LAKE SUPERIOR CANADIAN NEARSHORE
Assessment

2020 RESULTS REPORT

Canada

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This document supports Canadian commitments in the Lakewide Management Annex of the Great Lakes Water Quality Agreement of 2012 to provide an overall assessment of nearshore waters.

For information on Great Lakes Areas of Concern or the State of the Great Lakes, refer to https://www.canada.ca/en/environment-climate-change/services/great-lakes-protection.html

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Introduction

The Great Lakes, with their 16,000 kilometres of coastline, connecting river systems and watersheds, are the world's largest freshwater ecosystem and socially, economically and environmentally significant to the region, the nation and the planet. While efforts to restore and protect the Great Lakes have been largely successful over the last 50 years, water quality and ecosystem health in many nearshore areas continues to be degraded. At numerous places along the Great Lakes nearshore, conditions are degraded due to a variety of human-induced, climate-induced and invasive species-induced stressors. Human activities in the landscape have a more direct influence on nearshore water quality than on offshore water quality[1]. Nearshore water quality may serve as a sentinel for the longer-term trajectory of offshore water quality and lake-wide condition[2]. Management of the nearshore is challenging because it is a complex, highly variable environment in which tributary inflows and open water processes vary spatially and across daily, seasonal and annual temporal scales. In addition, Great Lakes nearshore areas are especially vulnerable to the effects of climate change and impacts can result in loss of biodiversity of aquatic species and fundamental changes to ecosystem character, distribution, structure and function. Human-induced stressors on ecosystems further limit their ability to adapt and recover.

Although significant investment has been made in localized monitoring, assessment and restoration, the lack of a comprehensive assessment of the overall state of nearshore waters has meant that there was not a robust mechanism for identifying cumulative stress on nearshore ecosystems nor a way to identify and prioritize areas in need of remediation or protection. Action is needed to address stresses and threats in nearshore areas, as they are the critical ecological link between watersheds and the open waters of the Great Lakes.

Nearshore Framework

As envisioned by the updated Great Lakes Water Quality Agreement (GLWQA) of 2012, Canada is implementing a "Nearshore Framework" that provides an overall assessment of the state of the nearshore waters of the Great Lakes. The Nearshore Framework is a systematic, integrated and collective approach for assessing nearshore health and identifying and communicating cumulative impacts and stress. It is intended to inform and promote action at all levels in order to restore and protect the ecological health of Great Lakes nearshore areas.

The purpose of the Nearshore Framework is to address ongoing and emerging challenges to the nearshore waters of the Great Lakes, where restoration, protection and prevention activities are critical to improving and sustaining the ecological health of Great Lakes coastal areas and supporting attendant social, cultural, recreational and economic benefits. Nearshore assessments and communication of results provide the basis for determining factors and

[1] Yurista, P.M., Kelly, J.R., Cotter, A.M., Miller, S.E., and Van Alstine, J.D. 2015. Lake Michigan: Nearshore variability and a nearshore-offshore distinction in water quality. Journal of Great Lakes Research. 41:111-122.

[2] Yurista, P.M., Kelly, J.R. and Scharold, J.V. 2016 Great Lakes nearshore-offshore: distinct water quality regions. Journal of Great Lakes Research. 42: 375-385.

cumulative effects that are causing stress or threatening areas of high ecological value. Continued and strengthened coordination and collaboration are needed to manage and protect our nearshore waters and to prevent and minimize water quality and ecosystem impacts which may result from chemical, physical, or biological stresses within the Great Lakes Basin. The Nearshore Framework will support action for nearshore areas under stress and protection for nearshore areas of high ecological value by communicating results, establishing priorities and engaging organizations and entities that are developing and implementing prevention, restoration and protection strategies.

The scope of the Nearshore Framework includes the nearshore waters and embayments along the coast of the Canadian Great Lakes, the lakes' connecting river systems and the St. Lawrence River. The GLWQA recognizes the interconnectedness of the Great Lakes basin watersheds where material and water flow from problem areas into the lakes and connecting channels. The Nearshore Framework aims to consider this relationship between the zone of influence and zone of impact and the nearshore is generally defined as the area of the Great Lakes and connecting rivers near the coast where waters are subject to direct influences from watersheds, while recognizing that there are also offshore influences.

This report provides a synthesis of the results for the 2020 Lake Superior Nearshore Assessment; for a detailed methodology of the Overall Assessment of Nearshore Waters, including descriptions of assessment categories and measures and data sources refer to the *Canadian Great Lakes Nearshore Assessment Detailed Methodology*.

Regional Unit Delineation

The first step in the Nearshore Assessment is the classification of the nearshore into Regional Units based on ecosystem type. Slow changing variables such as depth, substrate, river mouth boundaries, wave energy density and high water conditions were used for delineating the offshore, onshore and lateral boundaries of ecologically relevant units.

Offshore boundary

A review of relevant literature and methods for nearshore monitoring concluded that a maximum depth of up to 30 m is considered "nearshore". With an average depth of approximately 149 m, Lake Superior is the deepest Great Lake and features a very steep nearshore slope (Figure 1). When an offshore boundary of the Regional Units was mapped using a 30 m depth (which was used in Lake Ontario and Huron), the nearshore was too narrow in many locations to characterize. Based on this profile, a depth of 100 m was selected as the offshore boundary. The Great Lakes Aquatic Habitat Framework (GLAHF) lakewide bathymetry raster dataset[3] was converted into 5 m contour lines, and the 100 m line was used to create a seamless offshore boundary.

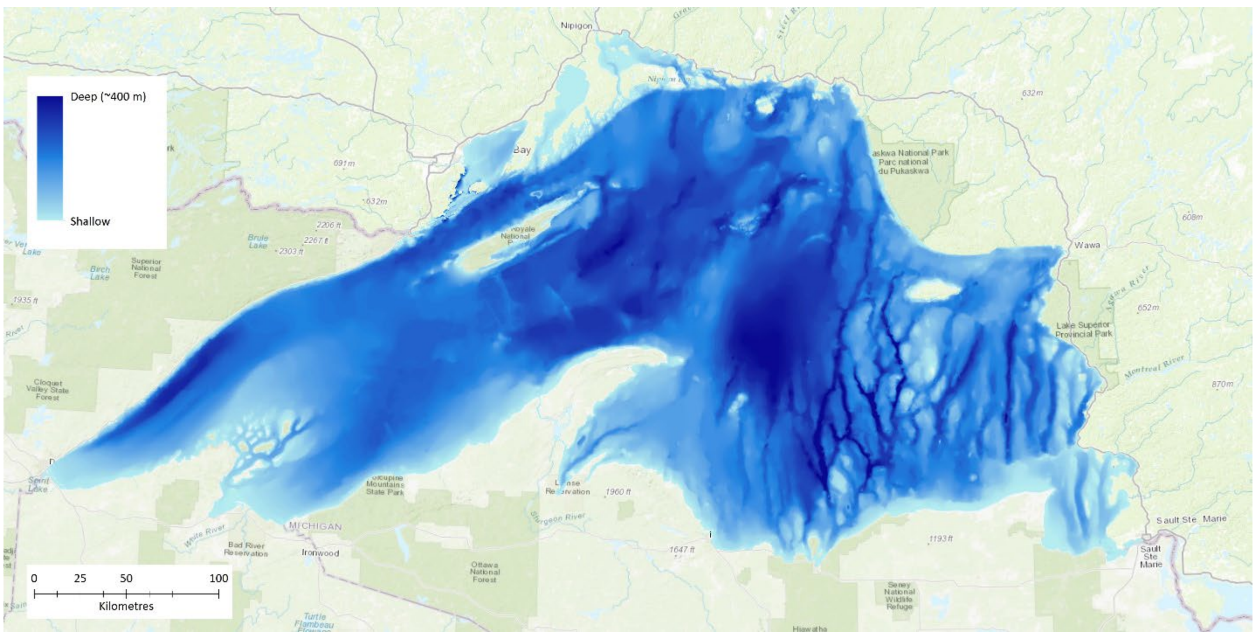
[3] Great Lakes Aquatic Habitat Framework (GLAHF) – Geomorphology – Lake Bottom: https://www.glahf.org/data/

Onshore boundary

Since the assessment is focused on the nearshore of Lake Superior, the onshore boundary was defined by a high water mark. Historical monthly mean lake levels from Fisheries and Oceans Canada's coordinated network of gauges for Lake Superior[4] were reviewed and the maximum monthly mean was found to be 0.7 m above Chart Datum.

On Lake Superior, Chart Datum is 183.2 m, making the maximum monthly mean 183.9 m (183.2 [Chart Datum] + 0.7 [Maximum Monthly Mean]). Although the lake surface can exceed this elevation due to wave effects and storm surge, the focus here is the static 'non-storm' lake surface. To extract the 183.9 m contour, Digital Elevation Models (DEM) were obtained from the Ontario Ministry of Natural Resources and Forestry (OMNRF) [5] and used to extract the contour to establish the onshore limit of the Regional Units.

Figure 1. Lake Superior Bathymetry (from the Great Lakes Aquatic Habitat Framework); 100 m depth was used to delineate the offshore boundary for Regional Units



Lateral boundary

The lateral boundaries were generated by assessing substrate data, shoreline morphology and wave energy. The nearshore areas of Lake Superior are not homogeneous; variations in substrate (Figure 2) and wave energy (Figure 3) result in spatially explicit characteristics that were used to delineate Regional Units.

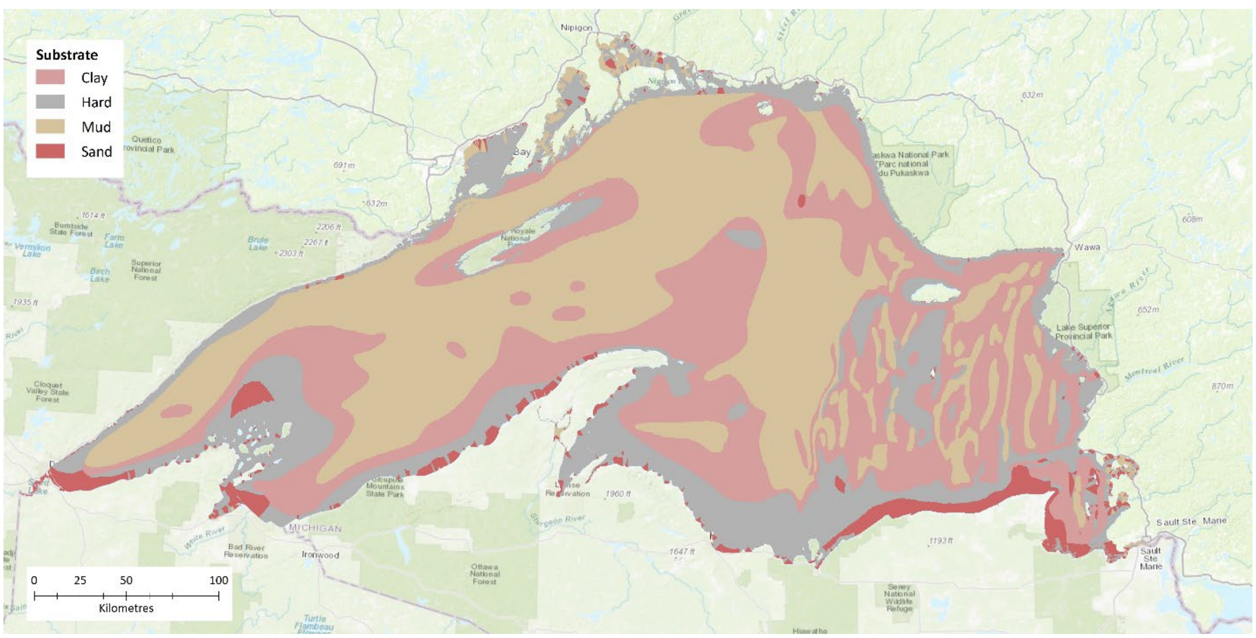
[4] Fisheries and Oceans Canada. *Historical Monthly Mean Water Levels from the Coordinated network for Lake Superior* Historical Monthly Mean Water Levels from the Coordinated network for Lake Superior (tides.gc.ca)

[5] Ontario Ministry of Natural Resources and Forestry. *Ontario Digital Elevation Model (Imagery-Derived).* https://geohub.lio.gov.on.ca/datasets/mnrf::ontario-digital-elevation-model-imagery-derived

Wave energy can have a significant influence on the coastline; on a lakewide scale, gradients in wave energy can influence erosion and deposition patterns that shape the nearshore. In addition, exposure to wave energy is a major factor in the presence or absence of submerged/emerged aquatic vegetation. High wave exposure may result in an absence of aquatic vegetation. Wave energy also influences sediment characteristics along the coast, with sheltered environments featuring fine-grained sediment and open coast areas featuring sand sized substrate and/or coarser materials.

Due to its influence on nearshore processes, wave energy was included as a physical variable in the alongshore boundary delineation. Average annual wave energy density was calculated at the 5 m depth contour around Lake Superior, at 2 km increments (Figure 3). The input wave conditions were generated by a historical wind-wave hind cast on Lake Superior, and then transformed to the 5 m depth accounting for lake bottom contours and linear wave theory. The results of the wave energy reveal additional patterns with other physical variables. Much of the Lake Superior coastline is exposed, and in these areas – such as along Pukaskwa National Park and Lake Superior Provincial Park – wave energy is very high. The nature of this high energy, open and exposed coast that are characterized by harder substrate types means that few coastal wetlands exist in the nearshore. Although there are coastal wetlands, they are largely in the more sheltered areas.

Figure 2. Substrate types in Lake Superior (from the Great Lakes Aquatic Habitat Framework[6])



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[6] Great Lakes Aquatic Habitat Framework (GLAHF) – Geomorphology – Substrate: https://www.glahf.org/data/

Figure 3. Results of the wave energy density analysis on Lake Superior. Wave energy density was not modelled in bays or connecting channels

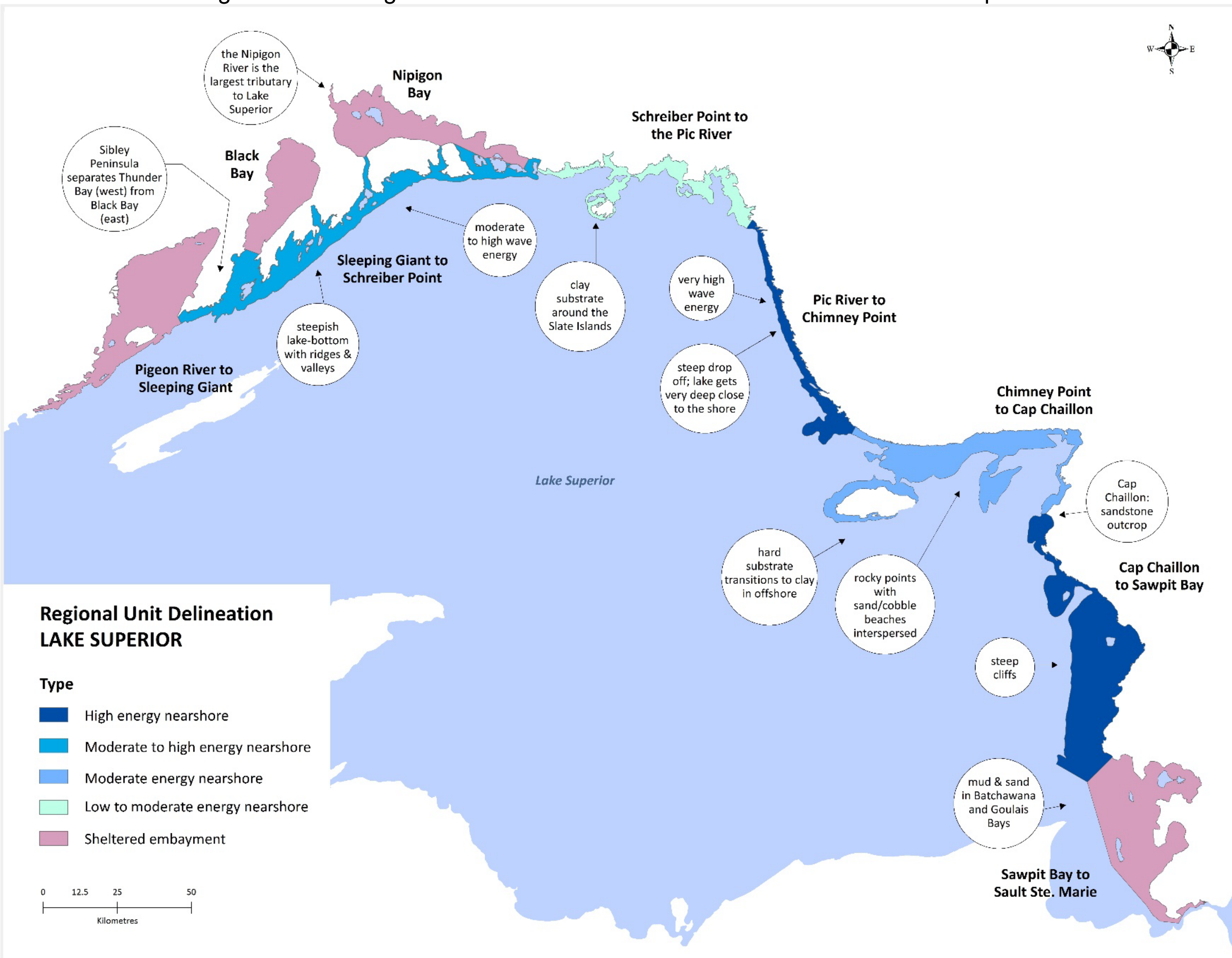
Overlaying these slow-changing variables revealed several unique patterns from which nine Regional Units with five ecosystem classifications were identified (Table 1 and Figure 4).

Table 1. Nine ecologically relevant Regional Units were delineated using slow changing variables

Regional Unit Name and Ecosystem Type	Size	Substrate (GLAHF)	Wave Energy (Zuzek Inc.)	Description
SHELTERED EMBAYMENT				
PIGEON RIVER TO SLEEPING GIANT (LS01)	95,055 ha	Hard with mud/sand	Low energy	Characterized by hard substrate with mud/silts and sand off the city of Thunder Bay north of McKellar Island. Steeper slopes in the west from the Pigeon River to Whiskeyjack Creek. Till/bedrock around Pie Island, where the lake bottom slope is also steep. Thunder Bay is partly sheltered by Sibley Peninsula from wind and wave energy.
BLACK BAY (LS02)	47,025 ha	Hard, mud/silt	n/a	Sheltered from Lake Superior wind and wave action; fairly shallow, with a few coastal wetlands. Hard substrate with mud/silt closer to shore. Separated from Thunder Bay by the Sibley Peninsula.

NIPIGON BAY (LS03)	61,524 ha	Hard, mud	n/a	Northernmost point of Lake Superior; shallow, sheltered from the lakes wind and wave action; hard substrate with mud on the west side of Vert Island and steep ridges and valleys in the east. The Nipigon River is the largest tributary to Lake Superior.
SAWPIT BAY TO SAULT STE. MARIE (LS09)	103,802 ha	Hard/clay, sand	Low energy	Batchawana Bay and Goulais Bay characterized by mud and sand bottom; outside of the bays, mix of hard and clay substrate transitions to sand towards Sault Ste. Marie.
HIGH ENERGY NEARSHORE				
PIC RIVER TO CHIMNEY POINT (LS06)	30,021 ha	Hard	High energy	Very high energy coast, with a steep lake-bottom slope resulting in a narrow Regional Unit. Shoreline characterized hard, pink-and-slate granite interspersed with small sandy beaches.
CAP CHAILLON TO SAWPIT BAY (LS08)	122,432 ha	Hard, clay	High energy	Wave energy higher in south extent of Regional Unit. Characterized by hard bottom that transitions to clay in deeper areas; steep cliffs and rocky outcrops interspersed with sand beaches along the shore. Cap Chaillon is an outcrop of sandstone.
MODERATE TO HIGH ENERGY NEARSHORE				
SLEEPING GIANT TO SCHREIBER POINT (LS04)	85,276 ha	Hard	Moderate to high energy	Characterized by hard substrate that transitions to clay and mud at the offshore boundary; moderate energy south of Black Bay Peninsula transitioning to high energy east of St. Ignace Island. On the Sibley Peninsula, the Sleeping Giant is a significant geomorphological rock formation.
MODERATE ENERGY NEARSHORE				
CHIMNEY POINT TO CAP CHAILLON (LS07)	89,801 ha	Hard, clay	Moderate energy	Hard substrate that transitions to clay in the offshore. Steep slopes with ridges and valleys characterize the bottom close to shore and around Michipicoten Island; rocky points with sand/cobble beaches interspersed. Wave energy increases at Michipicoten Bay south to Cap Chaillon.
LOW TO MODERATE ENERGY NEARSHORE				
SCHREIBER POINT TO THE PIC RIVER (LS05)	38,210 ha	Hard	Low to moderate energy	Coast is characterized by steep slopes, resulting in a very narrow Regional Unit as the water becomes very deep close to shore. Hard bottom with glaciolacustrine clay around the Slate Islands.

Figure 4. Nine Regional Units were delineated in the nearshore of Lake Superior



2020 Lake Superior Canadian Nearshore Assessment

In 2020, Environment and Climate Change Canada (ECCC) undertook the Overall Assessment of the State of Nearshore Waters in Lake Superior. This report summarizes the findings of cumulative stress across nine Regional Units.

The assessment considered eleven measures (see text box), however one was not applicable (Littoral Barriers) and one could not be assessed due to lack of data (*Cladophora*). The remaining nine measures grouped into four evidence categories that were developed with consideration of the GLWQA General Objectives and specific requirements of the Nearshore Framework. Each of the measures in a category is assigned as "low," "moderate" or "high" stress on the nearshore of each Regional Unit, and then rolled up into an overall level of stress for each category using a Weight of Evidence approach. The four category scores are subsequently combined into an overall cumulative stress for each Regional Unit.

A **Weight of Evidence** approach was used to develop a structured decision making process for the overall assessment. Weight of Evidence is a process for systematic and transparent integration of multiple datasets where "weight" (+ or ++) is assigned to each assessment measure based on a categorical rating of three factors: relevance, strength and reliability. Categories and measures include:

- Coastal Processes: Shoreline Hardening (+), Littoral Barriers (not applicable), Tributary Connectivity (+)
- Contaminants in Water & Sediment: Water Quality (+), Sediment Quality (++), Benthic Community (++)
- Nuisance & Harmful Algae: *Cladophora* (data gap), Cyanobacteria (++)
- Human Use: Beach Postings (+), Fish Consumption (+), Treated Drinking Water (+)

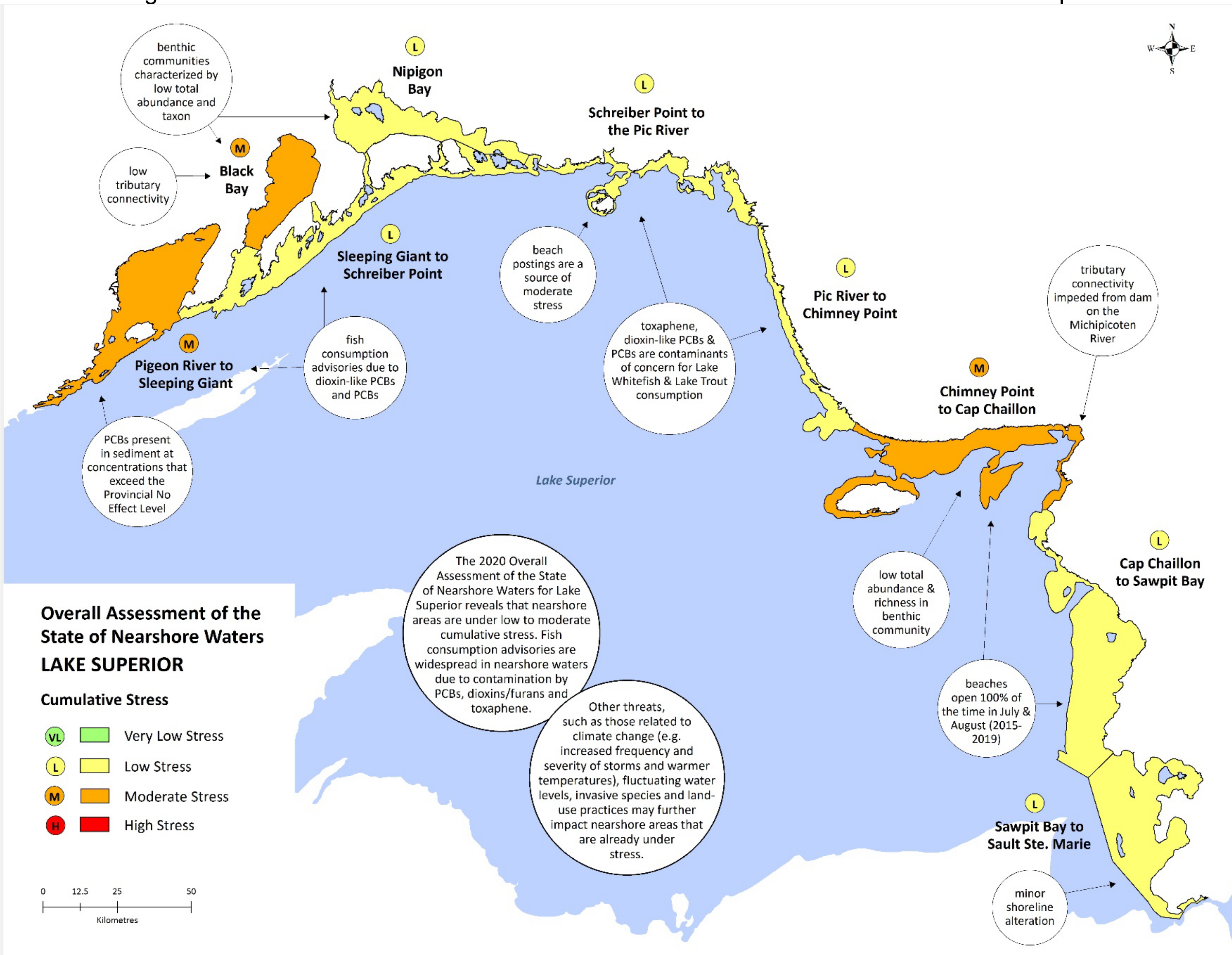
For details on the assessment methodology, see the *Canadian Great Lakes Nearshore Assessment Detailed Methodology*.

Key findings from the assessment are summarized below and in Figure 5.

Overall, Lake Superior's nearshore areas are under low or moderate stress; there are no areas assessed as high stress, although there are still some localized Areas of Concern within several regional units. As illustrated in Figure 5 the Regional Units assessed as moderate stress include Pigeon River to Sleeping Giant (including the Thunder Bay Area of Concern), Black Bay and Chimney Point to Cap Chaillon. Issues in these areas include advisories against consumption of some fish species, PCBs in sediment, gradients at the low end of benthic invertebrate community health for Lake Superior, presence of dams, which impede tributary connectivity and beach postings based on exceedances of *E.coli* concentrations. The fish consumption measure indicates moderate stress for the whole lake with average consumption advisories ranging from two to seven meals per month. No harmful algae blooms were detected in Canadian nearshore waters in 2019. Measures of shoreline hardening and treated drinking water are all within thresholds for low stress. At the time of the assessment, there was no available data on *Cladophora* in Lake Superior. There was a significant lack of spatial and temporal data in Lake Superior's nearshore particularly for water quality, sediment and benthos. The Ministry of the Environment Conservation and Parks monitoring surveys were last undertaken in 2019, however only data from 2011 was available at the time of this assessment. Many Canadian federal monitoring programs are designed to either measure open lake conditions as reported in State of the Great Lakes reports or focus on specific Areas of Concern.

Three Regional Units have a Great Lakes Areas of Concern (AOC) within their boundary. Areas of Concern are locations within the Great Lakes identified as having experienced high levels of environmental harm. Under the 1987 Great Lakes Water Quality Agreement between Canada and the United States, 43 such areas were identified, 12 of which were Canadian and 5 of which were shared binationally. Since 1987, the Governments of Canada and Ontario have supported local action to clean up Areas of Concern. On Lake Superior, all clean-up actions in Jackfish Bay have been completed, allowing this site to be designated as an Area of Concern in Recovery. This means that all actions are complete and the area now needs more time for the environment to recover naturally.

Figure 5. Results of the Overall Assessment of the State of Nearshore Waters in Lake Superior



Coastal Processes

Map of category results in Figure 6, individual measure descriptions below.

Shoreline Hardening

Low Stress	<25% of the total length of shoreline in a Regional Unit is hardened
Moderate Stress	25-50% of the total length of shoreline in a Regional Unit is hardened
High Stress	>50% of the total length of shoreline in a Regional Unit is hardened

Thresholds based on best professional judgement.

The nearshore provides a unique set of conditions and processes that together meet the life-stage requirements of aquatic species and biological communities. These coastal processes also play a significant role in determining the distribution and health of fish populations through impacts to their habitat including migration corridors, spawning grounds, nursery and feeding areas. Hardening of the shoreline can reduce coastal resilience; in the absence of natural vegetation or features like coastal wetlands, the shoreline may no longer adapt to rising and falling water levels, leading to the physical reduction of available aquatic habitat.

Shoreline hardening is a low source of stress in Lake Superior. In all, less than 5% of the total length of shoreline has been hardened, and in six Regional Units, almost the entire shoreline remains natural. Alteration to the shore is primarily associated with urban and marine transportation settings, such as in the Pigeon River to Sleeping Giant and Sawpit Bay to Sault Ste. Marie Regional Units. At 10% shoreline hardening, the Pigeon River to Sleeping Giant Regional Unit has the highest percent of hardened shoreline but alteration is largely restricted to the mouth of the Kaministiquia River (Mission and MacIntyre Rivers) and along the Thunder Bay waterfront. Similarly, the altered shoreline in the Sawpit Bay to Sault Ste. Marie Regional Unit is largely around the urban area of Sault Ste. Marie.

Small recreational and seasonal development as well as small marina infrastructure dot the shoreline in other Regional Units, but cumulatively is not likely creating stress on the nearshore.

Littoral Barriers – Measure does not apply

Low Stress	0 littoral barriers
Moderate Stress	1 littoral barrier

High Stress	>1 littoral barriers

Thresholds based on best professional judgement.

Littoral barriers are defined in the Overall Assessment of the State of Nearshore Waters as shore perpendicular features that are greater than 100 m in length and that disrupt the natural movement of sediment (littoral drift). Littoral drift is the natural movement of sand and gravel in the nearshore and in areas where this is an important physical process, the presence of littoral barriers can impede natural coastal processes related to sediment dynamics.

In Lake Superior, the nearshore is characterized by bedrock substrate and littoral drift is not a significant process. This measure does not apply.

Tributary Connectivity

Low Stress	>75% of the total length of tributaries (excluding upstream of a waterfall) are connected to the Regional Unit
Moderate Stress	25-75% of the total length of tributaries (excluding upstream of a waterfall) are connected to the Regional Unit
High Stress	<25% of the total length of tributaries (excluding upstream of a waterfall) are connected to the Regional Unit

Thresholds based on the State of the Great Lakes Sub-indicator report for Aquatic Habitat Connectivity using Ontario Ministry of Northern Development, Mines, Natural Resources and Forestry data.

Across Lake Superior, tributary connectivity is complex. There are numerous waterfalls that act as natural barriers and large rivers have been developed for hydroelectric power. Black Bay is the only Regional Unit where tributary connectivity is a source of high stress. The Pic River to Chimney Point and Chimney Point to Cap Chaillon Regional Units have between 25 and 75% of tributaries connected to the nearshore due to the presence of barriers (i.e. dams). All other Regional Units retain high tributary connectivity and in two Regional Units, 100% of tributaries downstream of a waterfall remain connected to the nearshore.

Many Regional Units have waterfalls that naturally disconnect a large proportion of the total length of tributaries from the nearshore (Table 2). Tributaries upstream of a waterfall are considered to be naturally disconnected and not included in the overall tributary connectivity measure, as it is unlikely that the barrier (i.e. waterfall) would ever be removed.

Table 2. Summary of tributary connectivity within each Regional Unit; tributaries that are upstream of a waterfalls (i.e. naturally disconnected) are not included when calculating overall tributary connectivity

Regional Unit	Total Length of Tributaries	Length of Tributaries Upstream of a Waterfall (naturally disconnected)	Length of Tributaries Upstream of a Dam (disconnected)	Length of Tributaries Downstream of a Waterfall or Dam (connected)
Pigeon River to Sleeping Giant	13,849 km	11,313 km	208 km	2,328 km
Black Bay	3,919 km	473 km	2,805 km	641 km
Nipigon Bay	25,042 km	22,198 km	337 km	2,507 km
Sleeping Giant to Schreiber Point	1,001 km	No waterfalls	44 km	957 km
Schreiber Point to the Pic River	5,353 km	2,658 km	0 km	2,695 km
Pic River to Chimney Point	16,478 km	8,836 km	2,415 km	5,227 km
Chimney Point to Cap Chaillon	13,379 km	4,312 km	6,651 km	2,416 km
Cap Chaillon to Sawpit Bay	7,072 km	6,382 km	0 km	690 km
Sawpit Bay to Sault Ste. Marie	6,809 km	4,774 km	389 km	1,646 km

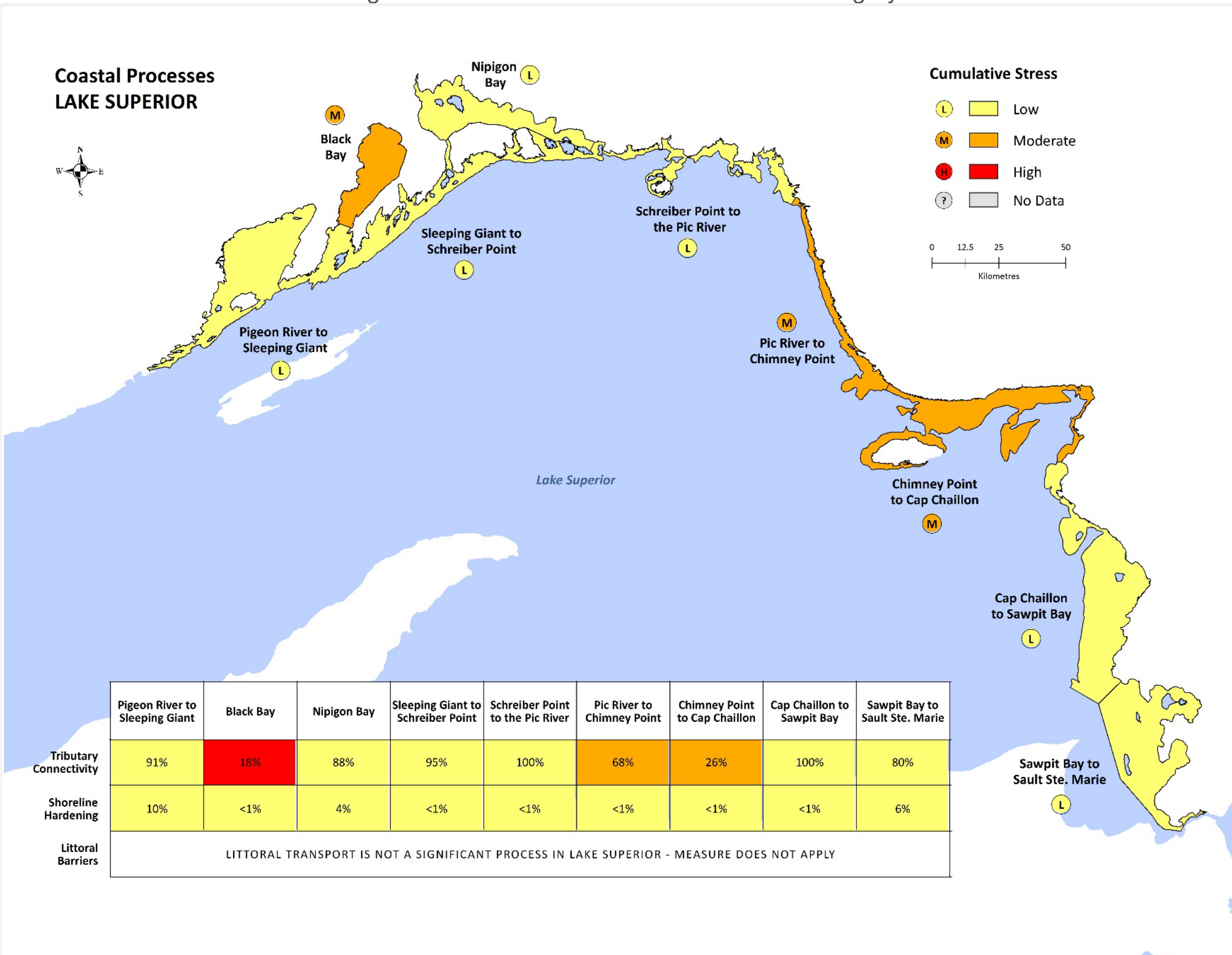
The Nipigon River is the largest tributary to Lake Superior (Nipigon Bay Regional Unit) however much of its length as well as thousands of kilometres of its tributaries are upstream of a waterfall and naturally disconnected from the nearshore. There are three hydroelectric dams on the Nipigon River however; the tributary connectivity measure considers the first barrier to be the impediment to connectivity and on the Nipigon River, this is a waterfall.

The Michipicoten River has been developed for hydroelectric power, with numerous dams along its length. The Scott Falls generating station is the most downstream of these barriers, and impedes connectivity for over 6,000 km of tributaries (approximately 76%).

Barriers that limit tributary connectivity can have adverse impacts on the health of aquatic ecosystems by limiting access of fishes to spawning and nursery habitats, affecting nutrient flows and riparian and coastal processes. The degree of impact of a dam varies, for example in areas where a water management plan is in place, optimal flows and water levels may be implemented to support spawning, nursery and rearing habitats for fishes. This assessment does not account for the severity of impact.

Although road crossings have not been included in this assessment, there have been several regional initiatives to identify and mitigate culverts that act as barriers and in future assessments they could be considered. In addition, some barriers help to control sea lamprey by blocking access to spawning areas and their removal may have greater detrimental impact on the ecosystem, this consideration has not been incorporated in the measure.

Figure 6. Results of the Coastal Processes category



	Pigeon River to Sleeping Giant	Black Bay	Nipigon Bay	Sleeping Giant to Schreiber Point	Schreiber Point to the Pic River	Pic River to Chimney Point	Chimney Point to Cap Chaillon	Cap Chaillon to Sawpit Bay	Sawpit Bay to Sault Ste. Marie
Tributary Connectivity	91%	18%	88%	95%	100%	68%	26%	100%	80%
Shoreline Hardening	10%	<1%	4%	<1%	<1%	<1%	<1%	<1%	6%
Littoral Barriers	LITTORAL TRANSPORT IS NOT A SIGNIFICANT PROCESS IN LAKE SUPERIOR - MEASURE DOES NOT APPLY								

Contaminants in Water & Sediment

Map of category results in Figure 7, individual measure descriptions below.

Water Quality

Low Stress	0 exceedances
Moderate Stress	1 or 2 exceedances
High Stress	>2 exceedances

Thresholds based on Provincial and Federal Guidelines and best professional judgement using data from Environment and Climate Change Canada (ECCC) and the Ontario Ministry of the Environment, Conservation and Parks (MECP).

Across Lake Superior, water quality is a source of low stress. The 2016 and 2019 ECCC monitoring data was assessed for any exceedances in published Federal or Provincial water quality guidelines and no contaminants were found to be in excess of those guidelines. In the Black Bay and Nipigon Bay Regional Units, there are no ECCC sites and in the Chimney Point to Cap Chaillon Regional Unit there are ECCC sites; however there was no data for the water quality parameters of relevance to this assessment. In these three Regional Units, water quality data from MECP (2011) was used instead and no contaminants exceeded the guidelines in any of the three Regional Units.

Sediment Quality

Low Stress	• PCBs < No Effect Level • Organochlorine pesticides & PAHs < Lowest Effect Levels • Metals < Probable or Severe Effect Levels
Moderate Stress	• PCBs > No Effect Level OR, • Organochlorine pesticides & PAHs > Lowest Effect Levels but < Severe Effect Levels OR, • Metals > Probable Effect Levels but < Severe Effect Levels
High Stress	• Any contaminant > Severe Effect Levels

Thresholds based on Provincial and Federal Guidelines and best professional judgement using data from the Ontario Ministry of the Environment, Conservation and Parks Great Lakes Nearshore Sediment Chemistry.

Across Lake Superior, contaminants in sediment are a source of low stress (Table 2), with the exception of the Pigeon River to Sleeping Giant Regional Unit where Polychlorinated Biphenyls (PCBs) were recorded above the Provincial No Effect Level (NEL). The most recent sampling data available for Lake Superior is from 2011, and although there are index stations in all of the Regional Units, only four Regional Units have data on chemicals of interest, which include metals, PCBs, organochlorine pesticides and Polycyclic Aromatic Hydrocarbons (PAHs). In each of these Regional Units, metals were detected above Provincial Lowest Effect Levels (LELs), but this generally reflects background conditions and are not at levels of concern.

Table 3. Number of contaminants that exceeded Federal or Provincial guidelines within each Regional Unit for each category of contaminant. As a rule, LEL<PEL<SEL, so if the contaminant exceeds the PEL it also exceeds the LEL, and if it exceeds the SEL it exceeds the LEL and PEL. NELs are used only for PCBs.

Regional Unit	**Metals**			**PCBs**	**Organochlorine Pesticides**			**PAHs**		
	LEL	PEL	SEL	NEL	LEL	PEL	SEL	LEL	PEL	SEL
Pigeon River to Sleeping Giant	8			1						
Black Bay	4									
Nipigon Bay	6									
Sleeping Giant to Schreiber Point	No recent data									
Schreiber Point to the Pic River	3									
Pic River to Chimney Point	No recent data									
Chimney Point to Cap Chaillon	No recent data									
Cap Chaillon to Sawpit Bay	No recent data									
Sawpit Bay to Sault Ste. Marie	No recent data									

Benthic Community

Low Stress	Benthic community condition is functional and of high diversity (top 67th percentile of scores)
Moderate Stress	Benthic community condition is degraded but functional (33rd to 67th percentile of scores)
High Stress	Benthic community condition is severely degraded and not functional (bottom 33rd percentile of scores)

Thresholds based on statistical analysis using data from Ontario Ministry of the Environment, Conservation and Parks (2011).

Benthic invertebrate community composition can vary substantially due to natural habitat conditions and human stressors, but the general health of an ecosystem may be reflected in the benthic community and is used as a measure of contaminant exposure (from sediment and water) in this assessment. Across Lake Superior, benthic community quality varies (Table 3).

In the Black Bay, Nipigon Bay and Chimney Point to Cap Chaillon Regional Units, the benthic community score indicates high stress as the relative condition of benthic invertebrate communities was low. In the Chimney Point to Cap Chaillon Regional Unit the low total richness and abundance departs from the west to east gradient in overall community quality. The MECP station is in deep water (in the 65-80 m range), which may affect the benthic community through natural impoverishment.

The Pigeon River to Sleeping Giant, Sleeping Giant to Schreiber Point and Schreiber Point to the Pic River Regional Units were assessed as having relatively moderate benthic community quality. Generally, this means that the benthic invertebrate communities at these sites had lower total benthos, lower taxon richness and lower evenness.

Sites in the Pic River to Chimney Point, Cap Chaillon to Sawpit Bay and, Sawpit Bay to Sault Ste. Marie Regional Units were assessed as being in the top percentile of the range of quality across all sites. In these Regional Units, the benthic community is of high quality and represents a score of low stress.

See Appendix A for details on the statistical analysis used to assess Benthic Community.

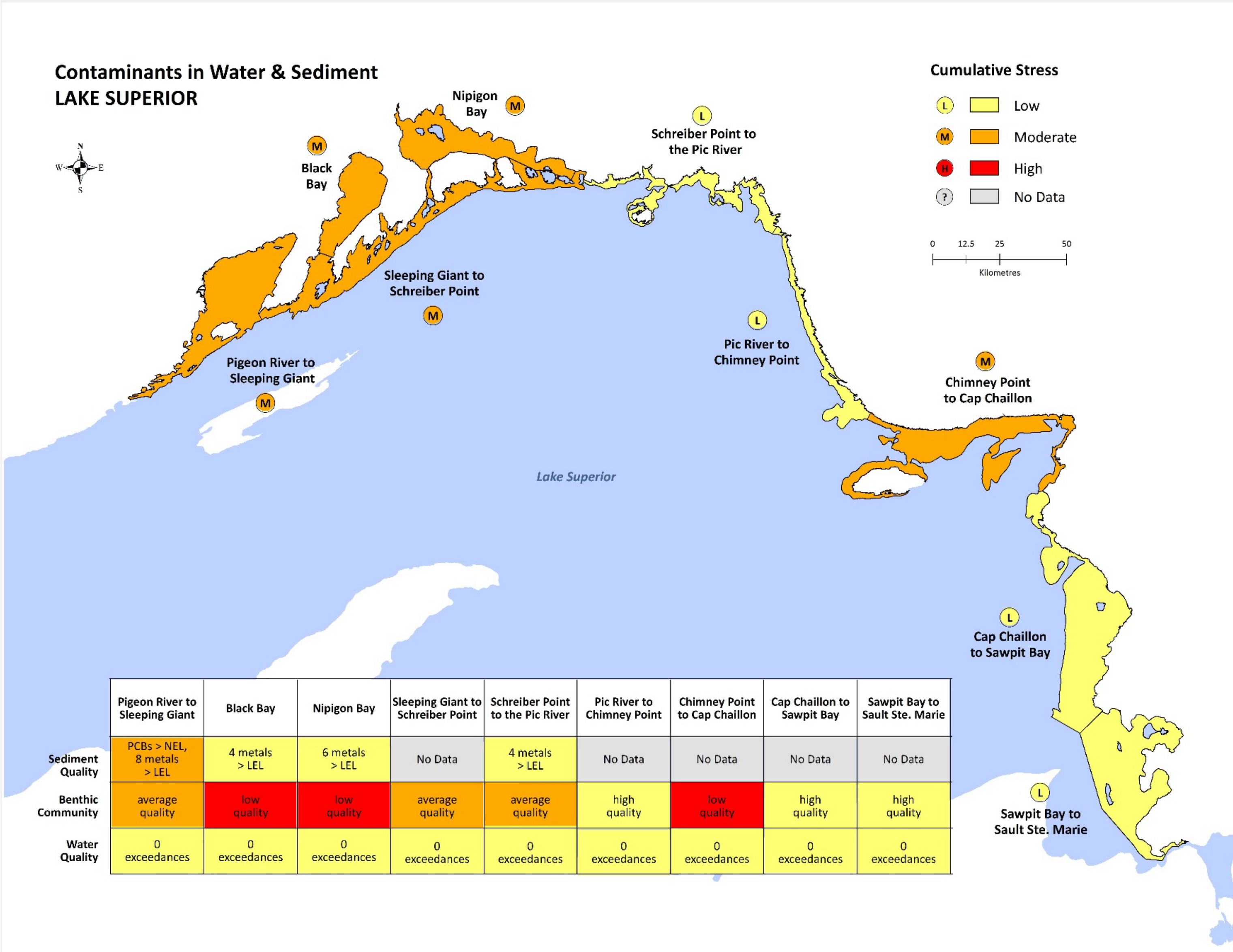
Benthos data limitations: MECP particle size data, GIS habitat (Wang et al. 2015) and stressor data (Allan et al. 2013) are available for Lake Superior. Including these data in the analyses was beyond the scope of the 2020 assessment, however incorporating habitat and stressor data for stations in the future would allow for a more comprehensive assessment. Analyses of ECCC habitat and benthos data have shown relationships between benthic community descriptors and habitat attributes such as depth, sediment particle size and sediment nutrient concentrations.

The most recent ECCC benthos data (2011 and 2013) were not considered suitable due to gaps in coverage and lack of reference sites.

Table 4. Benthic community quality for Regional Units for MECP stations, using 2011 data. Generally, low stress corresponds to higher total benthos, higher taxon and higher evenness.

Regional Unit	Benthic Community Quality		
	No. of Sites	Stress Score	Comments
Pigeon River to Sleeping Giant	4	Moderate Stress	On average, low total abundance, richness and evenness; AOC present
Black Bay	1	High Stress	Low total abundance, richness and evenness; moderately high in *Diporeia* and low in other taxa
Nipigon Bay	2	High Stress	Low total abundance and richness; moderate evenness; AOC present
Sleeping Giant to Schreiber Point	1	Moderate Stress	High total abundance and richness; high in *Diporeia* and *Pisidium*
Schreiber Point to the Pic River	3	Moderate Stress	On average, moderate in total abundance, richness and evenness; 2 AOCs present
Pic River to Chimney Point	1	Low Stress	High total abundance and richness
Chimney Point to Cap Chaillon	1	High Stress	Low total abundance and richness; deep water station; possibly naturally impoverished
Cap Chaillon to Sawpit Bay	1	Low Stress	High total abundance, richness and evenness
Sawpit Bay to Sault Ste. Marie	2	Low Stress	Low total abundance; high richness and evenness

Figure 7. Results of the Contaminants in Water & Sediment category



	Pigeon River to Sleeping Giant	Black Bay	Nipigon Bay	Sleeping Giant to Schreiber Point	Schreiber Point to the Pic River	Pic River to Chimney Point	Chimney Point to Cap Chaillon	Cap Chaillon to Sawpit Bay	Sawpit Bay to Sault Ste. Marie
Sediment Quality	PCBs > NEL, 8 metals > LEL	4 metals > LEL	6 metals > LEL	No Data	4 metals > LEL	No Data	No Data	No Data	No Data
Benthic Community	average quality	low quality	low quality	average quality	average quality	high quality	low quality	high quality	high quality
Water Quality	0 exceedances	0 exceedances	0 exceedances	0 exceedances	0 exceedances	0 exceedances	0 exceedances	0 exceedances	0 exceedances

Nuisance & Harmful Algae

Map of category results in Figure 8, individual measure descriptions below.

Cyanobacteria

Low Stress	No cyanobacteria bloom that exceeds 2% of the Regional Unit detected in any 7-day composite
Moderate Stress	Not applicable
High Stress	Cyanobacteria bloom exceeds 2% of the Regional Unit in any 7-day composite

Thresholds based on the World Health Organization cyanobacteria guidelines using satellite composites from NOAA's Harmful Algal Bloom Forecasting Branch (2019).

Satellite imagery showing the extent of cyanobacteria blooms in Lake Superior was available in 7-day composites for June to October 2019. As no blooms were detected in any of the composites, cyanobacteria is a low source of stress and not a concern to human and ecosystem health in the Lake Superior Regional Units.

While no cyanobacteria blooms were detected on the north shore (Canadian side), blooms have been detected in some of the embayments on the southern side of Lake Superior near Duluth. These blooms have been associated with extreme rainfall events and occurred during peak summer temperatures. Blue-green algae, or cyanobacteria, usually doesn't bloom in the cold nutrient-poor waters of Lake Superior. Optimal water temperatures required for algae blooms are in the range of 25°C (77°F) and Lake Superior's average surface water temperature is usually closer to 15°C (59°F). The type of cyanobacteria in Lake Superior is primarily pico-cyanobacteria and although unsightly, these blooms rarely contain harmful levels of toxins, however Lake Superior is one of the fastest warmings lakes in the world and algal blooms could become more common in the future. Investigations into the toxicity of these blooms are ongoing.

Cladophora

Low Stress	<20% coverage
Moderate Stress	20-35% coverage
High Stress	>35% coverage

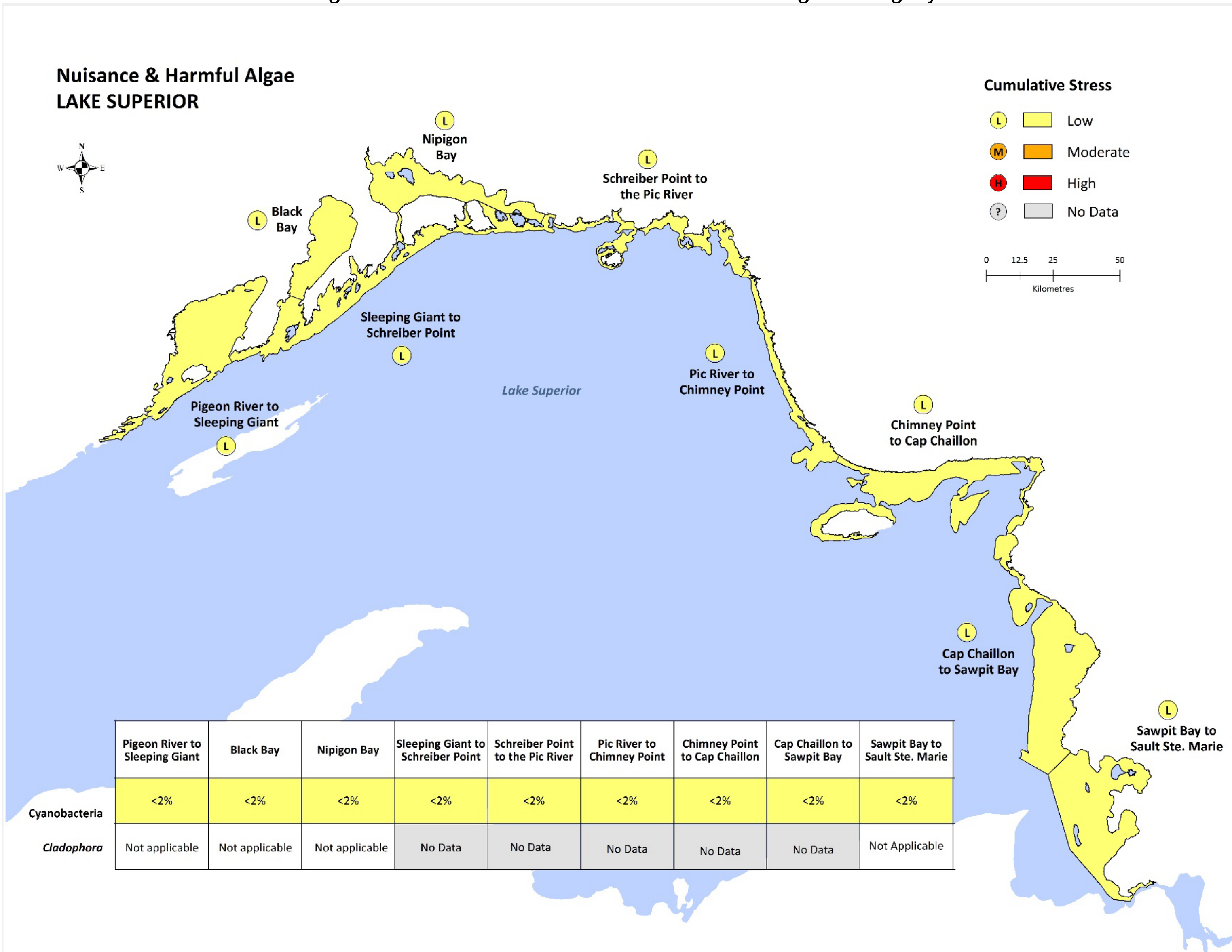
Thresholds developed using best professional judgement using 2016-2018 satellite-derived Submerged Aquatic Vegetation (SAV) Mapping from Michigan Tech Research Institute (MTRI).

Cladophora is filamentous green algae that grows on hard substrates in all of the Great Lakes. While not toxic, it is a nuisance and can pose threats to human health. Beyond clogging water intakes and degrading fish habitat, odorous rotting mats of *Cladophora* on beaches encourage the growth of bacteria and are a factor in beach postings.

While much of the nearshore is suitable habitat for *Cladophora* growth (hard substrate within the optically shallow areas), it is not likely to be a source of stress in Lake Superior without a significant source of phosphorus. Currently, there is no significant phosphorus source.

The satellite-derived mapping product from MTRI is currently unable to assign classification across Lake Superior and there are no *Cladophora* monitoring sites in Lake Superior. As a result, this measure cannot be assessed due to a lack of data.

Figure 8. Results of the Nuisance & Harmful Algae category



	Pigeon River to Sleeping Giant	Black Bay	Nipigon Bay	Sleeping Giant to Schreiber Point	Schreiber Point to the Pic River	Pic River to Chimney Point	Chimney Point to Cap Chaillon	Cap Chaillon to Sawpit Bay	Sawpit Bay to Sault Ste. Marie
Cyanobacteria	<2%	<2%	<2%	<2%	<2%	<2%	<2%	<2%	<2%
Cladophora	Not applicable	Not applicable	Not applicable	No Data	No Data	No Data	No Data	No Data	Not Applicable

Human Use

Map of category results in Figure 10, individual measure descriptions below.

Fish Consumption

Low Stress	Average ≥8 meals per month
Moderate Stress	Average 1-7 meals per month
High Stress	Average <1 meal per month

Thresholds developed in consultation with the Ontario Ministry of the Environment, Conservation and Parks using consumption advisories from the Guide to Eating Ontario Fish; average meals per month based on consumption advisories for Lake Trout, Lake Whitefish and Yellow Perch.

Fish from the Great Lakes provide a diverse and accessible source of food. They can however, be a source of contaminants and a risk to human health if consumption advisories are not considered. The province of Ontario provides consumption guidance based on a combination of fish size, species, location and contaminant (e.g. Mercury and PCBs). Many fish species are monitored for different contaminants throughout the Lake Superior basin. In the nearshore waters of Lake Superior, fish species most targeted by commercial and recreational fishing include Lake Trout, Yellow Perch and Lake Whitefish. The Guide to Eating Ontario Fish[7] provides consumption advisories for specific class sizes. The size classes most representative of fish caught and kept for consumption have been used to assess the Fish Consumption measure: size classes 40-70 cm for Lake Trout, 20-30 cm for Yellow Perch and 40-60 cm for Lake Whitefish. For this assessment, the advisories for the sensitive population (children under 15 and women of child-bearing age) were used.

Across Lake Superior, fish consumption advisories represent a source of moderate stress. The Black Bay and Schreiber Point to the Pic River Regional Units had the highest average number of meals per month (7); however, this is still within the moderate stress range.

The consumption advisories vary between species as do the contaminants of concern (see Table 5). Fish consumption advisories are due to concentrations of mercury in Yellow Perch and PCBs, dioxins/furans and toxaphene in Lake Whitefish and Lake Trout.

Dioxin-like PCBs and furans are unintentional by-products of industrial processes with toxic properties[8]. Toxaphene is a pesticide that was heavily used in the 1970's and although it has been banned in Canada and the U.S., it is extremely persistent in the aquatic environment.

[7] Ontario Ministry of the Environment, Conservation and Parks. *Guide to Eating Ontario Fish* https://data.ontario.ca/dataset/guide-to-eating-ontario-fish-advisory-database
[8] Ontario Ministry of the Environment, Conservation and Parks. Eating Ontario Fish (2017-18) *Contaminants in fish* Eating Ontario Fish (2017-18) | Ontario.ca

Levels have decreased however; it remains in Lake Superior, likely due to the ability of Lake Superior's cold water to absorb the pesticide[9].

For specific information on the consumption advisories for the species assessed as part of the Fish Consumption measure, and for other fish species within the Great Lakes, please consult the Guide to Eating Ontario Fish (https://data.ontario.ca/dataset/guide-to-eating-ontario-fish-advisory-database).

Table 5. Average fish consumption advisories (in meals per month, sensitive population) for species within each Regional Unit and the associated contaminant of concern.

	Lake Whitefish		**Yellow Perch**		**Lake Trout**		**Average # of meals/month**
Regional Unit	40-60 cm	Contaminant of Concern	20-30 cm	Contaminant of Concern	40-70 cm	Contaminant of Concern	
Pigeon River to Sleeping Giant	3	Dioxin-like PCBs, PCBs	0	Mercury	2	Toxaphene, PCBs, Dioxin-like PCBs	1
Black Bay*	5	Dioxin-like PCBs, Dioxins/Furans	6	Mercury	9	Mercury (40-45 cm), Dioxin-like PCBs (>50 cm)*	7
Nipigon Bay	3	PCBs, Dioxins/Furans	8	Mercury	4	PCBs, Dioxin-like PCBs	5
Sleeping Giant to Schreiber Point	2	Dioxin-like PCBs	-	N/A	0	PCBs, Dioxin-like PCBs	1
Schreiber Point to the Pic River	9	Toxaphene, PCBs, Dioxin-like PCBs	-	N/A	4	PCBs, Dioxin-like PCBs	7
Pic River to Chimney Point	9	Toxaphene, PCBs, Dioxin-like PCBs	-	N/A	1	Toxaphene, PCBs, Dioxin-like PCBs	5
Chimney Point to Cap Chaillon	8	Dioxin-like PCBs	-	N/A	0	PCBs, Toxaphene	4
Cap Chaillon to Sawpit Bay	10	Dioxins/Furans	4	Mercury	3	PCBs, Toxaphene	6
Sawpit Bay to Sault Ste. Marie	6	Dioxins/Furans	8	Mercury	2	Toxaphene, PCBs, Dioxin-like PCBs	5

*Only Regional Unit with contaminant of concern specific to size classes.

[9] Turek, M.E. et al. 2012. Risks and Benefits of Consumption of Great Lakes Fish. Environmental Health Perspectives, 120 (1): 11-18." Risks and Benefits of Consumption of Great Lakes Fish (nih.gov)

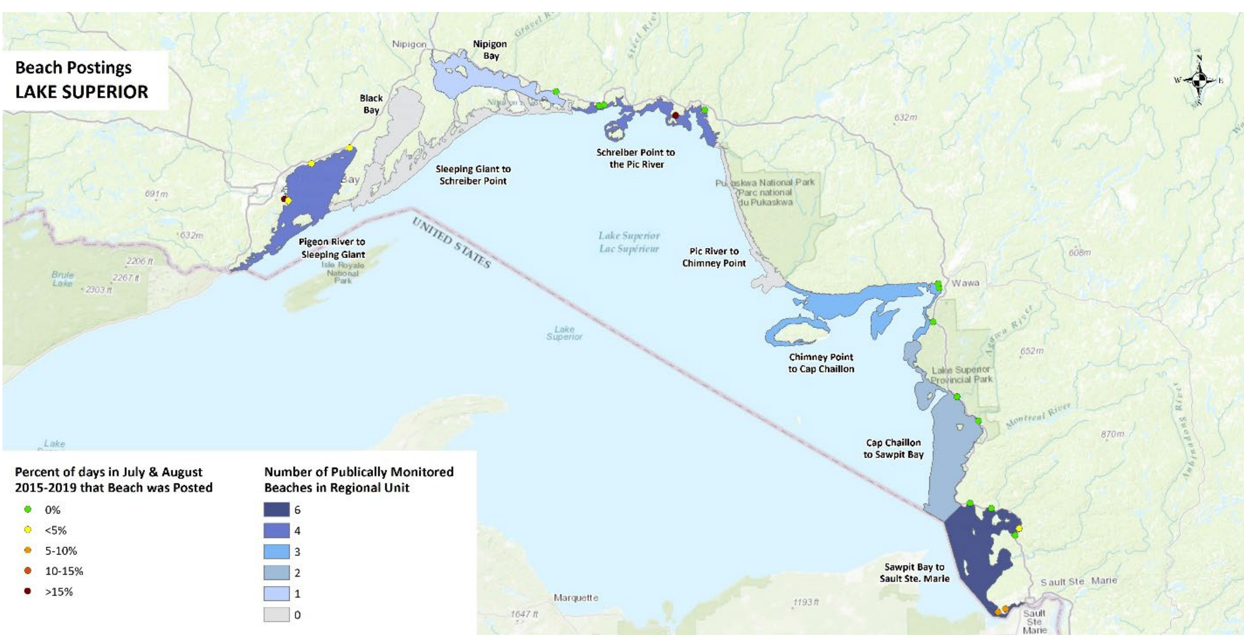
Beach Postings

Low Stress	Beaches posted 5% or less of the time during July and August 2015-2019
Moderate Stress	Beaches posted 5-20% of the time during July and August 2015-19
High Stress	Beaches posted more than 20% of the time during July and August 2015 -19

Thresholds developed using best professional judgement using data from Swim Drink Fish Canada and the Thunder Bay District Health Unit.

This assessment included information on 20 publically monitored beaches on the Lake Superior shoreline (Figure 9). Overall beach postings are a low to moderate source of stress to the Lake. Of the six Regional Units that have publically monitored beaches, two Regional Units (Pigeon River to Sleeping Giant and Schreiber Point to the Pic River) were found to be of moderate stress. These two Regional Units were just outside the low stress threshold of 5% with posting for 5.5% and 7.8% of July and August respectively. The remaining four were all low stress with three Regional Units (Nipigon Bay, Chimney Point to Cap Chaillon and Cap Chaillon to Sawpit Bay) having no postings in July and August for the 5 year period. When all Lake Superior beaches are considered together, beach water quality is excellent, with postings for just 3.8% of days in July and August over the 5-year period.

Figure 9. Publically monitored beach locations and % of days in July and August 2015-19 the beach was posted as unsafe for swimming



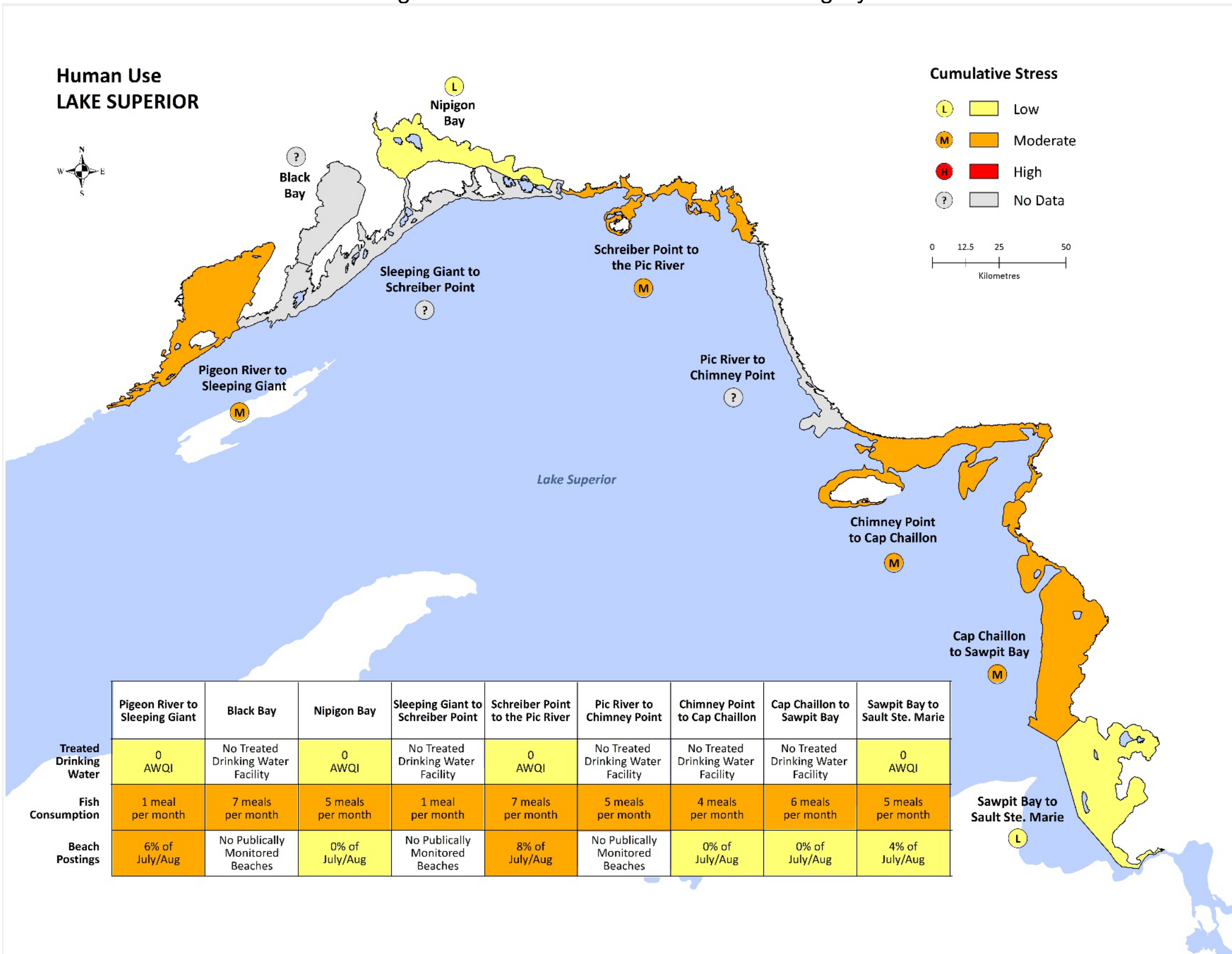
Treated Drinking Water Quality

Low Stress	No adverse water quality incidents
Moderate Stress	Does not apply - any incident is considered a high stress
High Stress	1 or more adverse water quality incidents

Thresholds based on Ontario Drinking Water Quality Standards.

None of the water treatment plants in Lake Superior's Regional Units had adverse water quality incidents (AWQIs) during the years 2015-2019 There are no water treatment plants within the Black Bay, Sleeping Giant to Schreiber Point, Pic River to Chimney Point, Chimney Point to Cap Chaillon and Cap Chaillon to Sawpit Bay Regional Units.

Figure 10. Results of the Human Use category



	Pigeon River to Sleeping Giant	Black Bay	Nipigon Bay	Sleeping Giant to Schreiber Point	Schreiber Point to the Pic River	Pic River to Chimney Point	Chimney Point to Cap Chaillon	Cap Chaillon to Sawpit Bay	Sawpit Bay to Sault Ste. Marie
Treated Drinking Water	0 AWQI	No Treated Drinking Water Facility	0 AWQI	No Treated Drinking Water Facility	0 AWQI	No Treated Drinking Water Facility	No Treated Drinking Water Facility	No Treated Drinking Water Facility	0 AWQI
Fish Consumption	1 meal per month	7 meals per month	5 meals per month	1 meal per month	7 meals per month	5 meals per month	4 meals per month	6 meals per month	5 meals per month
Beach Postings	6% of July/Aug	No Publically Monitored Beaches	0% of July/Aug	No Publically Monitored Beaches	8% of July/Aug	No Publically Monitored Beaches	0% of July/Aug	0% of July/Aug	4% of July/Aug

Data Gaps and Limitations in Nearshore Science

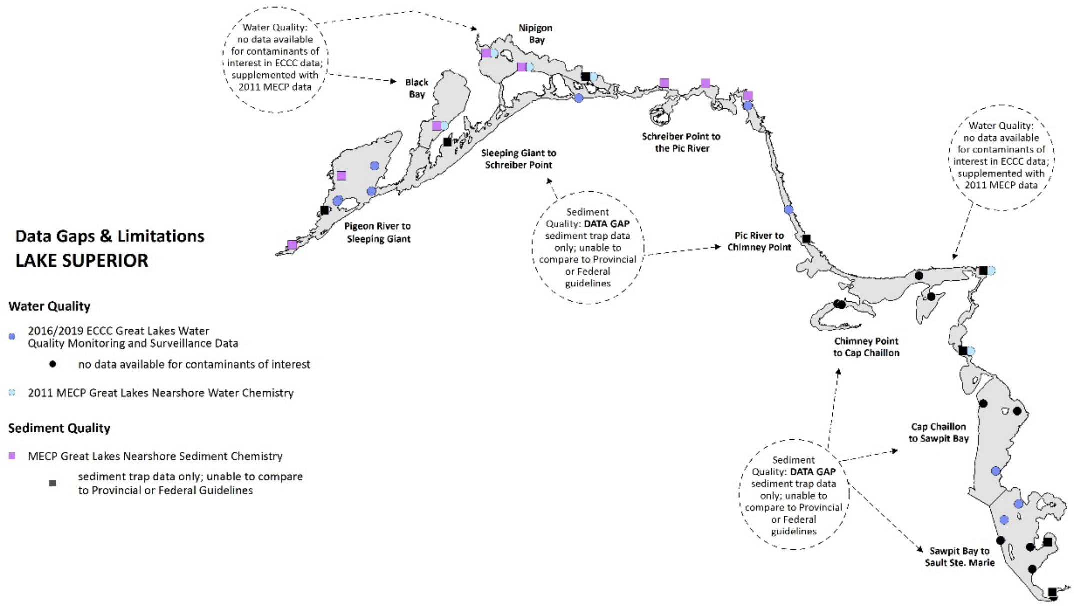
Data used in the assessment has been obtained from existing monitoring programs, from a range of partners, and varies in type, format and resolution. Where available, data from long-term monitoring programs is used. Various monitoring and surveying programs were considered, and key considerations in the selection of data included the spatial and temporal resolution, the amount of processing required (e.g. technical expertise, software requirements) and the availability of the data. Considerable effort was given to identify high-quality data sets. Where possible, data from remote-sensing technologies were used as they provide high temporal resolution.

The first cumulative assessment of the nearshore waters of Lake Superior demonstrated some gaps in scientific data and information on nearshore water quality, contaminants and ecological health. This includes gaps in temporal and spatial coverage of monitoring programs as well as robust information on stressor interactions. Figure 11 shows which Regional Units had data gaps and the associated measure(s) that could not be assessed. Improved understanding of nearshore health may be advanced by:

- Increased spatial and temporal resolution of nearshore monitoring;
- Advancing science on remote sensing for ecosystem health data;
- Continued commitment to existing long term monitoring programs and;
- Timely sharing of monitoring data through Open Data platforms.

Beyond the limitation of being unable to assess cumulative stress for categories with insufficient data, limitations in nearshore monitoring and data, based on lessons learned from this assessment, are briefly outlined below.

Figure 11. Overview of data gaps and limitations across Lake Superior



Coastal Processes

The MNRF Ontario Dam Inventory and the FishWerks database were used to evaluate barriers to tributary connectivity. Neither of these databases are regularly updated to reflect new dams or restoration of existing dams. This may affect the ability to assess changes over time to the Tributary Connectivity measure.

Contaminants in Water & Sediment

The overall assessment of nearshore waters relied on data collected by various ship-based sampling programs. This type of monitoring is typically limited spatially and temporally due to the size of the Great Lakes and weather, that restricts sampling effort. Large research vessels typically used for this program cannot always access the nearshore waters due to depth limitations. Increasing monitoring locations would improve understanding of water and sediment quality, as well as benthic communities, at the Regional Unit scale.

Federal and provincial monitoring programs are designed to measure contaminants in all media (air, water, sediment, fish, birds and benthos) but the temporal and spatial coverage as well as the parameters measured and purpose of various monitoring programs is diverse. Despite the diversity of the various monitoring programs, there is limited data available to assess contaminants in water and sediment at a scale that is regionally appropriate and offers coverage at the lake scale. Due to the geographic scale of the Great Lakes, the short weather windows for sampling and the high cost of laboratory analysis especially for organochlorine contaminants (e.g. dioxins and furans), very limited data is available to measure contaminant-related overall nearshore health. Many recent and emerging contaminants, such as Per- and polyfluoralkyl substances [PFAS], of which there are nearly 5,000 types (US FDA, 2020) are not understood well enough to set thresholds for safety or develop analysis methods. In addition, concentrations may be so low as to avoid detection with existing laboratory equipment.

Increased sampling effort at existing long-term monitoring stations would improve results for all of the Contaminant measures. Not only would more sites benefit the assessment by adding spatial coverage, but also site selection could consider areas where depositional sediment exists thereby improving the reliability of the data to reflect ambient conditions. Further, additional site selection for benthic community sampling, increases in temporal and spatial coverage and use of habitat information are critically needed to increase confidence in the overall assessment of nearshore waters.

Nuisance and Harmful Algae

There is no data to assess the coverage of *Cladophora* in Lake Superior. The satellite-derived mapping product from MTRI is currently unable to assign classification across Lake Superior and there are no *Cladophora* monitoring sites in Lake Superior. As a result, this measure cannot be assessed due to a lack of data. While it is not likely to be a source of stress in Lake Superior without a significant source of phosphorus, the capacity to identify changed in the presence or absence of nuisance algae like *Cladophora* would improve the effectiveness of the assessment.

Human Use

Not all areas accessible for swimming are regularly monitored for recreational water quality. Increasing the number of locations that are monitored would allow for a more thorough understanding of beach water quality at a Regional Unit scale. The number of sampling days per season varies between health units with some units sampling daily and others bi-weekly. In some cases, the beaches will remain posted as unsafe for swimming until the next sampling event even though the poor conditions may not have persisted for the whole time between sampling. More frequent sampling would allow for a more accurate count of the days that the water was actually unsafe for swimming since the duration of postings would be more reflective of actual conditions. There is potential to use modelling tools to predict beach water quality at a higher spatial and temporal scale to better understand where and when the nearshore is safe for swimming.

Next Steps

The overall assessment of Lake Superior's nearshore waters will be repeated to monitor change over time. Areas of high ecological value and other habitat factors will be integrated to complete the comprehensive assessment. Results will be included in the 2020-2024 Lake Superior Lakewide Action and Management Plan (LAMP) and will be provided to communities and stakeholders for collaboration on identification of management priorities to protect areas of high ecological value that are or may become subject to stress. The Lake Superior Partnership and the Canada-Ontario Agreement partners may support collaboration opportunities under the Nearshore Framework.

Identified data gaps, such as the need to increase spatial and temporal resolution of nearshore monitoring and the need to support advancements in remote sensing will be considered in the

Cooperative Science and Monitoring priority setting exercise for each lake (a component of the Lakewide Management process). Progress continues on the Nearshore Framework to complete a cumulative assessment for each of the Canadian Great Lakes nearshore as respective LAMPs are developed.

In 2022, the Overall Assessment of the State of Canadian Nearshore Waters – including results from Lakes Superior, Huron, Erie and Ontario – will be the first cumulative assessment of the Canadian Great Lakes nearshore waters.

Appendix A

Assessment of Benthic Invertebrate Communities in Lake Superior for the Nearshore Framework Assessment

Lee Grapentine, Research Scientist, WHERD, WSTD
7 November 2020

Introduction

As part of the development of the Great Lakes Nearshore Framework, an assessment of sediment dwelling organisms (benthic invertebrate communities = "benthos") was conducted for Lake Superior. Procedures for the assessment were similar to those used in previous assessments of benthic invertebrates in Lakes Erie and Ontario. Existing monitoring data from Environment and Climate Change Canada (ECCC) and Ontario Ministry of the Environment, Conservation and Parks (MECP) were obtained for stations located in the Regional Unit areas. The data were evaluated for their suitability for assessing benthos conditions in the Regional Units. Suitable data were used to describe basic community characteristics for each station and Regional Unit. Regional units were then rated for relative community quality.

Available Data on Benthic Conditions

ECCC

ECCC's monitoring includes the collection of 165 samples from 97 stations in Lake Superior Regional Units during years 2006 to 2013. Station locations and frequencies of sampling were designed for assessing benthic conditions in four Areas of Concern (AOCs). Of the 97 stations, 27 were designated as reference stations when they were first sampled in the early 1990s. In addition to benthic invertebrate densities, data on over 60 habitat variables are available for the 165 samples.

Because of the reference and AOC stations not being randomly located within the Regional Units, coverage of the Regional Units is not balanced. For example, there are no reference stations in two Regional Units, and no AOC stations in four Regional Units. Gaps in the coverage are even greater for the two most recent years of sampling (2011, 2013). Therefore, **the ECCC benthos data were not considered suitable for assessing benthos in the Lake Superior Regional Units.**

MECP

MECP conducted benthic monitoring at 16 stations in Regional Units of Lake Superior. All Regional Units have a least one station with the number of stations per Regional Unit ranging from one to four. Samples were collected in years 1991, 1992, 1999, 2005 and 2011; only data from 2011 were used in the benthos assessment. In 2011, all 16 stations were sampled and handled using standard MECP methods. These include:

- collecting by Ponar grab 5 replicate benthos samples per station (except station 1320, from which only 1 grab was taken in 2011),

- passing samples through a 0.600-mm mesh sieve and saving material retained on the screen for analysis, and
- identifying invertebrates to lowest possible level.

Benthos data units are number/m^2. MECP particle size data, GIS habitat (Wang et al. 2015) and stressor data (Allan et al. 2013) are available for Lake Superior. Including these data in the analyses was beyond the scope of the 2020 assessment, however incorporating obtaining habitat and stressor data for stations in the future would allow for a more comprehensive assessment. Analyses of ECCC habitat and benthos data have shown relationships between benthic community descriptors and habitat attributes, such as depth, sediment particle size, and sediment nutrient concentrations.

Assessment Methods

In preparation for analyses, data for station replicate samples were averaged. Taxon counts were then summed to genus level. This involves summing the counts for all species from the same genus, and improves the comparability of this data set to others. The resulting data set had counts (densities) for 80 taxa and 16 stations.

Assessing the condition or "health" of the benthic communities requires a definition of degraded vs undegraded conditions. This is not straightforward. Unlike physical and chemical measures of environmental quality, for which there are often benchmarks or thresholds associated with various levels of quality (e.g., good, fair, poor), benthic communities have few generally accepted indicators and benchmarks associated with defined levels of degradation. Many indices have been developed and applied, but these are often specific for particular study areas and require recalibration for use elsewhere. Therefore, assessments of benthos in test sites usually involve comparisons to the benthos in reference sites. So rather than there being a particular value of a descriptor that indicates community degradation, degradation is indicated by a statistical difference from reference conditions (in the direction associated with adverse effects). Unfortunately, as for Lakes Erie and Ontario, the data available from the MECP for the Regional Units are not well suited for comparisons to reference stations.

The benthic invertebrate samples were therefore quantified by three commonly used community descriptors:

- **total benthos** (the total number of individuals in the sample),
- **taxon richness** (the number of taxa present in the sample), and
- **evenness** (a measure of the distribution of individuals among the taxa).

While the first two descriptors are straightforward to calculate, there are several formulas for evenness. Here I calculated Pielou's evenness: E = H'/ln(richness), where H' is the Shannon diversity index ($H' = -\sum p_i \ln p_i$, where p_i is the relative frequency of taxon i in the sample). E ranges from 0 to 1 and is a measure of diversity adjusted for the number of taxa.

Benthic communities were compared among stations and among Regional Units based on each of these descriptors. In general, higher values for these descriptors are considered to indicate better condition or health of the community. However, high total abundance with low richness and/or evenness indicates an over-dominance of one or a few taxa, which could indicate degradation.

In order to convert the three benthos descriptors into one dimension of community condition, a principal components analysis (PCA) was conducted on a correlation matrix calculated from total benthos, taxon richness, and evenness. To adjust for any influence of the unequal number of stations per Regional Unit, before the PCA Regional Unit means were calculated for the descriptors.

Based on the first 2 axes of the PCA, a quality gradient aligning with increasing total benthos, increasing taxon richness and increasing evenness was assigned to the -1:1 line through the origin. Scores for the nine Regional Units were projected perpendicularly onto the quality gradient line. Positions on the line were grouped into three quality classes of three Regional Units corresponding to poor, fair and good benthos conditions.

Table A-1. Benthic community quality for Regional Units for MECP stations, using 2011 data. Generally, higher quality corresponds to higher total benthos, higher taxon and higher evenness; richness in the Chimney Point to Cap Chaillon Regional Unit was 2nd lowest overall and one of the lowest for total abundance, which strongly departs from the west to east gradient in quality (Pigeon River to Sleeping Giant is west) - the station is located in deep water (approximately 65-80 m), which may be a factor affecting the benthic community and may be a case of natural impoverishment.

Regional Unit	**Benthic Community Quality**		
	No. of Sites	**Quality Rating**	**Comments**
Pigeon River to Sleeping Giant	4	Fair	On average, low total abundance, richness and evenness; AOC present
Black Bay	1	Poor	Low total abundance, richness and evenness; moderately high in *Diporeia* and low in other taxa
Nipigon Bay	2	Poor	Low total abundance and richness; moderate evenness; AOC present
Sleeping Giant to Schreiber Point	1	Fair	High total abundance and richness; high in *Diporeia* and *Pisidium*
Schreiber Point to the Pic River	3	Fair	On average, moderate in total abundance, richness and evenness; 2 AOCs present

Pic River to Chimney Point	1	Good	High total abundance and richness
Chimney Point to Cap Chaillon	1	Poor	Low total abundance and richness; deep water station; possible naturally impoverished
Cap Chaillon to Sawpit Bay	1	Good	High total abundance, richness and evenness
Sawpit Bay to Sault Ste. Marie	2	Good	Low total abundance; high richness and evenness