	1.00	1.9 - 18.0	0.30	0.1 - 0.3
Bluegill	Trap net	1.17	6.5 - 59.6	0.07	0.1 - 0.2
Common Carp	**Trap net**	**0.17**	**0.3 - 2.6**	**0.15**	**2.0 - 4.5**
	Gill net	**1.50**	**0.5 - 4.0**	**3.39**	**1.0 - 3.2**
Golden Shiner	Gill net	2.50	0.7 - 3.9	0.13	0.1 - 0.1
Hybrid Sunfish	Trap net	1.00	N/A	0.03	N/A
Northern Pike	Gill net	0.50	2.5 - 7.9	3.35	1.8 - 3.3
Walleye	Gill net	4.50	0.5 - 3.5	0.96	1.1 - 3.0
White Crappie	Gill net	0.50	0.5 - 4.8	0.23	0.2 - 0.3
White Sucker	Trap net	0.33	0.3 - 1.6	1.36	1.0 - 2.2
Yellow Bullhead	Trap net	0.33	0.8 - 5.0	0.36	0.4 - 0.7
	Gill net	0.50	1.0 - 6.9	0.38	0.4 - 0.7
Yellow Perch	Trap net	3.17	0.3 - 1.5	0.10	0.1 - 0.2
	Gill net	49.50	1.5 - 12.8	0.11	0.1 - 0.2

Normal Ranges represent typical catches for lakes with similar physical and chemical.

Figure 14. A 20-foot seine was pulled in a Taft Lake outlet pool in 2015.
[left] A seine collected numerous fish in the outlet pool from Taft Lake in 2015 (the outlet pool is shown in Figure 13, top-left).
[right] Young of the year bluegills and largemouth bass were the dominant fish species sampled in the outlet pool.