Final Report

Implementing WI DNR's Lake Superior Nearshore Monitoring Plan

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Abbreviations

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

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

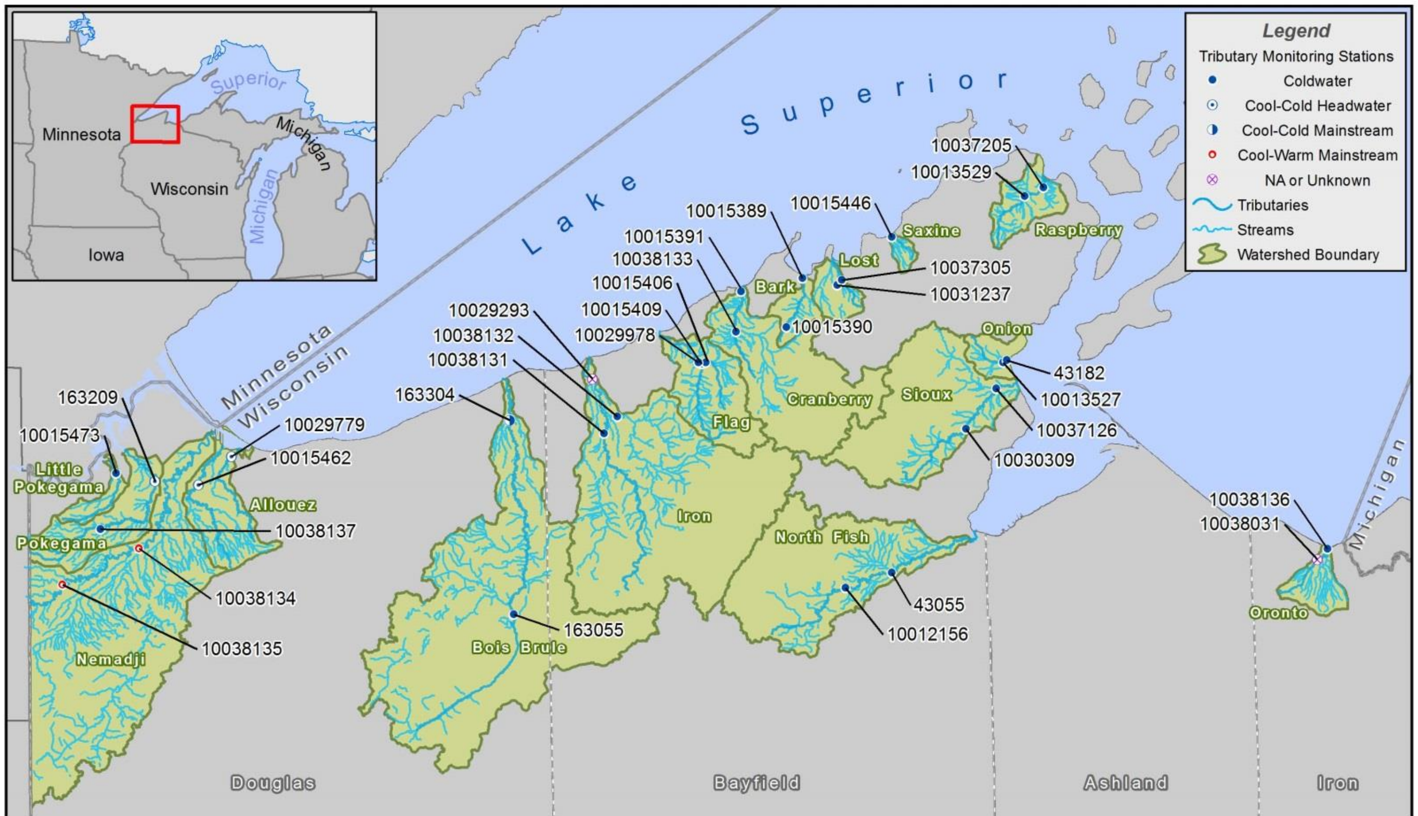
Site Selection

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

ID	Latitude	Longitude	Stream	ID	Latitude	Longitude	Stream	ID	Latitude	Longitude	Stream
10015390	46.7925	-91.2048	Bark	10029978	46.75985	-91.33171	Flag	043182	46.75473	-90.89029	Onion
10015389	46.8404	-91.18	Bark	10038132	46.70822	-91.44885	Iron	10038136	46.559856	-90.44025	Oronto
10029779	46.675255	-92.00138	Bear	10029293	46.74579	-91.483475	Iron	10038031	46.549862	-90.455376	Oronto
10015462	46.6475	-92.0488	Bluff	10038131	46.691555	-91.46829	Iron	10015473	46.65973	-92.16693	Little Pokegama
163055	46.51559	-91.60241	Bois Brul	10031237	46.832962	-91.130005	Lost	163209	46.651558	-92.11113	Pokegama
163304	46.70641	-91.60292	Bois Brule	10037305	46.837738	-91.12367	Lost	10038137	46.604996	-92.189575	Pokegama
10038133	46.78905	-91.27685	Cranberry	10038135	46.550648	-92.244774	Nemadji	10013529	46.91534	-90.85806	Raspberry
10015391	46.828771	-91.26823	Cranberry	10038134	46.58577	-92.13546	Nemadji	10037205	46.923424	-90.83084	Raspberry
10015409	46.7584	-91.32668	Flag	10012156	46.534573	-91.12888	North Fish	10015446	46.87878	-91.05033	Saxine
10015406	46.759743	-91.32102	Flag	043055	46.54856	-91.062164	North Fish	10030309	46.688034	-90.95109	Sioux
				10013527	46.75256	-90.89566	Onion	10037126	46.72683	-90.90615	Sioux

Scale:
1 in = 9 miles

N W E S

0 2.5 5 10 15 Miles

Map projection: UTM, Zone 15, Datum NAD83

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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 (NH3), 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/ 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

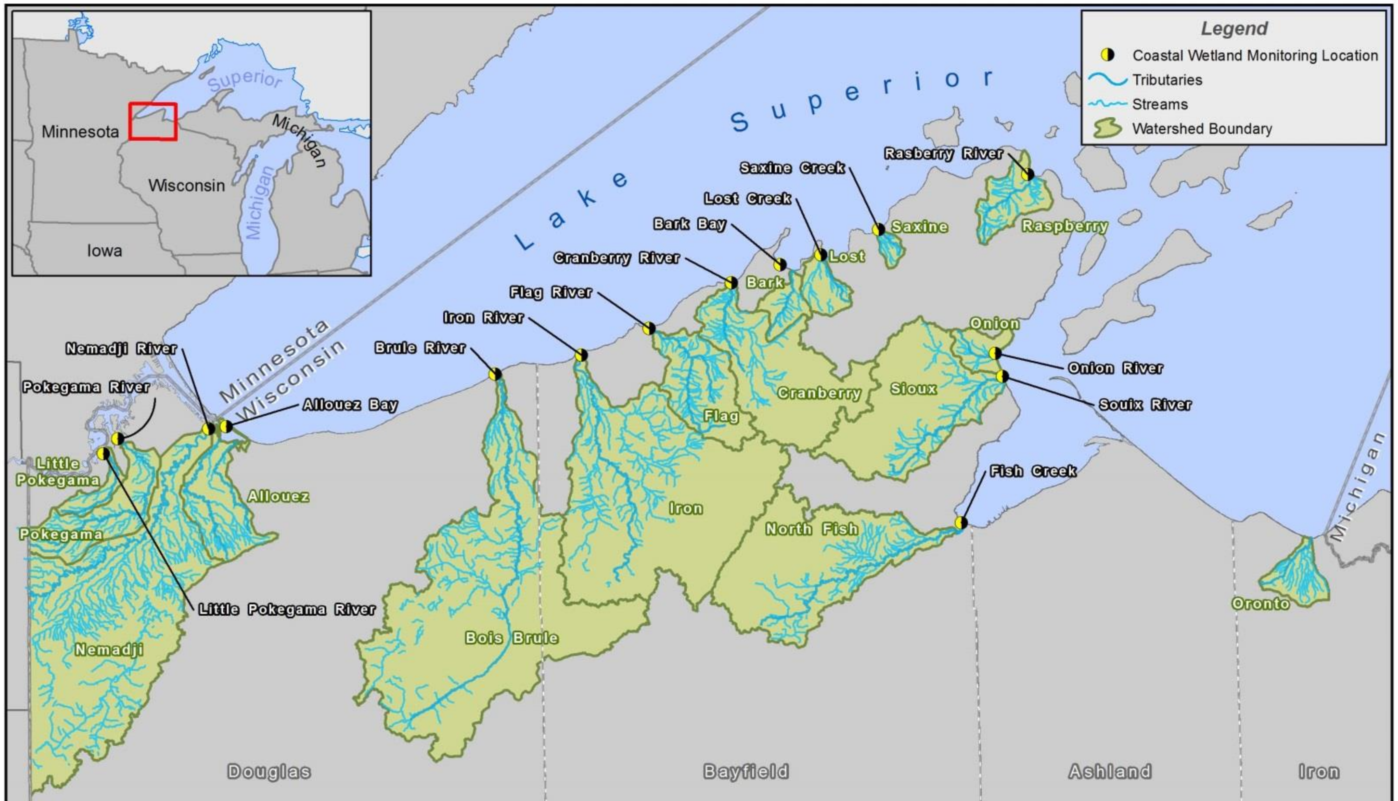
A mix of qualitative and quantitative habitat assessments were conducted at 18 stations using the protocols outlined in *Guidelines for Evaluating Habitat of Wadable Streams* (WDNR 2002). The habitat surveys were conducted along a station length ranging between 100 and 800 meters, depending on mean stream 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



Lake Superior Coastal Wetland Monitoring Stations 2010-2013

Station Name	ID	Latitude	Longitude	GLCWC Class	WWI Class
Allouez Bay	10034046	46.698055	-92.00361	LOS/LPS	F3/A2L
Brule River	10034074	46.74632	-91.61279	RRB	WOH/E2
Fish Creek	10034204	46.587765	-90.941910	RRO	F0H
Flag River	10034055	46.788887	-91.387665	RRB/BL	S6/E1H
Iron River	10034202	46.763466	-91.487120	Not Classed	< 2acres
Lost Creek	10034058	46.858612	-91.135830	RRO/RRB	S6/E2H
Onion River	10034203	46.75611	-90.886536	RRO/RRB	S3/E1k
Saxine Creek	10038138	46.88238	-91.050670	RRO	E1K
Bark Bay	10034054	46.849724	-91.195274	BL	S6/E2h/W0L
Cranberry River	10034205	46.832596	-91.266700	RRB	S3/E1k
Little Pokegama	10034057	46.67234	-92.182350	RRO	E2/A2H
Nemadji River	10034072	46.6962	-92.029150	RRB	E2H
Pokegama River	10034059	46.68706	-92.161270	RRO	E2H/W0H
Rasberry River	10038139	46.933544	-90.831990	RRO/RRB	S6/E2H
Souix River	10034060	46.732777	-90.876945	LOE	S3/E2H/W0H

Scale:
1 in = 9 miles
0 2.5 5 10 15 Miles
Map projection: UTM, Zone 15, Datum NAD83

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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 (NH3), 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 m^2) 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 quadrat around a sample point was selected randomly.

A two person team surveyed each quadrat, 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 quadrat. Emergent, floating and submergent plants present in each quadrat 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

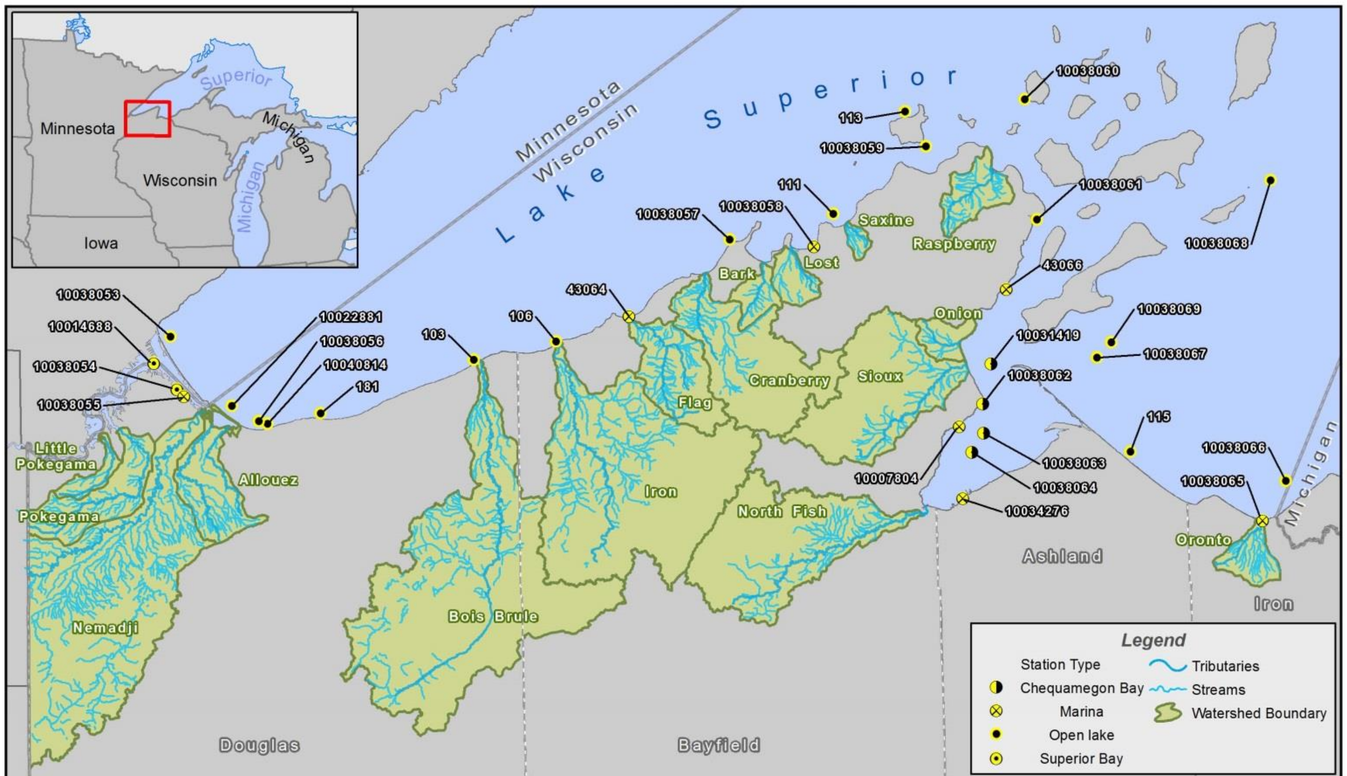
Thirty-two monitoring stations were established in the Lake Superior nearshore zone along Wisconsin's shoreline (Map 3). For the purposes of this project, the nearshore zone is defined as the area below the ordinary high water mark that is less than 30 meters in depth and within 5 km of the shoreline. 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



Lake Superior Nearshore Monitoring Stations 2012-2013

ID	Latitude	Longitude	Depth (M)
10038053	46.77722	-92.07445	17.6
10014688	46.75022	-92.09985	7.6
10022881	46.704628	-91.983345	14.5
10038054	46.723057	-92.06528	3.1
10038055	46.71528	-92.055	2.1
10040814	46.685917	-91.929726	3.6
10038056	46.68861	-91.94278	9.9
181	46.69583	-91.85001	7.0
103	46.748604	-91.618065	8.5
106	46.76604	-91.49313	8.3

ID	Latitude	Longitude	Depth (M)
043064	46.79069	-91.38209	2.1
10038057	46.8675	-91.22806	6.7
10038058	46.85836	-91.1013	2.0
111	46.891666	-91.07084	15.0
113	46.995827	-90.95834	7.5
10038059	46.95889	-90.928055	8.0
10038060	47.005	-90.77722	11.3
10038061	46.88028	-90.763885	14.7
043066	46.809303	-90.81292	3.8
10031419	46.732674	-90.8388	22.0

ID	Latitude	Longitude	Depth (M)
10038062	46.691387	-90.852776	15.7
10007804	46.668365	-90.88929	2.4
10038063	46.66111	-90.8525	5.0
10038064	46.641666	-90.87139	9.9
10034276	46.59394	-90.88694	2.0
10038065	46.562	-90.437614	2.0
10038066	46.601944	-90.40111	23.6
10038067	46.735554	-90.67917	13.9
115	46.6375	-90.63333	12.3
10038068	46.913334	-90.40889	20.5
10038069	46.75083	-90.65722	20.0

Scale:
1 in = 9 miles
0 2.5 5 10 15 Miles
Map projection: UTM, Zone 15, Datum NAD83

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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 (NH3), 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 T 1) 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 Rasberry 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 ^{o}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 Cemetary 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.

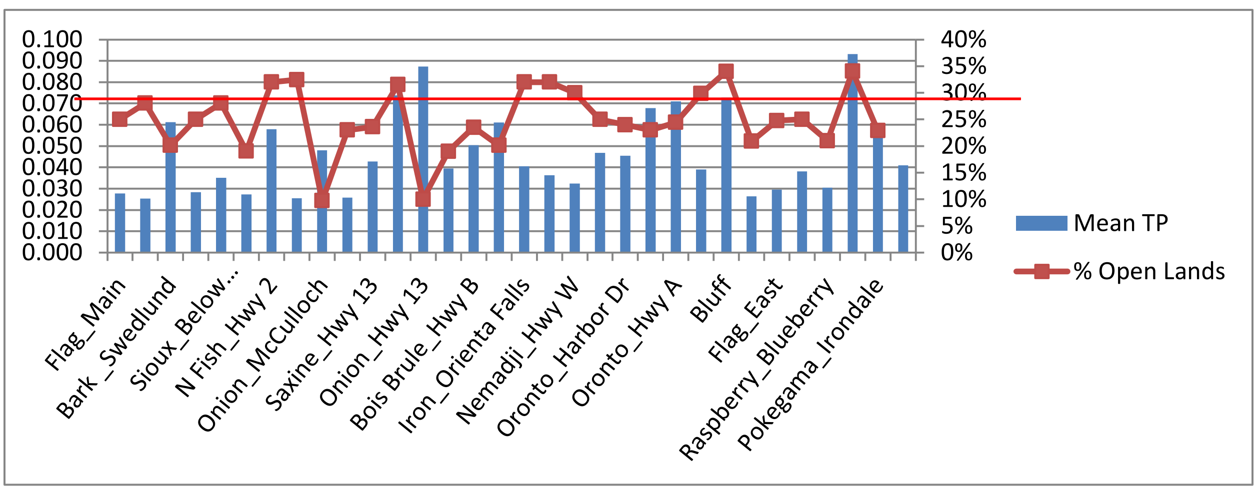
Table T 1. Summary Statistics for Tributary Water Chemistry

	All Tributary Lab Samples_2012-2013 / Spring and Fall						
	TP (Mg/l)	TDP (Mg/l)	NH3_N Diss (Mg/l)	N+N (Mg/l)	TKN (Mg/l)	Chl a (Ug/l)	TSS (Mg/l)
n	121	127	122	119	122	128	127
Mean	0.042	0.026	0.016	0.047	0.431	1.544	8.759
Min	0.011	0.007	0.008	0.010	0.070	0.240	1.150
Max	0.155	0.103	0.270	1.320	1.870	17.400	86.000
1 Std Dev (*s*)	0.025	0.014	0.025	0.123	0.423	2.593	12.959
2 Std Dev (*s*)	0.049	0.028	0.051	0.247	0.845	5.187	25.918
"Normal" Ranger Lower	-0.007	-0.002	-0.035	-0.200	-0.414	-3.642	-17.159
"Normal" Range Upper	0.091	0.053	0.067	0.294	1.276	6.731	34.677

Table T 2. Summary Statistics for Tributary In-Situ Measurements

	All Tributary In-Situ Samples_2012-2013 / Approx one per month						
	NTU	T-Tube (cm)	DO (Mg/l)	PH	Cond-Fld (uS/cm@25o)	Water Temp (°C)	Flow (cfs)
n	307	305	307	307	307	307	239
Mean	14.328	83.158	9.020	7.805	189.883	14.011	26.850
Min	-0.400	8.900	2.580	6.990	57.000	6.420	-0.301
Max	92.000	120.000	11.840	8.530	1045.000	26.130	361.600
1 Std Dev (*s*)	18.069	39.032	1.616	0.268	99.363	4.215	42.295
2 Std Dev (*s*)	36.137	78.064	3.231	0.536	198.725	8.430	84.591
"Normal" Ranger Lower	-21.809	5.093	5.093	7.269	-8.842	5.581	-57.741
"Normal" Range Upper	50.465	161.222	12.251	8.342	388.608	22.442	111.441

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

	All Tributary In-Situ and Macroinvertebrate Samples_2012-2013				
	DO (Mg/l)	Water Temp (oC)	Flow (cfs)	2012 HBI (Sprg/Fall)	2013 HBI (Sprg/Fall)
n	307	307	239	64	63
Mean	9.020	14.011	26.850	3.613	3.636
Min	2.580	6.420	-0.301	1.150	0.909
Max	11.840	26.130	361.600	8.843	7.034
1 Std Dev (s)	1.616	4.215	42.295	1.555	1.500
2 Std Dev (s)	3.231	8.430	84.591	3.111	3.001
"Normal" Ranger Lower	5.093	5.581	-57.741	0.502	0.635
"Normal" Range Upper	12.251	22.442	111.441	6.724	6.637

Table T 3b. Summary of Tributary HBIs

Station and Sampling Season	HBI 2012	HBI 2013	Mean
Bark River, Hwy 13 Fall	1.83	2.091	1.9605
Bark River, Hwy 13 Sprg	4.588	3.908	4.248
Bark River, Swedlund Rd Fall	2.542	1.678	2.11
Bark River, Swedlund Rd Sprg	1.305	2.514	1.9095
Bear Creek, NE Hwy 2 Fall	5.785	5.335	5.56
Bear Creek, NE Hwy 2 Sprg	5.23	5.625	5.4275
Bluff Creek, Hwy Z Fall	6.91	7.034	6.972
Bluff Creek, Hwy Z Sprg	2.855	5.878	4.3665
Brule River, Hwy B Fall	4	3.467	3.7335
Brule River, Hwy B Sprg	2.214	3.234	2.724

Brule River, McNeils Fall	2.962	2.644	2.803
Brule River, McNeils Sprg	2.44	2.972	2.706
Cranberry River, Old 13 Fall	5.266	5.551	5.4085
Cranberry River, Old 13 Sprg	5.333	3.373	4.353
Cranberry River, Touve Rd Fall	4.906	5.513	5.2095
Cranberry River, Touve Rd Sprg	2.518	5.405	3.9615
East Fork Flag R, ATV brdg Fall	5.319	4.138	4.7285
East Fork Flag R, ATV brdg Sprg	4.734	2.214	3.474
East Fork Iron River Fall	2.767	3.127	2.947
East Fork Iron River Sprg	3.857	3.987	3.922
Flag River, West Fall	2.653	2.281	2.467
Flag River, West Sprg	1.531	1.531	1.531
Flag River, Main Fall	2.512	2.815	2.6635
Flag River, Main Sprg	1.15	1.427	1.2885
Iron River, Orienta Fall	3.134	3.181	3.1575
Iron River, Orienta Sprg	3.444	3.588	3.516
Iron River, Sorenson Rd Fall	2.639	2.535	2.587
Iron River, Sorenson Rd Sprg	2.967	3.046	3.0065
Little Pokegama R, 105 Fall	8.843	5.357	7.1
Little Pokegama R, 105 Sprg	4.629	6.179	5.404
Lost Creek #1 Fall	2.806	4.704	3.755
Lost Creek #1 Sprg	1.868	2.985	2.4265
Lost Creek #2 Fall	2.917	2.017	2.467
Lost Creek #2 Sprg	2.942	3.015	2.9785
Nemadji River, Finn Fall	5.248	4.206	4.727
Nemadji River, Finn Sprg	4.326	5.685	5.0055
Nemadji River, Hwy W Fall	3.5	3.608	3.554
Nemadji River, Hwy W Sprg	3.252	3.328	3.29
North Fish, Old Hwy 2 Fall	1.841	2.016	1.9285
North Fish, Old Hwy 2 Sprg	2.982	3.192	3.087
North Fish, Town Dump Rd Fall	2.153	2.386	2.2695
North Fish, Town Dump Rd Sprg	2.92	2.362	2.641
Onion River, Hwy 13 Fall	2.872	1.873	2.3725
Onion River, Hwy 13 Sprg	2.948	2.655	2.8015
Onion River, McCullock Fall	2.371	2.083	2.227
Onion River, McCullock Sprg	3	2.009	2.5045
Oronto Creek, Harbor Dr Fall	4.318	4.847	4.5825
Oronto Creek, Harbor Dr Sprg	4.211	4.786	4.4985
Oronto Creek, Hwy A Fall	4.131	3.937	4.034
Oronto Creek, Hwy A Sprg	4.957	3.284	4.1205
Pokegama River, Cemetary Fall	5.69	6.447	6.0685
Pokegama River, Cemetary Sprg	3.076	6.044	4.56
Pokegama River, Irondale Fall	7.188	5.077	6.1325

Pokegama River, Irondale Sprg	4.693	4.937	4.815
Raspberry River, Hwy K Fall	5.411	5.325	5.368
Raspberry River, Hwy K Sprg	4.582	4.603	4.5925
Raspberry River, Blueberry Fall	5.939	5.441	5.69
Raspberry River, Blueberry Sprg	4.736	4.917	4.8265
Saxine Creek, Hwy 13 Fall	3.635	2.942	3.2885
Saxine Creek, Hwy 13 Sprg	1.845	2.592	2.2185
Sioux River, below conf Fall	2.385	x	2.385
Sioux River, below confl Sprg	1.941	1.279	1.61
Sioux River, Hwy C Fall	1.976	0.909	1.4425
Sioux River, Hwy C Sprg	1.711	1.94	1.8255

Table T 3c. Hilsenhoff Biotic Index Scores

Hilsenhoff Biotic Index Scores (Hilsenhoff, 1987)		
Index	**Water Quality**	**Degree of Organic Pollution**
0.00-3.50	Excellent	None apparent
3.51-4.50	Very Good	Possible slight
4.51-5.50	Good	Some
5.51-.6.50	Fair	Fairly significant
6.51-7.50	Fairly Poor	Significant
7.51-8.50	Poor	Very significant
8.51-10.00	Very Poor	Severe

Figure T 2. 2012_2013 Tributary – Hilsenhoff Biotic Index (HBI)

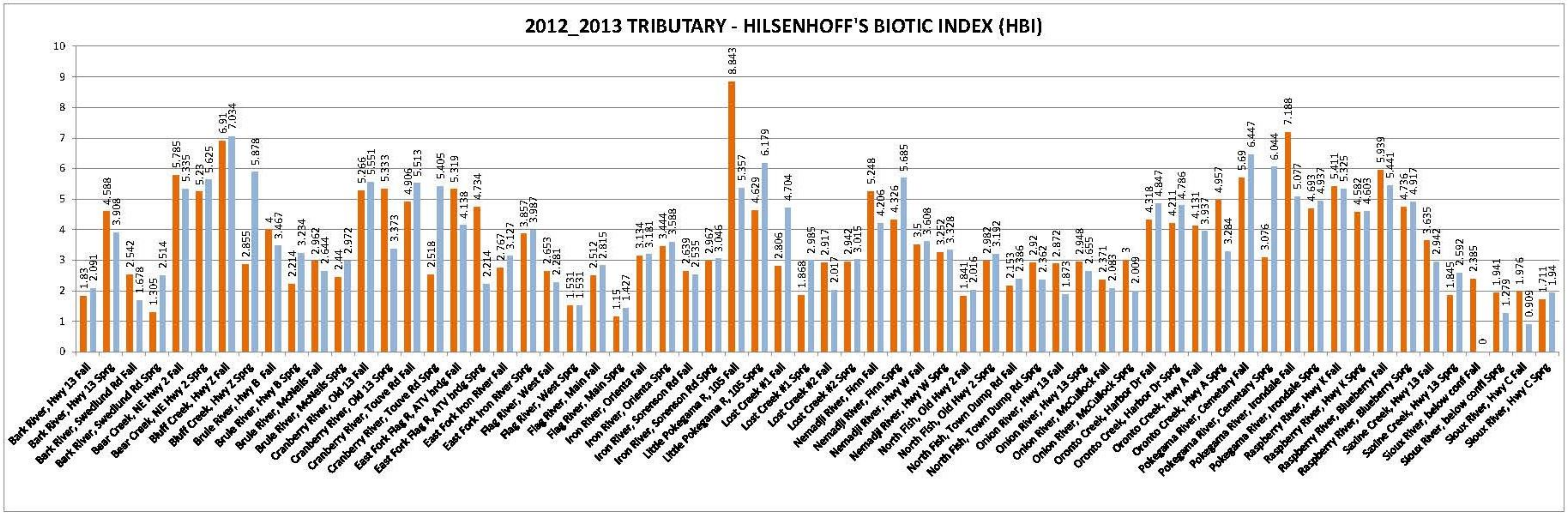
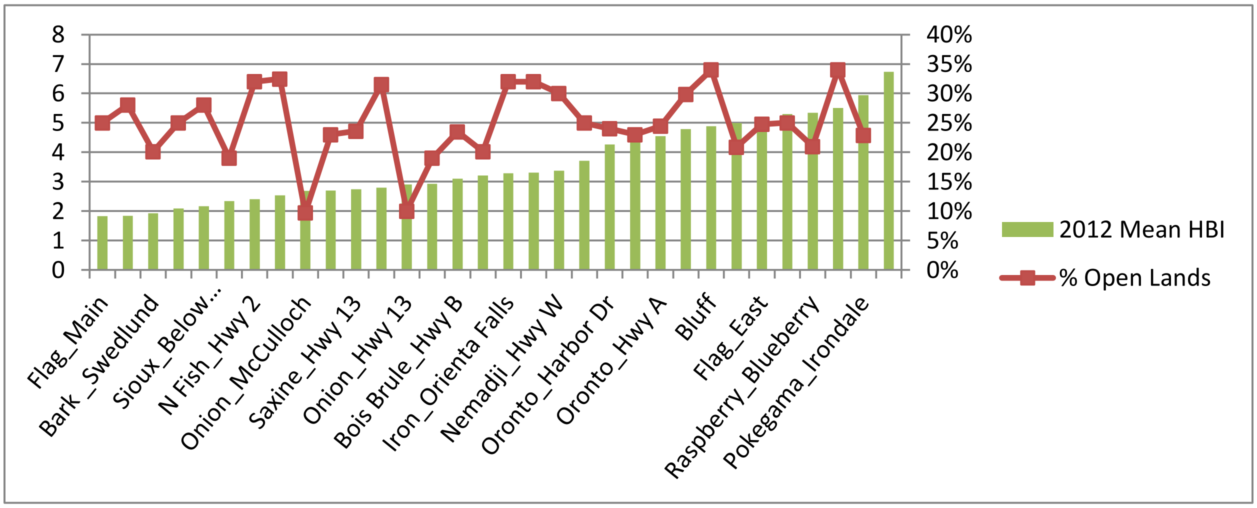


Figure T 3. Compare Mean HBI to % Open Lands



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'

County	Waterbody Name	Station	Survey Date	Habitat Score Small Streams	Habitat Rating Streams < 10'
BAYFIELD	BARK RIVER	McNeils Landing	29-Aug-2013	40	Fair
BAYFIELD	EAST FORK CRANBERRY RIVER	Touve Rd	28-Aug-2013	45	Fair
BAYFIELD	FLAG RIVER	West Fork	23-Aug-2013	65	Good
BAYFIELD	LOST CREEK # 1		10-Jul-2012	68	Good
BAYFIELD	LOST CREEK # 2		16-Jul-2012	75	Excellent
BAYFIELD	NORTH FISH CREEK	Town Dump Rd	23-Jul-2012	60	Good
BAYFIELD	ONION RIVER	McCulloch Rd	26-Jun-2012	35	Fair

Table T 4b. Tributary Habitat Rating_Streams > 10'

County	Waterbody Name	Station	Survey Date	Habitat Score Large Streams	Habitat Rating Streams >10'
BAYFIELD	IRON RIVER	SORENSON RD	17-Jul-2012	65	Good
DOUGLAS	BOIS BRULE RIVER	CTH B	15-Jun-2012	36	Fair

Table T 4c. Tributary Habitat Rating_Low Gradient Streams

County	Waterbody Name	Station Name	Survey Year	Habitat Score Low Gradient	Habitat Rating Low Gradient
BAYFIELD	IRON RIVER	IRON RIVER 170' US SORENSON RD	2012	70	Good
BAYFIELD	ONION RIVER	MCCULLOCH ROAD	2012	61	Good

Table T 4d. Tributary Habitat Rating_Qualitative Assessment

County	Waterbody Name	Station Name	Survey Date	Qualitative Habitat Score	Qualitative Habitat Rating
DOUGLAS	NEMADJI RIVER	FINN RD	07-Sep-2012	20	Poor
DOUGLAS	LITTLE POKEGAMA RIVER	HWY 105	20-Sep-2012	65	Good
BAYFIELD	EAST FORK FLAG RIVER	EAST FORK	14-Aug-2012	58	Good
BAYFIELD	EAST FORK CRANBERRY RIVER	TOUVE RD	15-Aug-2012	52	Good
BAYFIELD	BARK RIVER	HWY 13	07-Aug-2012	38	Fair
BAYFIELD	BARK RIVER	SWEDLUND RD	07-Aug-2012	53	Good
BAYFIELD	SAXINE CREEK	HWY 13	16-Aug-2012	40	Fair
BAYFIELD	RASPBERRY RIVER	OLD HWY K	16-Aug-2012	55	Good
BAYFIELD	SIOUX RIVER	CTH C	13-Aug-2012	68	Good

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, NH_3, 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 ^{o}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

	Coastal Wetland Lab Samples_2011-2012						
	TP (mg/l)	TDP (mg/l)	NH3_N Diss (mg/l)	N+N (mg/l)	TKN (mg/l)	Chl a (µg/l)	TSS (mg/l)
n	29	28	16	30	29	28	30
Mean	0.100	0.03	0.021	0.030	0.874	17.643	44.200
Min	0.021	0.01	0.008	0.010	0.070	1.590	2.000
Max	0.594	0.10	0.047	0.149	3.550	218.000	438.000
1 Std Dev (s)	0.134	0.02	0.014	0.033	0.746	40.596	95.744
2 Std Dev (s)	0.267	0.03	0.029	0.065	1.492	81.191	191.488
Normal Ranger Lower	-0.167	-0.01	-0.008	-0.035	-0.618	-63.548	-147.288
Normal Range Upper	0.367	0.06	0.050	0.095	2.366	98.834	235.688

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

	All Coastal Wetland In-Situ Samples_2011-2012						
	NTU	T-Tube (cm)	DO (mg/l)	PH	Cond-Fld (µS/cm@ 25° C)	Water Temp (°C)	Air Temp (°C)
n	28	19	29	29	29	29	28
Mean	16.375	60.179	6.396	7.229	140.414	19.920	24.893
Min	1.200	12.100	0.700	6.100	65.000	9.300	18.000
Max	81.400	120.000	10.100	8.000	213.000	25.900	33.000
1 Std Dev (s)	20.735	33.123	2.394	0.461	45.751	4.130	4.750
2 Std Dev (s)	41.471	66.247	4.789	0.923	91.501	8.260	9.500
Normal Ranger Lower	-25.096	-6.068	1.607	6.306	48.913	11.660	15.393
Normal Range Upper	57.846	126.426	11.184	8.151	231.915	28.180	34.393

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

Wetland Name	Year Sampled	TP (mg/l)	TKN (mg/l)	TSS (mg/l)	N+N (mg/l)	NTU	Invert IBI Score	IBI Description
allouez bay	**2011**	0.104	1.07	16	0.056	81.4	134[a]	MOI
allouez bay	**2012**	0.594	3.55	outlier	0.149	64	130[a]	MOI
bark river	**2011**	0.029	1.21	10	0.023	1.6	109[e]	REF
bark river	**2012**	0.022	0.98	14	0.0095	5.2	111[e]	REF
bois brule river	**2011**	0.054	1.11	12	0.0095	6.7	107[e]	REF
bois brule river	**2012**	0.053	1.75	45	0.0095	4.3	113[e]	REF
cranberry river	**2011**	0.051	0.2	10	0.028	3.5	142[a]	MII
cranberry river	**2012**	0.037	0.41	17	0.0095	12	140[a]	MII
fish creek	**2011**	0.024	0.17	6	0.0095	1.3	Pending	Pending
fish creek	**2012**	0.211	0.85	52	0.0095	38.8	Pending	Pending
flag river	**2011**	0.037	0.42	12	0.0095	1.8	Pending	Pending
flag river	**2012**	0.037	0.44	2	0.0095	2.3	Pending	Pending
iron river	**2011**	0.045	0.17	12	0.0095	14.4	Pending	Pending
iron river	**2012**	0.074	0.73	50	0.0095	55	Pending	Pending
little pokegama river	**2011**	0.073	1.17	18	0.08	8.2	Pending	Pending
little pokegama river	**2012**	0.04	1.61	42	0.0095	6.5	Pending	Pending
lost creek	**2011**	0.031	0.42	4	0.0095	2.4	Pending	Pending
lost creek	**2012**	0.04	0.63	13	0.022	2.6	Pending	Pending
nemadji river	**2011**	0.036	0.62	11	0.029	27.3	135[g]	REF

nemadji river	**2012**	0.124	0.91	39	0.047	16.5	117[g]	MII
Onion River	**2011**	0.082	0.45	8	0.0095	8	29[b]	MOI
Onion River	**2012**	0.088	0.07	23	0.0095	27.2	19[b]	DEG
pokegama river	**2011**	0.13	1.33	6	0.095	21.4	136[a]	MII
pokegama river	**2012**	0.179	1.76	38	0.067	30.3	162[a]	REF
raspberry river	**2012**	0.021	0.19	3	0.027	3.8	101[e]	REF
saxine creek	**2011**	0.047	0.43	out	0.05	no sample	66[f]	MOI
saxine creek	**2012**	0.528	1.98	25	0.032	6.8	74[f]	MOI
souix river	**2011**	0.06	0.65	10	0.0095	1.2	Pending	Pending
souix river	**2012**	0.042	0.07	11	0.0095	4	Pending	Pending

Exceeds State Standard >0.075 mg/l

Exceeds upper normal range

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

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

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

	Vegetation Community Indicators (Albert 2008)								
Wetland Name	**Year Sampled**	**GLCWC Class**	**Watershed Size (Acres)**	**Watershed % Open Land Cover**	**Mean C Entire Site**	**Mean C Zone 1**	**Mean C Zone 2**	**Combined Veg Quality Score**	**Combined Veg Quality Description**
allouez bay	**2008**	LOS/LPS	20619	34%	5.32	5.41	5.18	36	Med
allouez bay	**2009**	LOS/LPS	20619	34%	5.66	5.10	6.23	40	Med
bark river	**2008**	BL	10381	20%	8.88	8.89	8.88	50	High
bark river	**2011**	BL	10381	20%	8.42	9.10	7.74	50	High
bois brule river	**2011**	RRB	127242	23%	6.93	6.99	6.86	40	Med
bois brule river	**2012**	RRB	127242	23%	6.70	6.43	6.97	40	Med
cranberry river	**2011**	RRB	43742	25%	4.82	4.77	4.87	32	Med
cranberry river	**2012**	RRB	43742	25%	4.90	5.01	4.74	34	Med
fish creek	**2011**	RRO	56740	32%	4.25	4.17	4.34	32	Med
fish creek	**2012**	RRO	56740	32%	4.02	3.72	4.33	30	Med
flag river	**2008**	RRB/BL	29563	25%	6.34	6.98	5.39	36	Med
flag river	**2012**	RRB/BL	29563	25%	5.86	6.41	5.32	32	Med
iron river	**2011**	**not classed**	104330	32%	4.92	5.03	4.81	38	Med
iron river	**2012**	**not classed**	104330	32%	4.82	5.04	4.61	38	Med
little pokegama river	**2009**	RRO	4078	6%	5.32	4.44	6.20	34	Med
little pokegama river	**2012**	RRO	4078	6%	5.39	4.48	6.31	34	Med
lost creek	**2008**	RRO/RRB	6345	19%	8.16	8.29	7.32	46	High
lost creek	**2012**	RRO/RRB	6345	19%	7.52	8.27	6.77	42	High
nemadji river	**2011**	RRB	104004	30%	5.12	4.97	5.27	34	Med
nemadji river	**2012**	RRB	104004	30%	3.68	2.70	4.66	23	Med
pokegama river	**2009**	RRO	18965	23%	4.73	4.49	4.98	38	Med
pokegama river	**2012**	RRO	18965	23%	4.50	4.60	4.39	30	Med
raspberry river	**2012**	RRO/RRB	10279	21%	6.17	5.94	6.52	36	Med
saxine creek	**2011**	RRO	1950	24%	5.36	5.39	5.33	48	High
saxine creek	**2012**	RRO	1950	24%	5.57	5.41	5.73	36	Med
souix river	**2008**	LOE	15233	28%	6.52	6.71	4.81	36	Med
souix river	**2011**	LOE	15233	28%	5.14	5.97	4.32	30	Med

Table CW 6. Vegetation Community Indicators Scores and

Vegetation Community Indicators Scores and Descriptions (Albert 2008)	
COMBINED NUMERIC SCORE	COMBINED SCORE DESCRIPTION
0-5	VERY LOW
6-20	LOW
21-40	MEDIUM
41-50	HIGH

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), Chequemegon 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 ^{o}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

WDNR Water Clarity Index (Shaw 2004)	
Water Clarity	**Secchi Depth (m)**
Very poor	0.9
Poor	1.5
Fair	2.1
Good	3.0
Very Good	6.0
Excellent	9.7

Table N 2. Summary Statistics for Lake Superior Nearshore Water Chemistry

Lake Superior Nearshore Water Chemistry									
Sample Area	**Avg. # of Samples**	**Statistic**	**Chl-a (ug/l)**	**TKN (mg/l)**	**NH3-N (mg/l)**	**NO3+NO2 (mg/l)**	**TDP (mg/l)**	**TP (mg/l)**	**TSS (mg/l)**
All Nearshore	132	Mean	3.072	0.278	0.020	0.279	0.014	0.021	2.127
		Min	0.130	0.070	0.008	0.010	0.003	0.003	1.000
		Max	40.800	2.130	0.535	0.478	0.293	0.090	17.000
Open Lake	74	Mean	1.434	0.188	0.011	0.313	0.009	0.014	1.518
		Min	0.130	0.070	0.008	0.225	0.003	0.003	1.000
		Max	7.160	0.589	0.043	0.388	0.025	0.045	17.000
Harbor (Marinas)	29	Mean	5.302	0.336	0.019	0.212	0.025	0.029	3.053
		Min	0.422	0.070	0.008	0.010	0.003	0.010	1.000
		Max	29.500	0.866	0.077	0.431	0.293	0.059	7.800
Chequamegon Bay	16	Mean	1.411	0.145	0.008	0.272	0.010	0.014	1.105
		Min	0.262	0.070	0.008	0.235	0.003	0.003	1.000
		Max	3.170	0.578	0.016	0.310	0.017	0.025	3.000
Superior Bay	10	Mean	11.091	0.891	0.117	0.244	0.033	0.059	5.980
		Min	4.450	0.070	0.018	0.132	0.013	0.035	1.000
		Max	40.800	2.130	0.535	0.478	0.070	0.090	9.600

Figure N 1a. Geographic Variation in Mean Chlorophyll a

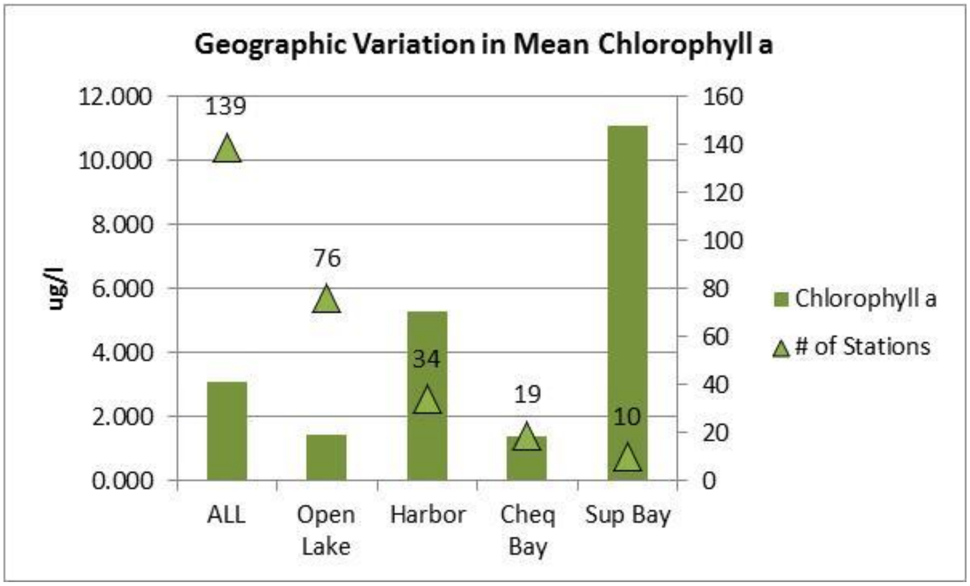


Figure N 1b. Geographic Variation in Mean Total Phosphorus

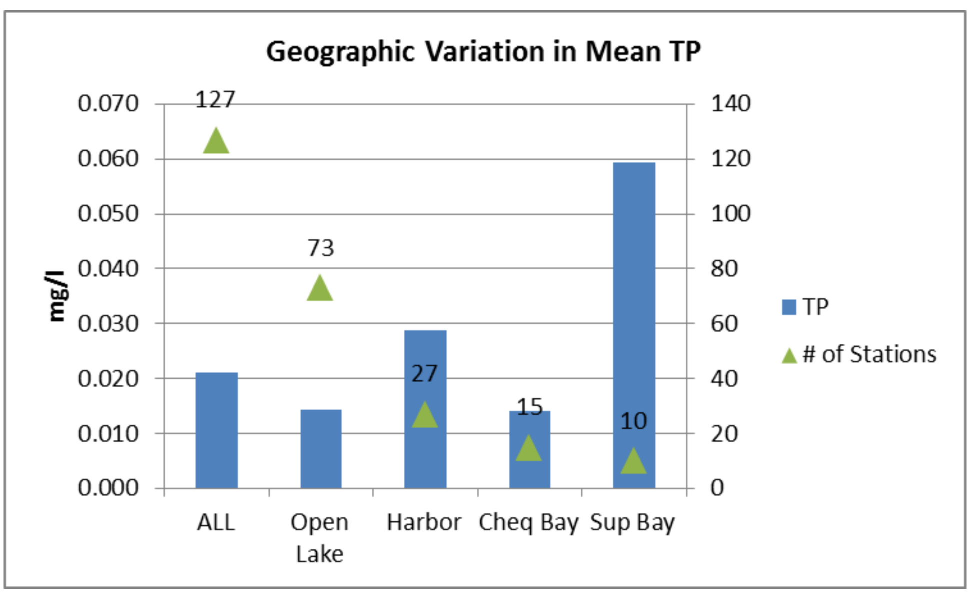


Figure N 1c. Geographic Variation in Mean Total Dissolved Phosphorus

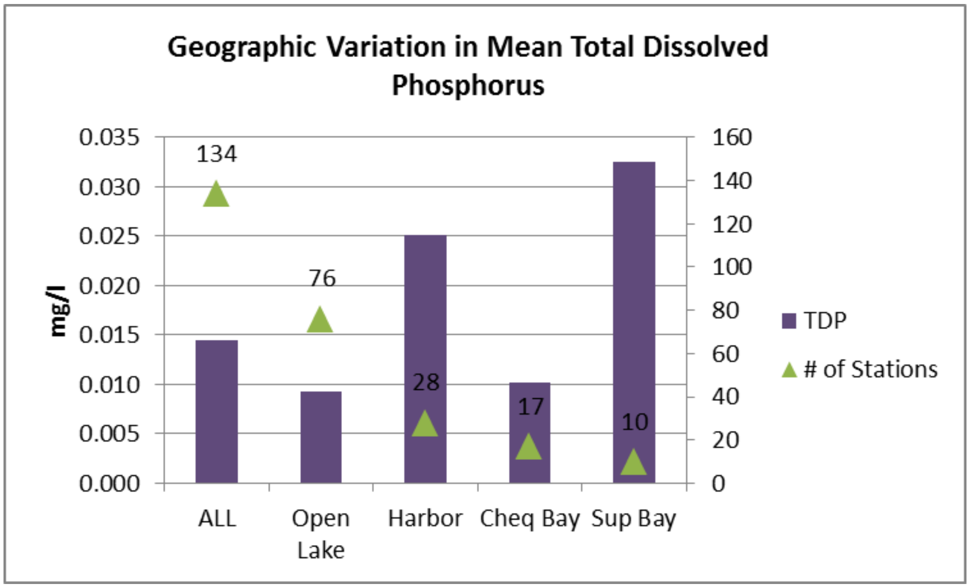


Figure N 1d. Geographic Variation in Mean TKN, NO3 + NO2 and NH3

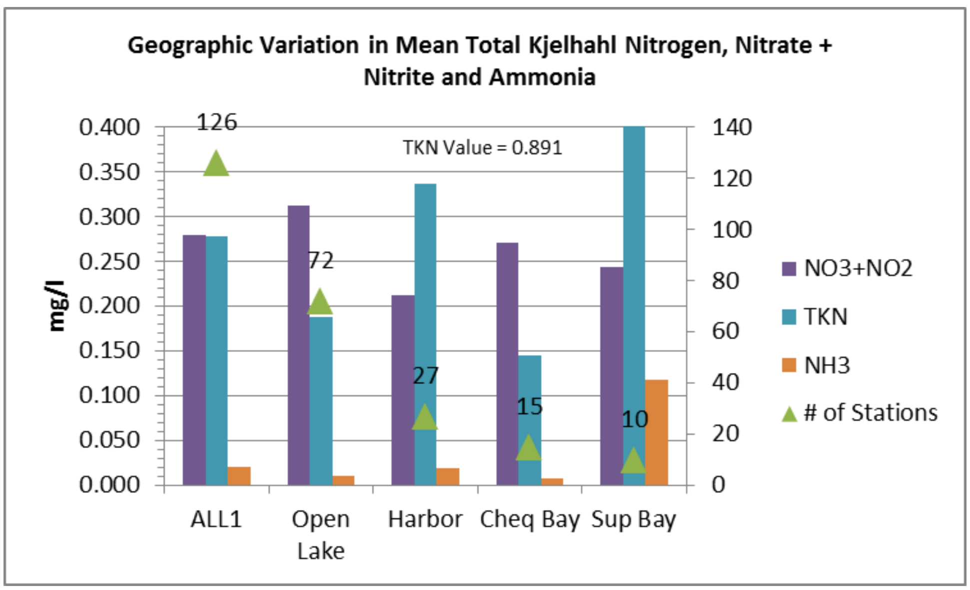


Figure N 1e. Geographic Variation in Mean Total Suspended Solids

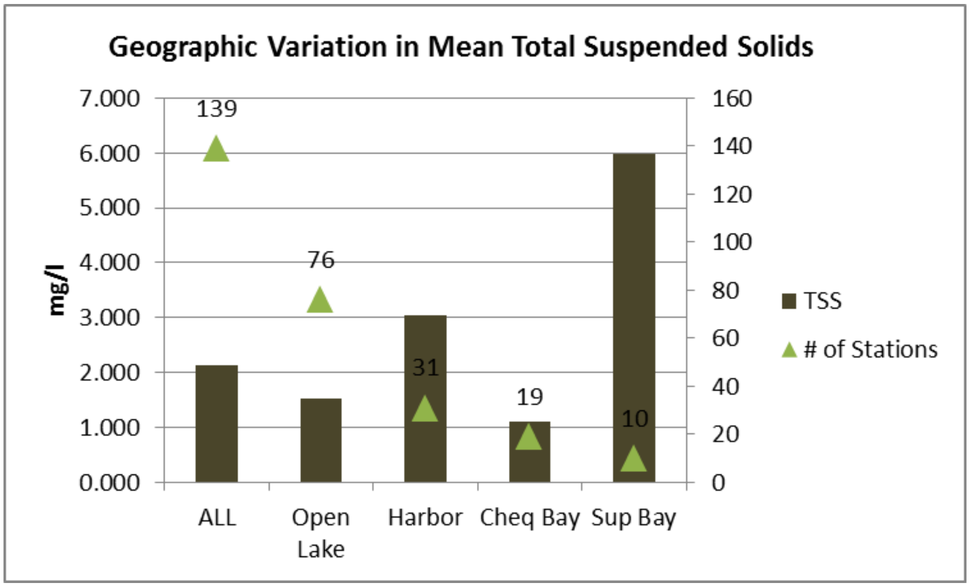


Table N 3. Summary Statistics for Lake Superior Nearshore Water Quality In-Situ

	TURBIDITY, FIELD NEPHELOMETRIC (NTU)				
	ALL[1]	Open Lake	Harbor	Cheq Bay	Sup Bay
n	137	75	33	18	10
Mean	2.120	1.184	3.406	0.106	8.460
Min	-2.300	-2.300	-1.500	-1.200	3.600
Max	19.400	14.100	19.400	2.300	13.900
1 Std Dev (*s*)	3.698	2.750	4.361	1.066	3.164
2 Std Dev (*s*)	7.396	5.501	8.722	2.132	6.328
"Normal" Ranger Lower	-5.276	-4.317	-5.316	-2.026	2.132
"Normal" Range Upper	9.516	6.684	12.128	2.237	14.788
	Dissolved Oxygen (mg/l)				
	ALL[1]	Open Lake	Harbor	Cheq Bay	Sup Bay
n	139	76	33	19	10
Mean	9.210	9.582	8.897	8.889	8.100
Min	7.000	8.300	7.100	8.300	7.000
Max	12.010	12.010	11.100	9.500	9.700
1 Std Dev (*s*)	0.833	0.726	0.791	0.387	0.794
2 Std Dev (*s*)	1.666	1.453	1.582	0.774	1.589
"Normal" Ranger Lower	7.544	8.129	7.315	8.115	6.511
"Normal" Range Upper	10.876	11.035	10.478	9.664	9.689
	CONDUCTIVITY FIELD (umhos/cm)				
	ALL[1]	Open Lake	Harbor	Cheq Bay	Sup Bay
n	139	76	33	19	10
Mean	112.712	102.645	119.879	99	185.400
Min	88.000	88.000	93.000	88	137.000
Max	264.000	137.000	183.000	105	264.000
1 Std Dev (*s*)	28.792	7.812	26.549	5	43.480
2 Std Dev (*s*)	57.583	15.625	53.098	10	86.960
"Normal" Ranger Lower	55.129	87.020	66.780	89	98.440
"Normal" Range Upper	170.295	118.269	172.977	109	272.360

Table N 3. Continued

	PH				
	ALL[1]	Open Lake	Harbor	Cheq Bay	Sup Bay
n	138	76	33	19	10
Mean	7.832	7.838	7.773	7.937	7.780
Min	7.100	7.200	7.100	7.600	7.400
Max	8.600	8.200	8.500	8.200	8.600
1 Std Dev (*s*)	0.233	0.198	0.270	0.154	0.397
2 Std Dev (*s*)	0.465	0.396	0.539	0.307	0.793
"Normal" Ranger Lower	7.367	7.442	7.234	7.630	6.987
"Normal" Range Upper	8.297	8.235	8.312	8.244	8.573

	SECCHI (M)				
	ALL[1]	Open Lake	Harbor	Cheq Bay	Sup Bay[2]
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

	Water Temp (^{o}C)				
	ALL[1]	Open Lake	Harbor	Cheq Bay	Sup Bay[2]
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)

Figure N 2a. Geographic Variation in Mean Turbidity and Secchi

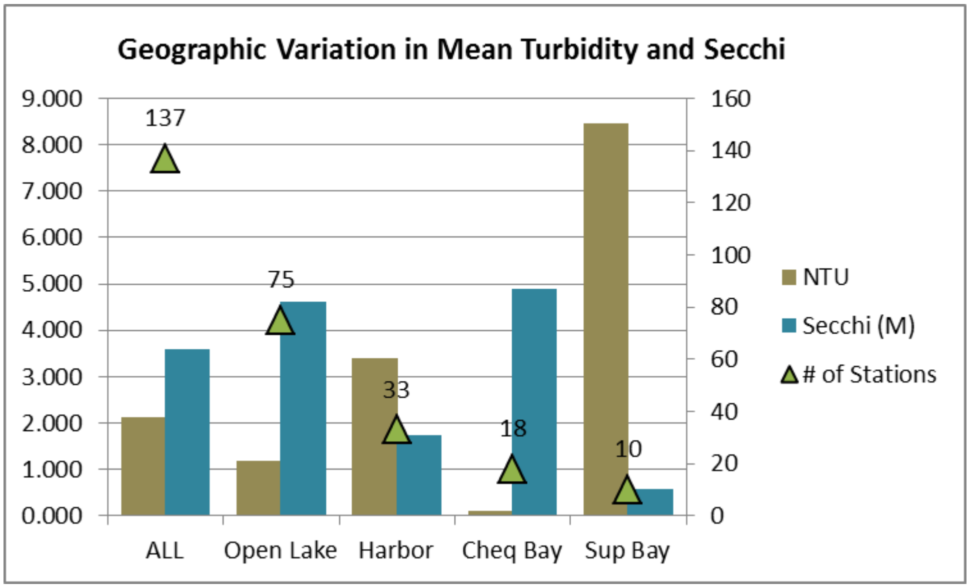


Figure N 2b. Geographic Variation in Mean DO, Water Temp, and pH

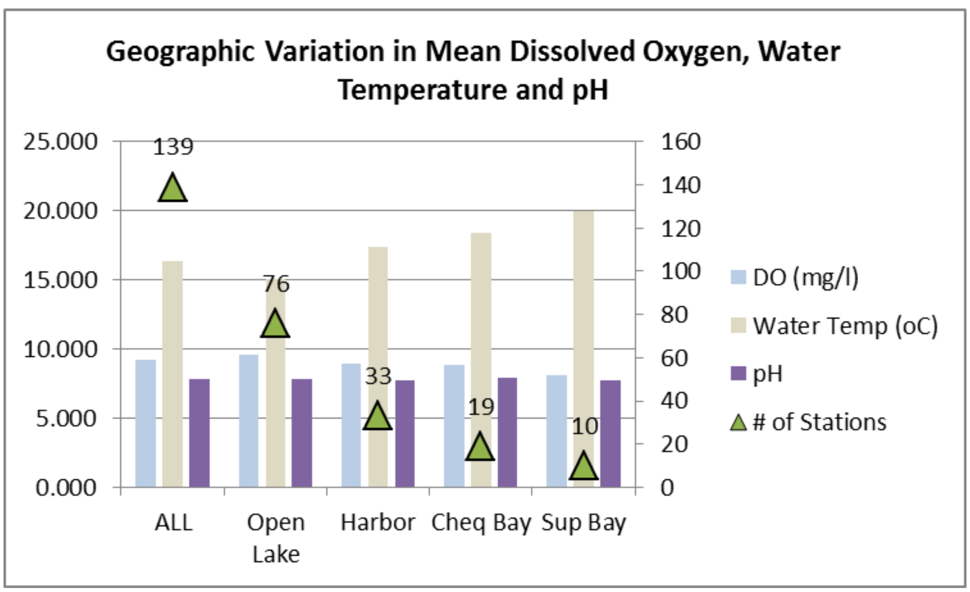
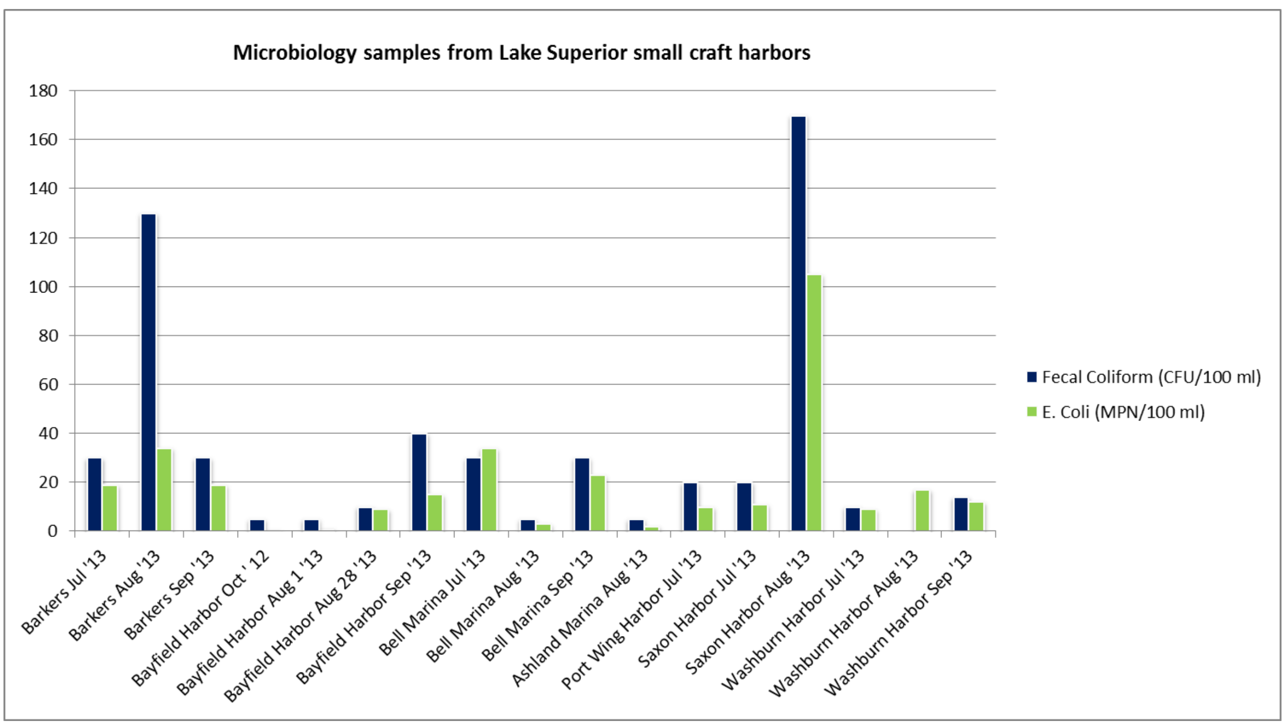


Table N 4. Summary statistics for microbiology samples from harbor stations

MICROBIOLOGY (HARBOR STATIONS) STATIONS		
	Fecal Coliform (CFU/100 ml)	**E. Coli (MPN/100 ml)**
n	17	18
Mean	32.882	18.000
Min	5.000	0.500
Max	170.000	105.000
1 Std Dev (σ)	44.682	23.347
2 Std Dev (*s*)	89.363	46.694
"Normal" Ranger Lower	-56.481	-28.694
"Normal" Range Upper	122.246	64.694

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



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

__Small Craft Harbor Stations:__

12LSNcom5bh (Barkers Island Marina)
Oligochaetes/Polychaetes = 86%
Chironomids = 13%

12LSNcom11bh (Lake Superior Port Wing Harbor)
Chironomids = 32%
Oligochaetes/Polychaetes = 60%
Fingernail clams and caddisflies = 4% each

12LSNcom13bh (Lake Superior Bell Marina)
Oligochaetes/Polychaetes = 72%
Fingernail clams = 7%
Chironomids = 16%

12LSNcom19bh (Bayfield Harbor S End Site 2)
Isopods (sowbugs) = 49%
Oligochaetes/Polychaetes = 29%
Fingernail clams = 8%
Amphipods (scuds) = 6%
Snails and chironomids = 3% each

12LSNcom22bh (Washburn Harbor)
Oligochaetes/Polychaetes = 28%
Isopods (sowbugs) and Chironomids = 23% each
Amphipods (scuds) = 12%
Snails = 7%
Fingernail clams = 3%

12LSNcom25bh (Ashland Marina 2 North Ellis Ave.)
Amphipods (scuds) = 36%
Chironomids = 22%
Oligochaetes/Polychaetes = 14%
Fingernail clams = 11%
Isopods (sowbugs) = 10%
Snails and caddisflies = 4% each

12LSNcom26bh (Saxon Harbor)
Chironomids = 20%
Oligochaetes/Polychaetes = 65%
Fingernail clams = 11%

__Superior Bay Stations:__

12LSNcom4b (Faxon)
Oligochaetes/Polychaetes = 87%
Fingernail clams = 6%
chironomids = 6%

12LSNcom2b (Old bridge by High Bridge)
Oligochaetes/Polychaetes = 52%
Chironomids = 42%

__Chequamegon Bay Stations:__

12LSNcom21 (S Houghton Point)
Oligochaetes/Polychaetes = 53%
Fingernail Clams and Chironomids = 20% each
Amphipods (scuds) = 3%

12LSNcom24 (Chequamegon By Ashland)
Oligochaetes/Polychaetes = 73%
Fingernail clams = 14%
Amphipods (scuds) = 8%
Chironomids = 3%

__Open Lake Stations:__

12LSNcom1b (SE Duluth Entry)
Oligochaetes/Polychaetes = 63%
Fingernail clams = 8%
chironomids = 26%

12LSNcom3b (WI Point NE Superior Entry)
Chironomids = 13%
Oligochaetes/Polychaetes = 81%
Fingernail clams = 5%

12LSNcom7b (N. Amnicon River)
caddisflies = 5%
chironomids = 95%
[**only a total of 14 specimens collected for all three replicates**]

12LSNcom10b (W of Iron River)
Oligochaetes/Polychaetes = 31%
Chironomids = 69%
[**a total of only 16 organisms collected for all three replicates]**

12LSNcom12b (W Bark Bay Point Clay Bluffs)
Oligochaetes/Polychaetes = 50%
Fingernail clams and caddisflies = 8% each
chironomids = 33%
[**a total of only 12 specimens collected for all three replicates**]

12LSNcom14bh (E of Squaw Bay)
Amphipods (scuds) = 33%
Oligochaetes/Polychaetes = 48%
Fingernail clams = 14%
Snails = 3%

(2013 results pending)

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.

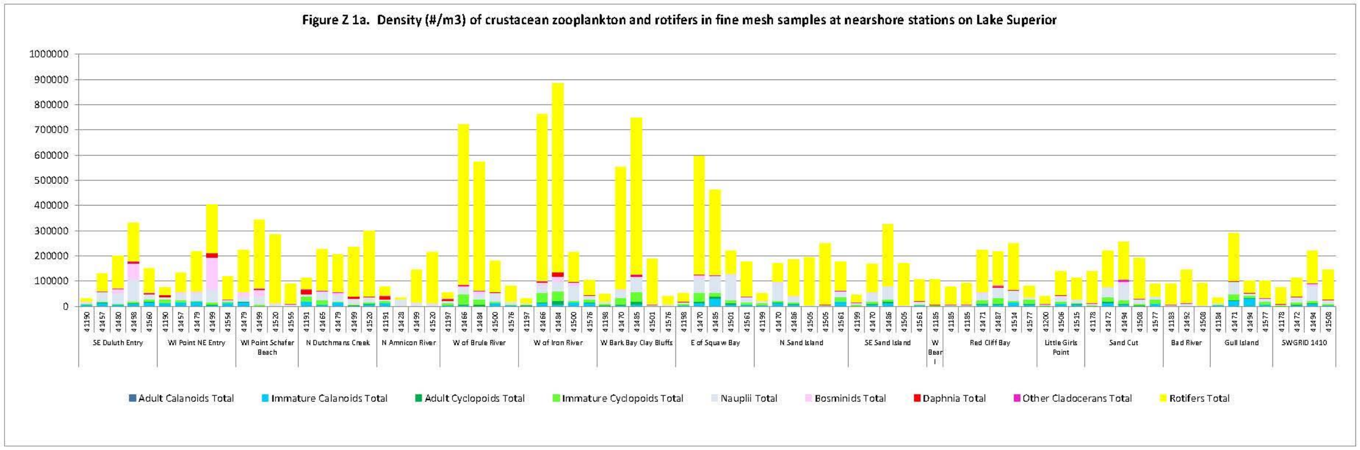
The 60 um fine mesh plankton net captured rotifers and copepod nauplii along with immature and adult copepods and cladocerans. Density at the nearshore stations ranged from 32,000 to 934,000 organisms m-3 with an average of 209,000 organisms m-3 (Figure Z 1a). Dominant taxa included rotifers in the genera 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



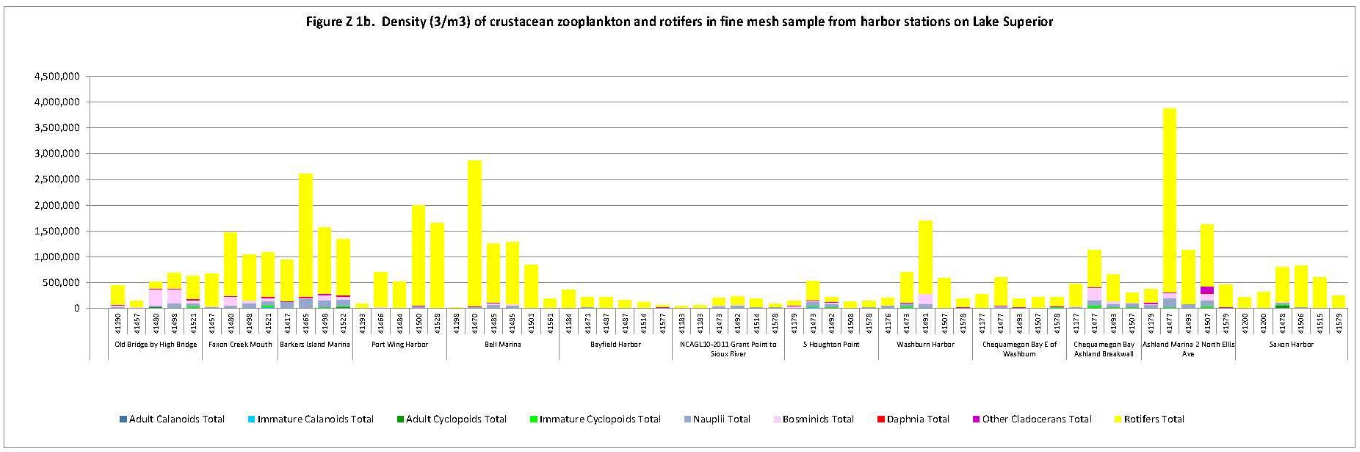


Figure Z 1b. Density (3/m3) of crustacean zooplankton and rotifers in fine mesh sample from harbor stations on Lake Superior

Figure Z 2a thru 2d. Most Common Taxa and Taxa with highest biomass in fine mesh samples from Lake Superior Harbor and Nearshore sites.

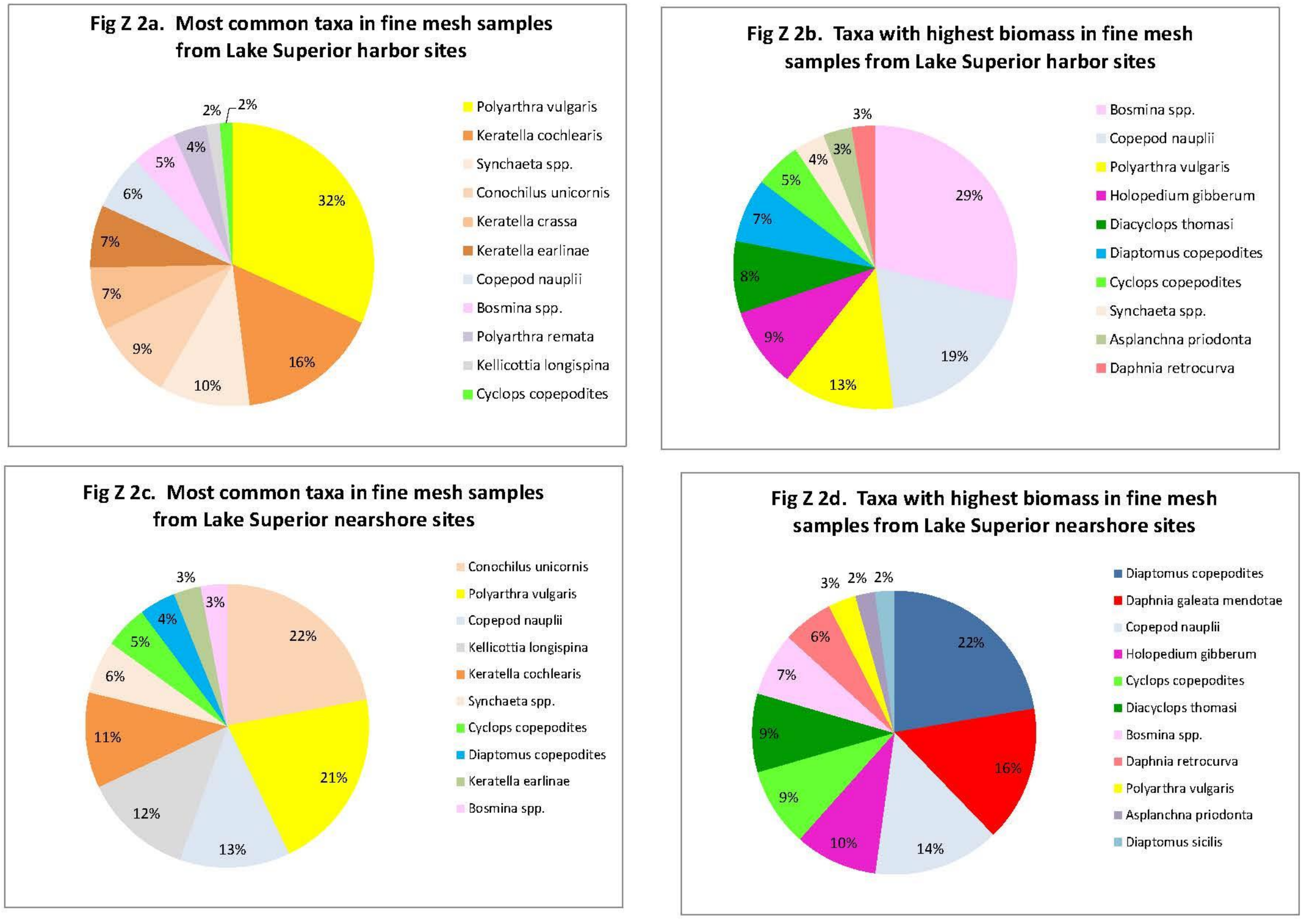
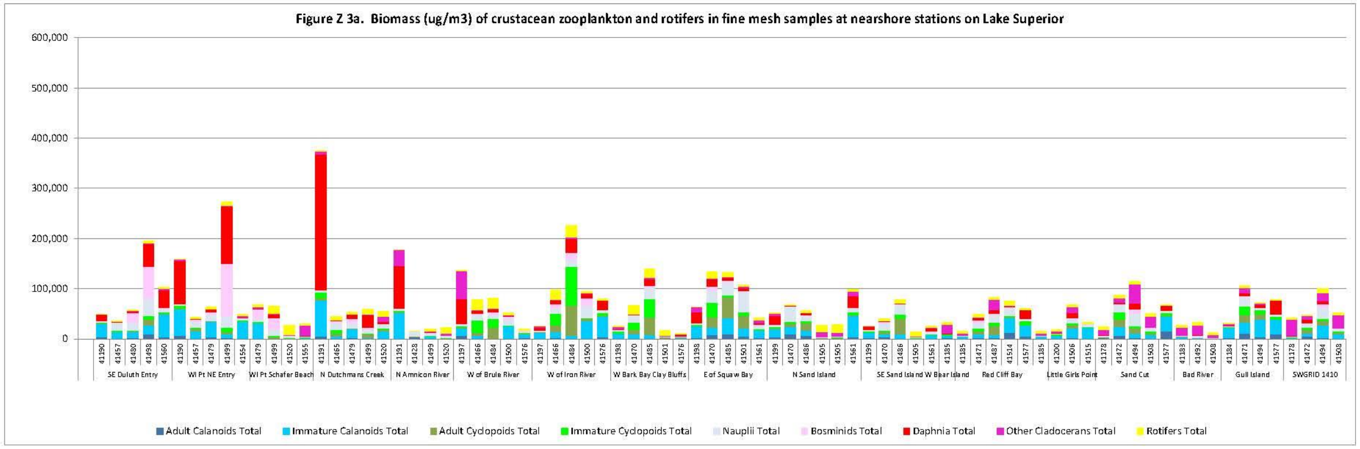


Figure Z 3a. Biomass (ug/m3) of crustacean zooplankton and rotifers in fine mesh samples at nearshore stations on Lake Superior



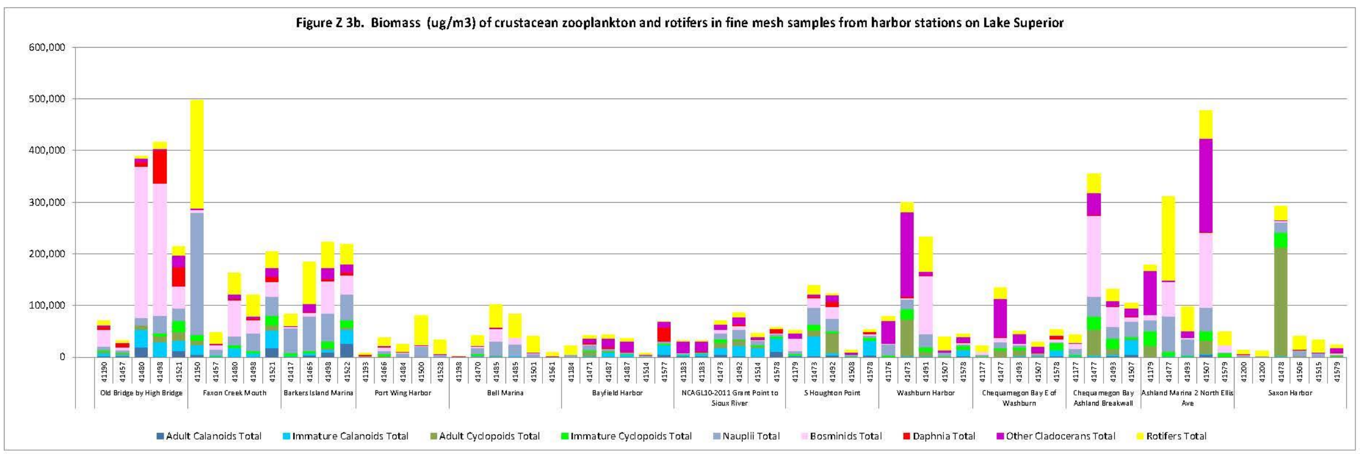
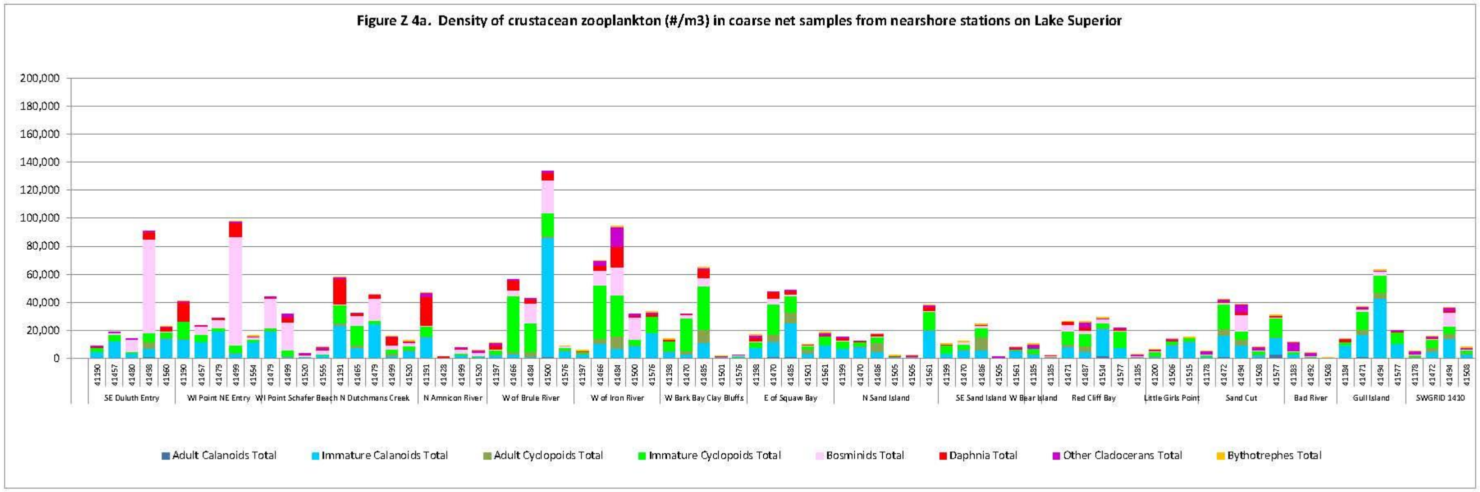


Figure Z 3b. Biomass (ug/m3) of crustacean zooplankton and rotifers in fine mesh samples from harbor stations on Lake Superior

Figure Z 4a. Density of crustacean zooplankton (#/m3) in coarse net samples from nearshore stations on Lake Superior



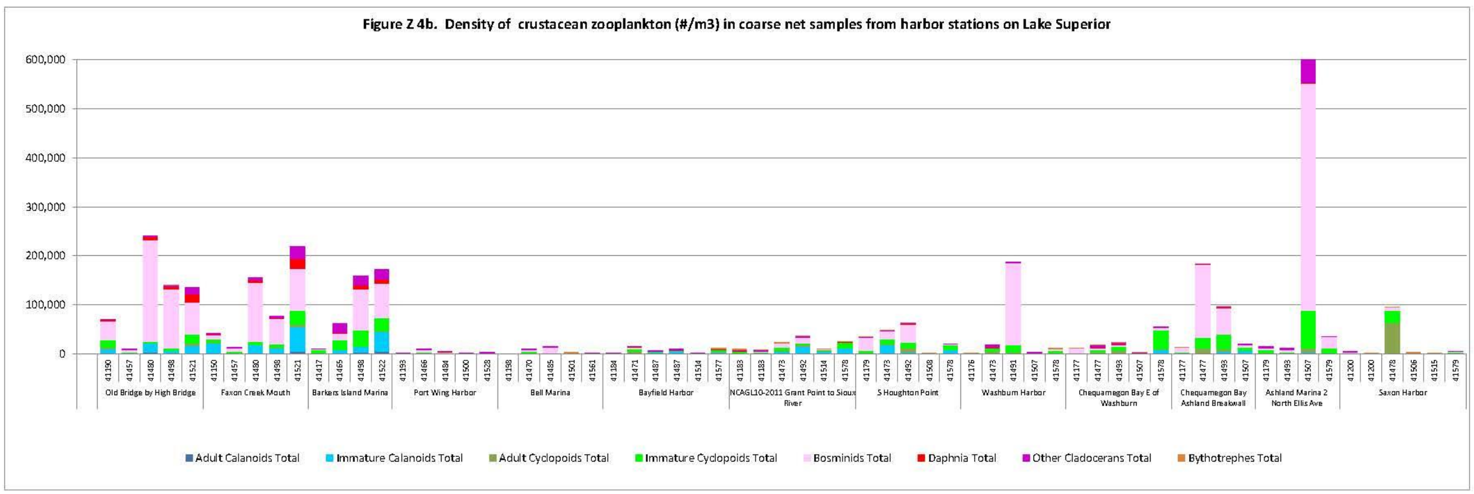


Figure Z 4b. Density of crustacean zooplankton (#/m3) in coarse net samples from harbor stations on Lake Superior

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Figure Z 5a thru 5d. Most Common Taxa in coarse mesh and Taxa with highest biomass in coarse mesh for nearshore and harbors sites

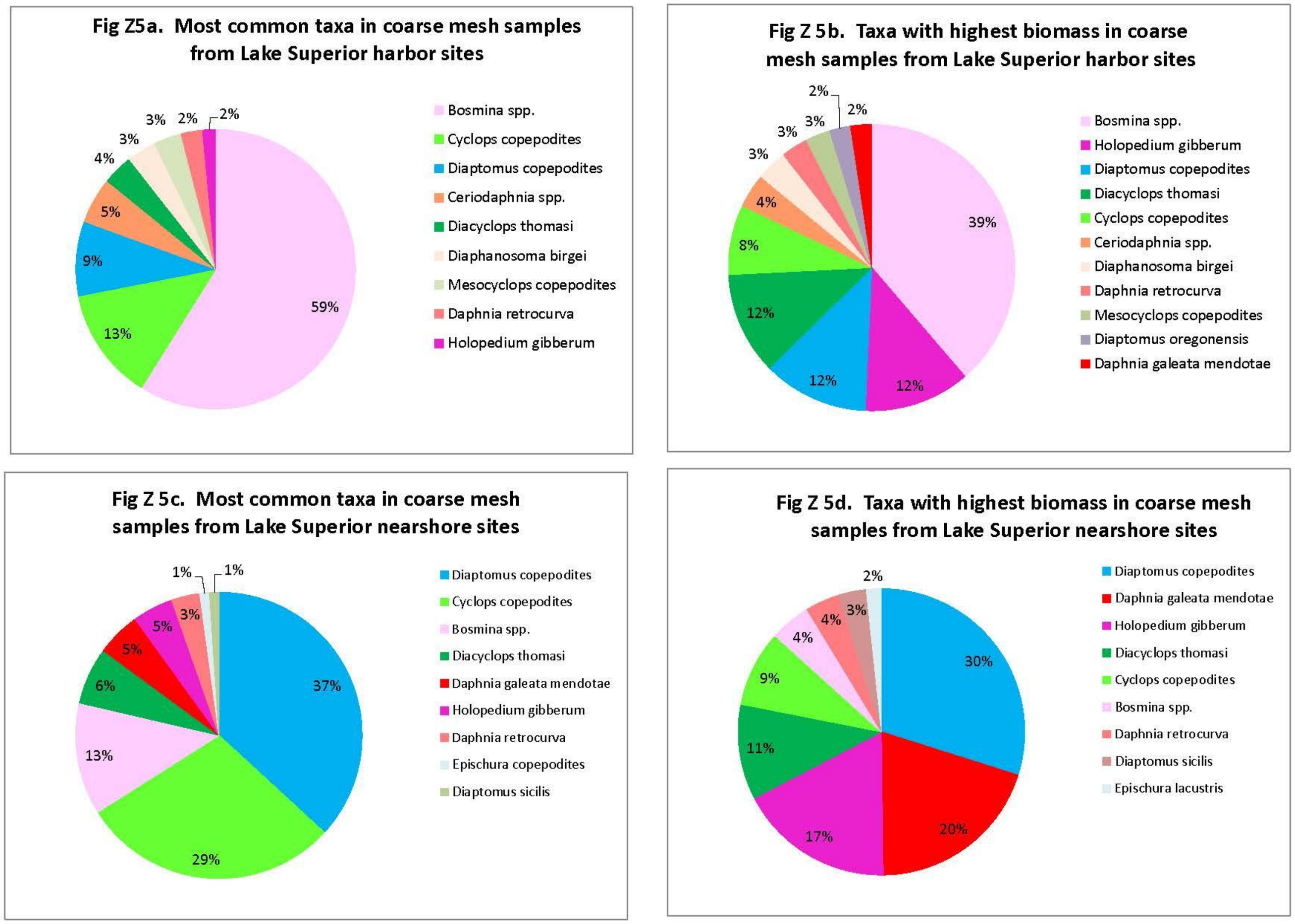
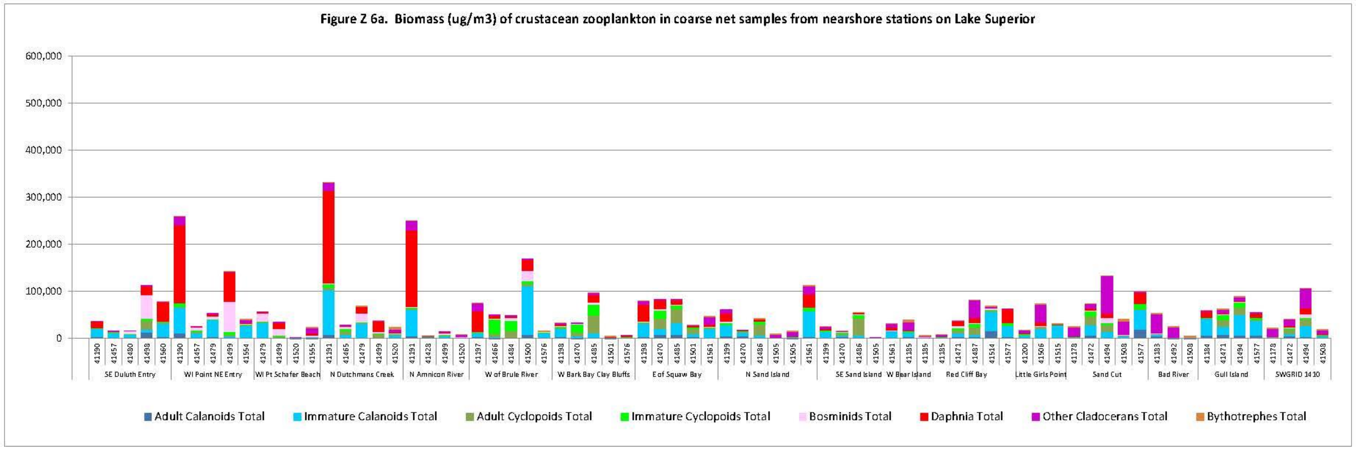


Figure Z 6a. Biomass (ug/m3) of crustacean zooplankton in coarse net samples from nearshore stations on Lake



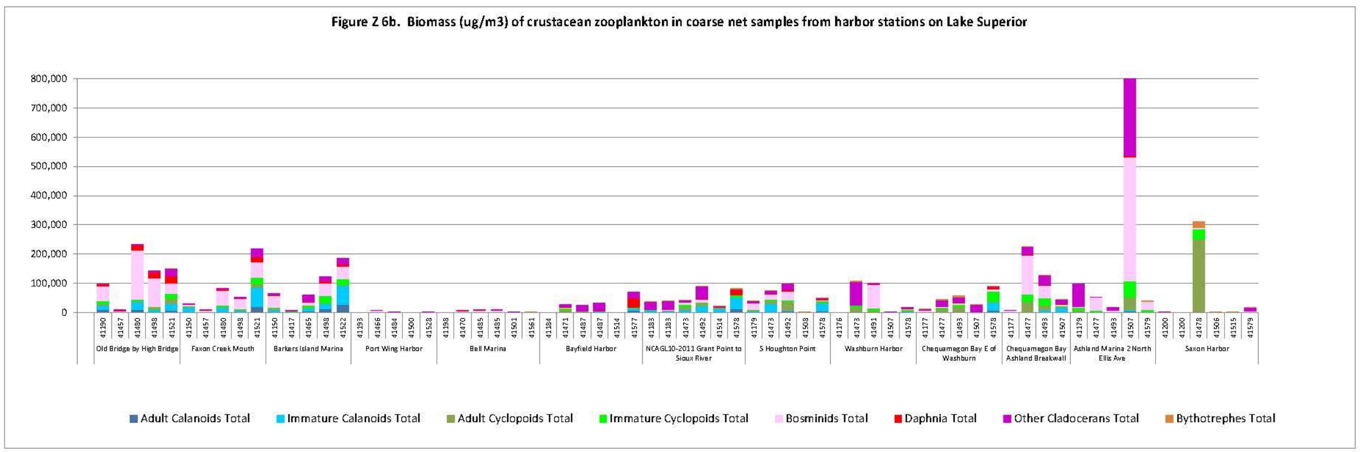


Figure Z 6b. Biomass (ug/m3) of crustacean zooplankton in coarse net samples from harbor stations on Lake Superior

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

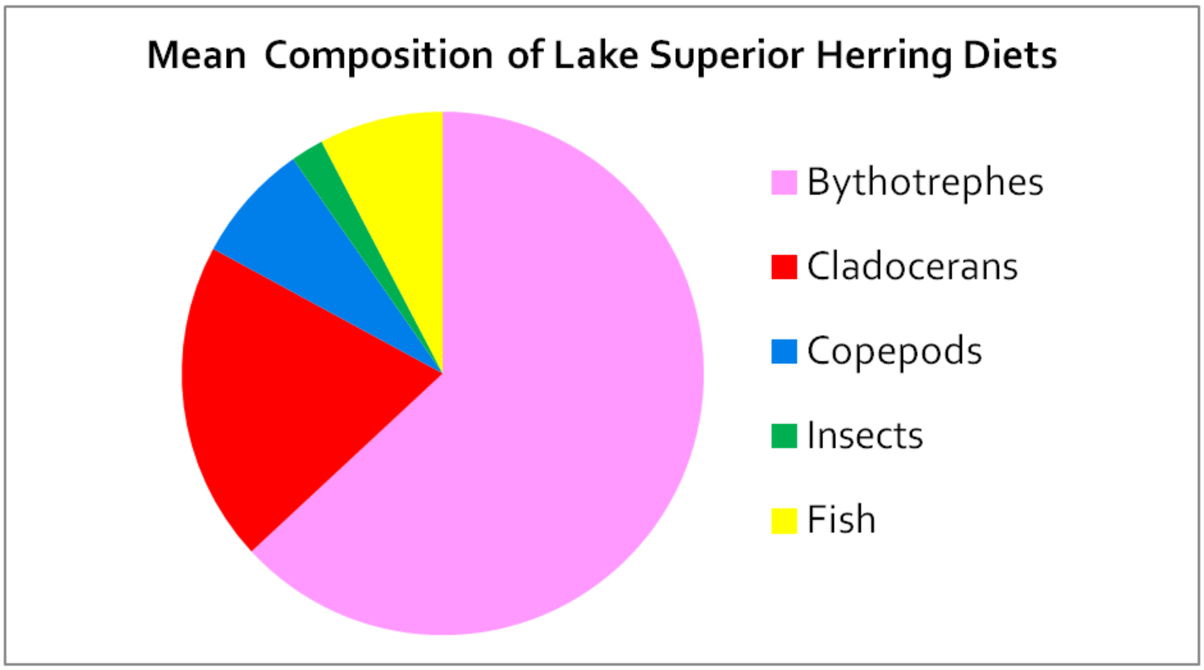


Table Z 1. Summary of diet composition of Lake herring

Summary of diet composition of Lake Superior Herring														
				Major stomach contents by percent of total										
Station	Date	Fish ID #	Biovolume of contents (ml)	Daphnia	Eurycercus	Bosmina	Holopedium	Leptodora	Bythotrephes	Chironomid	Insect	Cyclopoid	Calanoid	Fish
222	7/17/2012	912	0.2	90	0	3	0	0	0	0	0	5	2	0
222	7/17/2012	913	0.2	25.9	0.0	0	0.0	17.6	0	0.0	0.0	55.6	0.9	0.0
222	7/17/2012	915	0.2	44.8	0.0	2.6	0	10.3	0.9	0.0	0.0	41.4	0	0.0
222	7/17/2012	916	0.1	4.1	0.0	9.3	10.3	15.5	0	0.0	0.0	60.8	0	0.0
208	7/17/2012	1043	3.765	65.7	0	5.7	1.0	1.9	0	0	0	19.0	6.7	0
273	7/31/2012	2497	0.2	0	0	2.9	0	0	97.1	0	0	0	0	0
273	7/31/2012	2498	2.1	0	0	0	0	0	19.8	0	0	0	0.2	80
273	7/31/2012	2499	0.1	0	1.4	0	0	0	97.2	0.0	0.0	0	1.4	0
273	7/31/2012	2500	0.2	0	0	0	0	0	91.0	6.0	0.0	3.0	0	0
273	7/31/2012	2501	1.8	0	0	0	0	0	100	0	0	0	0	0
273	7/31/2012	2502	1	0	0	0	0	0	99	0	0	1	0	0
273	7/31/2012	2503	0.05	0	0	0	0	0	50	50	0	0	0	0
273	7/31/2012	2504	2.5	0	0	0	0	0	100	0	0	0	0	0
273	7/31/2012	2574	1.1	0	0.5	1	0	0	48	0	0	0	0.5	50
273	7/31/2012	2575	2	0	0	0	0	0	100	0	0	0	0	0
254	7/31/2012	2659	0.1	0	0	5	0	0	95	0	0	0	0	0
254	7/31/2012	2660	0.5	0	2	0	0	0	98	0	0	0	0	0
254	7/31/2012	2661	0.6	65.1	0	0.9	0	0	19.8	0	2.8	8.5	2.8	0
254	7/31/2012	2673	0.4	2.8	0	1.4	0	0	90.1	0	0	4.2	1.4	0
254	7/31/2012	2674	0.6	0	0	0	0	0	0	0	0	0	0	100
254	7/31/2012	2695	3.2	0	0	0	0	0	98	0	0	2	0	0
254	7/31/2012	2696	2.1	0	0	2	0	0	98	0	0	0	0	0
251	8/1/2012	2916	0.4	16.7	0	2.8	0	0	80.6	0	0	0	0	0
251	8/1/2012	2917	0.1	81.3	0	0	0	0	17.8	0.9	0	0	0	0
251	8/1/2012	2918	0.9	9.4	0	3.5	0	0	85.9	1.2	0	0	0	0
271	8/3/2012	3105	0.8	2.9	0	0	0	0	97.1	0	0	0	0	0
271	8/3/2012	3106	0.2	40.2	0	3.4	0	0	54.0	0	0	2.3	0	0
271	8/3/2012	3119	3	0	0	0	0	0	100	0	0	0	0	0
271	8/3/2012	3120	4.2	0	0	0	0	0	100	0	0	0	0	0
271	8/3/2012	3121	3	42	0	0	0	0	55	0	0	0	3	0

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).

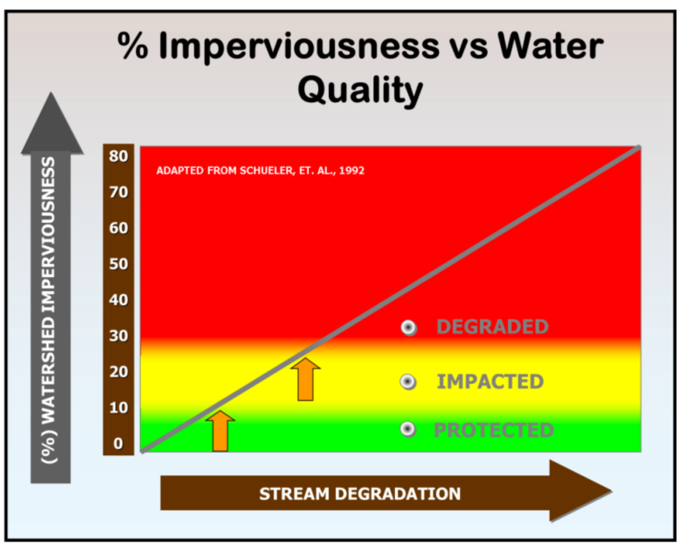


Figure WS 1. % Imperviousness vs Water Quality

Figure WS 2. Total Acres of Project Watersheds

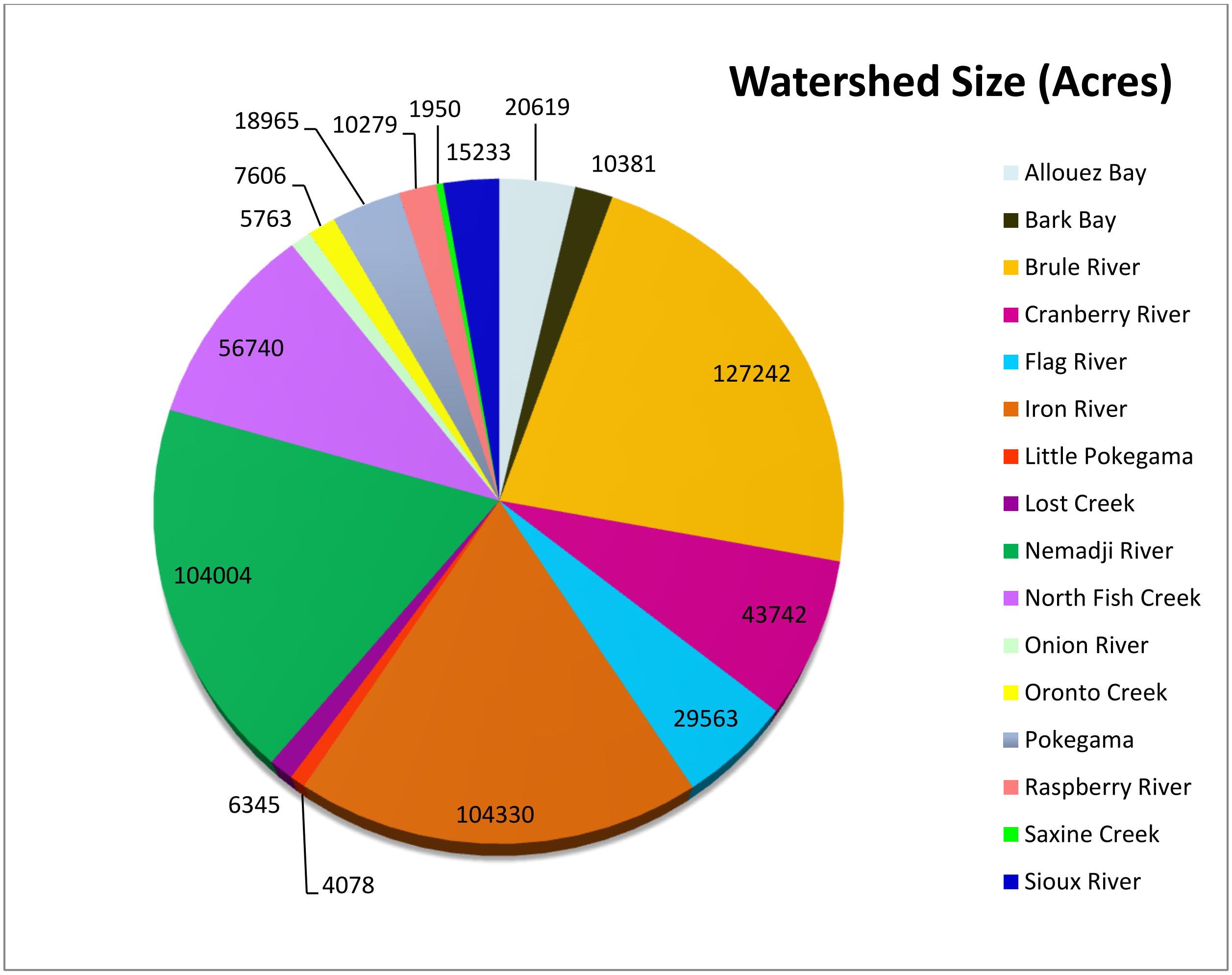


Figure WS 3. % Open Land Cover in Watersheds

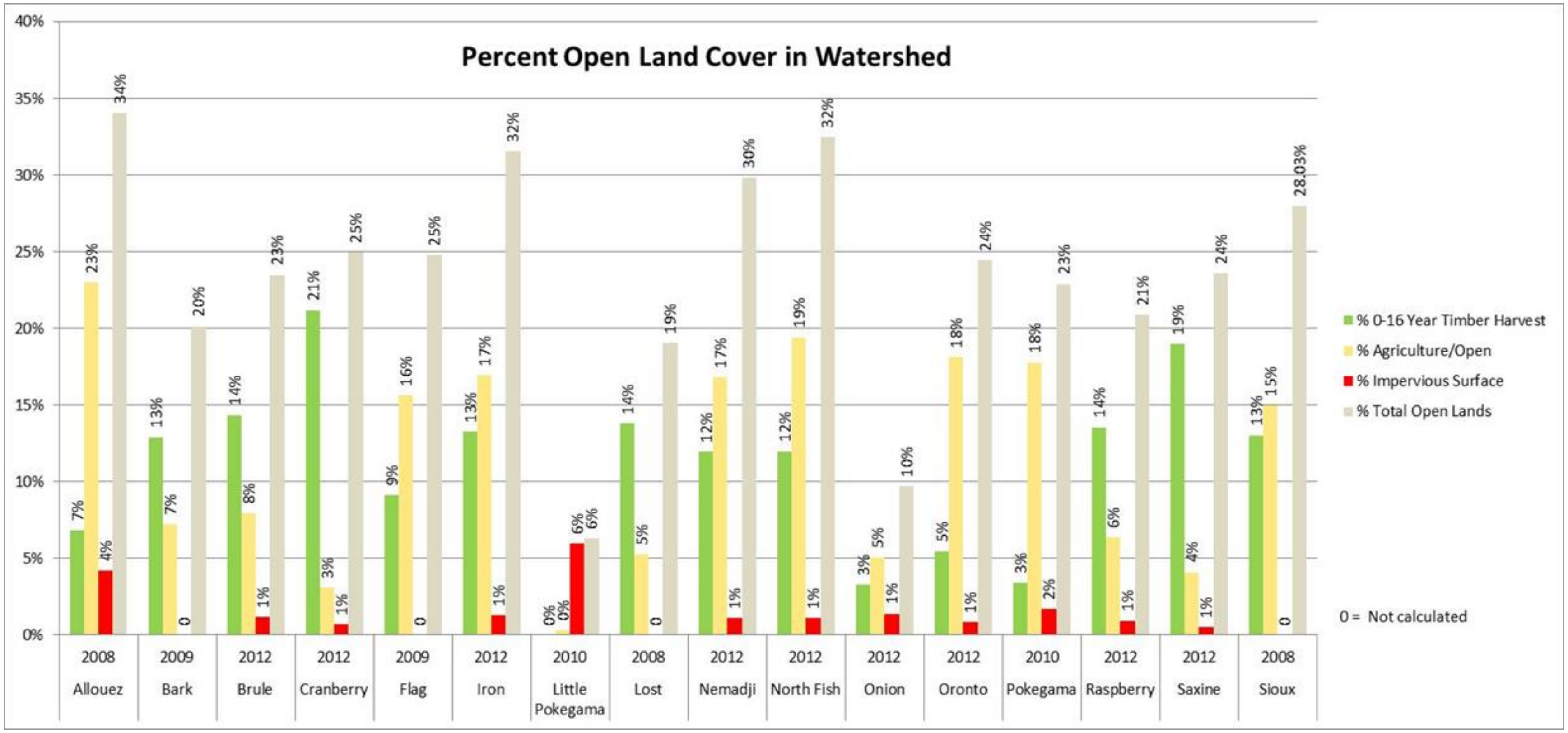


Table WS 4a. Summary of Watershed Size and Land Cover - Analyzed 2012

Watershed	Brule River	Cranberry River	Iron River	Nemadji River	North Fish Creek	Onion River	Oronto Creek	Raspberry River	Saxine Creek
Acres	127242	43742	104330	104004	56740	5763	7606	10279	1950
Public Lands Acres	28375	31958	45196	39634	27142	3087	2254	5814	1353
Percent of Watershed	22.3	73.06	43.32	38.1	47.83	53.56	29.63	56.56	69.38
0-16 Year Harvested Timber Lands Acres	18240.5	9261.5	13828.5	12413.5	6794	188	414.5	1395	370
Percent of Watershed	14.33	21.17	13.25	11.93	11.97	3.26	5.44	13.57	18.97
Agricultural/Urban Acres	10133.5	1350.5	17682	17471	11005.5	291	1378	654	80
Percent of Watershed	7.96	3.08	16.95	16.79	19.39	5.05	18.11	6.36	4.1
Roads, Trails, & Driveways Acres	1382	302.5	1268	1007.5	578	75	60	93.5	9.6
Buildings & Other Impervious Surfaces Acre	140	8.9	121.9	142.5	43	6	5.5	4	0.4
Total Impervious Surface Acres	1522	311.4	1389.9	1150	621	81	65.5	97.5	10
Percent of Watershed	1.19	0.71	1.33	1.1	1.09	1.4	0.086	0.95	0.51
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

Watershed	Allouez Bay	Bark Bay	Lost Creek	Sioux River	Flag River	Little Pokegama	Pokegama
Total Acres	20618.79	10381.08	6345.00	15233.13	29563.45	4077.76	18964.96
Year Analyzed	2008	2009	2008	2008	2009	2010	2010
Public Lands Acres	not calculated	not calculated	not calculated	not calculated	not calculated	not calculated	not calculated
Percent of Watershed	not calculated	not calculated	not calculated	not calculated	not calculated	not calculated	not calculated
0-16 Year Harvested Timber Lands Acre	1409.77	1338.31	875.65	1986.98	2704.37	0.00	645.67
Percent of Watershed	6.84%	12.89%	13.80%	13.04%	9.15%	0.00%	3.40%
Agricultural/Urban Acres	4739.75	751.26	332.20	2283.56	4620.44	12.93	3367.22
Percent of Watershed	22.99%	7.24%	5.24%	14.99%	15.63%	0.32%	17.75%
Roads, Trails, & Driveways Acres	not calculated	not calculated	not calculated	not calculated	not calculated	41.40	292.18
Buildings & Other Impervious Surfaces	not calculated	not calculated	not calculated	not calculated	not calculated	202.17	34.92
Total Impervious Surface Acres	868.83	not calculated	not calculated	not calculated	not calculated	243.57	327.11
Percent of Watershed	4.21%	not calculated	not calculated	not calculated	not calculated	5.97%	1.72%
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).

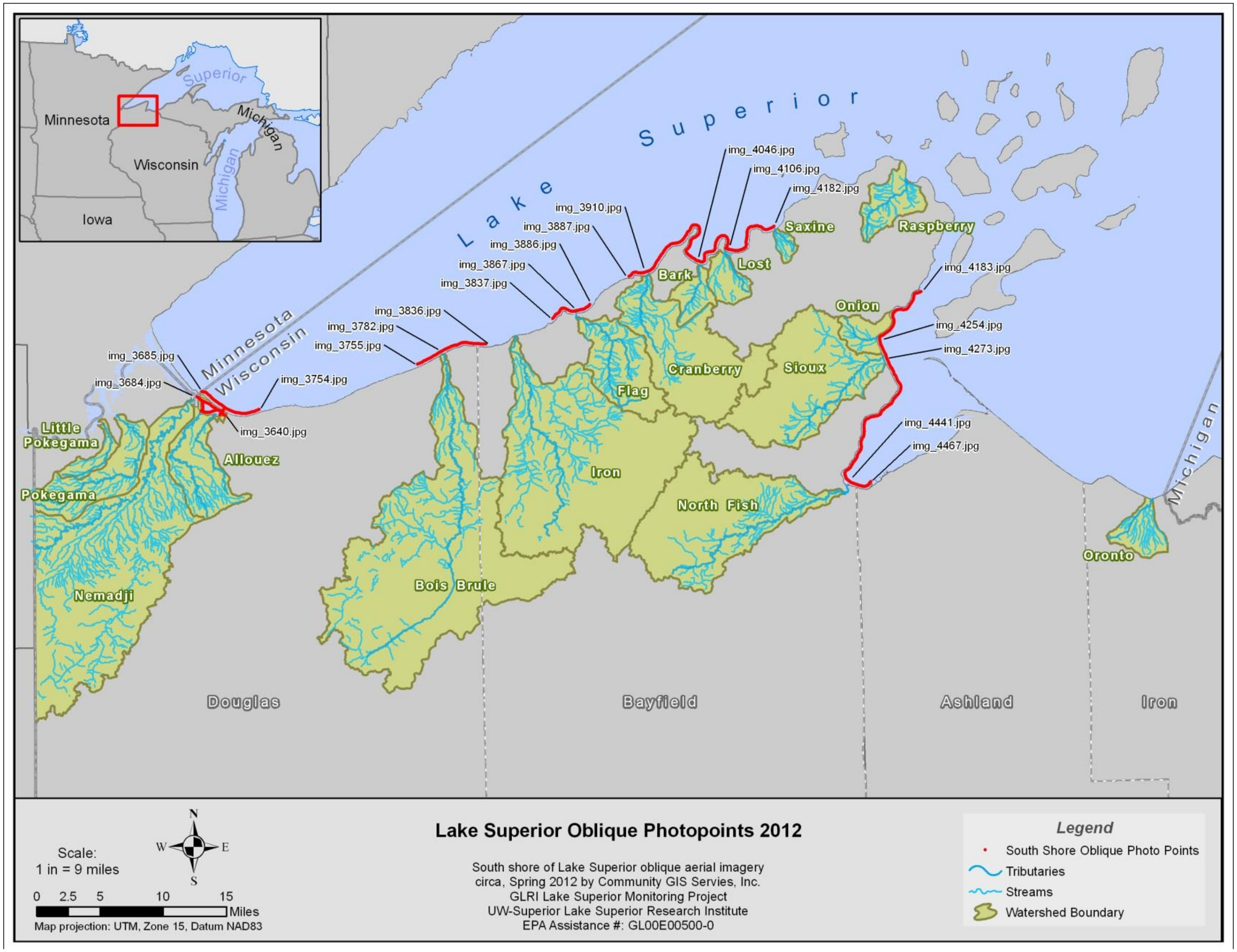
Figure M 1. Aerial Photograph Near Superior, Wisconsin

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.

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