Final Report

Implementing WI DNR’s Lake Superior Nearshore Monitoring Plan
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## Abbreviations

<table>
<thead>
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<th>Abbreviation</th>
<th>Description</th>
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<tbody>
<tr>
<td>AIS</td>
<td>Aquatic Invasive Species</td>
</tr>
<tr>
<td>BSC</td>
<td>Bird Studies Canada</td>
</tr>
<tr>
<td>Chl-a</td>
<td>Chlorophyll a</td>
</tr>
<tr>
<td>DO</td>
<td>Dissolved Oxygen</td>
</tr>
<tr>
<td>GLCWC</td>
<td>Great Lakes Coastal Wetlands Consortium</td>
</tr>
<tr>
<td>GPS</td>
<td>Global Positioning System</td>
</tr>
<tr>
<td>HBI</td>
<td>Hilsenhoff Biological Index</td>
</tr>
<tr>
<td>IBI</td>
<td>Index of Biotic Integrity</td>
</tr>
<tr>
<td>LSRI</td>
<td>University of Wisconsin-Superior Lake Superior Research Institute</td>
</tr>
<tr>
<td>MMP</td>
<td>Bird Studies Canada Marsh Monitoring Program</td>
</tr>
<tr>
<td>NCCA</td>
<td>National Coastal Condition Assessment</td>
</tr>
<tr>
<td>NO3 + NO2</td>
<td>Nitrate + Nitrite</td>
</tr>
<tr>
<td>NH3</td>
<td>Ammonia</td>
</tr>
<tr>
<td>NTU</td>
<td>Nephelometric Turbidity Units</td>
</tr>
<tr>
<td>SLOH</td>
<td>Wisconsin State Laboratory of Hygiene</td>
</tr>
<tr>
<td>SOLEC</td>
<td>State of the Lakes Ecosystem Conference</td>
</tr>
<tr>
<td>SOP</td>
<td>Standard Operating Procedure</td>
</tr>
<tr>
<td>SWIMS</td>
<td>WDNR Surface Water Integrated Monitoring System</td>
</tr>
<tr>
<td>TDP</td>
<td>Total Dissolved Phosphorous</td>
</tr>
<tr>
<td>TKN</td>
<td>Total Kjeldahl Nitrogen</td>
</tr>
<tr>
<td>TP</td>
<td>Total Phosphorus</td>
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<tr>
<td>USEPA</td>
<td>United States Environmental Protection Agency</td>
</tr>
<tr>
<td>UWS</td>
<td>University of Wisconsin – Superior</td>
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<td>WDNR</td>
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<td>WQ</td>
<td>Water Quality</td>
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Project Background and Methods

The 78 tributary, coastal wetland and nearshore sampling stations incorporated into this project provide a permanent framework for monitoring Lake Superior communities (Appendix A). The communities included in the project have been identified as priority areas or of particular management concern by the Wisconsin Department of Natural Resources.

The sampling stations were tested for basic parameters that are indicative of environmental conditions. Measurements included water quality, biological quality, land cover analyses and habitat assessments. To assume baseline conditions, tributary monitoring was delayed when stream flow conditions were “much above normal” (greater than 90th percentile) as determined by USGS stream gages. Tributary and nearshore data was collected and analyzed using accepted WDNR and USEPA standardized monitoring protocols. Coastal wetland data was collected and analyzed using accepted WDNR monitoring protocols and indicators developed under the SOLEC process for Great Lakes communities.

This baseline assessment reports on the range of conditions that currently exist in Wisconsin’s Lake Superior Basin ecosystems. It may be used as a comparison for future assessments and to help inform future research, monitoring and resource management. The quality assurance project plan (LSRI 2010) developed for the project was followed closely during sample collection, sample handling and laboratory analysis.

Tributary Stations

Site Selection

Selection criteria for the tributary stations were based on guidance from the Wisconsin Great Lakes Strategy, the Lake Superior Binational Workgroup 2011 Monitoring Priorities, and discussions with WDNR fisheries and water resource staff. A total of 32 stations were sampled on 20 streams (Map 1).

The following criteria were used to select each station:

- The tributary leads to one of 17 priority coastal wetlands identified by the WDNR which are also being sampled as a part of this project.
- Stations are not located in the Bad River Watershed to avoid duplication of effort by tribal and watershed studies.
- The station can be legally and physically accessed.
- The stream is wadeable at the sampling location.
- A riffle is present at the sampling station.
- The downstream station is located as close as possible to the mouth.
- When two stations are located on the same stream, there is a change in stream order between the downstream and upstream station. Stream order was determined using the WDNR SWIMS database.
- To take advantage of historical data, existing WDNR stations are selected if other criteria are met.
- Habitat stations were selected randomly based on time since last survey and survey team logistics.
Map 1 - Tributary Monitoring Stations

Lake Superior Tributary Monitoring Stations 2012-2013

<table>
<thead>
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<th>ID</th>
<th>Longitude</th>
<th>Latitude</th>
<th>Stream</th>
<th>ID</th>
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Legend
- Tributary Monitoring Stations
  - Coldwater
  - Cool-Cold Headwater
  - Cool-Cold Mainstream
  - Cool-Warm Mainstream
  - NA or Unknown
- Tributaries
- Streams
- Watershed Boundary
**Water Quality Testing**

A series of physical and chemical water quality parameters that provide a good indication of stream condition were measured at all of the 32 tributary stations. Water chemistry measurements included total phosphorus (TP), total dissolved phosphorus (TDP), total Kjeldahl nitrogen (TKN), and nitrate-nitrite (NO$_3$ + NO$_2$), ammonia (NH$_3$), chlorophyll-a (Chl-a) and total suspended solids (TSS). To provide a baseline condition, streams were not monitored if the stream flow was greater than 90$^{th}$ percentile as determined by the closest USGS stream gage. Real-time stream flow was accessed at [http://waterwatch.usgs.gov/](http://waterwatch.usgs.gov/) prior to sampling.

Water chemistry samples were collected in the spring and fall of 2012 and 2013 using protocols outlined in *Guidelines and Procedures for Surface Water Grab Sampling* (WDNR, Surface Water Assessment Team 2005) and *LSRI/SOP/FS/33 – Water Quality Monitoring Using IN SITU Measurements and Collection of Discrete Grab Samples*, (Eliot et al. 2013). Discrete grab samples were collected the middle of the channel, eight to twelve inches below the surface of the water or half way down from the surface in shallower waters. Grab samples were collected directly in pre-cleaned bottles supplied by the Wisconsin State Laboratory of Hygiene (SLOH), filtered, preserved and iced as required and shipped to the SLOH for analysis.

In situ measurements of temperature, dissolved oxygen, specific conductivity, turbidity (NTU), and pH were scheduled once per month for 5 months (May through September) using a Yellow Springs Instruments (YSI) multi-parameter water quality sonde. The YSI meter was calibrated once per week prior to sampling.

Transparency was measured once per month for 5 months (May through September) using a 120 cm transparency tube (t-tube). Stream water was collected twice and each time drained slowly from the t-tube until the target at the bottom was visible. The average distance of the water level above the target for both measurements was recorded in the field notebook.

Stream flow was measured once per month for 5 months (May through September) using a flow meter and following *WI DNR Field Procedures Manual - Part C: Field Measurement/2301 Open Channel Flow Measurement* (WDNR 2011). Several initial 2012 measurements were taken with a Swoffer 3000-1514 Current Velocity Meter. Later 2012 and 2013 flow measurements were taken with a Hach FH950 meter/sensor. A transect was positioned across a smooth flowing section with no obvious turbulence. Depth, velocity, and the distance between points (width interval) were measured at a minimum of 10 points along each transect. Flow (velocity) was measured at 60% of the stream depth in streams <0.8 meters deep and 20% and 80% at in streams > 0.8 meters deep. The stream discharge reported is the sum of the products of depth, velocity, and width interval for each measurement point.

Field measurements were recorded in a field notebook and entered into a LSRI database. Lab results and associated field measurements were entered directly into the WDNR SWIMS database by the SLOH and downloaded by LSRI for its project database.

**Biological Assessment**

Macroinvertebrate samples were collected at 32 tributary stations in the spring and fall of 2012 and 2013 using WDNR protocols (WDNR 1988 and WDNR 2000). Samples were collected with a 3 minute kick and D-net in a stream riffle. Samples were preserved, processed and identified by LSRI. Questionable individuals were sent to
outside labs for confirmation of identification. Family-level biotic index (FBI), HBI Max 10, Species Richness, Genera Richness, Percent Ephemeroptera, plecoptera, trichoptera (EPT) individuals, Percent EPT genera, Percent Chironomidae individuals, Shannon’s Diversity Index, Percent scrapers, Percent filterers, Percent shredders, Percent gatherers, Mean Pollution Tolerance Value, and Hilsenhoff Biotic Index (HBI) were calculated by the WDNR from raw data submitted by LSRI. Results were entered directly into the SWIMS database by WDNR and downloaded by LSRI for its project database.

**Habitat Assessment**

A mix of qualitative and quantitative habitat assessments were conducted at 18 stations using the protocols outlined in *Guidelines for Evaluating Habitat of Wadable Streams* (WDNR 2002). The habitat surveys were conducted along a station length ranging between 100 and 800 meters, depending on mean stream width. The qualitative assessments involved ranking 7 stream characteristics poor to excellent by observing the entire station length. The quantitative assessments included recording channel and basin characteristics, such as mean stream width, water depth, % and type of bottom material, % and type of stream cover, canopy cover/shading, bank stability, riparian land use, stream sinuosity, and pool, run and riffle structure, along a minimum of 12 transects. Assessments were postponed if water levels were > 0.15 m above normal. Data was recorded on WDNR data forms. Measurements were entered into an internal WDNR Fisheries Management Database by LSRI staff with assistance from WDNR staff. Habitat ratings were calculated by WDNR and downloaded by LSRI for its project database.

**Coastal Wetland Stations**

**Site Selection**

Monitoring sites were located in 15 wetlands identified as a Wisconsin Priority coastal wetland by the WDNR (Epstein et al. 2002). The project sites include most of the coastal wetlands located in Wisconsin’s Lake Superior basin (Map 2). Criteria for including a coastal wetland required that all of the stations could be legally and physically accessed. With the exception of Saxine Creek, coastal wetlands that were under the legal purview of the National Park Service or the Bad River Band of Lake Superior Chippewa were excluded from this project to avoid potential duplication of monitoring effort. Seven of the project wetlands which were monitored by the UWS-Lake Superior Research Institute (LSRI) between 2007 and 2010, were included in this project to allow comparison of past data.
Map 2 – Coastal Wetland Monitoring Stations
**Water Quality Testing**

A series of physical and chemical water quality parameters that provide a good indication of wetland condition were measured at the 15 stations one time in late summer of 2011 and 2012.

Water chemistry measurements included total phosphorus (TP), total dissolved phosphorus (TDP), total Kjeldahl nitrogen (TKN), and nitrate-nitrite (NO$_3$ + NO$_2$), ammonia (NH$_3$), chlorophyll-a (Chl-a) and total suspended solids (TSS). Water chemistry samples were collected using protocols outlined in Guidelines and Procedures for Surface Water Grab Sampling (WDNR, Surface Water Assessment Team 2005) and LSRI/SOP/FS/33 – Water Quality Monitoring Using IN SITU Measurements and Collection of Discrete Grab Samples, (Eliot et al. 2013). Discrete grab samples were collected 8-12 inches below the surface or mid-depth in shallower waters. Water was collected directly in pre-cleaned bottles supplied by the Wisconsin State Laboratory of Hygiene (SLOH) and samples were filtered, preserved and iced as required and shipped to the SLOH for analysis. The grab samples were collected from an area within the wetland identified as the “outer zone”. The delineation of three zones (wet meadow, inner and outer) for chemical and macroinvertebrate sampling follows the protocol outlined in Great Lakes Coastal Wetland Consortium (GLCWC) Invertebrate Community Indicators (Burton et al. 2008).

In-situ measurements of temperature, dissolved oxygen, specific conductivity, turbidity (NTU), and pH using a Yellow Springs Instruments (YSI) multi-parameter water quality sonde were also collected at each station. The YSI meter was calibrated at the beginning of each week prior to sampling.

Transparency was measured using a 120 cm transparency tube (t-tube). Sample water was collected twice and each time drained slowly from the t-tube until the target at the bottom was visible. The average distance of the water level above the target for both measurements was recorded in the field notebook.

Field measurements were recorded in a field notebook and entered into a LSRI database. Lab results and associated field measurements were entered directly into the WDNR SWIMS database by the SLOH and downloaded by LSRI for its project database.

**Biological Assessment**

*Macroinvertebrate Sampling*

Macroinvertebrates were collected from 15 coastal wetlands in late summer of 2011 and 2012. Methods outlined in the Great Lakes Coastal Wetland Monitoring Plan, Chapter 4 - GLCWC Invertebrate Community Indicators (Burton et al. 2008) were used to collect and analyze the samples. The collection method uses multiple D-net sweeps from each inundated plant zone to create a composite sample. Three distinct plant zones (wet meadow, inner zone, and outer zone) were identified by the dominant species present. Burton et al. 2008 specifies Scirpus as the dominant species in the inner and outer zones. Occasionally other species were dominant and therefore were used to define the inner and outer zones. This provision was made because the GLCWC protocols were based on a small sub-sample of the Great Lakes wetlands with few on Lake Superior and finding different dominant species in the plant zones was not unexpected. The inner and outer zones were dominated by the same species and only the density varied. We found the inner and outer zones were well defined and straightforward to identify as described in the protocol, even when not dominated by Scirpus. This did not present a problem since the stratification of the
plant zones is required to address water level fluctuations and not a particular species of plant. The dominant plant species and the percent cover were recorded on the field datasheet.

Only plant zones that were inundated were sampled. D-nets sweeps were made through the vegetation at the surface of the water, at the mid-depth and just above the bottom. Care was taken not to disturb the sediment. Each D-net sweep was combined into one picking pan with grids. The composite sample was systematically live-picked on site for 30 person minutes. A total of 150 organisms were picked, placed into labeled sample vials and preserved. Collection data was recorded in a field notebook. The samples were identified to genus level and an index of biotic integrity was calculated by LSRI. Data was and entered into a LSRI database and uploaded to the WDNR SWIMS database.

Vegetation Surveys

Vegetation was surveyed in 8 coastal wetlands in August of 2011 and in 11 coastal wetlands in August of 2012 following methods outlined in the Great Lakes Coastal Wetland Monitoring Plan, Chapter 3 - GLCWC Vegetation Community Indicator (Burton et al. 2008). Vegetation data was acquired from 7 coastal wetlands previously surveyed by LSRI between 2008 and 2010. The same methods described above were used in the 2008-2010 surveys. The acquired data was combined with the 2011/2012 surveys to give two years of vegetative data for each coastal wetland in the study.

In most cases, three sampling transects were established perpendicular to a drainage gradient that crossed two distinct vegetative zones; wet meadow/dry emergent and wet emergent/submergent. Ten quadrats (1 m²) were surveyed along each transect, approximately 25 meters apart. Quadrats were placed so that 5 quadrats were sampled in each of the two vegetative zones.

If the wetland was narrow, transects were angled along slope of wetland in order to allow all 30 quadrats to be placed in the proper zones. Alternatively, the 30 sample quadrats were located randomly throughout the wetland when it was extremely narrow, placing 15 quadrats in each of the two vegetative zones. An attempt was made to include any obvious monoculture (uniform) patches along each of the transects. The location of each sampling quadrant around a sample point was selected randomly.

A two person team surveyed each quadrant, one identifying the plant species and one recording the information on the datasheet. The GPS coordinates, vegetative zone, substrate type, depth of organic material and the water depth were also recorded for each quadrant. Emergent, floating and submergent plants present in each quadrant were recorded to species level along with an approximate coverage value (1%, 3%, 5%, 10%, and in increments of 5% for higher values). Representative specimens of plants that couldn’t be identified in the field were collected and preserved for identification in the laboratory. The plant taxonomic nomenclature followed the Checklist of the Vascular Plants of Wisconsin (Wetter et al. 2001).

Amphibian and Bird Surveys

Amphibians were surveyed in project wetlands three times each year in 2012 and in 2013 following protocols outlined in the Great Lakes Coastal Wetland Monitoring Plan, Chapter 6 - Amphibian Community Indicators (Burton et al. 2008) and LSRI Standard Operating Procedures (LSRI 2013b). The number of survey stations within each coastal wetland was determined by wetland size. Stations were separated by at least 550 yards and the total number of stations could vary from 1 to 8.
Birds were surveyed in project wetlands two times each year in 2012 and in 2013 following protocols outlined in the Great Lakes Coastal Wetland Monitoring Plan, Chapter 7 - Bird Community Indicators (Burton et al. 2008) and LSRI Standard Operating Procedures (LSRI 2013c). The number of survey stations within each coastal wetland was determined by wetland size. Stations were separated by at least 275 yards and the total number of stations could vary from 1 to 8.

Habitat assessments, which are a supplemental component of bird and amphibian surveys, were also conducted in project wetlands. When possible, bird and amphibian stations were combined.

Data was recorded on the bird, amphibian and habitat survey datasheets supplied by the Marsh Monitoring Program (MMP) (BSC 2009a-c). Data was submitted to MMP for inclusion in its database and for data summary and analysis. Data was downloaded from MMP to the LSRI project database and was submitted to the WDNR for entry into its SWIMS database.

**Nearshore**

Thirty-two monitoring stations were established in the Lake Superior nearshore zone along Wisconsin’s shoreline (Map 3). For the purposes of this project, the nearshore zone is defined as the area below the ordinary high water mark that is less than 30 meters in depth and within 5 km of the shoreline. Seven of the 32 stations were located in small craft harbors at Superior, Port Wing, Cornucopia, Bayfield, Washburn, Ashland, and Saxon. Monitoring was scheduled once per month (May-September) in 2012 and 2013. The total number of sampling stations was increased from 20 to 32 due to adverse conditions in 2012 that disrupted the original sampling schedule.

**Survey Design**

The following criteria, based on input from WDNR fisheries and water resources staff were used to select the nearshore stations:

- When possible, stations are located at or near the mouths of tributaries being sampled under this project.
- When possible, stations are established at existing WDNR summer fish survey sites.
- Stations are established at major outlets to the St. Louis River and Superior Bay.
- Stations are located in small craft harbors with public access in the major communities along the south shore.
- Stations are located at sites established under the USEPA National Coastal Condition Assessment (USEPA NCCA).
Map 3 – Nearshore Monitoring Stations
**Water Quality Testing**

A series of physical and chemical water quality parameters that provide a good indication of nearshore condition were measured at nearshore stations.

Water chemistry measurements included total phosphorus (TP), total dissolved phosphorus (TDP), total Kjeldahl nitrogen (TKN), and nitrate-nitrite (NO$_3^- + NO_2^-$), ammonia (NH$_3$), chlorophyll-a (Chl-a) and total suspended solids (TSS). Fecal coliform and Escherichia coli (E. coli) were measured at the small craft harbor stations. Water chemistry samples were collected monthly during 2012 and 2013 using protocols outlined in *Guidelines and Procedures for Surface Water Grab Sampling* (WDNR, Surface Water Assessment Team 2005) and *LSRI/SOP/FS/33 – Water Quality Monitoring Using IN SITU Measurements and Collection of Discrete Grab Samples*, (LSRI 2013a). Discrete grab samples were collected 0.5 meters below the surface of the water using a secondary sampling device. The Kemmerer samples were then poured into pre-cleaned bottles supplied by the Wisconsin State Laboratory of Hygiene (SLOH). Sample bottles were filtered, preserved and iced as required and shipped to the SLOH for analysis. The Kemmerer was cleaned and rinsed between each station.

In situ water quality parameters (dissolved oxygen, pH, conductivity, turbidity, transparency, temperature) were measured at each station monthly in 2012 and 2013 using a Yellow Springs Instruments (YSI) multi-parameter water quality sonde. The YSI meter was calibrated at the beginning of each week prior to sampling. In situ measurements were made on the down cast and the up cast, at the following depths: 0.1 and 0.5 meters below the surface; every meter between 1 and 10m; every 5m between 10 and 30 m; and 0.5m off the bottom. Field measurements were recorded in a field notebook.

Nearshore transparency measurements were made at each station visit using a standard 20-cm diameter black and white secchi disc. The disc was lowered on the shady side of the boat to the depth, at which it could no longer be discerned and then it was slowly retrieved until it reappeared - That depth (rounded to the nearest 0.5 m) was recorded as secchi depth. This process was repeated two additional times for a total of three depth readings. All six measurements were recorded in the field notebook. The secchi measurements were reported as an average of all six readings. If the secchi disk hit bottom, a note was made in the field notebook that the station was “clear to bottom” and the water depth was recorded.

Lab results, secchi depth and the in situ field measurements taken at the 0.1 meter depth were entered directly into the WDNR SWIMS database by the SLOH and downloaded by LSRI for its project database. Up and down cast in-situ measurements were entered into the LSRI database were submitted to WDNR for entry into its SWIMS database.

**Biological Assessment**

**Benthos**

Benthos was collected at 17 of the 32 stations once per year during late summer of 2012 and 2013. Benthos was collected and analyzed for density and relative abundance from the 7 small craft harbors and 10 additional nearshore stations. The benthos stations were selected based on the following criteria developed by LSRI and WDNR staff:

- All small craft harbors are sampled for benthos.
• Stations located in Superior Bay and at the outlets of Superior Bay/St. Louis River are sampled for benthos.
• At least one station located adjacent to eroding clay bluffs is sampled for benthos.
• At least one station located in Chequamegon Bay is sampled for benthos.
• The remaining stations sampled for benthos are located along the open lake shoreline.

The Standard Operating Procedure for Benthic Invertebrate Field Sampling /LG406 (USEPA 2002) was used to collect samples. The Standard Operating Procedure for Benthic Invertebrate Laboratory Analysis/LG407 (USEPA 2010); Standard Operating Procedure for Subsampling Benthic Invertebrate Samples in the Laboratory - FS/12 (LSRI 1996a); the Standard Operating Procedure for Identification of Benthic Invertebrates – FS/13 (LSRI 1996b); and the Standard Operating Procedure for Picking Benthic Invertebrates from Quantitative Samples FS/14 (LSRI 1996c) were followed to process and analyze the samples.

Three ponar grabs were collected at each station. Samples were collected by lowering the ponar dredge to the sediment surface, raising it to the deck and transferring the contents to a plastic tub. The sediment and organisms were gently rinsed from the top screen and the interior of the ponar dredge. If the ponar returned empty, another attempt was made before moving to a new location a short distance away. Each replicate was sieved and transferred into separate jars, labeled and preserved. An indication was made on each label when the replicate required multiple jars. Collection data was recorded in the field notebook. LSRI processed and analyzed the samples. Analytical and field data was entered into a LSRI database and submitted to the WDNR for entry into its SWIMS database.

Zooplankton

Zooplankton (crustacean and rotifer) was scheduled to be collected at 20 stations once per month for 5 months (May-September) in 2012 and 2013. Due to adverse conditions that prevented monthly sampling in 2012, the total number of sampling stations was increased from 20 to 32. Zooplankton samples were collected and analyzed by LSRI.

Standard Operating Procedure for Zooplankton Sample Collection and Preservation and Secchi Depth Measurement Field Procedures/LG402 (USEPA 2005) was used to collect the samples. Zooplankton was analyzed for density, diversity and biomass and QC’d using protocols outlined in Standard Operating Procedure for Zooplankton Analysis/LG403 (USEPA 2003); Standard Operating Procedure for Splitting Zooplankton Samples, LSRI/SOP/FS/18 (LSRI rev 2014); Standard Operating Procedure for Photographing Crustacean Zooplankton for Future Measurements, LSRI/SOP/FS/8 (LSRI rev 2013d); and Standard Operating Procedure for Measuring Crustacean Zooplankton Samples, LSRI/SOP/FS/19 (LSRI 2004). Data was recorded on LSRI datasheets, entered in the LSRI database and submitted to WDNR for entry into its SWIMS database.

Zooplankton was collected from 32 stations in the nearshore zone. The number of sampling tows performed at each station was determined by estimating the densities of organisms based on past data. In order to obtain the target number of organisms, two tows were done with the 60 µm and one tow was done using the 150 µm net. When two tows were done, the sample was combined into one bottle. Tows were taken from one meter above the bottom. The tow net attached to a screened sample bucket and flowmeter was lowered to the desired depth.
and raised at a constant speed to collect zooplankton from the water column. The net was gently rinsed to concentrate organisms into the sample bucket. The sample was transferred to a pre-labeled 500 mL sample bottle. The organisms were narcotized with 20 mL soda water and allowed to stand for 30 minutes on ice before being preserved with 20 mL of sucrose formalin solution. LSRI collected, processed and analyzed the zooplankton samples.

**Fish Sampling**

Lake herring (Coregonus artedi) fish stomachs were collected by WDNR Fisheries Department staff at six gill net sites between July 17 and August 3, 2013. Lake herring stomach contents were analyzed because they make up a large percentage of the summer catch, are planktivorous and are not routinely studied by the WDNR.

Stations were sampled with 3,600 feet of monofilament graded -mesh gill nets. The gang consisted of twelve 300 foot nets (panels) arranged in the following mesh (inch) sequence, set from shallow to deep: 5, 2, 4, 1.5, 6, 4.5, 2.5, 7, 3.5, 6.5, 3, and 5.5. Nets were set for one night (24 hours) at each station. Additional data to be collected at the outside (deepest) end of each station is: a secchi disk reading, temperature profile, and zooplankton tow (at certain sites).

Captured lake herring were separated by mesh size and biological information was collected and the number of herring was counted. Biological information gathered from individual fish consisted of: length, weight (if weather conditions permitted it), sex, aging structures taken (scales and/or otoliths), and 51 stomachs were removed for diet analysis. Each stomach sample collected was given a station number, a lift date and an individual ID number. Stomachs were frozen prior to analysis and sent to LSRI for analysis.

UWS staff thawed the stomachs slightly, and opened them using fine tipped dissection scissors. The stomach contents were scraped into a 10 ml graduated cylinder containing 5 ml of water. Total biovolume (ml) of the stomach contents was measured. The contents of the graduated cylinder were then washed into a small sieve with 60 µm mesh and rinsed well with deionized water. The rinsed material was examined under a dissecting microscope.

If fish remains were present in the stomachs, their contribution to total diet biovolume was determined prior to examination of the rest of the material. The remainder of the stomach contents consisted primarily of zooplankton, with a few insect remains. The material was teased apart and distributed in a counting chamber. Approximately 100 organisms were identified to major taxonomic group to determine percent composition of the diet.

**Land Cover Assessment**

**Watersheds**

A land cover analysis was conducted for each of the 16 study watersheds. Seven of the watersheds were analyzed in previous LSRI studies between 2007 and 2010 and 9 of the watersheds were analyzed between 2011 and 2013. Watersheds were analyzed by delineating the watershed boundaries and classifying and digitizing the open lands and 0-16 year timber age class within those boundaries. Open lands classifications included buffered roads and
trail data, railroad rail lines, driveways, buildings, gas pipeline easements, electrical transmission easements, and other impervious surfaces. Open lands information was obtained from high resolution aerial imagery and USDA NAIP imagery. Land cover totals and percentages were calculated for each land cover class. The land cover analysis was conducted by Community GIS Services, Inc. GIS data and maps were transferred to LSRI and submitted to the WDNR for entry into its SWIMS database.

Coastal Shoreline Aerial Photographs

Community GIS Services, Inc. provided the project oblique aerial imagery for 58 miles of selected shoreline from the Superior Entry to North Fish Creek in spring of 2012. Selected shoreline images include man-made structures such as piers, break walls, riprap, dams, fords, bridges, impediments to fish migration, marinas, areas with a high degree of development, and significant shoreline erosion. A flight plan allowed for flight efficiencies and logistics. The location of exposure for each image was collected with GPS and converted to ArcGIS shapefile format. Each point feature was classified and added to the master geo-database. Each point feature was hyperlinked to its corresponding aerial image in the feature database along with notations collected in the field. GIS data and maps were transferred to LSRI and submitted to the WDNR for entry into its SWIMS database.

Results and Discussion

Tributary Results

Water Quality

Thirty-two tributary stations were sampled for water quality in the spring and the fall of both 2012 and 2013 (Appendix B).

The water chemistry results (Table T1) show that Chlorophyll a ranges from 0.24 to 17.4 (ug/l) with the maximum and second to highest values occurring in Bear Creek. High values also occurred on the Bark River at Swedlund Rd, Bluff Creek at Hwy Z, Oronto Creek off of Harbor Drive and the Pokegama River off of Cemetery Rd. Chlorophyll a values above 6.73 ug/l exceeded the upper normal range and may be considered outliers, however, conditions on these streams are known to be degraded. Nitrate + nitrite ranges from 0.010 to 1.32 (mg/l) with the maximum value occurring at Oronto Creek, Hwy A. The next highest N+N value was at Bluff Creek. Both values exceeded the normal upper range. Ammonia ranges from 0.008 to 0.270 (mg/l) with the highest value exceeding the normal upper range and occurring at Oronto Creek, Hwy A. Total dissolved phosphorus (TDP) ranged from 0.007 to 0.103 (mg/l) with the highest 3 values occurring in the Pokegama River off Cemetery Rd. All 3 values exceeded the normal upper range. Total phosphorus (TP) ranges from 0.011 to 0.155 (mg/l) with the maximum and next highest values exceeding the upper normal range and occurring in the Pokegama River off of Cemetery Rd. TP values that also exceeded the upper normal range occurred at Bark River on Swedlund Rd, Bark River at Hwy 13, Bear Creek, and the Brule River at McNeil’s Landing. 9.9% of the samples exceeded the WI state standard of 0.075 mg/l. 5% of
the samples exceeded the upper normal range. Total suspended solids (TSS) values ranged from 1.15 to 86.0 (mg/l) with the maximum value occurring at Brule River at McNeil’s Landing. The next highest values that also exceeded the normal upper range occurred at Bark River at Hwy 13, Bear Creek and the Cranberry River at Touve Rd.

The tributary water quality in situ results (Table T 2) show dissolved oxygen ranges from 2.54 to 11.84 mg/l with the lowest value occurring in Raspberry River at Hwy K. DO values below 5.0 mg/l also occurred in Bear Creek, Bluff Creek, Pokegama River and the Raspberry River. The pH ranges from 6.99 to 8.53 with lowest value occurring in the Raspberry River at Hwy K. Water temperature ranges from 6.42 to 26.13 °C with the highest temperatures occurring in Oronto Creek at Hwy A. Other high temperatures occurred in Bluff Creek at Hwy Z, Iron River at Orienta Fall and Sorenson Rd, Little Pokegama River at Hwy 105, Nemadji River at Finn Rd, and Pokegama River off of Cemetery Rd and Irondale Rd. Specific conductivity ranges from 57 to 1045 (umhos/cm), with the highest values in Bear Creek. The high values were verified against the field datasheet, however they do exceed the upper normal range. Other high specific conductivity values occurred in Bluff Creek at Hwy Z, Little Pokegama at Hwy 105, Oronto Creek at Hwy A, Pokegama River at Cemetery Rd, Pokegama River at Irondale Rd, Nemadji River at Finn Rd, and Raspberry River at Hwy K. More surprisingly, high values also occurred at Lost Creek #1 and Lost Creek #2. T-tube measurements range from 8.9 to >120.00 cm with the lowest transparency occurring in the Bark River at Swedlund Rd, the Brule River at McNeils’s Landing, and the Pokegama River at Irondale Rd. NTU measurements range from -0.4 to 92.0 with the highest turbidity values (>70.0 NTU) occurring in Bark River at Swedlund Rd, Bear Creek, Bluff Creek at Hwy Z, Little Pokegama at Hwy 105, and Pokegama River at Cemetery Rd and Irondale Rd. Mean flow measurements ranged from -0.3 to 360.6 cfs. The lowest flows were typically during the late summer months and occurred in the Bark River on Swedlund Rd, Bear Creek, Little Pokegama at Hwy 105, Oronto Creek at Hwy A, Pokegama River at Cemetery Rd and Raspberry River at Hwy K.

Some of the water quality values indicate degraded conditions. A relationship could not be found between % open land cover and TP (Figure T 1). Further analysis should be done by station to determine if there are relationships between stream flow, stream bank condition and other stream characteristics. Identifying the source of high concentrations of nutrients and sediment could lead to restoration efforts in the basin.

<table>
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<tr>
<th></th>
<th>All Tributary Lab Samples_2012-2013 / Spring and Fall</th>
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<tr>
<td></td>
<td>TP (Mg/l)</td>
</tr>
<tr>
<td>n</td>
<td>121</td>
</tr>
<tr>
<td>Mean</td>
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<td>Min</td>
<td>0.011</td>
</tr>
<tr>
<td>Max</td>
<td>0.155</td>
</tr>
<tr>
<td>1 Std Dev (s)</td>
<td>0.025</td>
</tr>
<tr>
<td>2 Std Dev (s)</td>
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<td>&quot;Normal&quot; Range Lower</td>
<td>-0.007</td>
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<tr>
<td>&quot;Normal&quot; Range Upper</td>
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Table T 2. Summary Statistics for Tributary In-Situ Measurements

<table>
<thead>
<tr>
<th></th>
<th>NTU</th>
<th>T-Tube (cm)</th>
<th>DO (Mg/l)</th>
<th>PH</th>
<th>Cond-Fld (uS/cm@25o)</th>
<th>Water Temp (°C)</th>
<th>Flow (cfs)</th>
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</thead>
<tbody>
<tr>
<td>n</td>
<td>307</td>
<td>305</td>
<td>307</td>
<td>307</td>
<td>307</td>
<td>307</td>
<td>239</td>
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<td>Min</td>
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<td>8.900</td>
<td>2.580</td>
<td>6.990</td>
<td>57.000</td>
<td>6.420</td>
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<td>Max</td>
<td>92.000</td>
<td>120.000</td>
<td>11.840</td>
<td>8.530</td>
<td>1045.000</td>
<td>26.130</td>
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<td>1 Std Dev (s)</td>
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<td>39.032</td>
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<td>99.363</td>
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<td>42.295</td>
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<td>2 Std Dev (s)</td>
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<td>78.064</td>
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<td>198.725</td>
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<td>&quot;Normal&quot; Ranger Lower</td>
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<td>5.093</td>
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<td>&quot;Normal&quot; Range Upper</td>
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<td>8.342</td>
<td>388.608</td>
<td>22.442</td>
<td>111.441</td>
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</table>

Figure T 1. Compare Tributary Mean Total Phosphorus to % Open Lands
Macroinvertebrates

Macroinvertebrates were collected and analyzed from 32 tributary stations in spring and fall of 2012 and 2013. The HBIs range from 1.15 to 8.84 in 2012 and from .90 to 7.03 in 2013 (Table T 3a). In 2012, water quality ranked as excellent for 56% of the samples, very good for 11% of the samples, good for 21% of the samples; fair for 5% of the samples, fairly poor for 2% of the samples, and 2% for very poor. None of the samples in 2012 ranked as poor. There were minor changes in the 2013 samples. In 2013, water quality ranked as excellent for 56% of the samples; very good for 11% of the samples, good for 19% of the samples; fair for 13% of the samples, and fairly poor for 2% of the samples. None of the samples in 2013 ranked as poor or very poor.

Table T 3a. Summary of Tributary HBIs

<table>
<thead>
<tr>
<th>Station and Sampling Season</th>
<th>HBI 2012</th>
<th>HBI 2013</th>
<th>Mean</th>
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<tr>
<td>Bark River, Hwy 13 Fall</td>
<td>1.83</td>
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<td>3.908</td>
<td>4.248</td>
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<td>2.542</td>
<td>1.678</td>
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<td>Brule River, Hwy B Fall</td>
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<td>3.7335</td>
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<td>Brule River, Hwy B Sprg</td>
<td>2.214</td>
<td>3.234</td>
<td>2.724</td>
</tr>
<tr>
<td>Location</td>
<td>Fall 1</td>
<td>Fall 2</td>
<td>Fall 3</td>
</tr>
<tr>
<td>--------------------------------</td>
<td>--------</td>
<td>--------</td>
<td>--------</td>
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<td>Brule River, McNeils Fall</td>
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<td>Brule River, McNeils Sprg</td>
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<td>4.906</td>
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<td>2.518</td>
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<td>East Fork Flag R, ATV brdg Fall</td>
<td>5.319</td>
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<td>Onion River, McCullock Sprg</td>
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<td>Oronto Creek, Harbor Dr Fall</td>
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<td>7.188</td>
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Table T 3c. Hilsenhoff Biotic Index Scores

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<th>Index</th>
<th>Water Quality</th>
<th>Degree of Organic Pollution</th>
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<td>0.00-3.50</td>
<td>Excellent</td>
<td>None apparent</td>
</tr>
<tr>
<td>3.51-4.50</td>
<td>Very Good</td>
<td>Possible slight</td>
</tr>
<tr>
<td>4.51-5.50</td>
<td>Good</td>
<td>Some</td>
</tr>
<tr>
<td>5.51-6.50</td>
<td>Fair</td>
<td>Fairly significant</td>
</tr>
<tr>
<td>6.51-7.50</td>
<td>Fairly Poor</td>
<td>Significant</td>
</tr>
<tr>
<td>7.51-8.50</td>
<td>Poor</td>
<td>Very significant</td>
</tr>
<tr>
<td>8.51-10.00</td>
<td>Very Poor</td>
<td>Severe</td>
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</table>

Hilsenhoff Biotic Index Scores (Hilsenhoff, 1987)
Figure T 2. 2012_2013 Tributary – Hilsenhoff Biotic Index (HBI)
Habitat Assessment

Qualitative and Quantitative habitat Assessments were conducted at 20 stations in 2012 and 2013. The habitat rating for the Lake Superior tributaries ranges from fair to excellent (Table T 4a-b). 5% of the samples are poor, 5% of the samples are excellent, 30% of the assessments are fair, and 60% of the assessments are good.

Table T 4a. Tributary Habitat Rating Streams < 10'

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<thead>
<tr>
<th>County</th>
<th>Waterbody Name</th>
<th>Station</th>
<th>Survey Date</th>
<th>Habitat Score Small Streams</th>
<th>Habitat Rating Streams &lt; 10'</th>
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</thead>
<tbody>
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<td>BAYFIELD</td>
<td>BARK RIVER</td>
<td>McNeils Landing</td>
<td>29-Aug-2013</td>
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<td>BAYFIELD</td>
<td>EAST FORK CRANBERRY RIVER</td>
<td>Touve Rd</td>
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<td>Fair</td>
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<tr>
<td>BAYFIELD</td>
<td>FLAG RIVER</td>
<td>WestFork</td>
<td>23-Aug-2013</td>
<td>65</td>
<td>Good</td>
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<td>BAYFIELD</td>
<td>LOST CREEK # 1</td>
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<td>10-Jul-2012</td>
<td>68</td>
<td>Good</td>
</tr>
<tr>
<td>BAYFIELD</td>
<td>LOST CREEK # 2</td>
<td></td>
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<td>75</td>
<td>Excellent</td>
</tr>
<tr>
<td>BAYFIELD</td>
<td>NORTH FISH CREEK</td>
<td>Town Dump Rd</td>
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<td>60</td>
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<tr>
<td>BAYFIELD</td>
<td>ONION RIVER</td>
<td>McCulloch Rd</td>
<td>26-Jun-2012</td>
<td>35</td>
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</table>
### Table T 4b. Tributary Habitat Rating_Streams > 10’

<table>
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<th>County</th>
<th>Waterbody Name</th>
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<th>Survey Date</th>
<th>Habitat Score</th>
<th>Habitat Rating</th>
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<tr>
<td>BAYFIELD</td>
<td>IRON RIVER</td>
<td>SORENSON RD</td>
<td>17-Jul-2012</td>
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<tr>
<td>DOUGLAS</td>
<td>BOIS BRULE RIVER</td>
<td>CTH B</td>
<td>15-Jun-2012</td>
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### Table T 4c. Tributary Habitat Rating_Low Gradient Streams

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<thead>
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<td>IRON RIVER 170’ US SORENSON RD</td>
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<td>MCCULLOCH ROAD</td>
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### Table T 4d. Tributary Habitat Rating_Qualitative Assessment

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<th>County</th>
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<th>Station Name</th>
<th>Survey Date</th>
<th>Qualitative Habitat Score</th>
<th>Qualitative Habitat Rating</th>
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<tr>
<td>DOUGLAS</td>
<td>NEMADJI RIVER</td>
<td>FINN RD</td>
<td>07-Sep-2012</td>
<td>20</td>
<td>Poor</td>
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<tr>
<td>DOUGLAS</td>
<td>LITTLE POKEGAMA RIVER</td>
<td>HWY 105</td>
<td>20-Sep-2012</td>
<td>65</td>
<td>Good</td>
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<td>BAYFIELD</td>
<td>EAST FORK FLAT RIVER</td>
<td>EAST FORK</td>
<td>14-Aug-2012</td>
<td>58</td>
<td>Good</td>
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<tr>
<td>BAYFIELD</td>
<td>EAST FORK CRANBERRY RIVER</td>
<td>TOUVE RD</td>
<td>15-Aug-2012</td>
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<td>Good</td>
</tr>
<tr>
<td>BAYFIELD</td>
<td>BARK RIVER</td>
<td>HWY 13</td>
<td>07-Aug-2012</td>
<td>38</td>
<td>Fair</td>
</tr>
<tr>
<td>BAYFIELD</td>
<td>BARK RIVER</td>
<td>SWEDLUND RD</td>
<td>07-Aug-2012</td>
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<td>Good</td>
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<tr>
<td>BAYFIELD</td>
<td>SAXINE CREEK</td>
<td>HWY 13</td>
<td>16-Aug-2012</td>
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<td>Fair</td>
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<td>BAYFIELD</td>
<td>RASPBERRY RIVER</td>
<td>OLD HWY K</td>
<td>16-Aug-2012</td>
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<td>Good</td>
</tr>
<tr>
<td>BAYFIELD</td>
<td>SIOUX RIVER</td>
<td>CTH C</td>
<td>13-Aug-2012</td>
<td>68</td>
<td>Good</td>
</tr>
</tbody>
</table>
Coastal Wetland Results

Water Quality Testing

Fourteen coastal wetlands were sampled for water quality in 2011. In 2012 we were granted permission from the Red Cliff Band of Lake Superior Chippewa to access the Raspberry River wetland and therefore 15 coastal wetlands were sampled (Appendix C).

The water chemistry results (Table CW 1) show that Chlorophyll a ranges from 1.59 to 218.0 (ug/l) with the maximum value occurring in the Saxine Creek wetland. The max chlorophyll value in Saxine Creek, however, appears to be an outlier. The next highest chlorophyll a values are in the Brule River wetland and Allouez Bay; TKN ranges from 0.07 to 3.55 (mg/l) with the maximum value occurring in Allouez Bay. Nitrate + nitrite ranges from 0.010 to 0.149 (mg/l) with maximum values occurring in Allouez Bay and the Pokegama River wetland. Total dissolved phosphorus ranged from 0.003 to 0.293 (mg/l) with the maximum value occurring in the Pokegama River wetland. Ammonia ranges from 0.008 to 0.047 (mg/l); Total phosphorus (TP) ranges from 0.021 to 0.594 (mg/l); and Total suspended solids (TSS) ranges from 2.0 to 438 (mg/l) with the maximum values all occurring in Allouez Bay and Saxine Creek wetland. 32% of coastal wetland TP samples (Allouez Bay, Fish Creek Slough, Nemadji River wetland, Onion River wetland, Pokegama River wetland, and Saxine Creek wetland) exceeded the Wisconsin TP standard = 0.075 (mg/l).

The high TP, NH3, Chl a, and TSS values in Saxine Creek was unexpected since 69% of the watershed is in public ownership and only 24% of the watershed is classed as open land, most of that being harvested forest (19%) (Table WS 1a). It is unknown if watershed characteristics can be detected in coastal wetland water quality, however, the relatively low percentage of open land would suggest that the sources of nutrients and sediment are not strictly from watershed runoff.

The water quality in situ results (Table CW 2) show dissolved oxygen ranges from 0.70 to 10.10 mg/l. The lowest DO value occurs in Bark Bay; however it appears to be an outlier. DO values <4.0 mg/l occur in the Sioux River wetland, Flag River wetland and Allouez Bay. The pH ranges from 6.10 to 8.0 with lowest value occurring in Bark Bay, which is slightly below the normal range. Mean water temperature ranges from 9.3 to 25.90 °C with the highest temperatures occurring in Allouez Bay, Iron River wetland, Little Pokegama wetland and Lost Creek Bog all in late summer of 2012. Specific conductivity ranges from 65 to 213 (umhos/cm), with the highest value in Little Pokegama wetland. T-tube measurements range from 12.10 to 120.00 cm with the lowest transparency occurring in Allouez Bay. NTU measurements range from 1.2 to 81.4 with the highest turbidity values occurring in Allouez Bay, Fish Creek Slough and Iron River wetland. The highest value (81.4) which occurred in Allouez Bay appears to be an outlier. Conditions in Allouez Bay however can be excessively turbid following a rain event.
Table CW 1. Summary Statistics for Lake Superior Coastal Wetland Water Chemistry

<table>
<thead>
<tr>
<th></th>
<th>Coastal Wetland Lab Samples_2011-2012</th>
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<tbody>
<tr>
<td></td>
<td>TP (mg/l)</td>
</tr>
<tr>
<td>n</td>
<td>29</td>
</tr>
<tr>
<td>Mean</td>
<td>0.100</td>
</tr>
<tr>
<td>Min</td>
<td>0.021</td>
</tr>
<tr>
<td>Max</td>
<td>0.594</td>
</tr>
<tr>
<td>1 Std Dev (s)</td>
<td>0.134</td>
</tr>
<tr>
<td>2 Std Dev (s)</td>
<td>0.267</td>
</tr>
<tr>
<td>Normal Ranger Lower</td>
<td>-0.167</td>
</tr>
<tr>
<td>Normal Range Upper</td>
<td>0.367</td>
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</table>

Table CW 2. Summary Statistics for Lake Superior Coastal Wetland Water Quality In-Situ Measurements

<table>
<thead>
<tr>
<th></th>
<th>All Coastal Wetland In-Situ Samples_2011-2012</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>NTU</td>
</tr>
<tr>
<td>n</td>
<td>28</td>
</tr>
<tr>
<td>Mean</td>
<td>16.375</td>
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<tr>
<td>Min</td>
<td>1.200</td>
</tr>
<tr>
<td>Max</td>
<td>81.400</td>
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<tr>
<td>1 Std Dev (s)</td>
<td>20.735</td>
</tr>
<tr>
<td>2 Std Dev (s)</td>
<td>41.471</td>
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<tr>
<td>Normal Range Upper</td>
<td>57.846</td>
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Biological Assessment

Macroinvertebrate Sampling

Fifteen coastal wetlands were sampled for macroinvertebrates in 2011 and 2012. Invertebrates were identified to species level and an index of biotic integrity (IBI) was calculated (Table CW 3). The IBI, developed by the Great Lakes Coastal Wetland Consortium (Burton 2008), shows the wetland quality ranged from “degraded – the wetland show obvious signs of anthropogenic disturbance” to “reference conditions” (Table CW 4). Five Lake Superior coastal wetlands exhibit reference conditions: Bark River wetland, Brule River wetland, Nemadji River wetland, Pokegama River wetland and Raspberry River wetland. Data analysis from 6 coastal wetlands is pending. Nutrient and turbidity values are typically consistent with the IBI score with the exception of the high TP value in the Pokegama River.

Table CW 3. Coastal Wetland Nutrient and Macroinvertebrate Summaries

<table>
<thead>
<tr>
<th>Wetland Name</th>
<th>Year Sampled</th>
<th>TP (mg/l)</th>
<th>TKN (mg/l)</th>
<th>TSS (mg/l)</th>
<th>N+N (mg/l)</th>
<th>NTU</th>
<th>Invert IBI Score</th>
<th>IBI Description</th>
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<tr>
<td>allouez bay</td>
<td>2011</td>
<td>0.104</td>
<td>1.07</td>
<td>16</td>
<td>0.056</td>
<td>81.4</td>
<td>134</td>
<td>MOI</td>
</tr>
<tr>
<td>allouez bay</td>
<td>2012</td>
<td>0.594</td>
<td>3.55</td>
<td>outlier</td>
<td>0.149</td>
<td>64</td>
<td>130</td>
<td>MOI</td>
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<tr>
<td>bark river</td>
<td>2011</td>
<td>0.029</td>
<td>1.21</td>
<td>10</td>
<td>0.023</td>
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<td>109</td>
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<td>2012</td>
<td>0.022</td>
<td>0.98</td>
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<td>0.0095</td>
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<td>111</td>
<td>REF</td>
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<td>bois brule river</td>
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<td>1.11</td>
<td>12</td>
<td>0.0095</td>
<td>6.7</td>
<td>107</td>
<td>REF</td>
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<td>Pending</td>
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<td>Year</td>
<td>Score</td>
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<td>Outer Scirpus</td>
<td>Wetman Meadow and Scirpus</td>
<td>Inner and Outer Scirpus</td>
<td>Reference Conditions</td>
</tr>
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<td>-------</td>
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<td>--------------</td>
<td>---------------</td>
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<td>0.07</td>
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<td>19c</td>
<td>DEG</td>
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<tr>
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<td>0.13</td>
<td>1.33</td>
<td>6</td>
<td>0.095</td>
<td>21.4</td>
<td>136e</td>
<td>MII</td>
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<tr>
<td>Pokegama River</td>
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<td>0.179</td>
<td>1.76</td>
<td>38</td>
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<td>30.3</td>
<td>162f</td>
<td>REF</td>
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<td>0.082</td>
<td>0.45</td>
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<td>0.0095</td>
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<td>1.76</td>
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<td>162f</td>
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<tr>
<td>Saxon Creek</td>
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<td>66f</td>
<td>MOI</td>
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<td>2012</td>
<td>0.528</td>
<td>1.98</td>
<td>25</td>
<td>0.032</td>
<td>6.8</td>
<td>74f</td>
<td>MOI</td>
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<td>2011</td>
<td>0.06</td>
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<td>0.07</td>
<td>11</td>
<td>0.0095</td>
<td>4</td>
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</tbody>
</table>

Exceeds State Standard >0.075 mg/l
Exceeds upper normal range

Table CW 4. Macroinvertebrate Indicator of Biotic Integrity (IBI) Rank and Description

<table>
<thead>
<tr>
<th>Wetland Quality Description</th>
<th>All Zones Present</th>
<th>Wet Meadow Only</th>
<th>Inner Scirpus Only</th>
<th>Outer Scirpus Only</th>
<th>Wet Meadow and Inner Scirpus</th>
<th>Wet Meadow and Outer Scirpus</th>
<th>Inner and Outer Scirpus</th>
</tr>
</thead>
<tbody>
<tr>
<td>Extremely Degraded (EXD)– among the most impacted</td>
<td>31 to 53</td>
<td>9 to 14</td>
<td>11 to 19</td>
<td>11 to 18</td>
<td>20 to 33</td>
<td>20 to 32</td>
<td>22 to 38</td>
</tr>
<tr>
<td>Degraded (DEG)- shows obvious signs of anthropogenic disturbance</td>
<td>53 to 76</td>
<td>14 to 19</td>
<td>19 to 29</td>
<td>18 to 26</td>
<td>33 to 47</td>
<td>32 to 46</td>
<td>38 to 55</td>
</tr>
<tr>
<td>Moderately Degraded (MOD)- shows many obvious signs indicative of anthropogenic disturbance</td>
<td>76 to 106</td>
<td>19 to 27</td>
<td>29 to 41</td>
<td>26 to 37</td>
<td>47 to 66</td>
<td>46 to 64</td>
<td>55 to 79</td>
</tr>
<tr>
<td>Moderately Impacted (MOI) - shows few, but obvious, signs of anthropogenic disturbance</td>
<td>106 to 136</td>
<td>27 to 34</td>
<td>41 to 53</td>
<td>37 to 48</td>
<td>66 to 84</td>
<td>64 to 82</td>
<td>79 to 102</td>
</tr>
<tr>
<td>Mildly Impacted (MII) beginning to show signs indicative of anthropogenic disturbance</td>
<td>136 to 159</td>
<td>34 to 39</td>
<td>53 to 62</td>
<td>48 to 56</td>
<td>84 to 99</td>
<td>82 to 96</td>
<td>102 to 119</td>
</tr>
<tr>
<td>Reference Conditions (REF)- among the most pristine</td>
<td>159 to 182</td>
<td>39 to 45</td>
<td>62 to 72</td>
<td>56 to 65</td>
<td>99 to 113</td>
<td>96 to 110</td>
<td>119 to 137</td>
</tr>
</tbody>
</table>
**Vegetation Sampling**

Vegetation was surveyed in 8 coastal wetlands in August of 2011 and 11 coastal wetlands in August of 2012. To provide 2 years of data for all project wetlands, vegetation data was acquired for 7 coastal wetlands previously surveyed by LSRI between 2008 and 2010. Survey and analytical methods were consistent for all surveys. An indicator of biotic integrity (IBI) score (Table CW 6) was calculated for each wetland survey.

Results (Table CW 5) show that Lost Creek and Bark River wetland vegetation scores rank high in both years sampled. The Mean C scores in Lost Creek and Bark River wetlands were also highest. Eleven of the wetlands rank as medium in both years sampled and 1 (Saxine Creek) ranks high in 2011 and medium in 2012. Relationships are not found between % open lands or the GLCWC classifications and the vegetation IBI. None of the project wetlands ranked low or very low.

**Table CW 5. Vegetation Community Indicators, Wetland Classifications and % Open Lands**

<table>
<thead>
<tr>
<th>Wetland Name</th>
<th>Year Sampled</th>
<th>GLCWC Class</th>
<th>Watershed Size (Acres)</th>
<th>Watershed % Open Land Cover</th>
<th>Mean C Entire Site</th>
<th>Mean C Zone 1</th>
<th>Mean C Zone 2</th>
<th>Combined Veg Quality Score</th>
<th>Combined Veg Quality Description</th>
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<tr>
<td>allouez bay</td>
<td>2008</td>
<td>LOS/LPS</td>
<td>20619</td>
<td>34%</td>
<td>5.32</td>
<td>5.41</td>
<td>5.18</td>
<td>36</td>
<td>Med</td>
</tr>
<tr>
<td>allouez bay</td>
<td>2009</td>
<td>LOS/LPS</td>
<td>20619</td>
<td>34%</td>
<td>5.66</td>
<td>5.10</td>
<td>6.23</td>
<td>40</td>
<td>Med</td>
</tr>
<tr>
<td>bark river</td>
<td>2008</td>
<td>BL</td>
<td>10381</td>
<td>20%</td>
<td>8.88</td>
<td>8.99</td>
<td>8.88</td>
<td>50</td>
<td>High</td>
</tr>
<tr>
<td>bark river</td>
<td>2011</td>
<td>BL</td>
<td>10381</td>
<td>20%</td>
<td>8.42</td>
<td>9.10</td>
<td>7.74</td>
<td>50</td>
<td>High</td>
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<tr>
<td>bois brule river</td>
<td>2011</td>
<td>RRB</td>
<td>127242</td>
<td>23%</td>
<td>6.93</td>
<td>6.99</td>
<td>6.86</td>
<td>40</td>
<td>Med</td>
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<tr>
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<td>RRB</td>
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<td>6.70</td>
<td>6.43</td>
<td>6.97</td>
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<td>RRB</td>
<td>43742</td>
<td>25%</td>
<td>4.82</td>
<td>4.77</td>
<td>4.87</td>
<td>32</td>
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<tr>
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<td>RRB</td>
<td>43742</td>
<td>25%</td>
<td>4.90</td>
<td>5.01</td>
<td>4.74</td>
<td>34</td>
<td>Med</td>
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<tr>
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<td>2011</td>
<td>RRO</td>
<td>56740</td>
<td>32%</td>
<td>4.25</td>
<td>4.17</td>
<td>4.34</td>
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<td>Med</td>
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<tr>
<td>fish creek</td>
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<td>RRO</td>
<td>56740</td>
<td>32%</td>
<td>4.02</td>
<td>3.72</td>
<td>4.33</td>
<td>30</td>
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</tr>
<tr>
<td>flag river</td>
<td>2008</td>
<td>RRB/BL</td>
<td>29563</td>
<td>25%</td>
<td>6.34</td>
<td>6.98</td>
<td>5.39</td>
<td>36</td>
<td>Med</td>
</tr>
<tr>
<td>flag river</td>
<td>2012</td>
<td>RRB/BL</td>
<td>29563</td>
<td>25%</td>
<td>5.86</td>
<td>6.41</td>
<td>5.32</td>
<td>32</td>
<td>Med</td>
</tr>
<tr>
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<td>2011</td>
<td>not classed</td>
<td>104330</td>
<td>32%</td>
<td>4.92</td>
<td>5.03</td>
<td>4.81</td>
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<tr>
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<td>104330</td>
<td>32%</td>
<td>4.82</td>
<td>5.04</td>
<td>4.61</td>
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<td>4078</td>
<td>6%</td>
<td>5.32</td>
<td>4.44</td>
<td>6.20</td>
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<tr>
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<td>RRO</td>
<td>4078</td>
<td>6%</td>
<td>5.39</td>
<td>4.48</td>
<td>6.31</td>
<td>34</td>
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</tr>
<tr>
<td>lost creek</td>
<td>2008</td>
<td>RRO/RBB</td>
<td>6345</td>
<td>19%</td>
<td>8.16</td>
<td>8.29</td>
<td>7.32</td>
<td>46</td>
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<tr>
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<td>RRO/RBB</td>
<td>6345</td>
<td>19%</td>
<td>7.52</td>
<td>8.27</td>
<td>6.77</td>
<td>42</td>
<td>High</td>
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<td>RRB</td>
<td>104004</td>
<td>30%</td>
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<td>5.27</td>
<td>34</td>
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<td>4.73</td>
<td>4.49</td>
<td>4.98</td>
<td>38</td>
<td>Med</td>
</tr>
<tr>
<td>pokegama river</td>
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<td>18965</td>
<td>23%</td>
<td>4.50</td>
<td>4.60</td>
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<td>Med</td>
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<td>raspberry river</td>
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<td>10279</td>
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<td>36</td>
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<td>saxine creek</td>
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<td>RRO</td>
<td>1950</td>
<td>24%</td>
<td>5.36</td>
<td>5.39</td>
<td>5.33</td>
<td>48</td>
<td>High</td>
</tr>
<tr>
<td>saxine creek</td>
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<td>RRO</td>
<td>1950</td>
<td>24%</td>
<td>5.57</td>
<td>5.41</td>
<td>5.73</td>
<td>36</td>
<td>Med</td>
</tr>
<tr>
<td>souix river</td>
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<td>LOE</td>
<td>15233</td>
<td>28%</td>
<td>6.52</td>
<td>6.71</td>
<td>4.81</td>
<td>36</td>
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<tr>
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<td>LOE</td>
<td>15233</td>
<td>28%</td>
<td>5.14</td>
<td>5.97</td>
<td>4.32</td>
<td>30</td>
<td>Med</td>
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</table>
**Bird, Amphibian and Habitat Assessment**

Bird and amphibian data was collected by LSRI contract specialists in 14 of the project coastal wetlands in 2012 and 2013. The field data was transmitted to Bird Studies Canada (BSC) for inclusion in its Great Lakes Marsh Monitoring Program database. BSC analyzed the data and reported bird and frog IBIs for each of the coastal wetlands via an academic support service agreement with the LRSI. BSC provided an assessment of the health of the project wetlands based on bird and frog IBIs by comparing results among the 14 sites and across broader regions of the Great Lakes basin.

The following is an excerpt from the BSC report (Tozer 2014). See Appendix F for the full report.

**Bird IBIs:** A total of 74 species were observed across the 14 LRSI sites, including 1 marsh-nesting obligate, marsh wren, and 1 area-sensitive marsh-nesting obligate, sandhill crane. Bird IBIs ranged from a low of 27 at Fish Creek to a high of 35 at Bark Bay, all receiving a designation of “fair” marsh ecosystem health.

**Frog IBIs:** A total of 8 species were observed across 13 LRSI sites, including 4 woodland-associated species: chorus frog, gray treefrog, spring peeper, and wood frog. Surveys were not conducted at one of the sites (Onion River) due to its small size and difficult access at night. Frog-based IBIs for the 13 project sites ranged from a low of 60 at Allouez Bay to a high of 100 at Brule River. One site received a designation of “good” marsh ecosystem health; whereas two sites were designated as “very good” and the remaining 10 sites were designated as “excellent”.

**Comparison of IBIs from project sites with broader scales (2012-2013):** Bird IBIs for the LSRI project sites were within the range of variation for wetlands located throughout the upper and lower Great Lakes. By contrast, frog IBIs for the LSRI project sites tended to be higher than wetlands located within the upper and lower Great Lakes, with the difference being especially pronounced between the project sites and the lower Great Lakes sites.

IBIs suggested that the LSRI project wetlands surveyed in 2012 and 2013 were of “fair” ecosystem health according to bird observations and of “good” to “excellent” ecosystem health according to frog observations. The results also suggested that there was much less variation in ecosystem health among the LSRI project sites according to bird-based IBIs compared to frog-based IBIs. Regardless of how differences in bird and frog-based IBIs are interpreted, the 14 LSRI project sites surveyed in 2012 and 2013 appear to have relatively high marsh ecosystem health compared to most other coastal wetlands throughout the Great Lakes.
Nearshore Results

Water Quality Testing

140 water quality samples were collected from 32 stations (Appendix D). Water quality results were analyzed individually for each station and they were also combined into 5 main groups for analysis. The groups include: All stations combined, open lake stations, harbor stations (marinas), Chequamegon Bay, and Superior Bay.

The water chemistry results (Table N 2 and Figures N 1a-e) show that Chlorophyll a ranges from 0.13 to 40.80 (ug/l); TKN ranges from 0.07 to 2.13 (mg/l); Ammonia ranges from 0.008 to 0.535 (mg/l); nitrate + nitrite ranges from 0.010 to 0.478 (mg/l) with maximum values all occurring in Superior Bay. Total dissolved phosphorus ranged from 0.003 to 0.293 (mg/l) with the maximum value occurring in Saxon Harbor. Total phosphorus (TP) ranges from 1.00 to 17.00 (mg/l) with the maximum value occurring in the open lake station called East of Squaw Bay. The maximum value for TP appears to be an outlier, however, and the next highest value of 9.60 mg/l occurred in Superior Harbor.

Eighteen samples were collected from the 7 small craft harbors for fecal coliform and E. Coli testing. These samples were added to provide additional information about the water quality in the harbors. The range for fecal coliform was 5.0 to 170.0 (CFU/100 ml) and the range for E. Coli was 0.5 to 105.0 (MPN/100 ml) (Table N 4 and Figure N 3). The maximum values for fecal coliform and E. coli occurred in Saxon Harbor in August 2013. The USEPA 1986 criteria statement for bacteriological criteria follows: USEPA Criteria for Bathing (Full Body Contact)/Recreational Waters/Freshwater – “Based on a statistically sufficient number of samples (generally not less than 5 samples equally spaced over a 30-day period), the geometric mean of the indicated bacterial densities should not exceed E. coli 126 per 100 ml. Although some of the values did exceed 126 per 100 ml, sufficient sampling was not done to meet the USEPA criteria. None of the fecal coliform results exceeded Wisconsin’s criteria: WI FC = 200 (No more than 10% of samples > 400).

The water quality in situ results show dissolved oxygen ranges from 7.0 to 8.30 mg/l; pH ranges from 7.10 to 8.6 with maximum values occurring in Superior Bay; mean water temperature ranges from 15.03 to 19.97 °C with the highest temperatures in Chequamegon and Superior Bays; specific conductivity ranges from 88 to 137 (umhos/cm), with the highest value in Superior Bay; and Secchi disk measurements ranges from 0.3 to 10.30 meters. The deepest Secchi reading was off of Gull Island. Secchi readings routinely below 1 meter (that did not hit bottom) occurred at Barkers Island Marina, Port Wing Marina, Old bridge by high bridge and Faxon Creek mouth stations.

The WDNR water clarity index (Tables N 1) indicates that the mean Secchi depth for all nearshore stations (3.58 m) ranks as “good”, however, Superior Bay (0.58 m) ranks as very poor; the mean harbor depth (1.73 m) ranks as “fair”; and Chequamegon Bay (4.89 m) and the open lake (4.60 m) mean depths rank “good to very good” (Table N 3and Figure N 2a).
Table N 1. WDNR Water Clarity Index

<table>
<thead>
<tr>
<th>Water Clarity</th>
<th>Secchi Depth (m)</th>
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<tbody>
<tr>
<td>Very poor</td>
<td>0.9</td>
</tr>
<tr>
<td>Poor</td>
<td>1.5</td>
</tr>
<tr>
<td>Fair</td>
<td>2.1</td>
</tr>
<tr>
<td>Good</td>
<td>3.0</td>
</tr>
<tr>
<td>Very Good</td>
<td>6.0</td>
</tr>
<tr>
<td>Excellent</td>
<td>9.7</td>
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Table N 2. Summary Statistics for Lake Superior Nearshore Water Chemistry

<table>
<thead>
<tr>
<th>Sample Area</th>
<th>Avg. # of Samples</th>
<th>Statistic</th>
<th>Chl-a (ug/l)</th>
<th>TKN (mg/l)</th>
<th>NH3-N (mg/l)</th>
<th>NO3+NO2 (mg/l)</th>
<th>TDP (mg/l)</th>
<th>TP (mg/l)</th>
<th>TSS (mg/l)</th>
</tr>
</thead>
<tbody>
<tr>
<td>All Nearshore</td>
<td>132</td>
<td>Mean</td>
<td>3.072</td>
<td>0.278</td>
<td>0.020</td>
<td>0.279</td>
<td>0.014</td>
<td>0.021</td>
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<td></td>
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<td>Min</td>
<td>0.130</td>
<td>0.070</td>
<td>0.008</td>
<td>0.010</td>
<td>0.003</td>
<td>0.003</td>
<td>1.000</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Max</td>
<td>40.800</td>
<td>2.130</td>
<td>0.535</td>
<td>0.478</td>
<td>0.293</td>
<td>0.090</td>
<td>17.000</td>
</tr>
<tr>
<td>Open Lake</td>
<td>74</td>
<td>Mean</td>
<td>1.434</td>
<td>0.188</td>
<td>0.011</td>
<td>0.313</td>
<td>0.009</td>
<td>0.014</td>
<td>1.518</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Min</td>
<td>0.130</td>
<td>0.070</td>
<td>0.008</td>
<td>0.225</td>
<td>0.003</td>
<td>0.003</td>
<td>1.000</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Max</td>
<td>7.160</td>
<td>0.589</td>
<td>0.043</td>
<td>0.388</td>
<td>0.025</td>
<td>0.045</td>
<td>17.000</td>
</tr>
<tr>
<td>Harbor (Marinas)</td>
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<td>Mean</td>
<td>5.302</td>
<td>0.336</td>
<td>0.019</td>
<td>0.212</td>
<td>0.025</td>
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<td></td>
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<td>0.070</td>
<td>0.008</td>
<td>0.010</td>
<td>0.003</td>
<td>0.010</td>
<td>1.000</td>
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<tr>
<td></td>
<td></td>
<td>Max</td>
<td>29.500</td>
<td>0.866</td>
<td>0.077</td>
<td>0.431</td>
<td>0.293</td>
<td>0.059</td>
<td>7.800</td>
</tr>
<tr>
<td>Chequamegon Bay</td>
<td>16</td>
<td>Mean</td>
<td>1.411</td>
<td>0.145</td>
<td>0.008</td>
<td>0.272</td>
<td>0.010</td>
<td>0.014</td>
<td>1.105</td>
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<tr>
<td></td>
<td></td>
<td>Min</td>
<td>0.262</td>
<td>0.070</td>
<td>0.008</td>
<td>0.235</td>
<td>0.003</td>
<td>0.003</td>
<td>1.000</td>
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<tr>
<td></td>
<td></td>
<td>Max</td>
<td>3.170</td>
<td>0.578</td>
<td>0.016</td>
<td>0.310</td>
<td>0.017</td>
<td>0.025</td>
<td>3.000</td>
</tr>
<tr>
<td>Superior Bay</td>
<td>10</td>
<td>Mean</td>
<td>11.091</td>
<td>0.891</td>
<td>0.117</td>
<td>0.244</td>
<td>0.033</td>
<td>0.059</td>
<td>5.980</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Min</td>
<td>4.450</td>
<td>0.070</td>
<td>0.018</td>
<td>0.132</td>
<td>0.013</td>
<td>0.035</td>
<td>1.000</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Max</td>
<td>40.800</td>
<td>2.130</td>
<td>0.535</td>
<td>0.478</td>
<td>0.070</td>
<td>0.090</td>
<td>9.600</td>
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</table>
**Figure N 1a. Geographic Variation in Mean Chlorophyll a**

![Geographic Variation in Mean Chlorophyll a](image1)

**Figure N 1b. Geographic Variation in Mean Total Phosphorus**

![Geographic Variation in Mean TP](image2)
Figure N 1c. Geographic Variation in Mean Total Dissolved Phosphorus

Figure N 1d. Geographic Variation in Mean TKN, NO3 + NO2 and NH3
Figure N 1e. Geographic Variation in Mean Total Suspended Solids

![Geographic Variation in Mean Total Suspended Solids](image)
### Table N 3. Summary Statistics for Lake Superior Nearshore Water Quality In-Situ

#### TURBIDITY, FIELD NEPHELOMETRIC (NTU)

<table>
<thead>
<tr>
<th></th>
<th>ALL¹</th>
<th>Open Lake</th>
<th>Harbor</th>
<th>Cheq Bay</th>
<th>Sup Bay</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>n</strong></td>
<td>137</td>
<td>75</td>
<td>33</td>
<td>18</td>
<td>10</td>
</tr>
<tr>
<td><strong>Mean</strong></td>
<td>2.120</td>
<td>1.184</td>
<td>3.406</td>
<td>0.106</td>
<td>8.460</td>
</tr>
<tr>
<td><strong>Min</strong></td>
<td>-2.300</td>
<td>-2.300</td>
<td>-1.500</td>
<td>-1.200</td>
<td>3.600</td>
</tr>
<tr>
<td><strong>Max</strong></td>
<td>19.400</td>
<td>14.100</td>
<td>19.400</td>
<td>2.300</td>
<td>13.900</td>
</tr>
<tr>
<td>1 Std Dev (s)</td>
<td>3.698</td>
<td>2.750</td>
<td>4.361</td>
<td>1.066</td>
<td>3.164</td>
</tr>
<tr>
<td>2 Std Dev (s)</td>
<td>7.396</td>
<td>5.501</td>
<td>8.722</td>
<td>2.132</td>
<td>6.328</td>
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<td>&quot;Normal&quot; Ranger Lower</td>
<td>-5.276</td>
<td>-4.317</td>
<td>-5.316</td>
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#### Dissolved Oxygen (mg/l)

<table>
<thead>
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<th>Harbor</th>
<th>Cheq Bay</th>
<th>Sup Bay</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>n</strong></td>
<td>139</td>
<td>76</td>
<td>33</td>
<td>19</td>
<td>10</td>
</tr>
<tr>
<td><strong>Mean</strong></td>
<td>9.210</td>
<td>9.582</td>
<td>8.897</td>
<td>8.889</td>
<td>8.100</td>
</tr>
<tr>
<td><strong>Min</strong></td>
<td>7.000</td>
<td>8.300</td>
<td>7.100</td>
<td>8.300</td>
<td>7.000</td>
</tr>
<tr>
<td><strong>Max</strong></td>
<td>12.010</td>
<td>12.010</td>
<td>11.100</td>
<td>9.500</td>
<td>9.700</td>
</tr>
<tr>
<td>1 Std Dev (s)</td>
<td>0.833</td>
<td>0.726</td>
<td>0.791</td>
<td>0.387</td>
<td>0.794</td>
</tr>
<tr>
<td>2 Std Dev (s)</td>
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<td>1.582</td>
<td>0.774</td>
<td>1.589</td>
</tr>
<tr>
<td>&quot;Normal&quot; Ranger Lower</td>
<td>7.544</td>
<td>8.129</td>
<td>7.315</td>
<td>8.115</td>
<td>6.511</td>
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</table>

#### CONDUCTIVITY FIELD (umhos/cm)

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<th>Open Lake</th>
<th>Harbor</th>
<th>Cheq Bay</th>
<th>Sup Bay</th>
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<tbody>
<tr>
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<td>33</td>
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<tr>
<td><strong>Mean</strong></td>
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<td>88.000</td>
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<td>88</td>
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<td>264.000</td>
</tr>
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<td>43.480</td>
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<td>8.297</td>
<td>8.235</td>
<td>8.312</td>
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|               |            |               |                 |                |               |
| n             | 121        | 66            | 27              | 15             | 10            |
| Mean          | 3.583      | 4.602         | 1.730           | 4.887          | 0.580         |
| Min           | 0.300      | 0.400         | 0.400           | 1.900          | 0.300         |
| Max           | 10.300     | 10.300        | 3.900           | 9.800          | 0.900         |
| 1 Std Dev (s)| 2.742      | 2.823         | 1.072           | 2.200          | 0.199         |
| 2 Std Dev (s)| 5.484      | 5.645         | 2.144           | 4.401          | 0.398         |
| "Normal" Ranger Lower | -1.901 | -1.044 | -0.414 | 0.486 | 0.182 |
| "Normal" Range Upper | 9.066 | 10.247 | 3.874 | 9.287 | 0.978 |

|               |            |               |                 |                |               |
| n             | 137        | 76            | 31              | 19             | 10            |
| Mean          | 16.373     | 15.031        | 17.371          | 18.405         | 19.970        |
| Min           | 6.300      | 6.300         | 6.500           | 13.600         | 9.800         |
| Max           | 23.900     | 23.200        | 23.900          | 22.800         | 23.000        |
| 1 Std Dev (s)| 4.301      | 4.148         | 4.446           | 2.743          | 3.769         |
| 2 Std Dev (s)| 8.602      | 8.295         | 8.892           | 5.487          | 7.537         |
| "Normal" Ranger Lower | 7.772 | 6.736 | 8.479 | 12.919 | 12.433 |
| "Normal" Range Upper | 24.975 | 23.326 | 26.262 | 23.892 | 27.507 |

¹ Std Dev (σ)

---

1. USEPA Assistance Number: GL00E00500-0_Final Report
Figure N 2a. Geographic Variation in Mean Turbidity and Secchi

![Geographic Variation in Mean Turbidity and Secchi](image)

Figure N 2b. Geographic Variation in Mean DO, Water Temp, and pH

![Geographic Variation in Mean Dissolved Oxygen, Water Temperature and pH](image)
**Table N 4. Summary statistics for microbiology samples from harbor stations**

<table>
<thead>
<tr>
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<th>Fecal Coliform (CFU/100 ml)</th>
<th>E. Coli (MPN/100 ml)</th>
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<td><strong>n</strong></td>
<td>17</td>
<td>18</td>
</tr>
<tr>
<td><strong>Mean</strong></td>
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<td>18.000</td>
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<tr>
<td><strong>Min</strong></td>
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<td>0.500</td>
</tr>
<tr>
<td><strong>Max</strong></td>
<td>170.000</td>
<td>105.000</td>
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<tr>
<td><strong>1 Std Dev (σ)</strong></td>
<td>44.682</td>
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<td><strong>2 Std Dev (σ)</strong></td>
<td>89.363</td>
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<td>-28.694</td>
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<td><strong>&quot;Normal&quot; Range Upper</strong></td>
<td>122.246</td>
<td>64.694</td>
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</table>

**Figure N 3. Microbiology samples from Lake Superior small craft harbors**

![Microbiology samples from Lake Superior small craft harbors](image-url)
Biological Assessment

Benthos

Benthos was collected at 17 of the 32 stations once per year during late summers of 2012 and 2013. Sampling was conducted in all 7 harbors, 2 Superior Bay stations, 2 Chequamegon Bay stations and 6 open lake stations (Table B 1).

Two sites were dominated by abundant, tolerant worms, Barkers Island Marina and mouth of Faxon Creek. Informally, these sites would be characterized as highly eutrophic. Three sites also had tolerant worms, but their abundance was less and the community also featured a more diverse invertebrate group: SE Duluth Entry, Old Bridge by High Bridge, and WI Point NE Superior Entry. These sites would be informally characterized as eutrophic.

Eight sites had various numbers of tolerant and intolerant worms, but each site also had good number of diverse aquatic invertebrates, which suggests a healthier community. Five of those sites were in harbors (Ashland Marina, Bayfield Harbor, Bell Marina, Washburn Harbor and Saxon Harbor); 2 of those sites were in Chequamegon Bay (Chequamegon Bay Ashland Breakwall and S. Houghton Point) and 1 was in the open lake (E. of Squaw Bay).

Port Wing Harbor, also had a variety of organisms, but the numbers of specimens were low. This situation may be due to the type of substrate or anthropogenic sources or both.

Three sites (W. Bark Bay Point Clay Bluffs, W. of Iron River, and N. of Amnicon River) had very few organisms, making it impossible to judge the quality of the sites. This may be due to the type of substrate present, especially if the substrate was entirely shifting sands or hard pan bottom, which is the case near the W. Bark Bay Point site.
Table B 1. Benthos % Composition, 2012

<table>
<thead>
<tr>
<th>Station Description</th>
<th>Oligochaeetes/Polychaetes</th>
<th>Chironomids</th>
<th>Fingernail clams</th>
<th>Isopods</th>
<th>Caddisflies</th>
<th>Total Organisms</th>
</tr>
</thead>
<tbody>
<tr>
<td>12LSNcom5bh (Barkers Island Marina)</td>
<td>86%</td>
<td>13%</td>
<td>4%</td>
<td>4%</td>
<td>4%</td>
<td>14 specimens</td>
</tr>
<tr>
<td>12LSNcom11bh (Lake Superior Port Wing Harbor)</td>
<td>60%</td>
<td>32%</td>
<td>8%</td>
<td>6%</td>
<td>3%</td>
<td>16 organisms</td>
</tr>
<tr>
<td>12LSNcom13bh (Lake Superior Bell Marina)</td>
<td>72%</td>
<td>7%</td>
<td>16%</td>
<td>7%</td>
<td>8%</td>
<td>12 specimens</td>
</tr>
<tr>
<td>12LSNcom19bh (Bayfield Harbor S End Site 2)</td>
<td>29%</td>
<td>49%</td>
<td>8%</td>
<td>6%</td>
<td>3%</td>
<td>14 specimens</td>
</tr>
<tr>
<td>12LSNcom22bh (Washburn Harbor)</td>
<td>28%</td>
<td>23%</td>
<td>12%</td>
<td>7%</td>
<td>3%</td>
<td>14 specimens</td>
</tr>
<tr>
<td>12LSNcom25bh (Ashland Marina 2 North Ellis Ave.)</td>
<td>14%</td>
<td>22%</td>
<td>11%</td>
<td>10%</td>
<td>4%</td>
<td>14 specimens</td>
</tr>
<tr>
<td>12LSNcom26bh (Saxon Harbor)</td>
<td>20%</td>
<td>65%</td>
<td>11%</td>
<td>6%</td>
<td>6%</td>
<td>14 specimens</td>
</tr>
<tr>
<td>12LSNcom4b (Faxon)</td>
<td>87%</td>
<td>6%</td>
<td>6%</td>
<td>6%</td>
<td>6%</td>
<td>14 specimens</td>
</tr>
<tr>
<td>12LSNcom2b (Old bridge by High Bridge)</td>
<td>52%</td>
<td>42%</td>
<td>14%</td>
<td>3%</td>
<td>3%</td>
<td>14 specimens</td>
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</table>

Chequamegon Bay Stations:

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<thead>
<tr>
<th>Station Description</th>
<th>Oligochaeetes/Polychaetes</th>
<th>Chironomids</th>
<th>Fingernail Clams and Chironomids</th>
<th>Isopods</th>
<th>Caddisflies</th>
<th>Total Organisms</th>
</tr>
</thead>
<tbody>
<tr>
<td>12LSNcom21 (S Houghton Point)</td>
<td>53%</td>
<td>3%</td>
<td>8%</td>
<td>8%</td>
<td>2%</td>
<td>14 specimens</td>
</tr>
<tr>
<td>12LSNcom24 (Chequamegon By Ashland)</td>
<td>73%</td>
<td>14%</td>
<td>12%</td>
<td>6%</td>
<td>8%</td>
<td>14 specimens</td>
</tr>
</tbody>
</table>

Superior Bay Stations:

<table>
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<tr>
<th>Station Description</th>
<th>Oligochaeetes/Polychaetes</th>
<th>Chironomids</th>
<th>Fingernail Clams and Chironomids</th>
<th>Isopods</th>
<th>Caddisflies</th>
<th>Total Organisms</th>
</tr>
</thead>
<tbody>
<tr>
<td>12LSNcom7b (N. Amnicon River)</td>
<td>81%</td>
<td>69%</td>
<td>13%</td>
<td>6%</td>
<td>5%</td>
<td>14 specimens</td>
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<tr>
<td>12LSNcom10b (W of Iron River)</td>
<td>31%</td>
<td>69%</td>
<td>3%</td>
<td>6%</td>
<td>3%</td>
<td>14 specimens</td>
</tr>
<tr>
<td>12LSNcom12b (W Bark Bay Point Clay Bluffs)</td>
<td>50%</td>
<td>33%</td>
<td>8%</td>
<td>6%</td>
<td>3%</td>
<td>14 specimens</td>
</tr>
<tr>
<td>12LSNcom14bh (E of Squaw Bay)</td>
<td>48%</td>
<td>42%</td>
<td>14%</td>
<td>3%</td>
<td>3%</td>
<td>14 specimens</td>
</tr>
</tbody>
</table>
Zooplankton

Thirty-two stations were analyzed for zooplankton (Appendix E). The percent similarity of the 29 samples that were analyzed in duplicate for quality assurance ranged from 94.2 to 99.7% for density and 97.1 to 99.5% for biomass, meeting our data quality objectives. Data was omitted for two samples collected on 8/29/2012 due to erroneous flow meter readings.

The 60 um fine mesh plankton net captured rotifers and copepod nauplii along with immature and adult copepods and cladocerans. Density at the nearshore stations ranged from 32,000 to 934,000 organisms m\(^{-3}\) with an average of 209,000 organisms m\(^{-3}\) (Figure Z 1a). Dominant taxa included rotifers in the genera Conochilus, Polyarthra, Kellicottia, Keratella, and Synchaeta. Copepod nauplii, immature cyclopoid and calanoid copepods, and the cladoceran Bosmina were also found in high densities (Figure Z 2c). Dreissenid mussel veligers were frequently found in low numbers at all nearshore stations between the Duluth entry and Sand Island, but were not found at stations located further to the east. While small bodied rotifers numerically dominated the zooplankton community, the majority of the plankton biomass was contributed by larger organisms including diaptomid and cyclopoid copepedites, Daphnia, Holopedium, and Bosmina (Figure Z 2d). Biomass ranged from 11,400 to 375,800 ug m\(^{-3}\) and averaged 70,500 ug m\(^{-3}\) at the nearshore stations (Figure Z 3a).

The coarser 150 um mesh plankton net effectively captured copepods and cladocerans with densities ranging from 824 to 133,700 organisms m\(^{-3}\) at the nearshore sites (Figure Z4a). Diaptomid and cyclopoid copepedites were the numerically dominant taxa captured with the coarser mesh net (Figure Z 5c). The cladocerans Bosmina and Daphnia were most abundant at the more western sampling stations. The majority of the biomass at the nearshore sites was due to the diaptomid and cyclopoid copepods and the cladocerans Daphnia, Holopedium, and Bosmina (Figure Z 5d). Daphnia and Bosmina contributed significantly to the biomass of plankton communities at the western end of the lake while Holopedium was more common at the eastern sites (Figure Z 6a). The spiny water flea Bythotrephes was found at all of the nearshore stations in relatively low densities between late July and October, but did not contribute significantly to the biomass of the plankton community.

Zooplankton density and biomass was generally higher in the harbor samples than in the nearshore lake samples (Figures Z 1b, 3b, 4b and 6b), with highest concentrations in the Duluth-Superior and Chequamegon Bay regions. Dreissenid veligers were collected from sites ranging from the Duluth harbor west to Port Wing. Bythotrephes were also found at low densities in most of the harbor sites.

The zooplankton communities of western Lake Superior’s nearshore regions and harbors showed seasonal variation, with highest densities and biomass occurring during midsummer. Rotifers were most abundant in the shallower harbor regions, but generally did not contribute significantly to the biomass of the zooplankton community. Bosmina, Holopedium, Daphnia, and diaptomid and cyclopoid copepedites were common in the nearshore sites and comprised a majority of the plankton biomass at these sites.
Figure Z 1a. Density (#/m³) of crustacean zooplankton and rotifers in fine mesh samples at nearshore stations on Lake Superior

Figure Z 1b. Density (3/m³) of crustacean zooplankton and rotifers in fine mesh sample from harbor stations on Lake Superior
Figure Z 2a thru 2d. Most Common Taxa and Taxa with highest biomass in fine mesh samples from Lake Superior Harbor and Nearshore sites.
Figure Z 3a. Biomass (ug/m3) of crustacean zooplankton and rotifers in fine mesh samples at nearshore stations on Lake Superior

Figure Z 3b. Biomass (ug/m3) of crustacean zooplankton and rotifers in fine mesh samples from harbor stations on Lake Superior
Figure Z 4a. Density of crustacean zooplankton (#/m3) in coarse net samples from nearshore stations on Lake Superior

Figure Z 4b. Density of crustacean zooplankton (#/m3) in coarse net samples from harbor stations on Lake Superior
Figure Z 5a thru 5d. Most Common Taxa in coarse mesh and Taxa with highest biomass in coarse mesh for nearshore and harbors sites

Fig Z 5a. Most common taxa in coarse mesh samples from Lake Superior harbor sites

Fig Z 5b. Taxa with highest biomass in coarse mesh samples from Lake Superior harbor sites

Fig Z 5c. Most common taxa in coarse mesh samples from Lake Superior nearshore sites

Fig Z 5d. Taxa with highest biomass in coarse mesh samples from Lake Superior nearshore sites
Figure Z6a. Biomass (ug/m³) of crustacean zooplankton in coarse net samples from nearshore stations on Lake Superior

Figure Z6b. Biomass (ug/m³) of crustacean zooplankton in coarse net samples from harbor stations on Lake Superior
Fish Stomachs

The percentage of lake herring with food in their stomachs varied by collection site and date and ranged from 0 to 91% empty stomachs (Table Z 1). Overall, 59% of the stomachs contained food remains with an average biovolume of 1.19 ml. During the summer months, the diet of Lake Superior lake herring consisted primarily of zooplankton although three of the herring had consumed small fish. During late July and August the herring consumed large amounts of the spiny water flea, Bythotrephes, with some fish containing over 4000 organisms with a biovolume of 4.2 ml (Figure Z 7). Lake Herring showed a definite preference for Bythotrephes in their diets even though these organisms made up less than 1% of the zooplankton community.

Figure Z 7. Mean composition of Lake Superior herring diets

![Mean Composition of Lake Superior Herring Diets](image)
### Table 1. Summary of diet composition of Lake Superior Herring

#### Summary of diet composition of Lake Superior Herring

<table>
<thead>
<tr>
<th>Station</th>
<th>Date</th>
<th>Fish ID #</th>
<th>Biovolume of contents (ml)</th>
<th>Daphnia</th>
<th>Eury cercus</th>
<th>Bosmina</th>
<th>Holopedium</th>
<th>Leptodora</th>
<th>Bythotrephes</th>
<th>Chironomid</th>
<th>Insect</th>
<th>Cyclopoid</th>
<th>Calanoid</th>
<th>Fish</th>
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<td>912</td>
<td>0.2</td>
<td>90</td>
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<td>3</td>
<td>0</td>
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<td>5</td>
<td>2</td>
<td>0</td>
<td>0</td>
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Land Cover Assessment

Watersheds

Watershed boundaries were delineated and land cover was classified and digitized in the 16 watersheds included in this study (See maps in Appendix G). Acreages and percentages of the watershed were calculated for all four land classes defined below (Table WS 4a and 4b).

- **0-16 age timber**: Includes timber harvests that are 16 years old or less.
- **Agriculture/Open**: Includes agriculture land, pasture, pipeline easements, transmission lines and other non-impervious open lands.
- **Impervious Surface**: Includes buffered roads, trails, and driveways; buildings, and other Impervious surfaces
- **Total Impervious Surface**: Includes 0-16 age timber, agriculture/open, and impervious lands.

Young forests (0 to age 16) are added to the open land classification because precipitation runs quickly off this type of landscape contributing to increased volume, velocity and pollutants reaching surface waters. Studies show that high percentages of open lands in a watershed (60%) can lead to degradation of water quality (Verry 1972).

The size of the watersheds ranged from 1,950 acres in Saxine Creek to 127,242 acres in the Brule River watershed (Figure WS 2). The percentage of public lands ranged from 22% in the Brule River to 73% in the Cranberry River watershed. Public lands do not contribute to increased runoff; however, they do provide opportunities for land management, protection and restoration.

Total open lands in the watersheds ranged from 6% to 34% (Table WS 4a and 4b). Allouez Bay has the highest percent of agriculture/open lands (23%), although the Iron River watershed has the highest number of acres in agriculture (17,682). The Cranberry River watershed, which is 43,742 acres, has the highest percentage of public lands (73%) and the highest percentage of 0-16 age forests (21%).

The Little Pokegama River watershed has the least amount of 0-16 year old forests (0%) and agriculture/open land (0%) and the highest percentage of impervious surface (6%). Impervious surface in other watersheds range from 1% in 9 of the watersheds to 4% in Allouez Bay. Impervious surface was not calculated in 3 of the watersheds; however, it is unlikely that impervious surface in these watersheds is higher than 6%. A land cover indicator developed to show how increased imperviousness degrades water quality suggests that when impervious surface percentages are <10%, the watershed is protected (Schueler 1992) (Figure WS 1).

![Figure WS 1. % Imperviousness vs Water Quality](image-url)
### Figure WS 2. Total Acres of Project Watersheds

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<tr>
<th>Watershed</th>
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<td>Brule River</td>
<td>6,345</td>
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<tr>
<td>Cranberry River</td>
<td>4,078</td>
</tr>
<tr>
<td>Flag River</td>
<td>1,0381</td>
</tr>
<tr>
<td>Iron River</td>
<td>2,9563</td>
</tr>
<tr>
<td>Little Pokegama</td>
<td>5,6740</td>
</tr>
<tr>
<td>Lost Creek</td>
<td>5,763</td>
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<tr>
<td>Nemadji River</td>
<td>43,742</td>
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<tr>
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<td>Onion River</td>
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<td>Oronto Creek</td>
<td>2,0619</td>
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<td>Pokegama</td>
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<tr>
<td>Raspberry River</td>
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<tr>
<td>Sioux River</td>
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The pie chart illustrates the total acres of project watersheds for each watershed, with Allouez Bay having the largest acreage at 127,242 acres, followed by Bark Bay at 10,4004 acres.
Figure WS 3. % Open Land Cover in Watersheds

[Image: Bar chart showing % Open Land Cover in Watersheds for various years and locations.]

- % 0-16 Year Timber Harvest
- % Agriculture/Open
- % Impervious Surface
- % Total Open Lands

0 = Not calculated
### Table WS 4a. Summary of Watershed Size and Land Cover - Analyzed 2012

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<th>Watershed</th>
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<th>Iron River</th>
<th>Nemadji River</th>
<th>North Fish Creek</th>
<th>Onion River</th>
<th>Oronto Creek</th>
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<th>Saxine Creek</th>
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Total Open Lands (Acres) 29896.00 10923.40 32900.40 31034.50 18420.50 560.00 1858.00 2146.50 460.00
% of Watershed in Open Land Cover 23.50% 24.97% 31.53% 29.84% 32.46% 9.72% 24.43% 20.88% 23.59%

### Table WS 4b. Summary of Watershed Size and Land Cover – Analyzed 2007-2010

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Total Open Land* (Acres) 7018.68 2089.56 1207.85 4270.54 7324.81 256.50 4340.00
% of Watershed in Open Land Cover 34.04% 20.13% 19.04% 28.03% 24.78% 6.29% 22.88%
Coastal Shoreline Aerial Photographs

871 images (Appendix H, Map 3) of shoreline were captured with each photo encompassing an estimated 900 feet of horizontal and 600 feet vertical planar distances of shoreline. Twenty-three aerial photographs were also taken at points along 8 tributaries during leaf off conditions. The photographs show the extreme range of conditions along the Lake Superior shoreline from the slumping clay bluffs and turbid waters near Superior, Wisconsin (Figure M 1) and the sandstone cliffs and clear waters along the Bayfield County peninsula (Figure M 2). Photos also show a significant number of large residential homes constructed along the shoreline (Figures M 3a and M 3b).

Figure M 1. Aerial Photograph Near Superior, Wisconsin
Figure M 2. Aerial Photograph of Bayfield, Wisconsin Peninsula

Figure M 3a. Aerial Photograph of Residential Development
Figure M 3a. Aerial Photograph of Residential Development
Map 4 – Lake Superior Oblique Photopoints 2012
Recommendations and Next Steps

This project provides a baseline assessment of the current conditions in Wisconsin’s Lake Superior basin. The data shows that conditions in the Lake Superior basin are relatively good, although not always pristine as described in some publications. Ecosystems in the basin that are exhibiting degraded conditions, presence of AIS, or exceeding state water quality standards should be investigated further. The tributary, coastal wetland and land cover data should be reorganized and analyzed by watershed to look for relationships, identify further data needs and look for opportunities for restoration and protection. This comprehensive assessment could provide the starting point for watershed planning and TMDLs. Data from the nearshore zone of Lake Superior should also be investigated further and targeted sampling should be done to better understand Lake Superior nearshore conditions.
References


Wisconsin Department of Natural Resources. 2002 Revised. Guidelines for Evaluating Habitat of Wadable Streams. Bureau of Fisheries Management and Habitat Protection Monitoring and Data Assessment Section.

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