MI/DEQ/WRD-15/046

Michigan National Lakes Assessment Project 2012

Summary of Water and Trophic Status Results

Introduction

The state of Michigan has over 11,000 inland lakes, which provide numerous uses for both residents and tourists and are vital to Michigan's economy and ecology (Vaccaro et al., 2009; Austin, 2013). These inland lakes support diverse plant, invertebrate, fish, and amphibian populations. Wetland and littoral zone environments along the margins of lakes also provide habitat for various reptiles, birds, and mammals (O'Neal and Soulliere, 2006). These lakes offer critical habitat for state-threatened species, and species of special concern, such as lake sturgeon (*Acipenser fulvescens*; Altenritter et al., 2013), Trumpeter swans (*Cygnus buccinator*; Corace et al., 2006), and Blanding's turtles (*Emydoidea blandingii*; Harding, 1997).

During the summer of 2012, the Michigan Department of Environmental Quality (MDEQ) partnered with the United States Environmental Protection Agency (USEPA) to complete the National Lakes Assessment (NLA), one of four statistical surveys that make up the National Aquatic Resource Surveys. The NLA is designed to answer the following questions about lakes across the United States.

- What is the current biological, chemical, physical, and recreational condition of lakes?
    - What is the extent of degradation among lakes?
    - Is degradation widespread (e.g., national) or localized (e.g., regional)?
- Is the condition of lakes getting better, worse, or staying the same over time?
- Which environmental stressors are most associated with degraded biological condition in lakes?

Michigan's 2012 NLA effort was led by the MDEQ and was supported by USEPA Section 106 grant funds. Initially, 38 randomly selected lakes in Michigan were included as part of the national survey. Michigan included 15 additional lakes from the national draw to provide for the statistically-based estimates of condition statewide. Based on the NLA survey design, 50 randomly selected lakes was the minimum number needed to apply the results statewide with ±15% margin of error and 95% confidence.

The purpose of this report is to provide a summary of the 2012 NLA findings for trophic status indicators and water chemistry parameters for Michigan's lakes. Because of the NLA survey's statistically-based design, this dataset provides a good basis for describing the typical range of, and interrelationships among, constituents in Michigan's lakes on a statewide basis. Each lake was sampled for a suite of chemical/physical parameters including two emerging chemicals of concern (atrazine and microcystin, Table 2). The 2012 results were compared to those from the 2007 NLA, the MDEQ Lake Water Quality Assessment (LWQA) monitoring project, and Michigan's volunteer lake monitoring network (Michigan Clean Water Corps [MiCorps]). Because the national lake results and the associated report are not yet finalized, this report does not compare the state-level data to the ecoregion and national results. Those comparisons will have to be made later, once the USEPA issues the final 2012 NLA report.

In addition to the water/trophic state parameters, biological and physical habitat indicators also were collected from each lake. The biological components included benthic macroinvertebrates, zooplankton, and littoral zone aquatic macrophytes. These parameters are not discussed in this report, and may be summarized at a later time. The data are available to interested parties upon request.

Lake Selection

The USEPA used a statistical sampling approach that incorporated survey design techniques to select lakes for this survey. To ascertain the number of lakes in the country, analysts used the United States Geological Survey/USEPA National Hydrography Dataset Plus (NHD Plus), version 2. The NHDPlus is a multi-layered series of digital maps that reveal topography, area, flow, location, and other attributes of the nation's surface waters. NHDPlus has 389,005 features listed that could potentially be lakes.

In 2012, 1,038 lakes (>1 hectare and >1 meter [m] depth) from a statistically representative selection process were sampled in the lower 48 states. To be included in the survey, a water body had to be a natural or man-made freshwater lake, pond, or reservoir greater than 2.47 acres (1 hectare), at least 3.3 feet (1 meter) deep, and with a minimum quarter acre (0.1 hectare) of open water. The lake area criteria differed from 2007, in which only lakes >4 hectares were sampled, resulting in a larger pool of lakes available for sampling. The Great Lakes were not included in the survey, nor were commercial treatment and/or disposal ponds, brackish lakes, or ephemeral lakes. After applying these criteria, analysts estimate that 159,652 water bodies are considered lakes by the NLA definition and thus comprise the target population.

Another factor in lake selection was accessibility. In some cases, crews were either denied permission by the landowner or unable to reach the lake because of safety reasons, such as sharp cliffs or unstable ridges. Using data from crew experience and presampling reconnaissance, an estimated 30% or 47,833 lakes nationwide fell into the inaccessible category. This left 111,819 lakes that the NLA 2012 was able to assess. This group of lakes available for assessment was called the inference population.

The site-selection process for the survey ensured that the USEPA can make unbiased estimates concerning the health of the target population of lakes with statistical confidence. The greater the number of sites sampled, the more confidence in the results. The number of sites included in the 2012 NLA allows the USEPA to determine the percentage of lakes nationwide and within predetermined ecoregions that exceed a threshold of concern with 95% confidence.

The intent of the 2012 NLA was to sample approximately 80 lakes within each of the nine course-scale, aggregated Omernik ecoregions (904 base sites and 96 revisit sites) delineated by Olsen and Peck (2008). A spatially balanced, unequal probability design (Stevens and Olsen, 2004) was used to select the lakes in each aggregated Omernik ecoregion. The state of Michigan was initially assigned 38 randomly-drawn lakes. Fifteen additional lakes were added to Michigan's survey design for state-scale assessment (Figure 1 and Table 1).

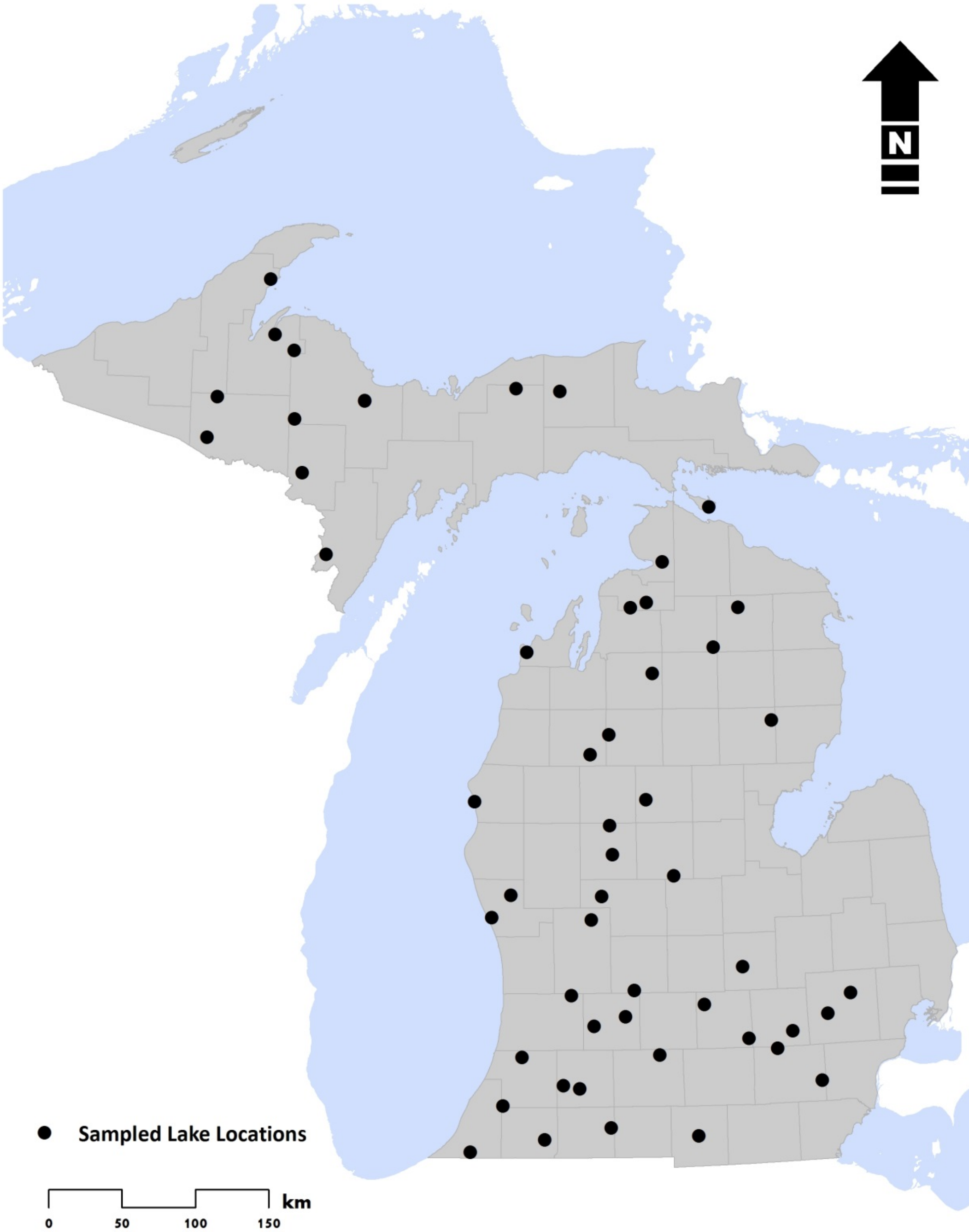

Figure 1. Distribution of the 53 Michigan lakes sampled for the 2012 NLA.

Table 1. The 53 lakes sampled for the 2012 NLA in Michigan. See appendix for individual lake results. Note: Lakes Ottawa and Ste. Kathryn were sampled by the USEPA as reference lakes.

Lake Name	County		Lake Name	County
AuSable Lake	Ogemaw		Little Portage Lake	Washtenaw
Bass Lake	Luce		Middle Black Lake	Kalkaska
Bella Lake	Baraga		Mill Lake	Oakland
Blue Lake	Mecosta		Mud Lake	Houghton
Bogie Lake	Oakland		Mud Lake	Isabella
Brighton Lake	Livingston		Muskegon Lake	Muskegon
Clear Lake	Missaukee		Palmer Lake	St Joseph
Clear Lake	Montmorency		Patricia Lake	Charlevoix
Coady Lake	Montcalm		Pere Marquette Lake	Mason
Crocker Lake	Muskegon		Pine Lake	Kent
Crooked Lake	Kalamazoo		Pogy Lake	Mecosta
Crooked Lake	Emmet		Powell Lake	Marquette
Deer Lake	Charlevoix		Round Lake	Van Buren
Ford Lake	Washtenaw		Saddle Lake	Van Buren
Forest Lake	Shiawassee		School Lake	Calhoun
Fourth Lake	Hillsdale		Seventh Spectacle Lake	Otsego
Garwood Lake	Berrien		Silver Lake	Iron
Gasley	Iron		South Pond	Dickenson
Hawk Island Park Lake	Ingham		Stewart Lake	Barry
Huckleberry Lake	Allegan		Sucker Lake	Schoolcraft
Ionia Lake	Alger		Thompson Lake	Mackinac
Jones Lake	Ingham		Thornapple Lake	Barry
Lake Alice	Baraga		Tupper Lake	Ionia
Lake Mary	Menominee		Unnamed Lake	Cass
Lake Mitchell	Wexford		Unnamed Lake	Marquette
Lake Ottawa	Iron		West Lake	Kalamazoo
Lake Ste. Kathryn	Iron		Windover Lake	Clare
Little Glen Lake	Leelanau			

Field Sampling

Water chemistry samples (Table 2) were collected at the deepest part of the lakes, or "index sites." Vertical profile measurements of dissolved oxygen, temperature, and pH were taken at 1 m intervals. Water chemistry samples were collected with an integrated water sampler in the top two meters of the water surface and transferred to sterile containers and bottles (USEPA, 2011). Additional chlorophyll-*a* and microcystin samples were taken from the lake littoral zones. Water samples were stored on ice and shipped overnight to a USEPA laboratory for analyses (See USEPA [2012] for details of laboratory analyses).

Table 2. Chemical/physical parameters sampled at each lake. Ug/l = micrograms per liter; mg/l = milligrams per liter; C = degrees Celcius; us/cm = microsiemens per centimeter; m = meters; µeq/l = microequivalents per liter; and mg N/l = milligrams nitrogen per liter.

Variable	Measurement units
Atrazine	µg/l
Chlorophyl a	µg/l
Microcystin	µg/l
Dissolved oxygen	mg/l
Temperature	°C
pH	.
Conductivity	µs/cm
Secchi depth	m
Aluminum	mg/l
Calcium	mg/l
Chloride	mg/l
Color	Platinum-cobalt units
Dissolved organic carbon	mg/l
Potassium	mg/l
Magnesium	mg/l
Ammonia	mg N/l
Nitrite	mg N/l
Nitrate	mg N/l
Nitrate-nitrite	mg N/l
Total nitrogen	mg/l
Total phosphorus	µg/l
Silica	mg/l
Sulfate	mg/l
Sodium	mg/l
Acid neutralizing capacity	µeq/l
Turbidity	Nephelometric Turbidity Units

Data Analysis

Modified trophic status indices were calculated for each lake using the Secchi depth, total phosphorus, and chlorophyll-a data (Michigan Department of Natural Resources [MDNR], 1982; Fuller and Taricska, 2012). Based on the trophic status indices' values, lakes were assigned a trophic status (oligotrophic, mesotrophic, eutrophic, or hypereutrophic) and compared to the trophic status results from the 2007 NLA, the LWQA project (Fuller and Taricska, 2012), and the 2012 MiCorps volunteer monitoring results (MDEQ, 2013). Linear regressions of the total phosphorus-chlorophyll-*a* relationship were performed on all of the lakes sampled in the 2007 and 2012 NLAs and the 2012 MiCorps sampling. Additional linear regressions were performed on total phosphorus-chlorophyll-*a* and chlorophyll-*a*-Secchi depth measurement relationships in

18 lakes that were sampled in both the 2007 and 2012 NLAs. Selected parameters were summarized in boxplots. If the same parameters were measured in the 2007 NLA, LWQA, or MiCorps sampling, those results were included for comparison.

The values presented in the figures and Table 3 of this report are based on unweighted lake data. That is, they have not been weighted (by surface area and proportion in the size-class assessment unit) to reflect the random stratified sample design.

Results

Fifty-five sampling events took place during the 2012 NLA in Michigan, with 53 lakes visited; two of which were sampled twice. The median total phosphorus level found in the 2012 NLA (25 ug/L) was substantially higher than in the 2007 NLA (10.5 ug/L), the 2001-2010 LWQA (12 ug/L), and the 2012 MiCorps (11.0 ug/L) (Table 3). In light of the higher median values found with the 2012 NLA data, linear regressions were run for total phosphorus and chlorophyll *a* concentrations since total phosphorus and chlorophyll *a* are correlated in freshwater ecosystems (Dillon and Rigler, 1974; Stow and Cha, 2013). For example, linear regression found total phosphorus and chlorophyll *a* to be strongly correlated in MiCorps lakes ($R^2 = 0.50$; $P<0.001$; Figure 3).

The linear regression showed a weak correlation existed between the 2012 NLA chlorophyll *a* and total phosphorus data ($R^2 = 0.09$; $P = 0.02$; Figure 2). Of the 53 lakes sampled in the 2012 NLA, 18 were also sampled in 2007. Linear regressions were run for chlorophyll *a* and total phosphorus on those 18 lakes. A strong correlation was found using the 2007 data ($R^2 = 0.82$, $P < 0.001$; Figure 4). It is also noteworthy that, among these 18 lakes, only 4 (22%) had a total phosphorus concentration greater than 30 ug/L in 2007 (Figure 4) whereas phosphorus levels in 10 lakes (56%) exceeded 30 ug/L in 2012 (Figure 5).

Secchi depth and chlorophyll *a* values were similar amongst different sampling efforts (Figures 6 and 7), while total phosphorus concentrations from the 2012 NLA appeared to be high compared to the other projects as discussed previously (Figure 8). Linear regressions of the chlorophyll a-Secchi depth relationships in the 18 lakes sampled in the 2007 and 2012 NLAs were significant for both sampling events (2007: $R^2 = 0.41$, $P = 0.004$ [Figure 9]; 2012: $R^2 = 0.42$, $P = 0.004$ [Figure 10]).

Trophic status indices from other assessment efforts have indicated the majority of lakes sampled in Michigan are oligotrophic or mesotrophic (Figure 11) and are generally high-quality waters. The higher percentage of eutrophic lakes (38%) found during the 2012 NLA relative to the other lake monitoring projects is likely the result of the elevated phosphorus levels mentioned above. Few Michigan lakes are hypereutrophic. Figures 12 and 13 show the trophic status of the 53 2012 NLA lakes based on chlorophyll *a* and total phosphorus.

A majority of lakes sampled during the 2012 NLA had microcystin concentrations either below detection or less than 1 ug/L, consistent with previous assessments for this algal toxin (Figure 14). Of the lakes with greater than 1 ug/L of microcystin, one was in the western Upper Peninsula, one was in the northeast Lower Peninsula, and two were in southern Michigan (Figures 15-16). Surprisingly, more index site samples (towards the middle of the lakes) than littoral zone samples (closer to the shore) were greater than 1 ug/L. No samples from the 2007 and 2012 NLA exceeded 10 ug/L (Figure 14). As a comparison, the World Health Organization's provisional recreational guideline is 20 ug/l.

Mean atrazine concentrations were low (0.07 ug/l ± 0.23 standard deviation) with a maximum level of 1.5 ug/l. These values were well below current Michigan water quality standards (7.3 ug/l final chronic value, 50 ug/l aquatic maximum value, and 100 ug/l final acute value). The highest concentrations were recorded in the southern Lower Peninsula where agriculture is most intensive (Figure 17).

Other key water parameters measured in the 2012 NLA are summarized in Figures 18-25 and Table 3, and compared to levels found during the 2007 NLA and the 2001-2010 LWQA project. Concentrations for almost all parameters are remarkably similar, with the exception of a lower level of acid neutralizing capacity in LWQA lakes compared to the 2007 and 2012 NLAs (Figure 25).

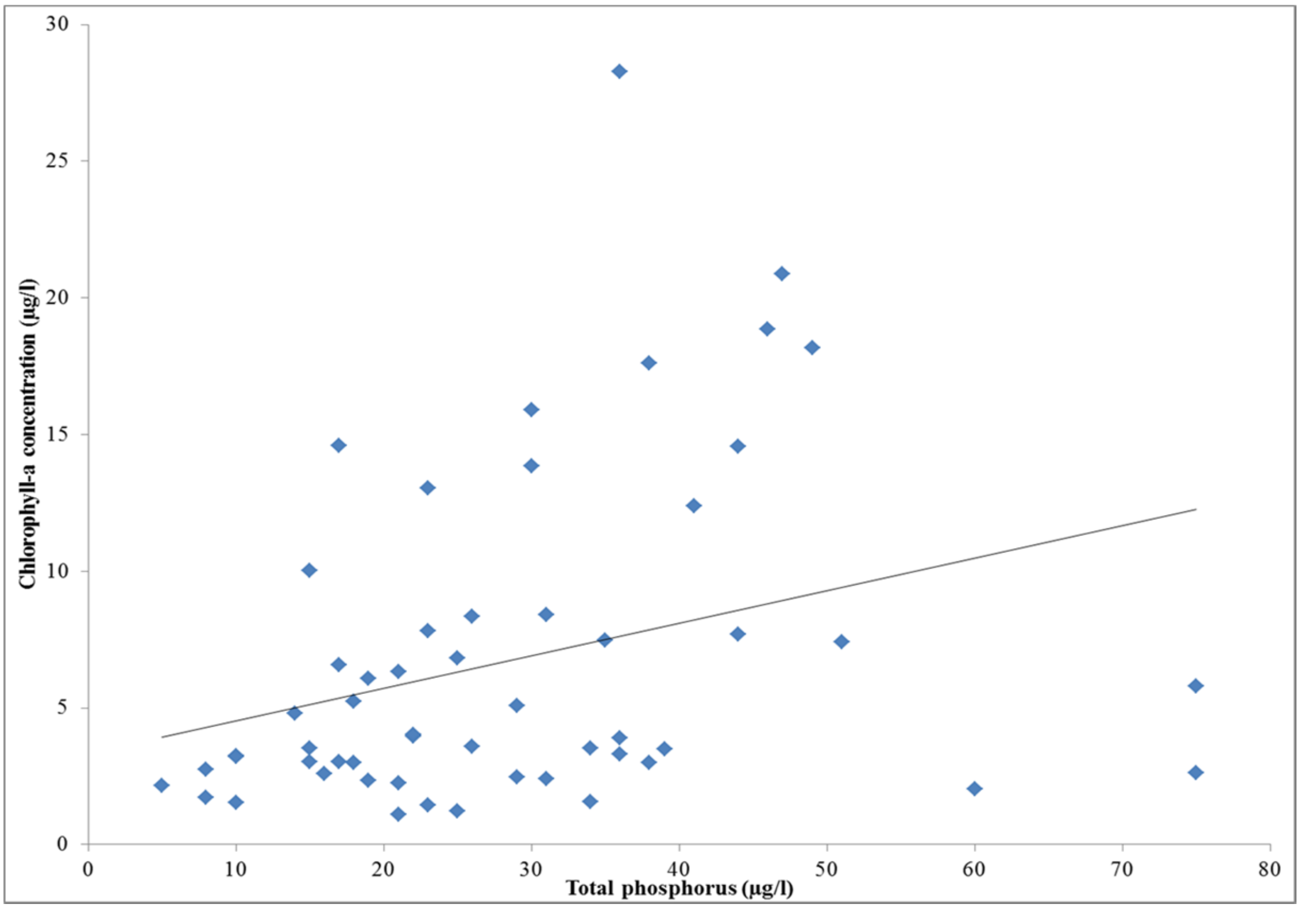

Figure 2. Linear regression of total phosphorus and chlorophyll *a* concentrations in Michigan 2012 NLA lakes.

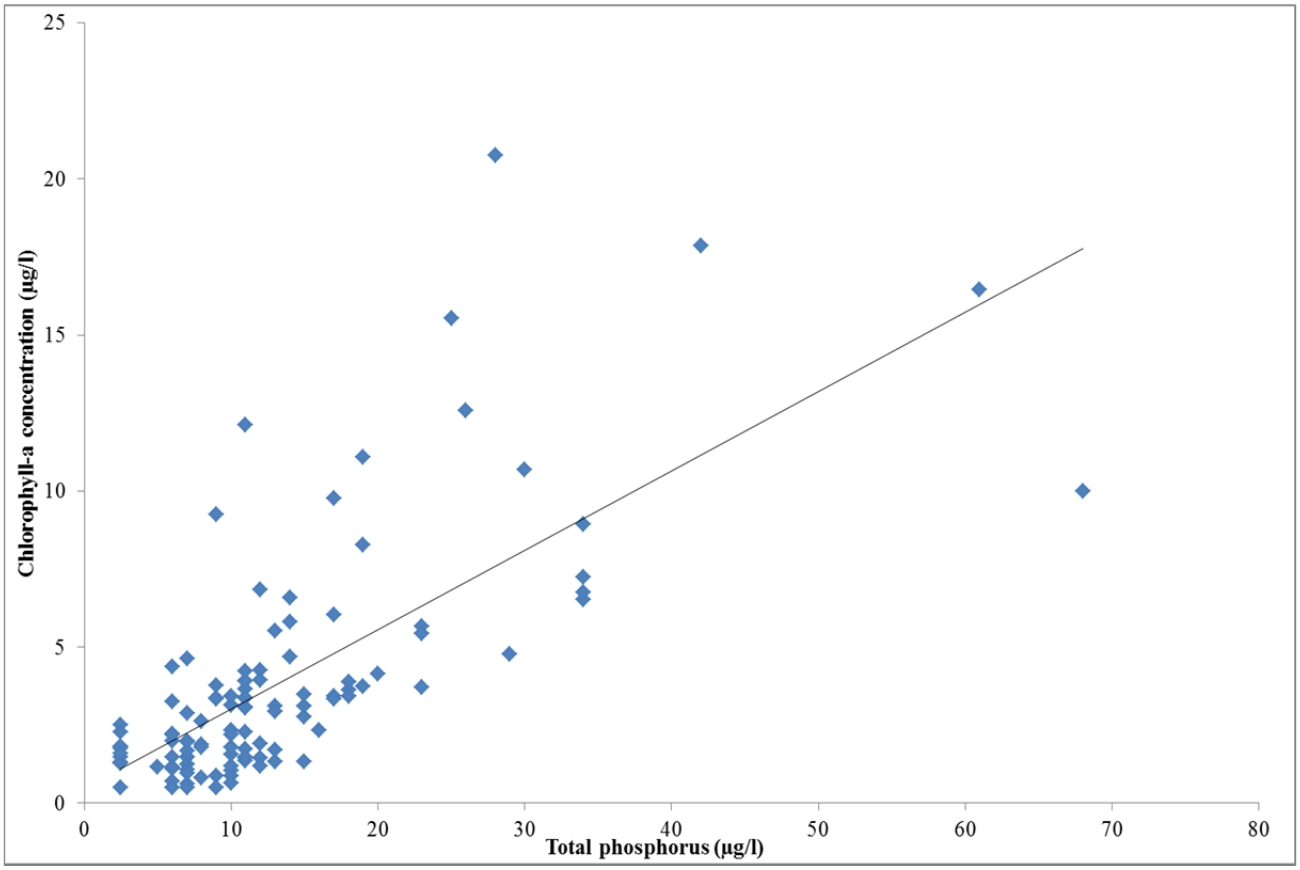

Figure 3. Linear regression of total phosphorus and chlorophyll *a* concentrations in Michigan 2012 MiCorps lakes.

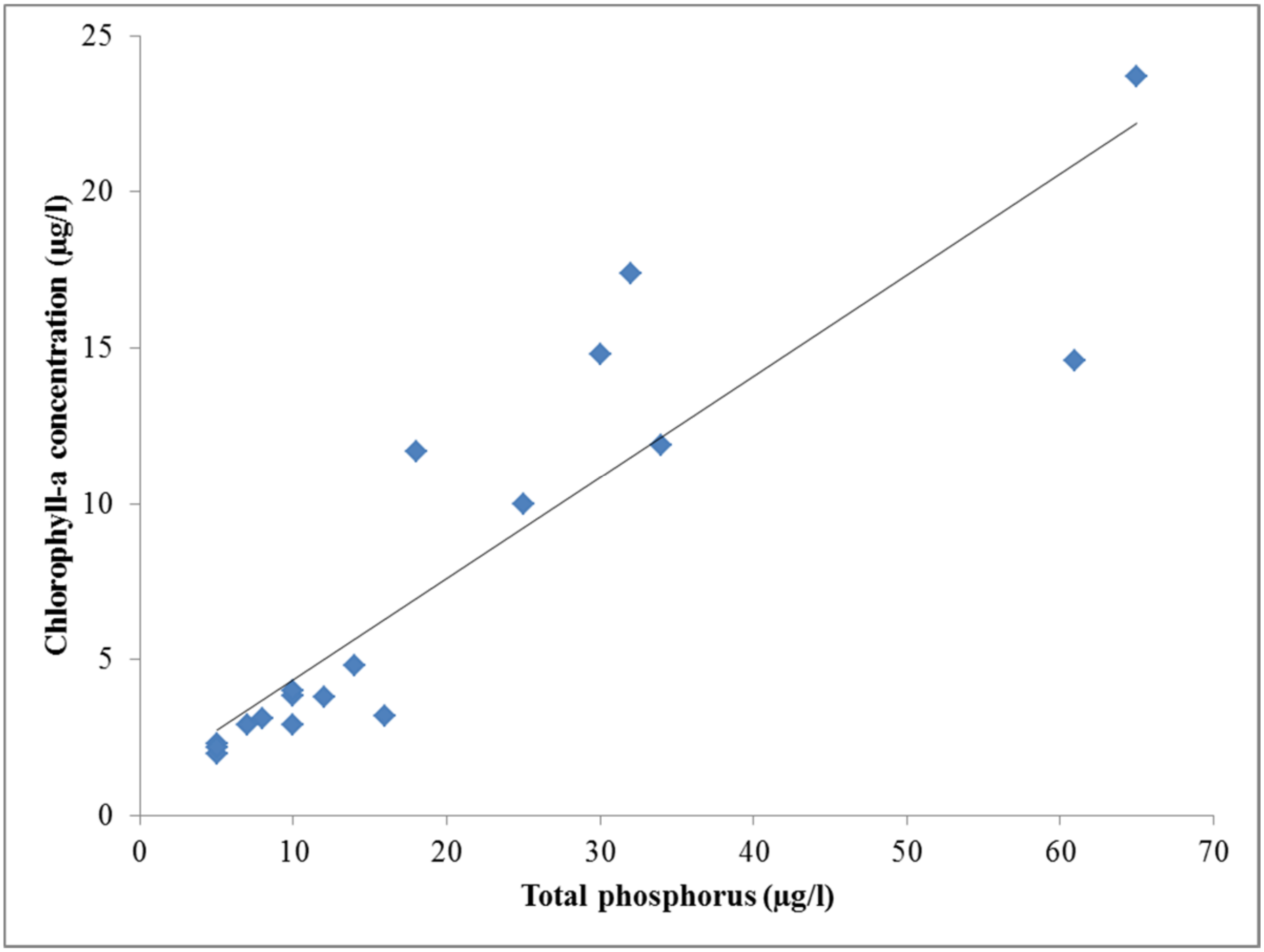

Figure 4. Linear regression (using 2007 data) of total phosphorus and chlorophyll *a* concentrations of the 18 Michigan inland lakes sampled for the 2007 and 2012 NLAs.

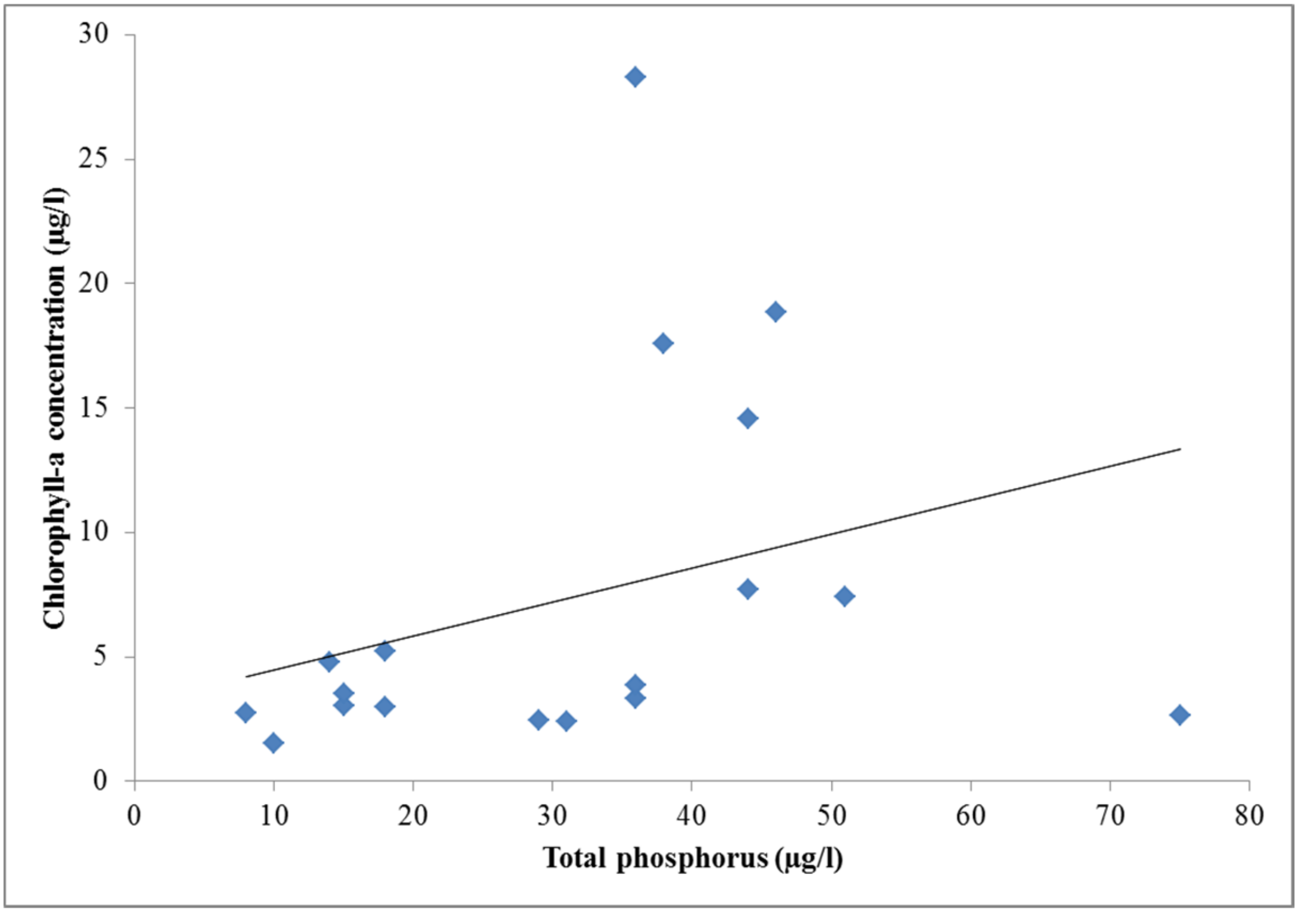

Figure 5. Linear regression (using 2012 data) of total phosphorus and chlorophyll *a* concentrations of the 18 Michigan inland lakes sampled for the 2007 and 2012 NLAs.

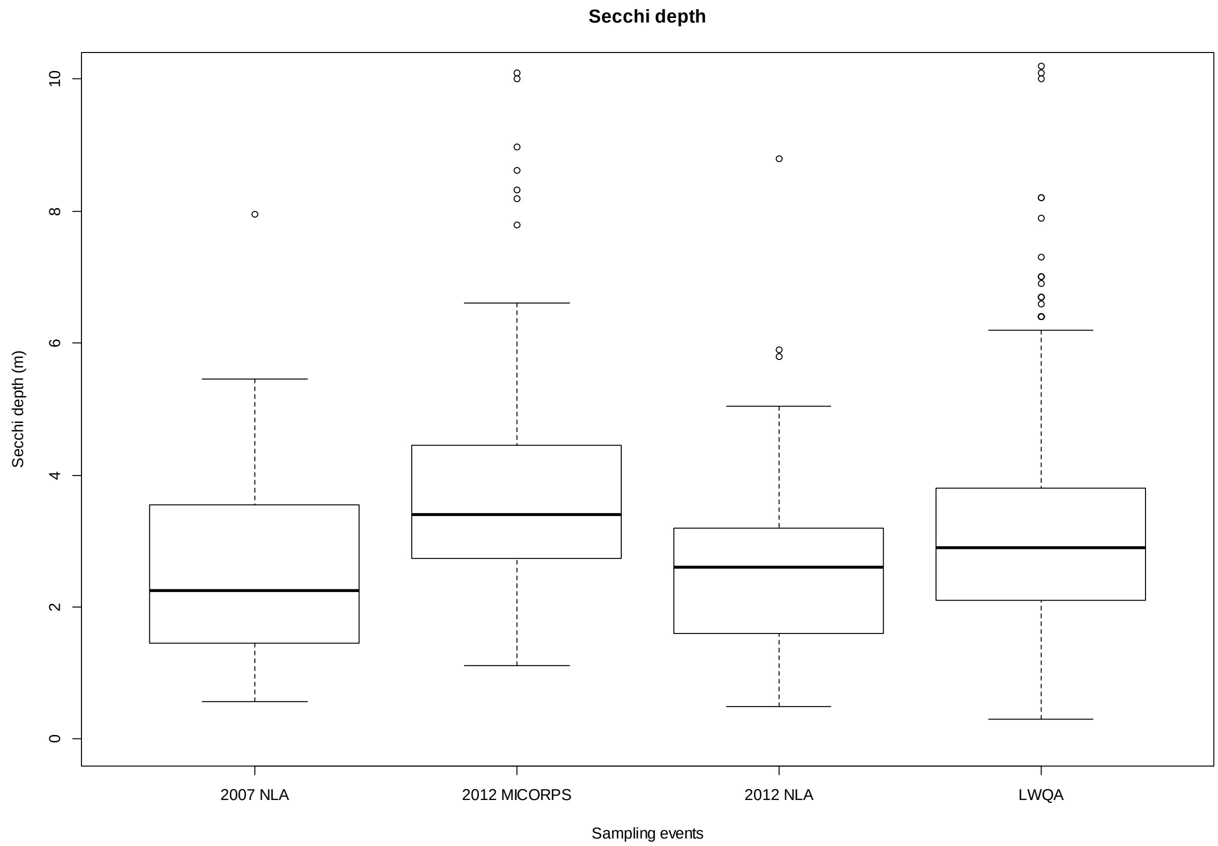

Figure 6. Box plots of Secchi depths (m) recorded during 2007 (50 lakes) and 2012 (53 lakes) NLA surveys, the LWQA (730 lakes), and 2012 MiCorps surveys (113 lakes). Note: 3 values from the LWQA and 2 values from the 2012 MiCorps sampling were > 10 m.

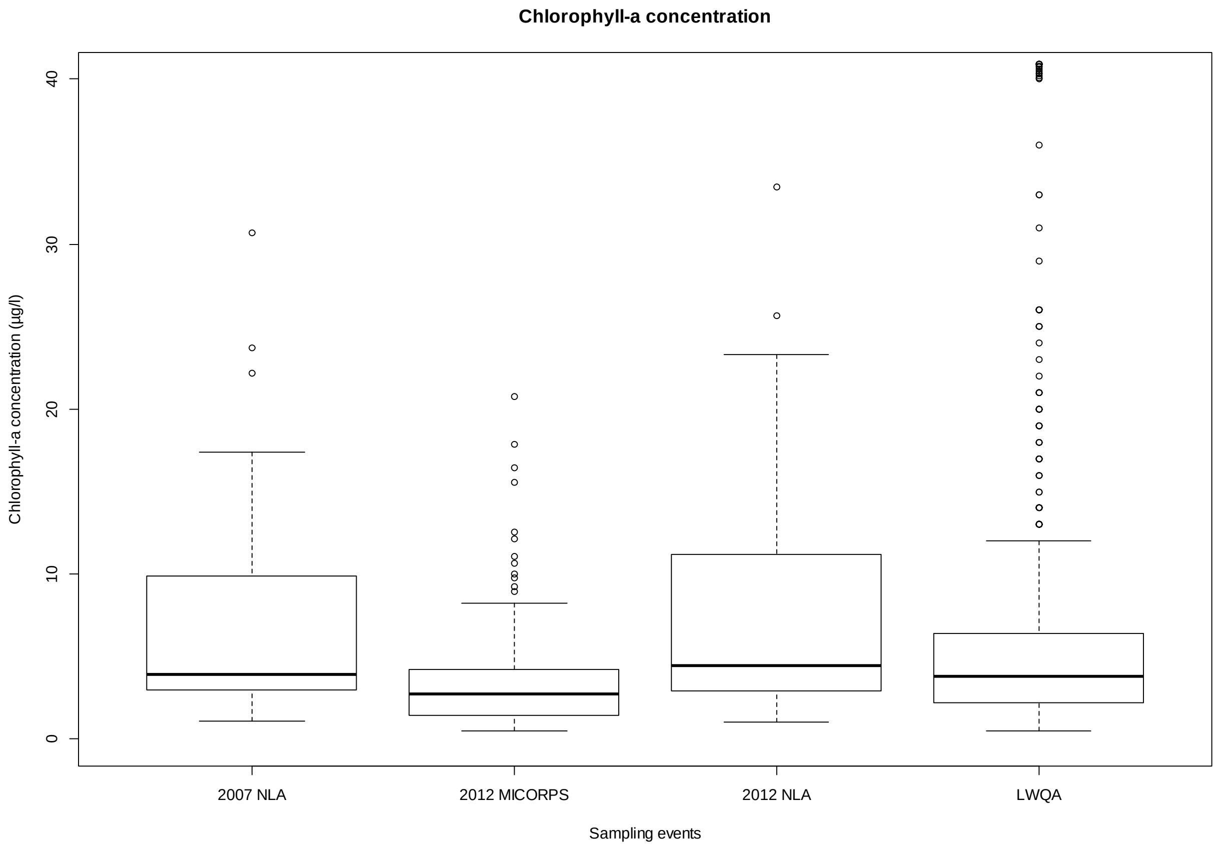

Figure 7. Boxplots of chlorophyll *a* concentrations (ug/l) recorded during 2007 and 2012 NLA surveys, the LWQA, and 2012 MiCorps surveys. Note: 17 sites from the LWQA had concentrations > 40 ug/l.

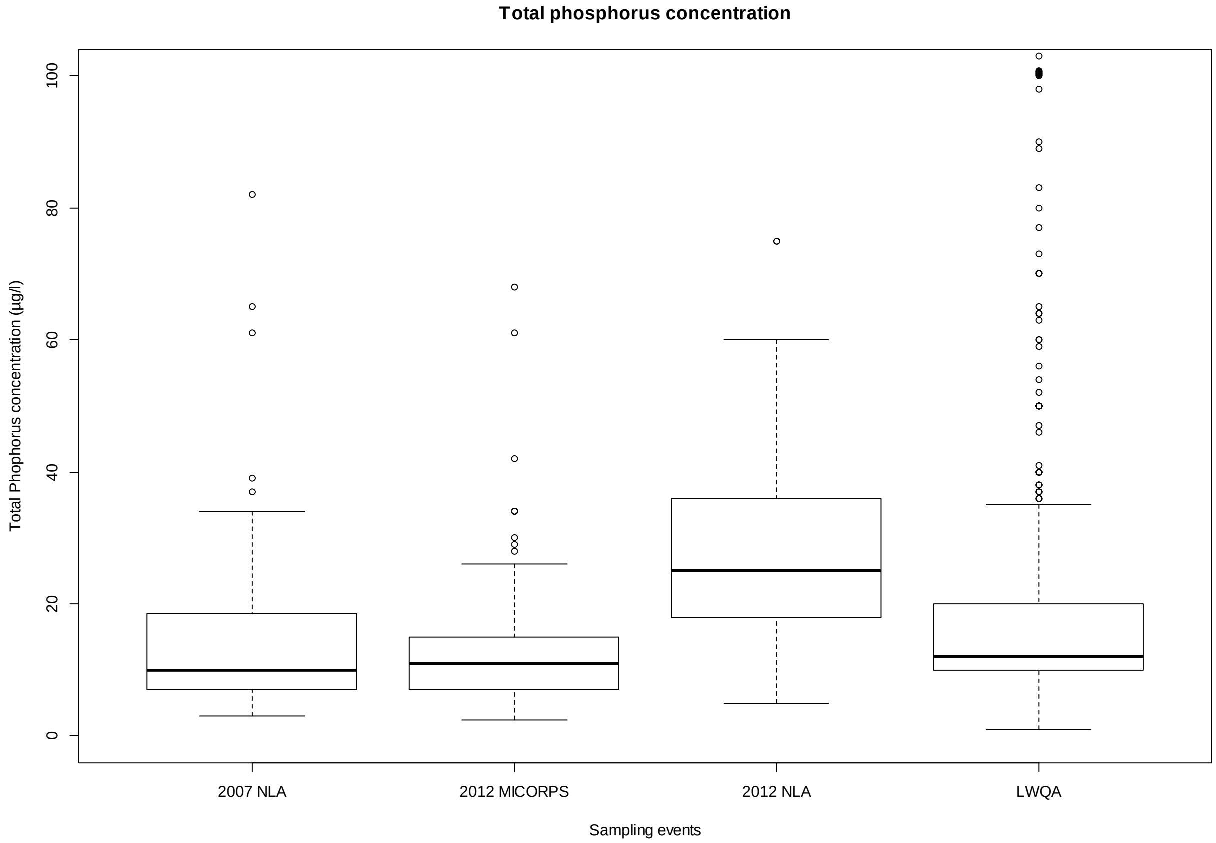

Figure 8. Boxplots total phosphorus concentrations (ug/l) recorded during the 2007 and 2012 NLA surveys, the LWQA, and the 2012 MiCorps surveys. Note: 9 sites from the LWQA had total phosphorus concentrations > 100 ug/l.

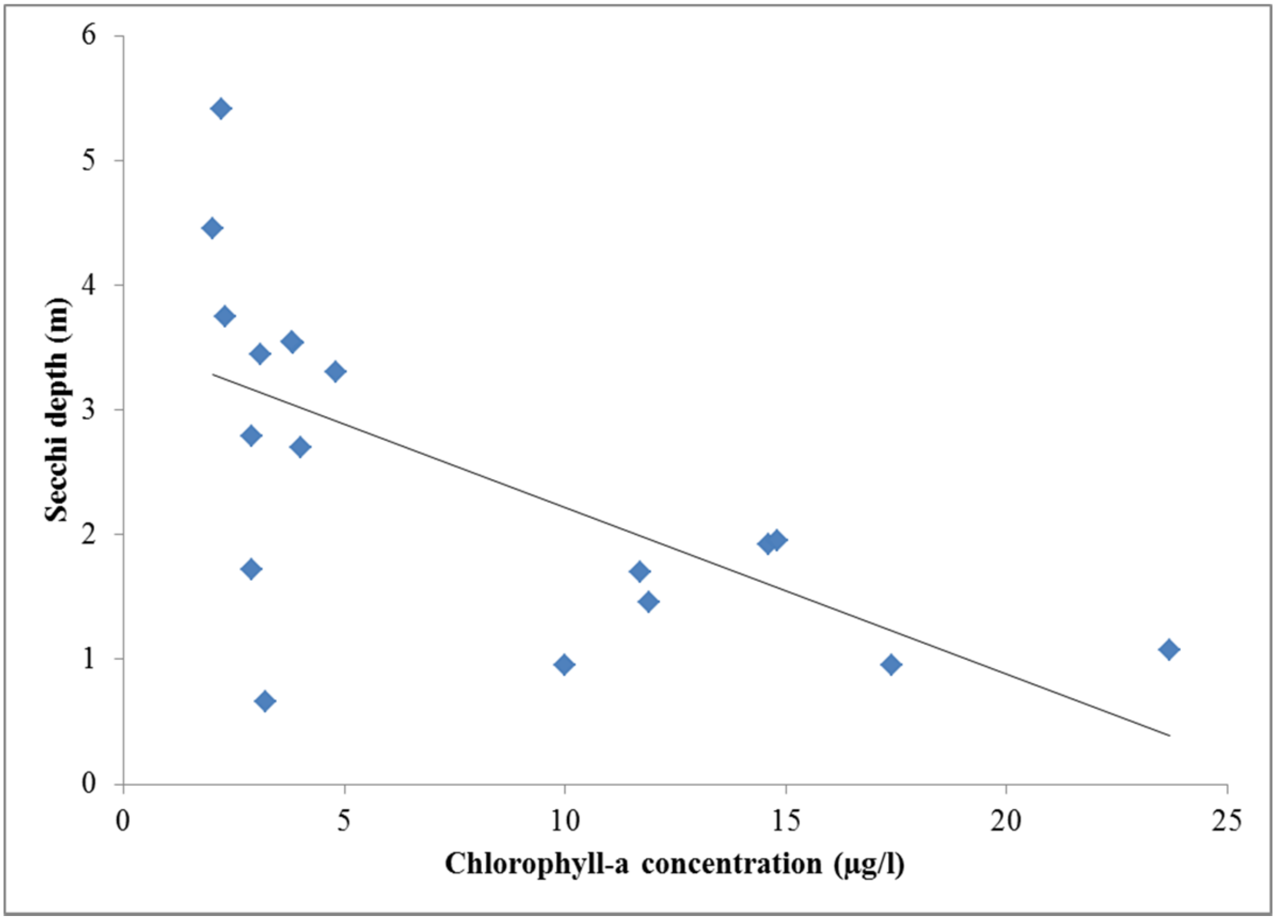

Figure 9. Linear regression of Secchi depth and chlorophyll *a* concentrations in Michigan inland lakes sampled during the 2007 NLA that were also sampled in the 2012 NLA.

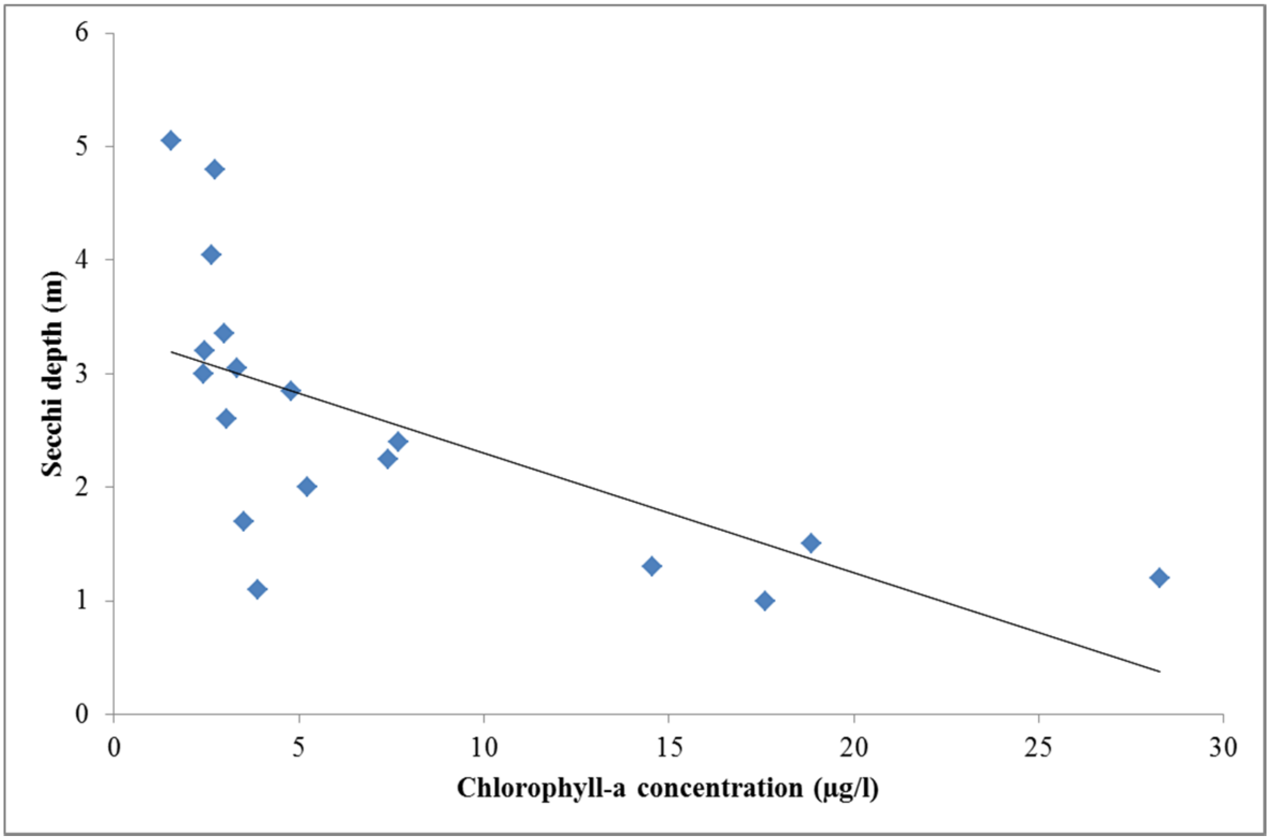

Figure 10. Linear regression of Secchi depth and chlorophyll *a* concentrations in Michigan 2012 NLA lakes that were also sampled in the 2007 NLA.

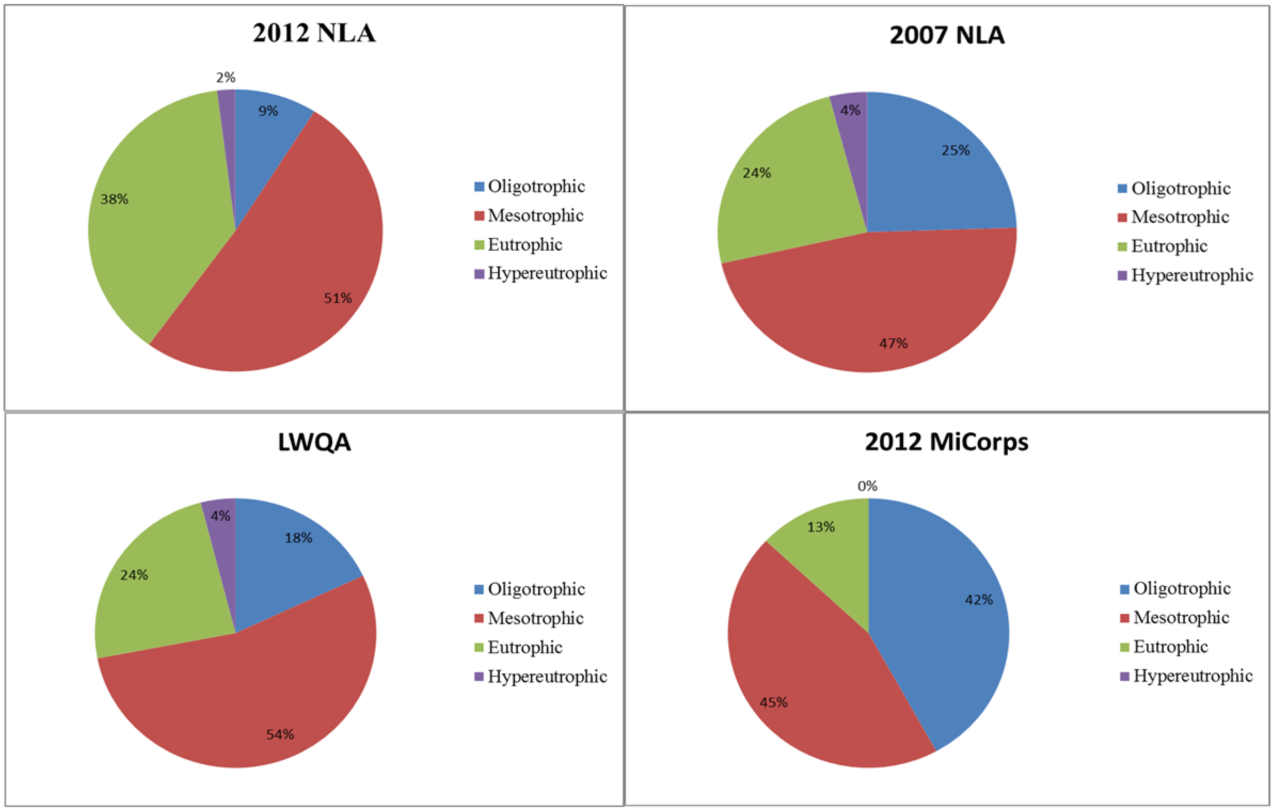

Figure 11. Trophic status of lakes sampled during the 2007 and 2012 NLA surveys, the LWQA, and the 2012 MiCorps surveys.

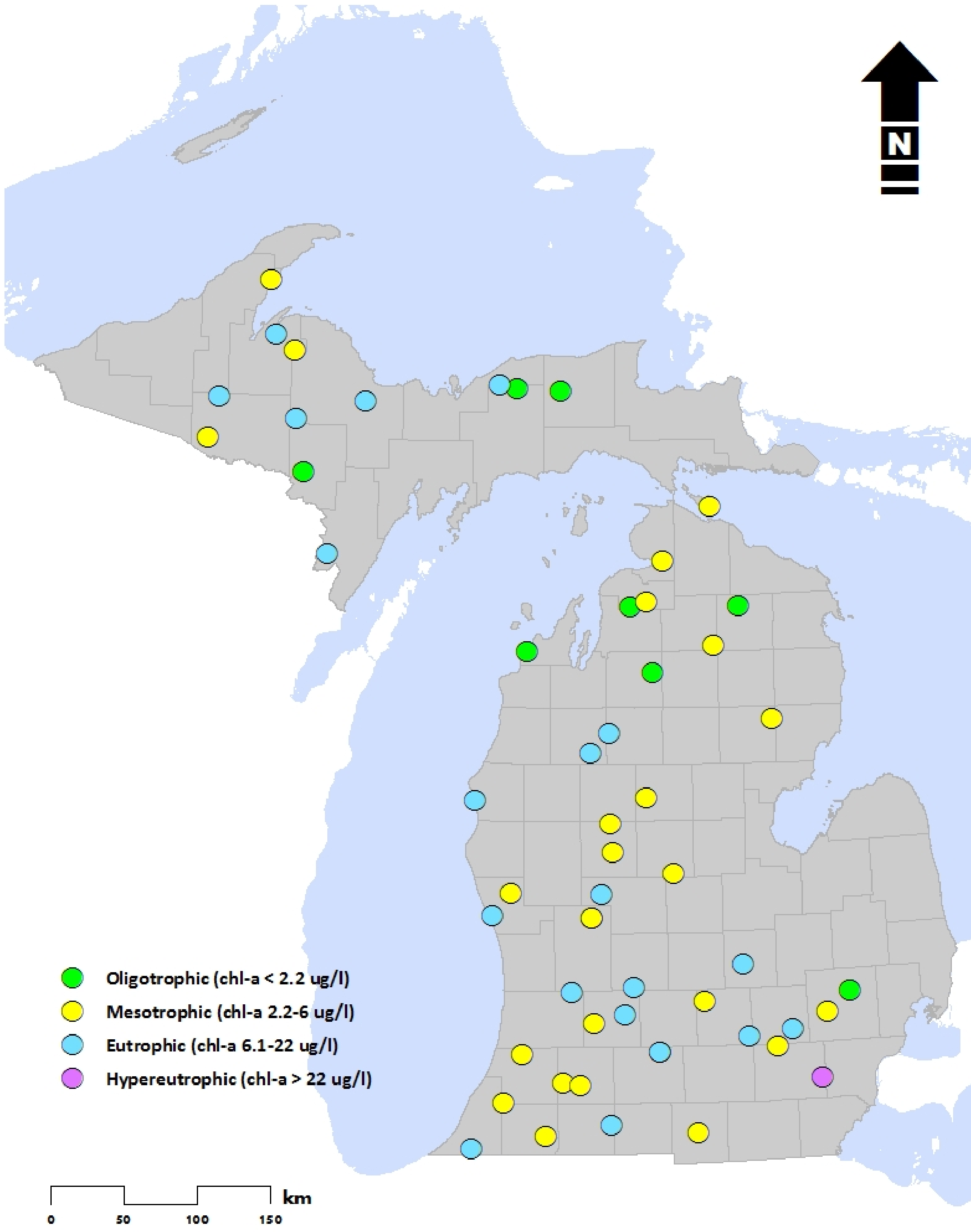

Figure 12. 2012 NLA lake trophic status based on chlorophyll *a* concentrations (ug/l).

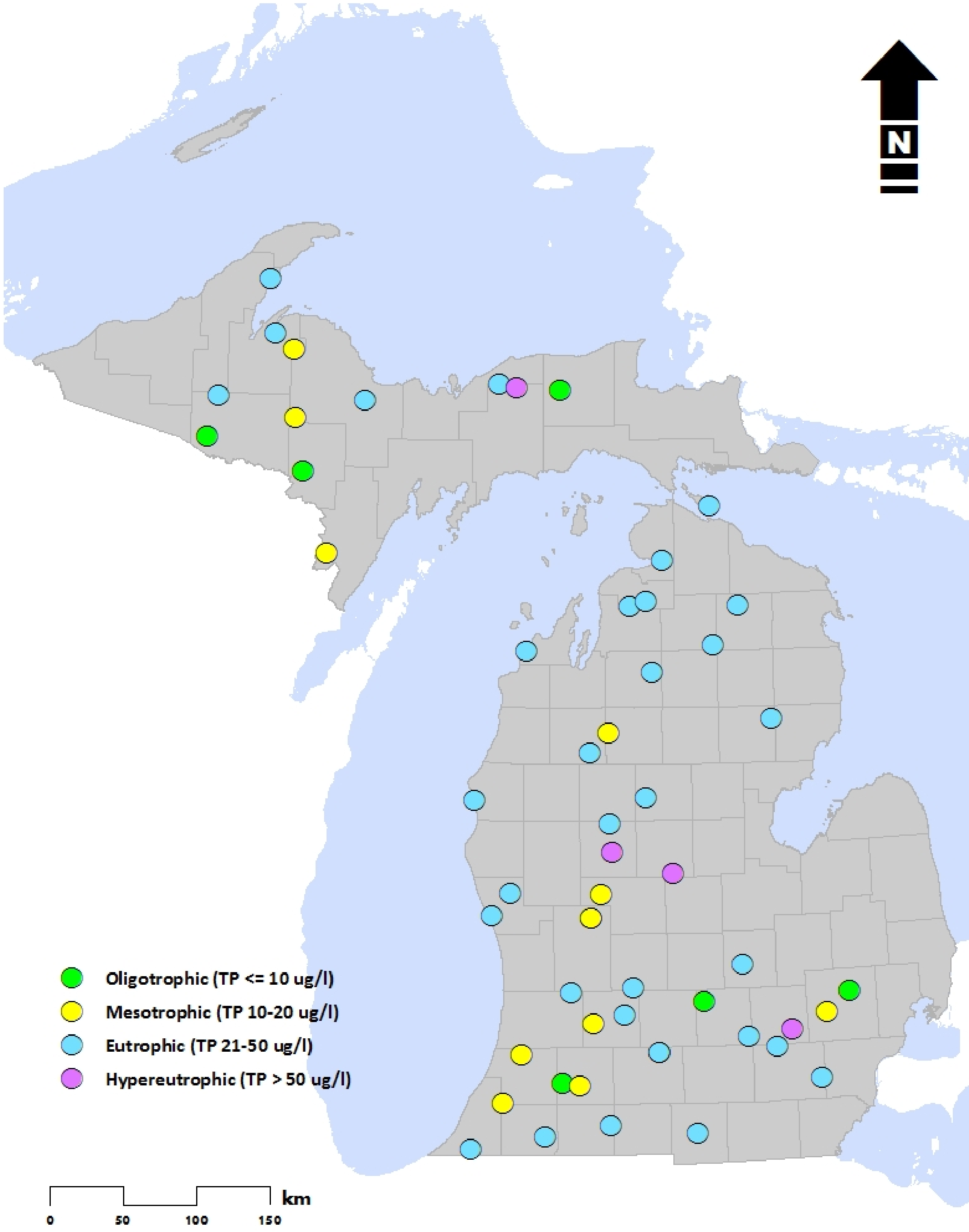

Figure 13. 2012 NLA lake trophic status based on total phosphorus concentrations (ug/l).

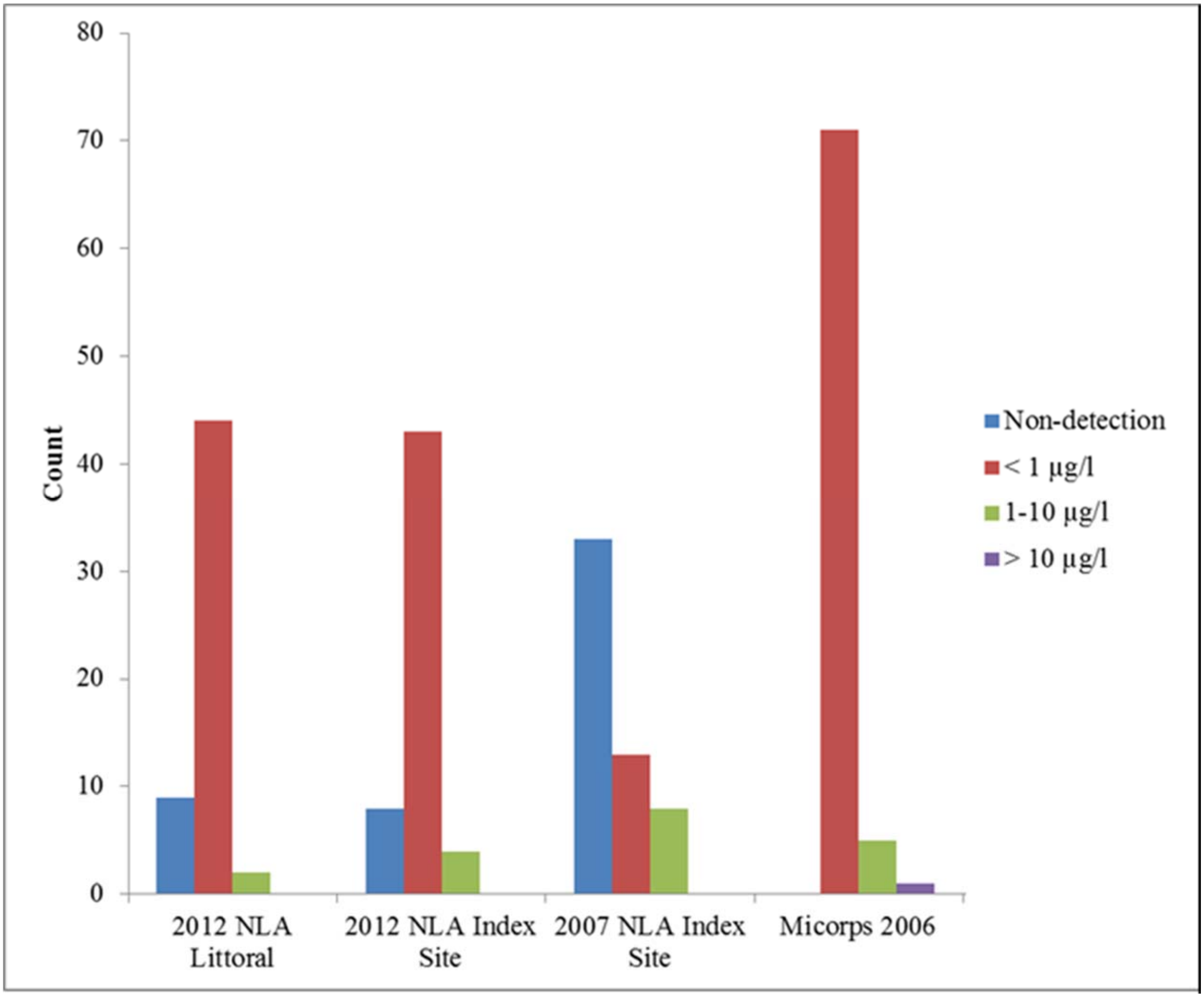

Figure 14. Microcystin concentrations from the 2007 and 2012 NLA surveys (samples taken at littoral and index sites) and the 2006 MiCorps sampling (Sarnelle et al., 2010).

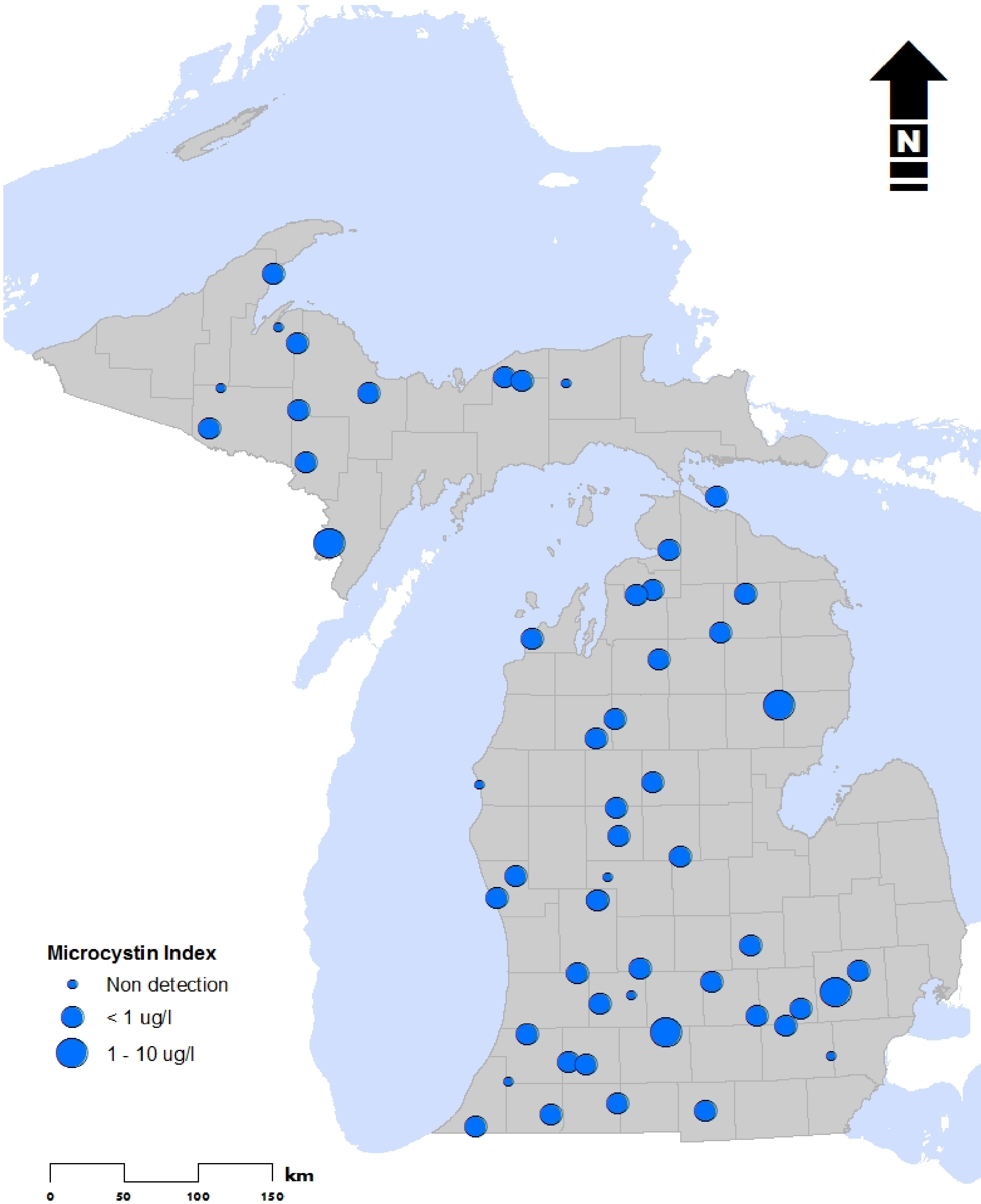

Figure 15. Index site microcystin concentrations: non-detects, < 1 ug/l, or 1-10 ug/l.

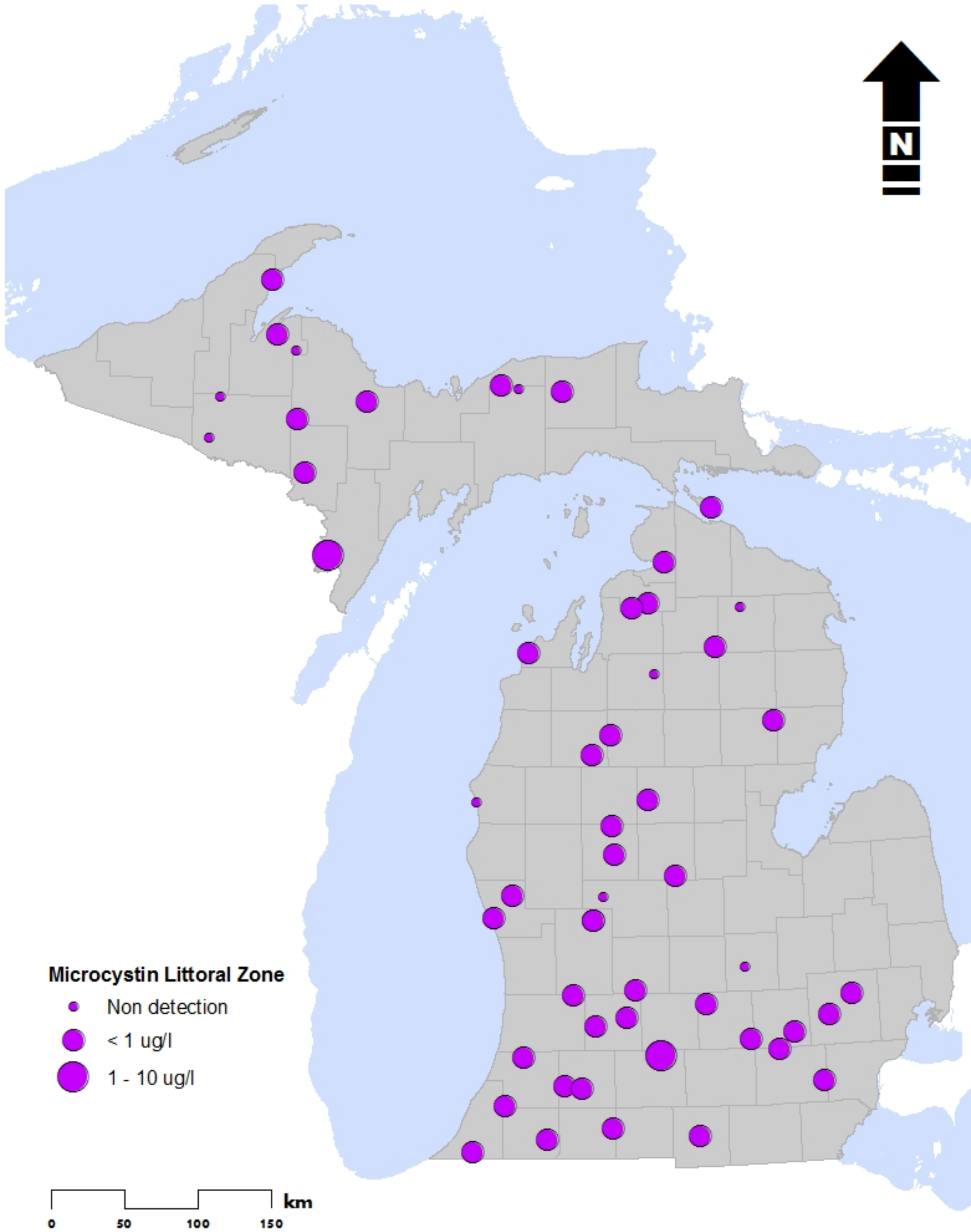

Figure 16. Littoral zone microcystin concentrations: non-detect, < 1 ug/l, or 1-10 ug/l.

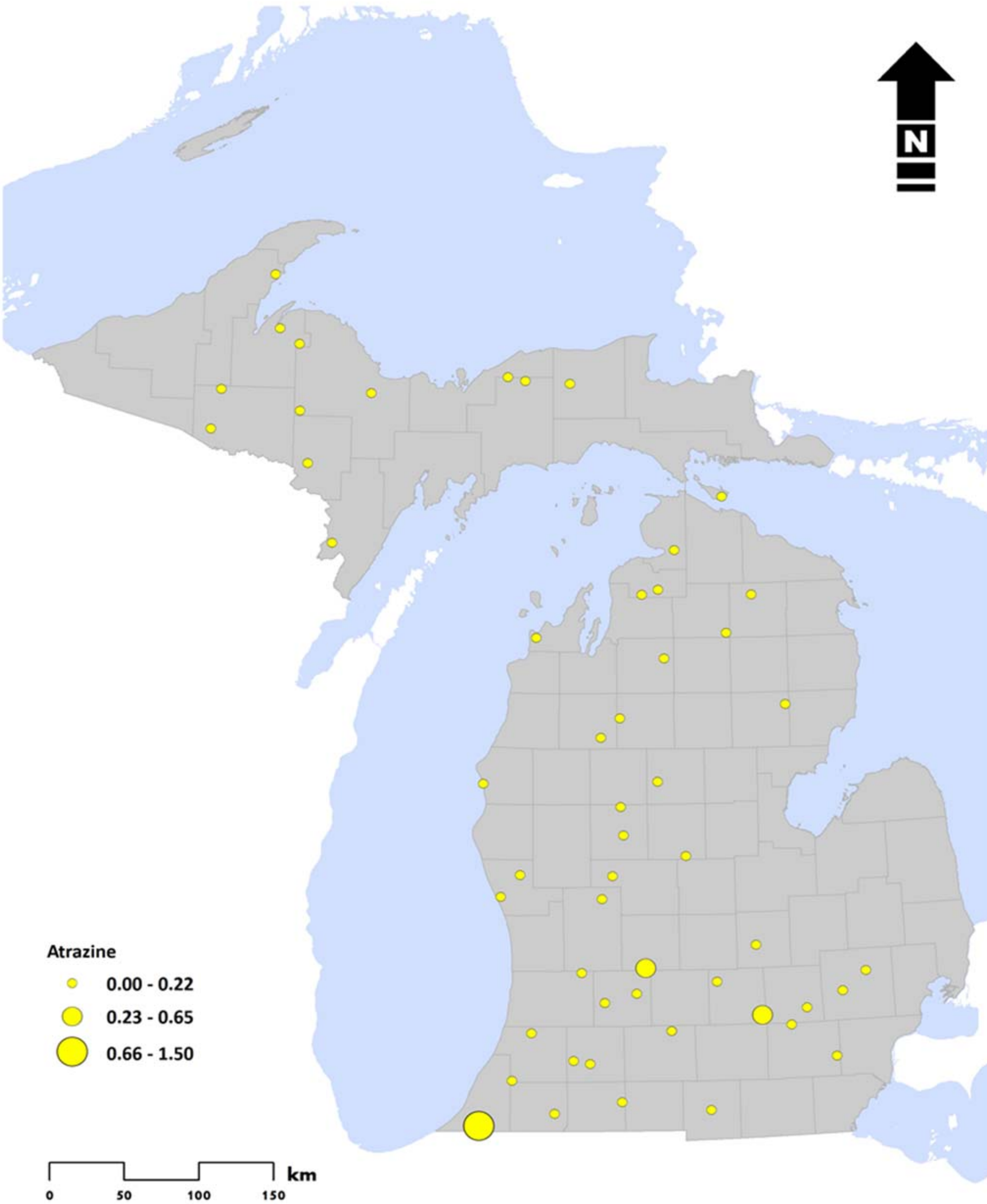

Figure 17. Atrazine concentrations (ug/l) throughout Michigan from the 2012 NLA.

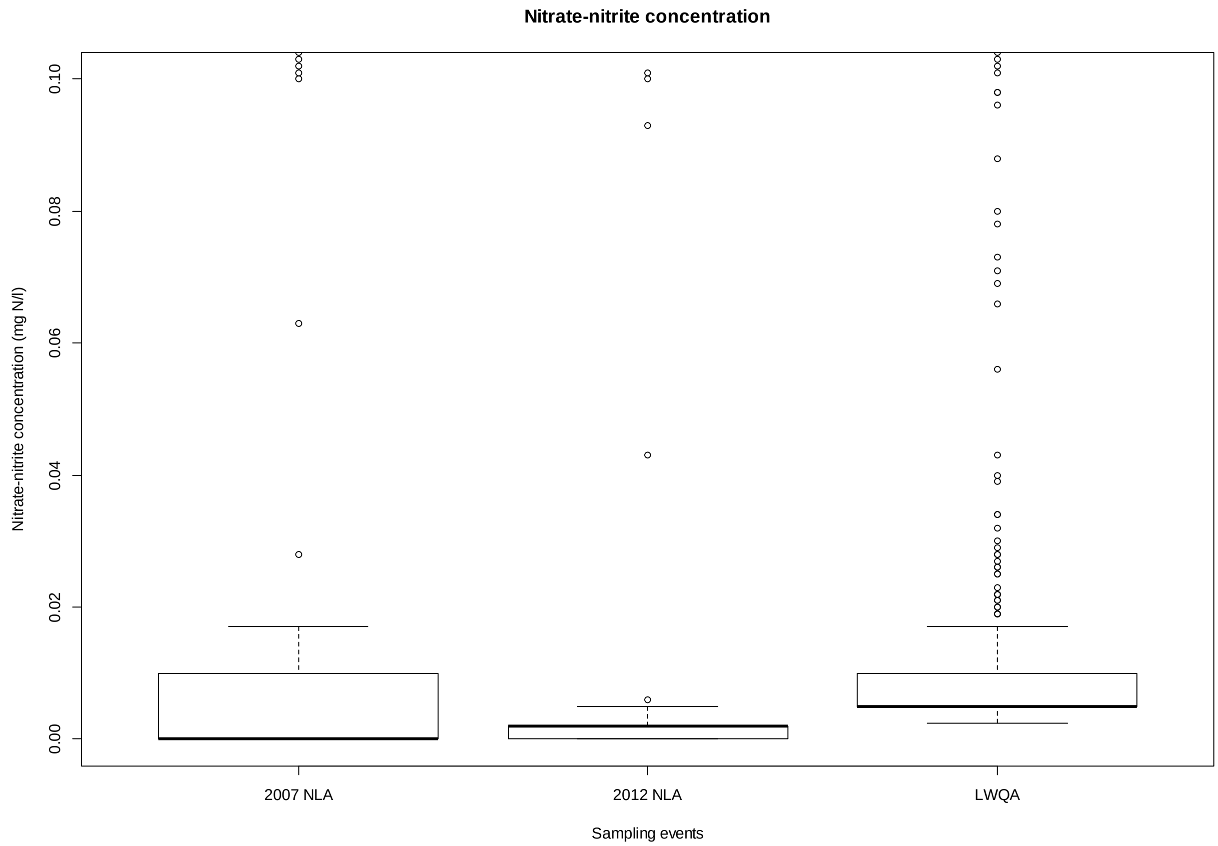

Figure 18. Boxplots of nitrate-nitrite concentrations (mg N/l) recorded during 2007 and 2012 NLA surveys, and the LWQA. Note: 6 sites from the 2007 NLA, 4 sites from the 2012 NLA, and 78 sites from the LWQA had nitrate-nitrite concentrations > 0.1 mg/l.

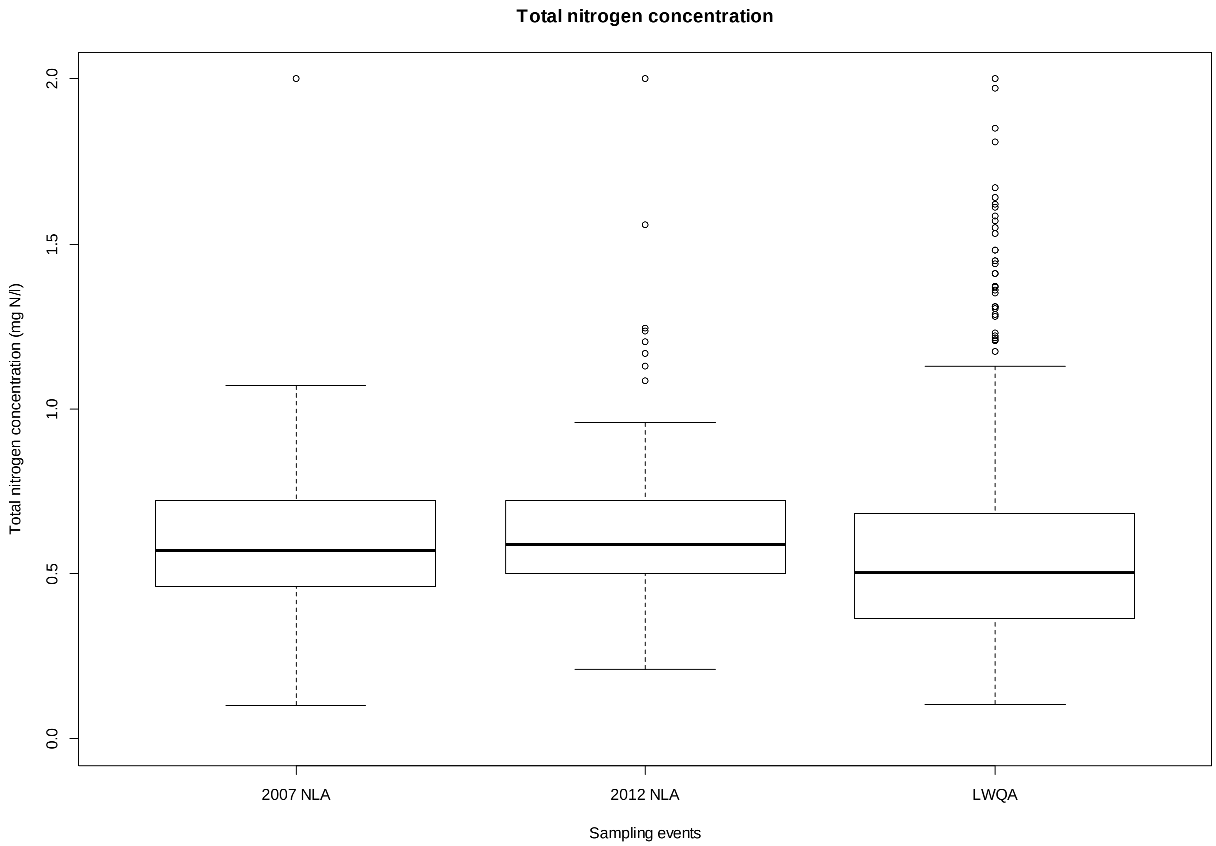

Figure 19. Boxplots of total nitrogen concentrations (mg/l) recorded during 2007 and 2012 NLA surveys, and the LWQA. Note: 1 site from the 2007 NLA, 1 site from the 2012 NLA, and 5 sites from the LWQA had total nitrogen concentrations > 2 mg/l.

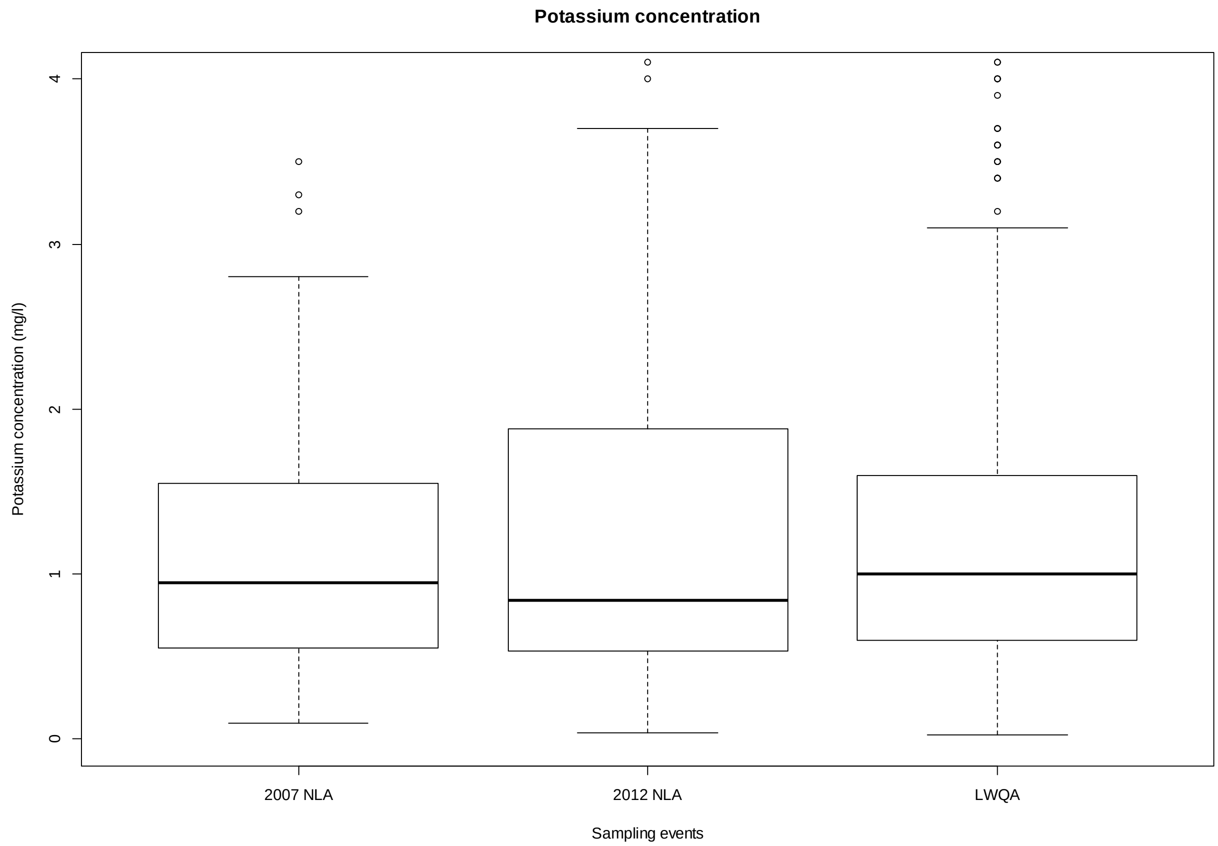

Figure 20. Boxplots of potassium concentrations (mg/l) recorded during 2007 and 2012 NLA surveys and LWQA. Note: 2 sites from the 2012 NLA and 6 sites from the LWQA had potassium concentrations > 4 mg/l.

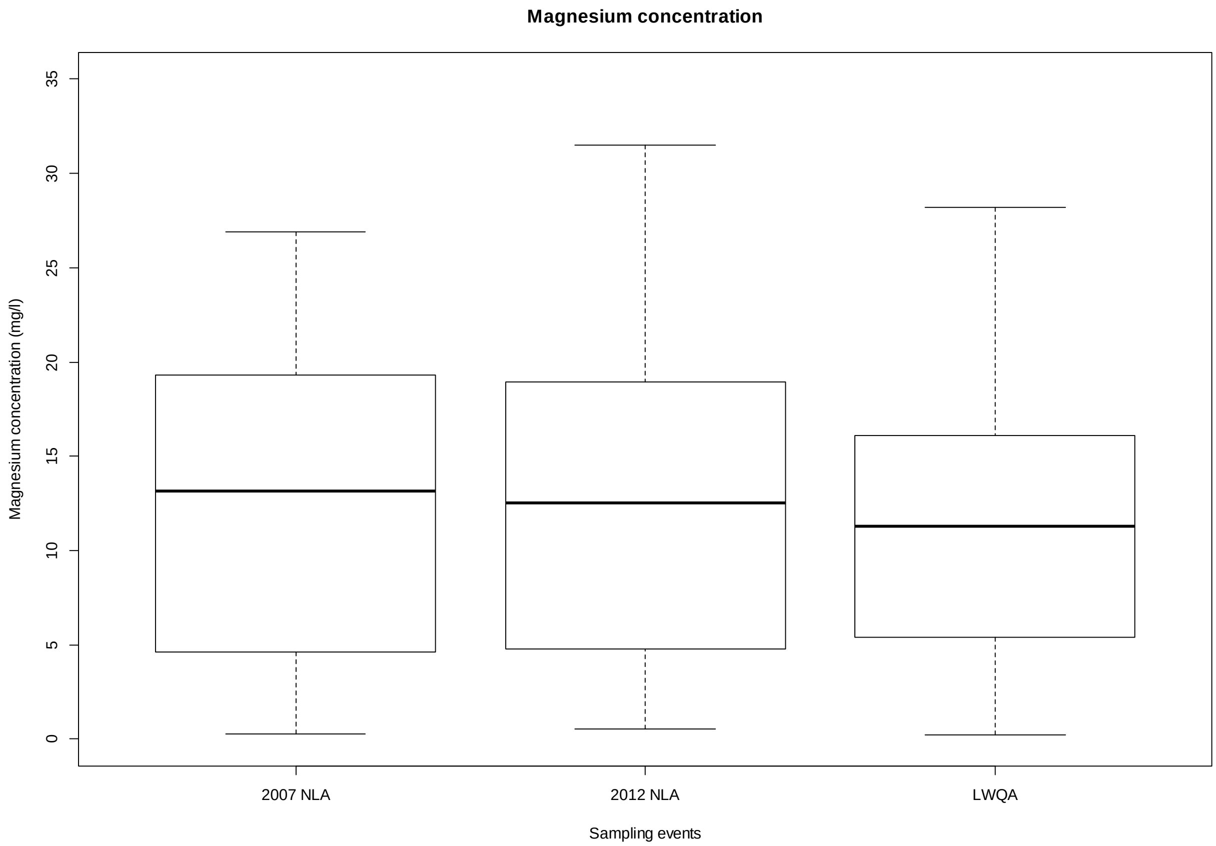

Figure 21. Boxplots of magnesium concentrations (mg/l) recorded during 2007 and 2012 NLA surveys and LWQA.

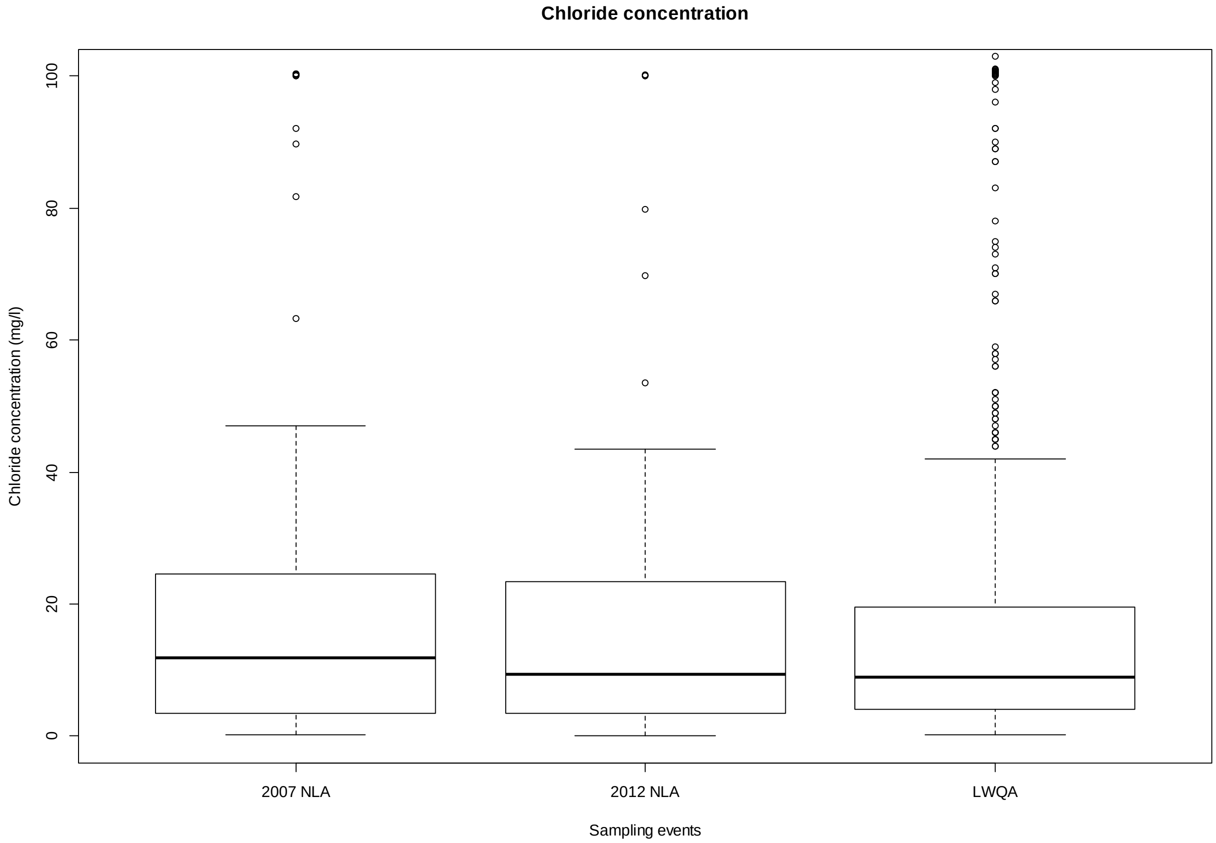

Figure 22. Boxplots of chloride concentrations (mg/l) recorded during 2007 and 2012 NLA surveys and LWQA. Note: 5 sites from the 2007 NLA, 3 sites from the 2012 NLA, and 12 sites from the LWQA had total chloride concentrations > 100 mg/l.

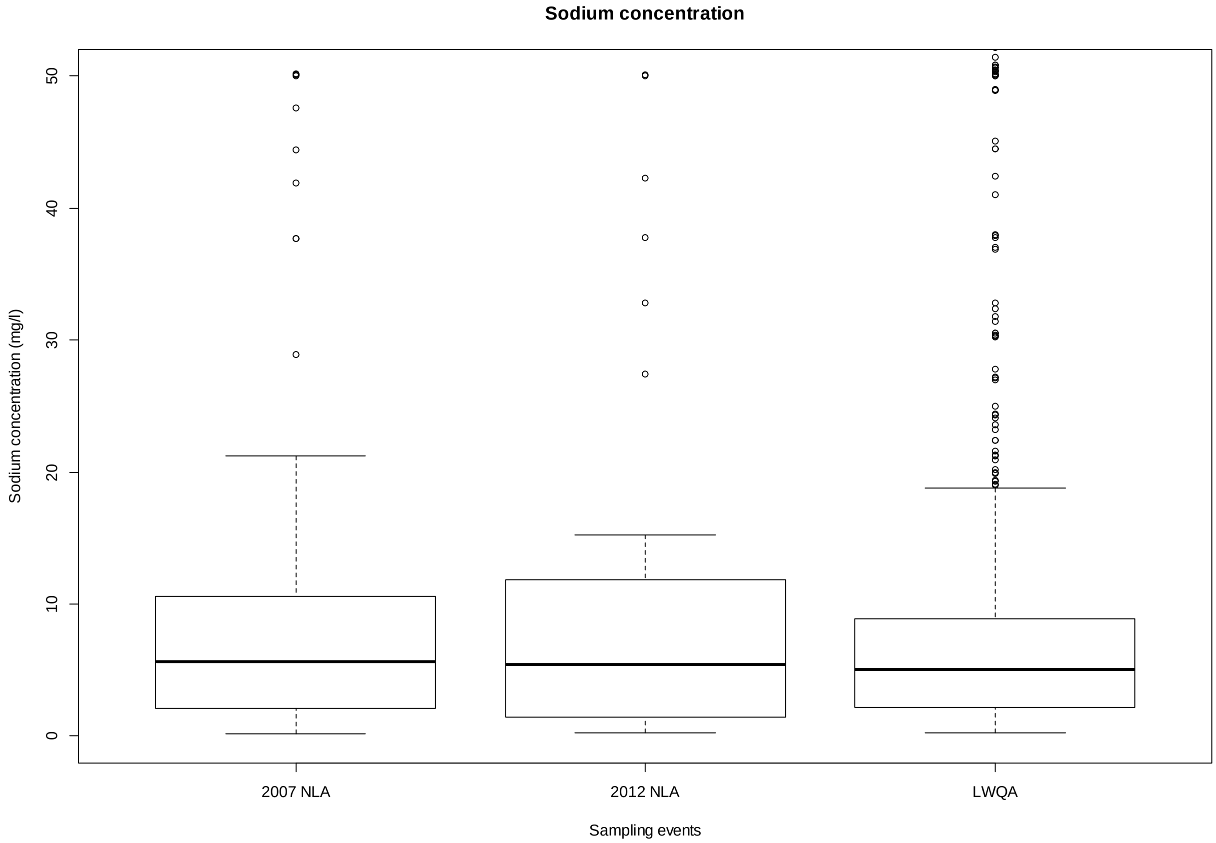

Figure 23. Boxplots of sodium concentrations (mg/l) recorded during 2007 and 2012 NLA surveys and LWQA. Note: 3 sites from the 2007 NLA, 3 sites from the 2012 NLA, and 9 sites from the LWQA had total chloride concentrations > 50 mg/l.

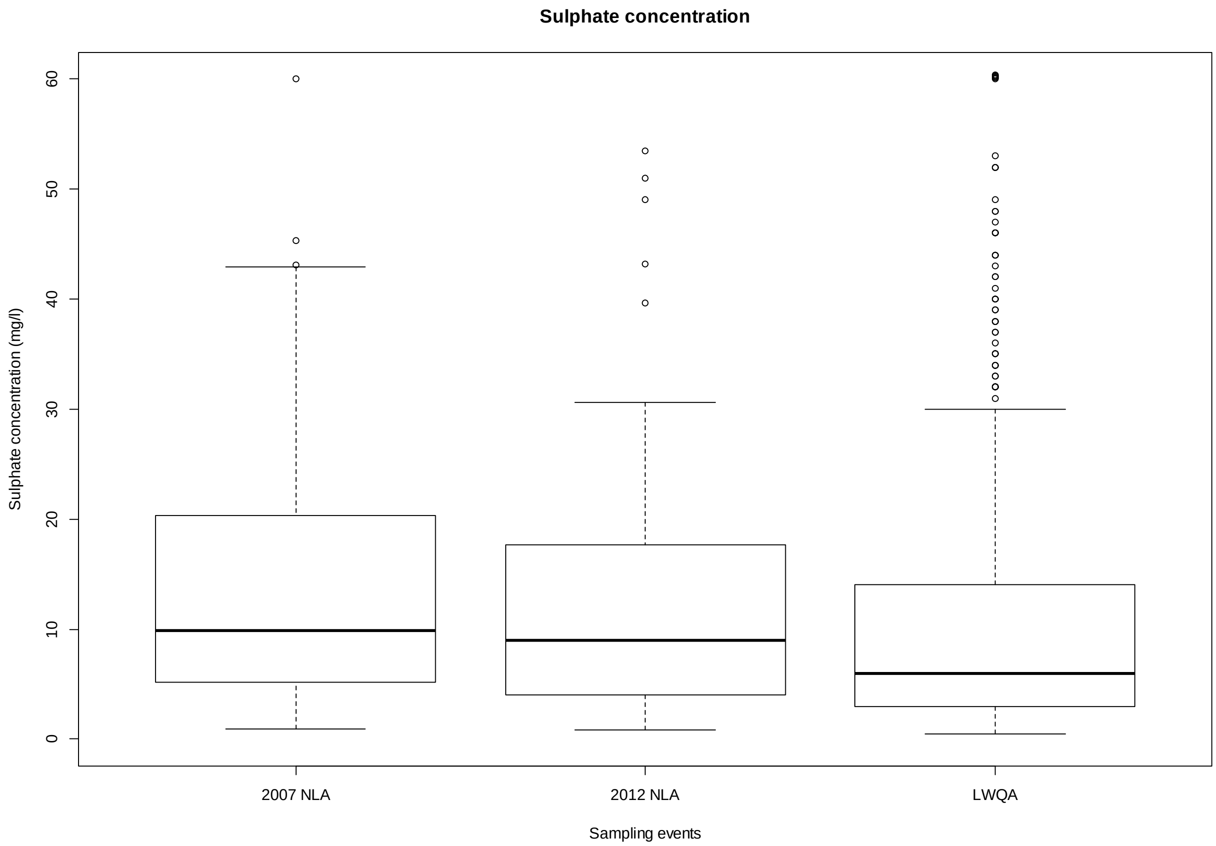

Figure 24. Boxplots of sulphate concentrations (mg/l) recorded during 2007 and 2012 NLA surveys and LWQA. Note: 5 sites from the LWQA had sulphate concentrations > 60 mg/l.

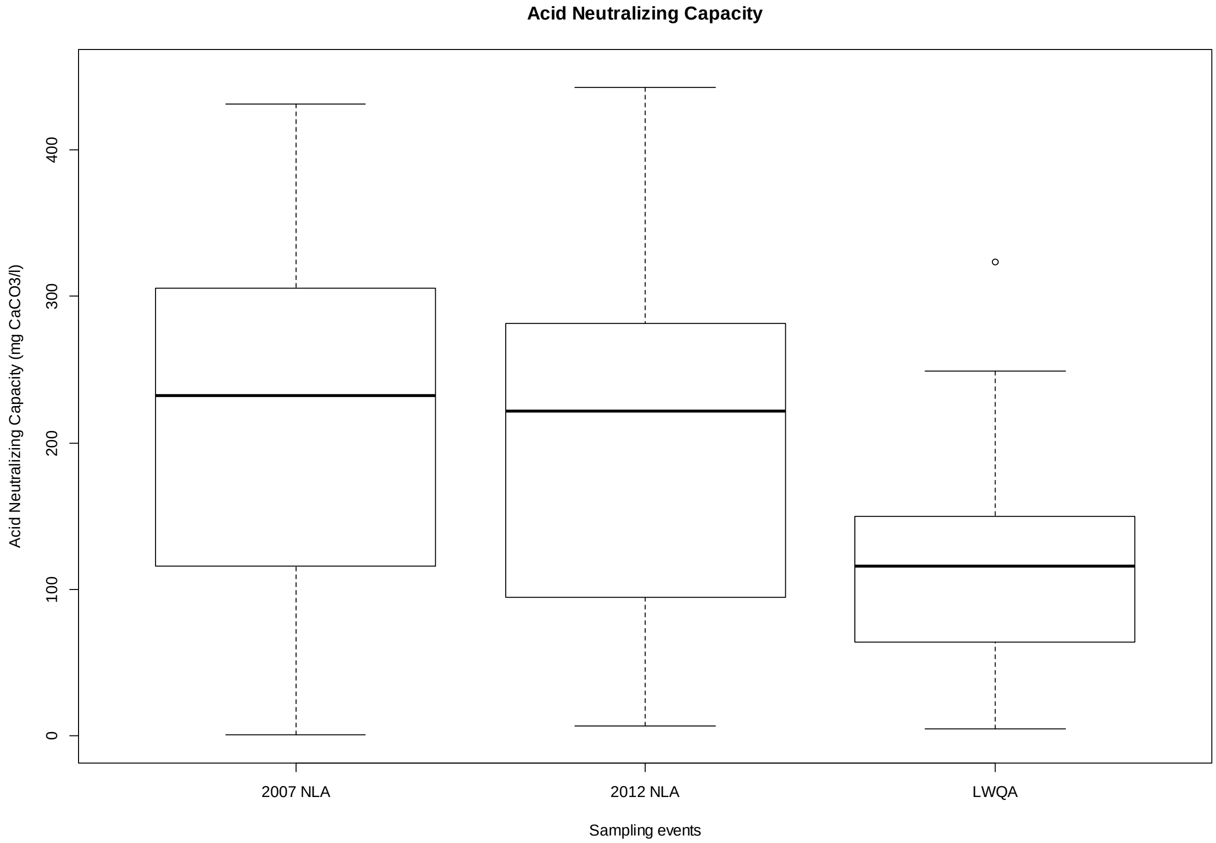

Figure 25. Boxplots of acid neutralizing capacity (mg $CaCO_3$/l) recorded during 2007 and 2012 NLA surveys and LWQA.

Table 3. Summary statistics of measured parameters from 2012 NLA, 2007 NLA, LWQA, and 2012 MiCorps.

Sampling Event	Summary statistics	Maximum depth (m)	Area (acres)	pH	Secchi depth (m)	Chlorophyll-a concentration (µg/l)	Total phosphorus (µg/l)	Nitrate-nitrite (mg N/l)	Ammonia (mg N/l)	Total nitrogen (mg/l)
2012 NLA	Mean	9.1	337.7	8.2	2.7	7.8	28.6	0.1	0.02	0.7
(n = 53)	Standard deviation	5.8	794.2	0.7	1.5	7.6	15.5	0.5	0.01	0.5
	Maximum	26.3	4694.0	9.5	8.8	33.4	75.0	3.5	0.05	3.7
	75th percentile	12.9	251.8	8.5	3.2	11.2	36.0	0.0	0.02	0.7
	median	7.7	64.0	8.4	2.6	4.5	25.0	0.0	0.01	0.6
	25th percentile	3.7	30.1	8.1	1.6	2.9	18.0	0.0	0.01	0.5
	Minimum	0.9	4.0	5.8	0.5	1.0	5.0	0.0	0.00	0.2
2007 NLA	Mean	8.3	631.8	7.8	2.6	7.0	17.1	0.1	.	0.6
(n = 50)	Standard deviation	5.2	1960.6	0.7	1.5	6.5	16.6	0.4	.	0.5
	Maximum	21.1	13047.8	9.4	8.0	30.7	82.0	3.1	.	3.4
	75th percentile	11.6	359.0	8.2	3.5	9.9	18.4	0.0	.	0.7
	median	7.4	152.4	7.9	2.3	3.9	10.0	0.0	.	0.6
	25th percentile	4.2	75.8	7.6	1.5	3.0	7.0	0.0	.	0.5
	Minimum	1.0	10.4	6.0	0.6	1.1	3.0	0.0	.	0.1
LWQA	Mean	42.8	278.8	8.2	3.1	6.1	16.0	0.1	0.02	0.6
(n = 730)	Standard deviation	24.6	795.6	0.5	1.5	10.0	16.0	0.2	0.05	0.4
	Maximum	115.0	8111.8	9.6	11.3	120.0	172.0	3.1	0.82	3.9
	75th percentile	57.0	181.9	8.5	4.0	6.0	17.0	0.0	0.03	0.7
	median	39.0	76.3	8.3	3.0	3.6	12.0	0.0	0.01	0.5
	25th percentile	25.0	38.4	8.0	2.1	2.0	8.0	0.0	0.01	0.4
	Minimum	3.0	9.1	5.1	0.3	0.5	2.5	0.0	0.00	0.1
2012 MiCorps	Mean	.	.	.	3.8	3.8	13.1	.	.	.
(n = 113)	Standard deviation	.	.	.	1.9	3.7	10.4	.	.	.
	Maximum	.	.	.	11.9	20.8	68.0	.	.	.
	75th percentile	.	.	.	4.5	4.2	15.0	.	.	.
	median	.	.	.	3.4	2.8	11.0	.	.	.
	25th percentile	.	.	.	2.7	1.5	7.0	.	.	.
	Minimum	.	.	.	1.1	0.5	2.5	.	.	.

Table 3 continued. Summary statistics of water parameters from 2012 NLA, 2007 NLA, and the LWQA.

Sampling Event	Summary statistics	Acid neutralizing capacity (mg $CaCO_3$/L)	Calcium (mg/l)	Chloride (mg/l)	Potassium (mg/l)	Magnesium (mg/l)	Sulfate (mg/l)	Sodium (mg/l)
2012 NLA	Mean	202.3	28.4	20.7	1.3	12.2	13.8	11.2
(n = 53)	Standard deviation	119.6	18.2	30.2	1.4	8.1	13.6	16.5
	Maximum	442.2	70.3	137.7	7.9	31.5	53.5	71.7
	75th percentile	281.1	40.9	23.5	1.9	19.0	17.7	11.8
	median	221.7	26.9	9.4	0.8	12.5	9.0	5.4
	25th percentile	94.4	13.4	3.4	0.5	4.8	4.1	1.5
	Minimum	6.7	1.7	0.1	0.0	0.6	0.9	0.2
2007 NLA	Mean	211.1	29.6	27.1	1.1	12.6	14.7	12.7
(n = 50)	Standard deviation	115.4	17.1	36.1	0.8	7.9	13.5	16.9
	Maximum	431.1	66.6	128.7	3.5	26.9	61.4	62.4
	75th percentile	303.0	39.1	24.6	1.5	19.3	20.2	10.5
	median	232.5	32.2	12.0	1.0	13.2	9.9	5.7
	25th percentile	120.0	15.9	3.7	0.6	4.8	5.2	2.1
	Minimum	1.3	0.9	0.2	0.1	0.3	0.9	0.2
LWQA	Mean	109.5	34.2	16.7	1.2	11.1	10.5	8.3
(n = 730)	Standard deviation	58.6	19.0	25.1	0.8	6.6	12.6	13.0
	Maximum	323.0	98.6	278.0	5.4	28.2	142.0	154.0
	75th percentile	150.0	45.8	19.0	1.6	16.1	14.0	8.6
	median	116.0	35.0	9.0	1.0	11.3	6.0	5.0
	25th percentile	64.0	20.5	4.0	0.6	5.4	3.0	2.2
	Minimum	5.0	1.1	0.3	0.0	0.3	0.5	0.3

Discussion

This report summarizes the 2012 NLA results for lake trophic state indicators in Michigan inland lakes, as well as other water parameters. To provide context for these results, we compared the 2012 NLA data to other existing statewide datasets including the 2007 NLA, the 2001-2010 LWQA project, and the 2012 MiCorps volunteer data. Some caution must be used in making these comparisons because the lake selection processes were not identical for these projects. Inland lakes were randomly selected in the 2007 and 2012 NLAs; however, only lakes greater than 4 hectares were eligible for selection in 2007, whereas lakes greater than 1 hectare were eligible in 2012. For the LWQA project, all 730 Michigan public access lakes with a surface area greater than 25 acres were monitored, resulting in a pool of larger lakes relative to the 2007 and 2012 NLAs. For the 2012 MiCorps lakes, sampling is contingent on volunteer interest, resulting in a non-random selection of lakes of various sizes. As a result, we would not expect complete agreement among the results of these projects. However, despite these differences in selection methodology, we believe that comparisons can provide a useful tool for reporting on the overall trophic status and quality of Michigan inland lakes.

The majority of lakes (60%) sampled for the 2012 NLA were classified as oligotrophic or mesotrophic (Figure 11). This percentage is lower than those found during the 2007 NLA (72%), the LWQA project (72%), and the 2012 volunteer MiCorps lakes (87%). In addition to natural variation among specific lakes sampled and across years, the inclusion of smaller lakes in the 2012 NLA may contribute to the higher percentage of eutrophic lakes. In addition, we believe the overall 2012 NLA trophic state data are inflated towards productivity because of high reported total phosphorus concentrations (one of 3 parameters, along with Secchi depth and chlorophyll *a*, used to calculate the Trophic State Index). Secchi depth measurements and chlorophyll *a* concentrations were much more consistent with other project results, while the 2012 total phosphorus concentrations were noticeably greater than those measured in other surveys (Table 3). A linear regression between total phosphorus and chlorophyll *a* concentrations measured in the 2012 NLA revealed a much weaker relationship (Figure 2) than would be expected in phosphorus-limited, temperate lakes (e.g. Horne and Goldman 1994). A linear regression between total phosphorus and chlorophyll *a* concentrations from the 2012 MiCorps (Figure 3) showed a much stronger relationship with lower total phosphorus concentrations. Of the 18 lakes sampled for both the 2007 and 2012 NLA projects, total phosphorus levels were notably higher in 2012 (Figures 4 and 5). Given the summer of 2012 was extremely dry throughout the midwestern United States (Mallya et al., 2013), external loading from runoff events would have been minimal.

Regardless of the apparent trophic status discrepancy in the 2012 NLA results, all statewide lake monitoring projects indicate that most Michigan inland lakes are in relatively good condition. Although not enough sites were sampled to statistically evaluate geographic patterns in trophic state indicators, it is worth noting that the 2012 NLA lakes with the lowest chlorophyll *a* levels were found in the Upper Peninsula and the northern Lower Peninsula (Figure 12). A similar pattern was not evident for total phosphorus, where lakes with the lowest and highest levels were pretty well distributed throughout the state (Figure 13).

Consistent with previous statewide sampling events (Rediske et al., 2007; Sarnelle et al. 2010; Bednarz et al., 2012), microcystin concentrations were low throughout the state. None of the 2012 NLA lakes had microcystin concentrations above the provisional World Health Organization's recreational guideline of 20 ug/l. Of the 53 lakes sampled, only 4 had a microcystin concentration greater than 1 ug/L at the index site. These 4 lakes were in different geographic regions of the state (Figure 15). It is somewhat surprising that only 2 of the 4 lakes had microcystin levels greater than 1 ug/L in the littoral zone (Figure 16). We might have expected that because algal blooms are more likely to occur in nearshore locations where higher levels of toxins would occur in nearshore areas as well. However, these lakes were only sampled one time, making it difficult to assess algal toxin prevalence and extent. The MDEQ conducted a more expansive study of algal toxins in inland lakes in 2015, and those results will be summarized in a separate report.

Atrazine concentrations were low statewide, with a mean concentration of 0.07 ug/L across the 53 lakes, and a maximum level of 1.5 ug/L. Most of the water samples were either non-detect or had very low atrazine concentrations, especially in the Upper Peninsula and northern Lower Peninsula (Figure 17). None of the samples exceeded Michigan water quality standards (aquatic maximum value of 50 ug/L). Consistent with use patterns (Kannan et al., 2006), the highest atrazine concentrations were in the southern Lower Peninsula. Because atrazine persists in soil longer than most other commonly used pesticides, it has a greater runoff potential (Goss, 1992). Even so, atrazine levels are stongly seasonal (Crocker et al., 2002). In the midwest, atrazine is generally applied in the spring and elevated concentrations are more likely to be found in surface waters in May and early June, with lower levels found in July and August. As noted earlier, the midwestern United States experienced drought conditions during the summer of 2012 (Mallya et al., 2013), likely contributing to the low levels of atrazine.

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