LAKE HURON CANADIAN NEARSHORE
Assessment

2021 RESULTS REPORT

Cat. No.: En164-71/5-2021E-2-PDF
ISBN: 978-0-660-36634-0
EC21052,01

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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

Environment and Climate Change Canada would like to thank the individuals and agencies who provided data, advice and reviews of this document. The Lake Huron Canadian Nearshore Assessment would not have been possible without contributions from the Ontario Ministry of Environment, Conservation and Parks, the Ontario Ministry of Northern Development, Mines, Natural Resources and Forestry, Swim Drink Fish Canada, the National Oceanic and Atmospheric Administration, Dr. Lee Grapentine (ECCC), Peter Zuzek and Kevin Grootendorst (Zuzek Inc.) and various ECCC program staff.

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 2021 Lake Huron 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.

The Canadian nearshore of Lake Huron is unique in that there are three interacting water bodies: St. Marys River and the North Channel, Georgian Bay and the main basin. The North Channel stretches from the St. Marys River to Georgian Bay and is sheltered from the main basin by Manitoulin Island. Eastern Georgian Bay is a huge freshwater archipelago along a complex shoreline characterized by embayments and a number of wetlands. Each of these areas are characterized by unique physiographic elements but are collectively referred to as Lake Huron.

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 (measured at low water) of approximately 59 m, Lake Huron is the second shallowest Great Lake (Figure 1) and although nearshore bathymetry varies across the North Channel, Georgian Bay and main basin, a depth of 30 m was selected as the offshore boundary. The unique depth profile of Lake Huron means that the 30 m contour is quite a distance offshore in some areas. For example, the Killarney Regional Unit has an 'arm' that extends nearly 50 km offshore along Grand Bank to Lonely Island and in the French River to Parry Sound Regional Unit the offshore boundary is a bit irregular around the Limestone Islands. In some Regional Units (e.g. North Manitoulin Island, South Manitoulin Island, Killarney, Parry Sound and Christian Island) there are pockets of deeper water within the offshore 30 m boundary due to ridges and valleys on the lake bottom.

The Great Lakes Aquatic Habitat Framework (GLAHF) lakewide bathymetry raster dataset[3] was converted into 5 m contour lines, and the 30 m line was used to create a seamless offshore boundary.

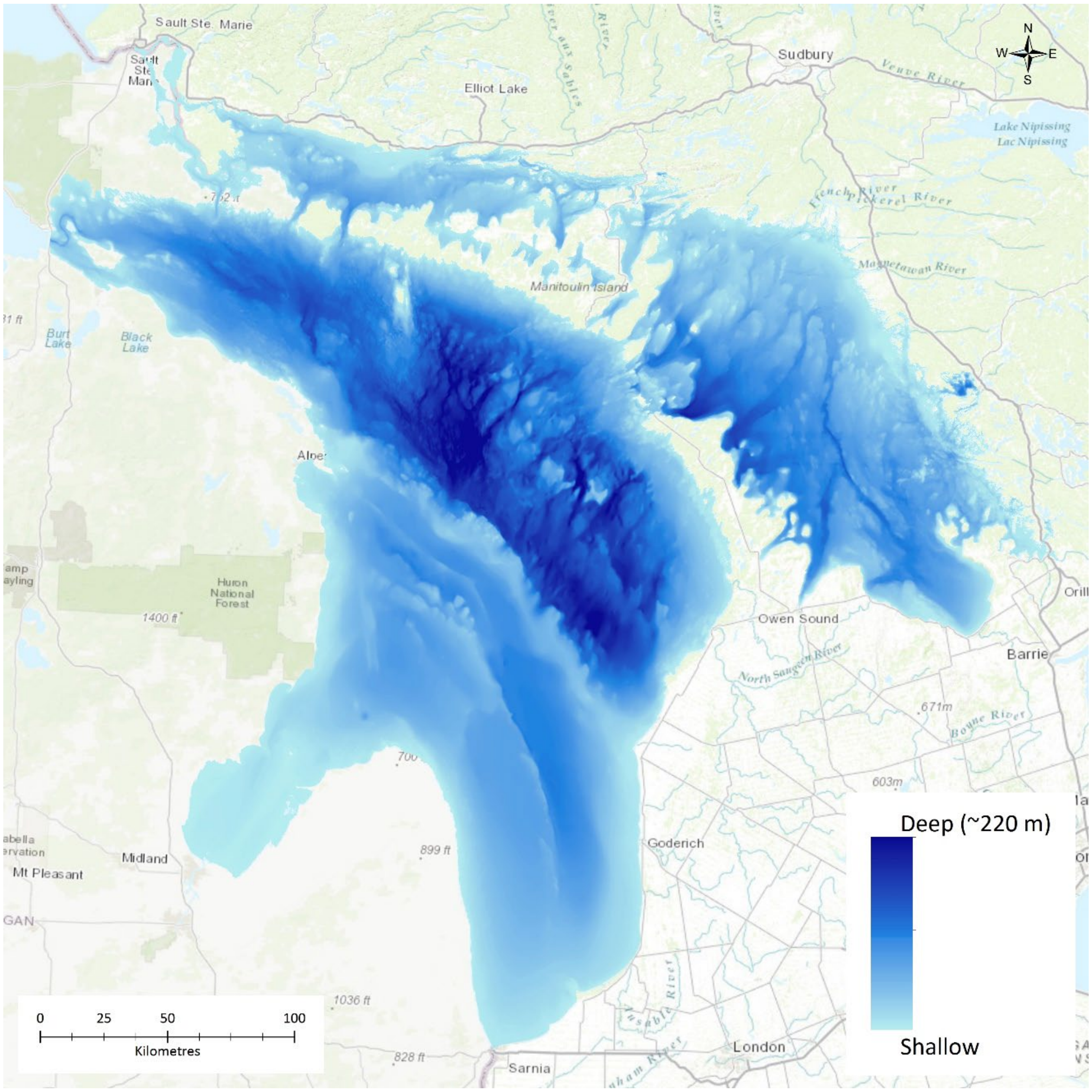
Onshore boundary

Since the assessment is focused on the nearshore of Lake Huron, the onshore boundary was defined by a high water mark. Historical maximum monthly mean lake levels from Fisheries and Oceans Canada coordinated network of gauges for Lake Michigan-Huron[4] were reviewed and the maximum monthly mean was found to be 1.5 m above Chart Datum.

On Lake Huron, Chart Datum is 176 m, making the maximum monthly mean 177.5 m (176 [Chart Datum] + 1.5 [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 177.5 m contour, Digital Elevation Models (DEMs) were obtained from the Ontario Ministry of Northern Development, Mines, Natural Resources and Forestry (NDMNRF) [5] to establish the onshore limit of the Regional Units.

[3] Great Lakes Aquatic Habitat Framework (GLAHF) – Geomorphology – Lake Bottom: https://www.glahf.org/data/
[4] Fisheries and Oceans Canada. *Historical Monthly Mean Water Levels from the Coordinated network for Lake Michigan/Huron* Historical Monthly Mean Water Levels from the Coordinated network for Lake Michigan/Huron (tides.gc.ca)
[5] Ontario Ministry of Northern Development, Mines, Natural Resources and Forestry. *Ontario Digital Elevation Model (Imagery-Derived)*. https://geohub.lio.gov.on.ca/datasets/mnrf::ontario-digital-elevation-model-imagery-derived

Figure 1. Lake Huron Bathymetry (from the Great Lakes Aquatic Habitat Framework); the 30 m contour was used to delineate the offshore boundary of the Regional Units.



Lateral boundary

The lateral boundaries were generated by assessing substrate data, shoreline morphology and wave energy. The nearshore areas of Lake Huron 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.

Much of Lake Huron's nearshore is dominated by coarse, hard substrate (Figure 2). Shoals and deep basins and channels are associated with glacial scouring activity. Rocky shores associated with the Precambrian Shield extend across the northern and eastern shores of Georgian Bay and the North Channel. Limestone dominates the shores of Manitoulin Island – the largest freshwater island in the world – and the northern shore of the Bruce Peninsula. In the south, glacial deposits in coastal areas provide fine, white sand beaches dunes including some of the longest freshwater beaches in the world – Wasaga and Sauble. The orientation and morphology of the shoreline can influence the presence (or absence) of coastal features. For example there are numerous bays in the nearshore of the North Channel and Georgian Bay that are sheltered from the main lake by rocky outcrops. The 30,000 islands of Georgian Bay create complex shorelines with shallow warm waters that support abundant and pristine coastal wetlands.

Wave energy also has 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 Huron, at 2 km increments (Figure 3). The input wave conditions were generated by a historical wind-wave hind cast 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.

From Cape Hurd south to Goderich, annual wave energy is high. The coastline is exposed, and the high wave energy transports sediment southwards. Southeastern Manitoulin Island also experiences high annual wave energy, transitioning from moderate to higher energy towards Fathom Five. Generally, annual wave energy density is lower in the more sheltered areas of the North Channel and Georgian Bay.

Figure 2. Substrate types in Lake Huron (from the Great Lakes Aquatic Habitat Framework).

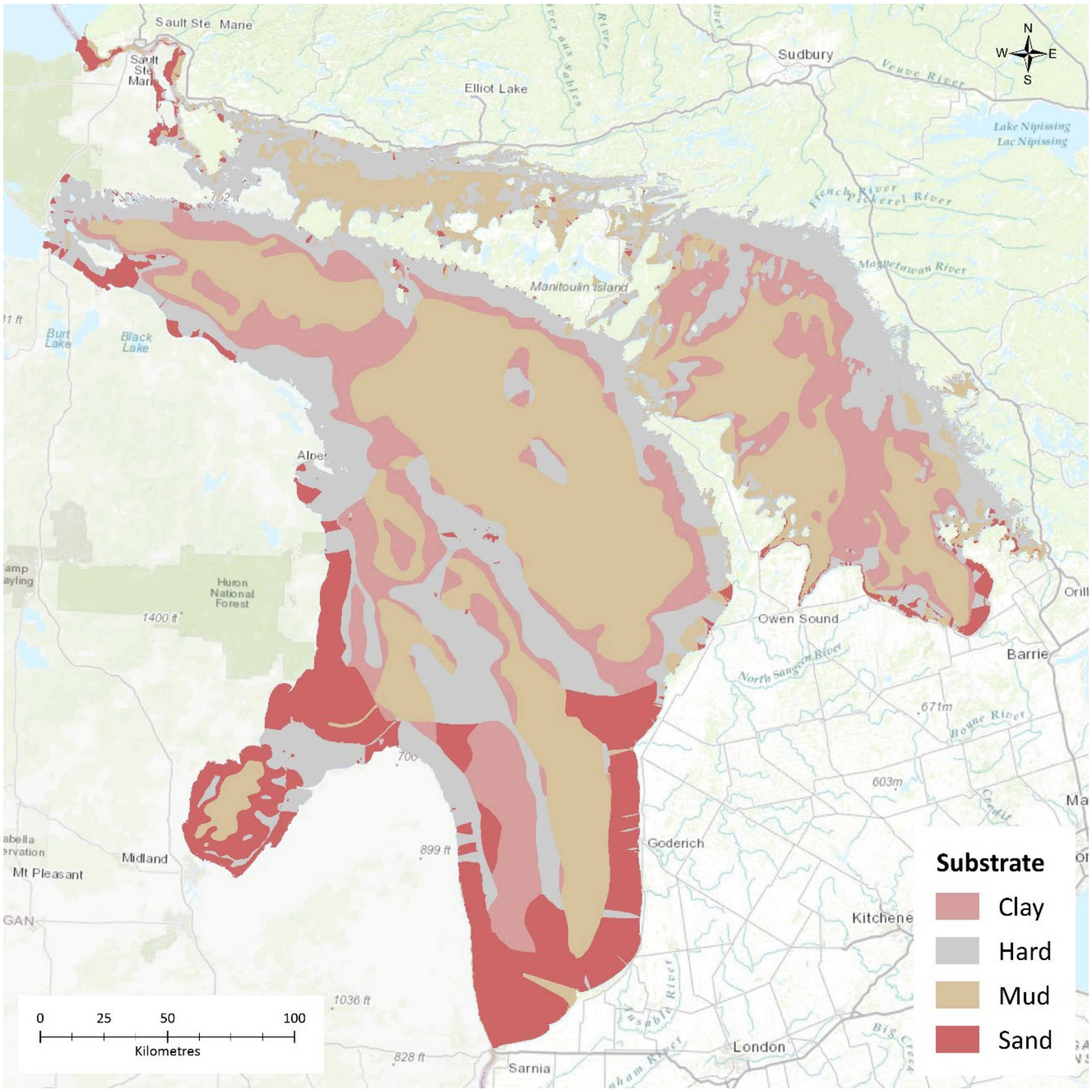
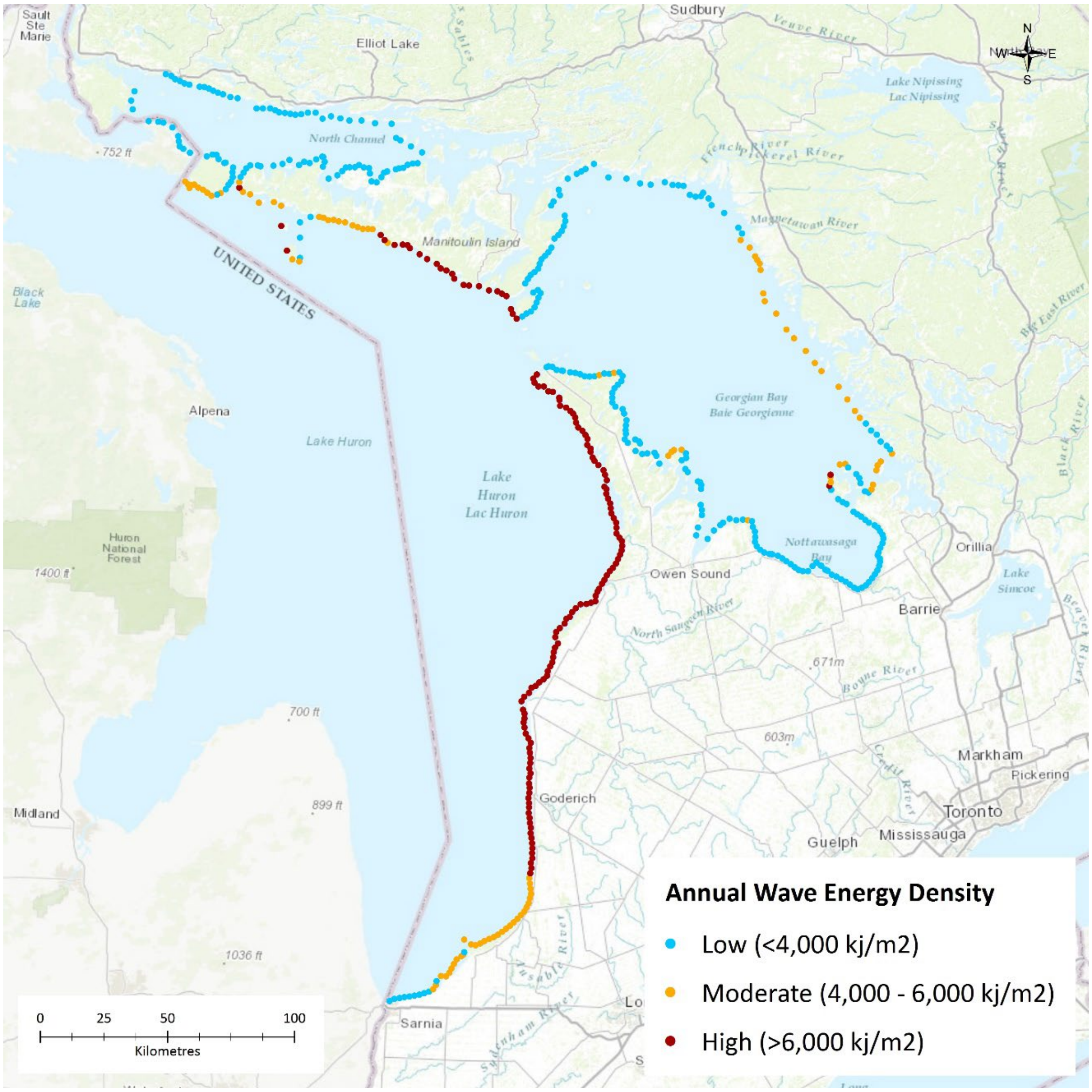


Figure 3. Results of the annual wave energy density analysis on Lake Huron; note that wave energy density was not modelled in the St. Marys River or in embayments.



Overlaying these slow-changing variables revealed several unique patterns from which 23 Regional Units with five ecosystem classifications were identified (Table 1 and Figure 4).

Table 1. Twenty-three ecologically relevant Regional Units were delineated using slow changing variables

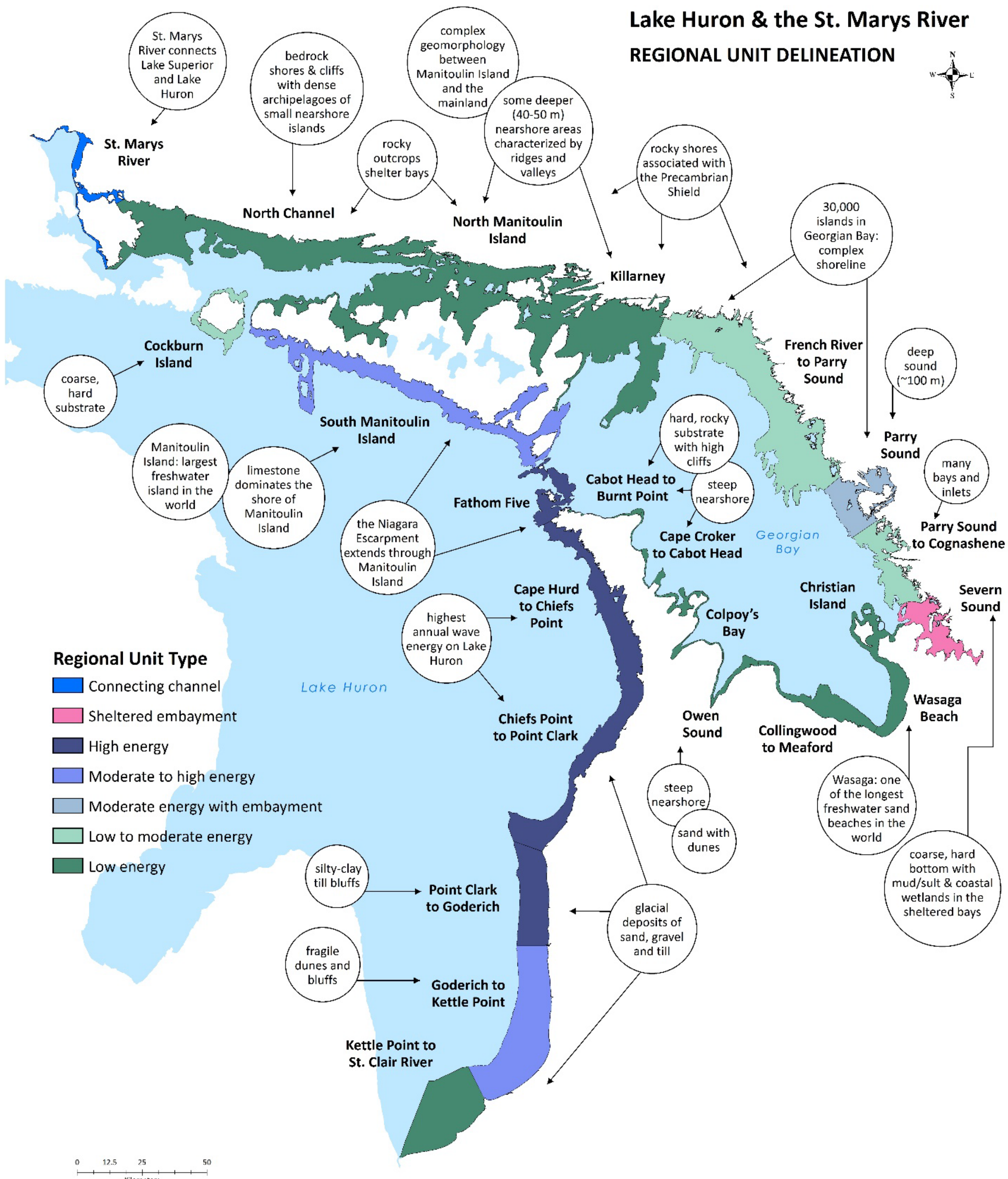
Regional Unit Name and Ecosystem Type	Size	Substrate (GLAHF)	Wave Energy (Zuzek Inc.)	Description
CONNECTING CHANNEL				
ST. MARYS RIVER (LH01)	14,050 ha	Mud	n/a (not calculated in Connecting Channel)	Canadian portion of the St. Marys River predominantly mud and sand from Sault Ste. Marie to the southern extent where the substrate transitions to hard bottom. Western side of St. Joseph Island characterized by a mix of mud and hard substrates. St. Marys River includes a rapids section with facilities and channels for navigation, hydropower, water regulation; and a lower section largely at Lake Huron elevation. Lower river has morphology of a complex strait. Narrow channels, broad and wide lakes, four large islands and many small islands are present
SHELTERED EMBAYMENT				
SEVERN SOUND (LH10)	26,972 ha	Hard	n/a (not calculated in Sheltered Embayment)	Group of bays covering sheltered from Georgian Bay; coarse, hard bottom in the middle of Severn Sound with mud, silt and coastal wetlands in the sheltered bays and areas of sand in the southeast. Includes Musquash Channel
HIGH ENERGY NEARSHORE				
FATHOM FIVE (LH18)	20,083 ha	Hard	High energy	Northern terminus of the Niagara Escarpment; characterized by very coarse (hard) substrate; includes Fathom Five National Marine Park, where rock structures made of sedimentary rock resemble flower pots
CAPE HURD TO CHIEFS POINT (LH19)	53,148 ha	Hard	High energy	Highest energy nearshore in Lake Huron; dominant substrate is coarse, hard bottom with small pockets of mud, silt in more sheltered areas (e.g. Gauley and Myles Bays and Chiefs Point)
CHIEFS POINT TO POINT CLARK (LH20)	56,573 ha	Mud, hard	High energy	High-energy nearshore; mud and hard substrate transitions to sand near Stoney Island Conservation Area. In the north, Sauble Beach is one of the longest

				freshwater sand beaches in the world, other sandy beaches characterize the area; large river mouths – Sauble River
POINT CLARK TO GODERICH (LH21)	42,784 ha	Sand	High energy	Coarse sand; shoreline characterized by bluffs that increase in height towards Goderich; bluffs are developed by silty-clay till with sand and gravel
MODERATE TO HIGH ENERGY NEARSHORE				
SOUTH MANITOULIN ISLAND (LH05)	92,835 ha	Hard	Moderate to high energy	Extends along the entire southern extent of Manitoulin Island – the largest freshwater island in the world – and around Great Duck Island. Primarily coarse, hard substrate but pockets of mud, silt and undifferentiated till or bedrock in South Bay. Fairly exposed coast with moderate energy transitioning to high annual wave energy in the east.
GODERICH TO KETTLE POINT (LH22)	90,992 ha	Sand	Moderate to high energy	High energy in the north end of the Regional Unit transitions to moderate energy towards Kettle Point; sand substrate with eroding bluffs
MODERATE ENERGY WITH EMBAYMENT				
PARRY SOUND (LH08)	31,956 ha	Hard	Moderate energy with embayment	Moderate energy nearshore from south of Franklin Island to south of Parry Island, mud in Parry Sound embayment. Parry Sound is sheltered from Georgian Bay and much deeper (approximate maximum depth of 105 m). Many small islands along the coast.
LOW TO MODERATE ENERGY NEARSHORE				
COCKBURN ISLAND (LH04)	14,285 ha	Hard	Low to moderate energy	Separated from the westernmost point of Manitoulin Island by the Mississagi Strait; very coarse, hard substrate
FRENCH RIVER TO PARRY SOUND (LH07)	147,539 ha	Hard	Low to moderate energy	Nearshore dominated by hard substrate; many bays and inlets with coastal wetlands; numerous islands
PARRY SOUND TO COGNASHENE (LH09)	34,150 ha	Hard	Low to moderate energy	Dominated by very coarse, hard substrate and bays and inlets interspersed by islands. Area of mud and deeper water offshore, with littoral ridges and valleys that slope back up to shallower water.
LOW ENERGY NEARSHORE				
NORTH CHANNEL (LH02)	131,364 ha	Hard	Low energy	Characterized by very coarse substrate (limestone), with pockets of mud and silt along the coast (in particular at rivermouths); bedrock shores and cliffs, dense archipelagoes of small nearshore Precambrian Shield islands; steep

				slopes/ridges and valleys at the Whalesback Channel; the Spanish River delta is an important deposition zone with coastal wetlands
NORTH MANITOULIN ISLAND (LH03)	125,608 ha	Hard, mud	Low energy	Includes bays and coves on northern Manitoulin Island characterized by mud, silt. Hard, coarse substrate dominates the channel between Manitoulin Island the mainland with an area of deep (~40-50 m) ridges/valleys and soft mud substrate.
KILLARNEY (LH06)	141,101 ha	Hard	Low energy	Characterized by very coarse (hard) substrate with patches of mud and silt; area of deeper (~40-50 m) ridges/valleys and soft mud substrate extend along the South La Cloche Range/Badgeley Point. Very narrow/steep nearshore along east side of Manitoulin Island. Includes Manitowaning Bay and up into McGregor Bay.
CHRISTIAN ISLAND (LH11)	13,171 ha	Hard	Low energy	Lake bottom characterized by ridges and valleys; dominated by hard substrate with pockets of sand with a pocket of deeper waters (~40 m) characterized by mud between Christian Island, Beckwith Island and the mainland.
WASAGA BEACH (LH12)	19,337 ha	Sand	Low energy	Wasaga Beach is one of the longest freshwater beaches in the world; many other beaches along the coast, all dominated by sand.
COLLINGWOOD TO MEAFORD (LH13)	24,729 ha	Hard; sand	Low energy	Substrate characterized by a mix of hard, mud, silt and sand. Areas of sand with dunes. Nearshore slope becomes steeper west of Meaford.
OWEN SOUND (LH14)	6,281 ha	Hard	Low energy	Steep nearshore slope north of Owen Sound with ridges and valleys; hard substrate with gravel and boulders in the east and west transitions to sand/dunes, mud and silts within Owen Sound
COLPOY'S BAY (LH15)	3,376 ha	Sand	Low energy	Coast is characterized by steep slope, resulting in a narrow Regional Unit as the water becomes deep very close to shore. Sand bottom transitioning to hard substrate at Kings Point
CAPE CROKER TO CABOT HEAD (LH16)	9,761 ha	Hard	Low energy	Nearshore predominantly hard substrate, with sand in Sydney Bay; coast characterized by high cliffs and steep slopes in the nearshore, with ridges and valleys. Formations of bedrock are exposed in the cliffs, with glacial outwash and eroded potholes; mounds of rock debris overgrown with vegetation lie at the bottom

CABOT HEAD TO BURNT POINT (LH17)	1,696 ha	Hard	Low energy	Steep slopes result in a very narrow Regional Unit along the coast of Bruce Peninsula National Park; hard, rocky substrate with limestone caves
KETTLE POINT TO ST. CLAIR RIVER (LH23)	63,274 ha	Sand	Low energy	Characterized by sandy substrate with mud, silt around Kettle Point

Figure 4. The nearshore of Lake Huron and the St. Marys River was delineated into 23 Regional Units.



2021 Lake Huron Canadian Nearshore Assessment

In 2021, Environment and Climate Change Canada (ECCC) undertook the Overall Assessment of the State of Nearshore Waters in Lake Huron. This report summarizes the findings of cumulative stress across 23 Regional Units.

The assessment considered eleven measures (see text box) 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 having "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 (+), Tributary Connectivity (+)
- Contaminants in Water & Sediment: Water Quality (+), Sediment Quality (++), Benthic Community (++)
- Nuisance & Harmful Algae: *Cladophora* (+), 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 Huron's nearshore areas are under low or moderate stress. One Regional Unit – South Manitoulin Island – is under very low stress. This means that all measures and categories are low stress.

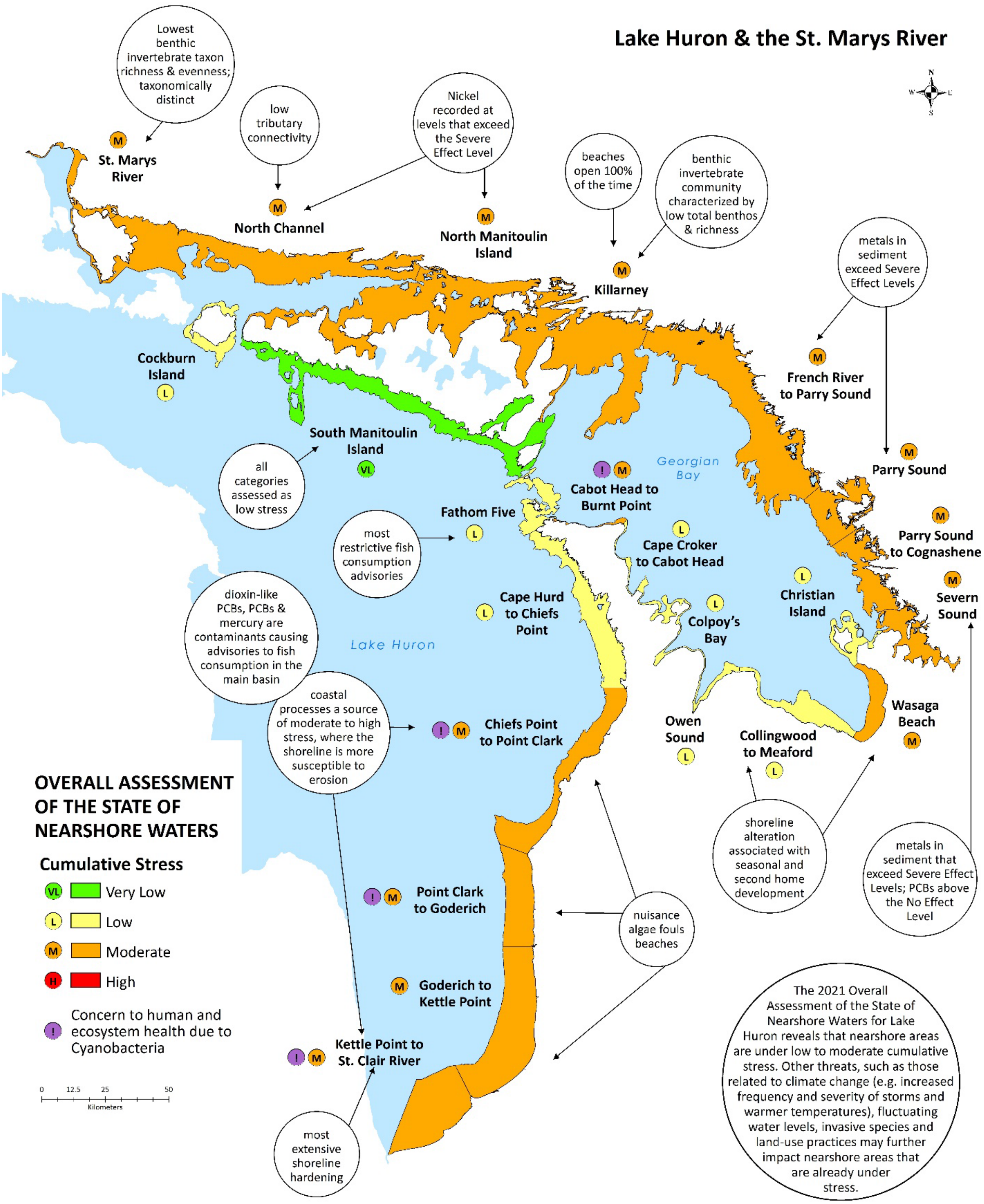
There are no areas assessed as high stress, although there are still some localized Areas of Concern within two regional units. As illustrated in Figure 5, the Regional Units assessed as low stress are Cockburn Island, Christian Island, Collingwood to Meaford, Owen Sound, Colpoy's Bay, Cape Croker to Cabot Head, Fathom Five and Cape Hurd to Chiefs Point. Although Regional Units in southern Georgian Bay are under low stress, there are some issues related to shoreline alteration. This is largely associated with cottage and recreational development in the Collingwood to Meaford, Owen Sound and Colpoy's Bay Regional Units.

All other Regional Units are under moderate stress. In the North Channel and eastern Georgian Bay, issues include; moderate to poor benthic community quality, elevated levels of metals in sediment and advisories against consumption of some fish species. The fish consumption measure indicates moderate stress from Cabot Head down to the St. Clair River with average consumption advisories ranging from three to seven meals per month. Four Regional Units (Cabot Head to Burnt Point, Chiefs Point to Point Clark, Point Clark to Goderich and Kettle Point to St. Clair River) are flagged as having concerns for human and ecosystem health due to the presence of cyanobacteria. Small areas of cyanobacteria were detected in some of the larger bays in Georgian Bay and further investigation is required.

There was a significant lack of spatial and temporal data in Lake Huron's nearshore particularly for water quality, sediment and benthos. 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 and there are no federal sampling stations in twelve Regional Units.

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. In Lake Huron, two Regional Units have a Great Lakes Areas of Concern (AOC) within their boundary. In the St. Marys River Regional Unit, the St. Marys River AOC has seen improvements in water quality and ecosystem health through combined efforts of many partners. The Spanish Harbour AOC, in the North Channel Regional Unit, has been designated as an AOC in Recovery as all actions are complete and the area now needs time for environment to recover naturally. Since 1987, the Governments of Canada and Ontario have supported local action to clean up AOCs and on Lake Huron, two AOCs – Severn Sound and Collingwood Harbour – have been delisted and are considered restored.

Figure 5. Results of the 2021 Overall Assessment of the State of Nearshore Waters in Lake Huron and the St. Marys River.



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.

Lake Huron has the longest shoreline of all the Great Lakes and accounts for half of the Canadian Great Lakes coast. In all, less than 10% of the total length of shoreline has been hardened, and in ten Regional Units, over 95% of the shoreline remains natural. At 56% shoreline hardening, the Kettle Point to St. Clair River Regional Unit has the highest percent of hardened shoreline. Much of the armoured shoreline in this area is associated with efforts to protect property from the impacts of waves and helping to slow erosion.

In southern Georgian Bay, from Severn Sound to Colpoy's Bay, alteration to the shore is primarily associated with cottage and second home development. Due to its proximity to Toronto, many cottages have been converted to year round homes, resulting in development and alteration along the shoreline. In eastern Georgian Bay, the French River to Parry Sound, Parry Sound and Parry Sound to Cognashene Regional Units are characterized by natural shorelines with just a small amount of alteration along the town of Parry Sound. Seasonal development and small marina infrastructure dot the shoreline in these Regional Units, but the cumulative impact is likely not creating significant stress on nearshore waters.

Littoral Barriers

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 Huron, littoral drift does not apply in all Regional Units. From the St. Marys River, across the North Channel and into Georgian Bay, nearshore substrate is characterized by bedrock and littoral drift is not a significant process. However, in Regional Units characterized by sand, mud or silt, littoral drift is an important process that moves sediment along the coast.

The Wasaga Beach Regional Unit includes Wasaga Beach Provincial Park, which is one of the longest continuous freshwater beaches in the world. Maintaining natural processes that allow sediment transport is important for beach replenishment and there are no artificial barriers over 100 m in length in the Regional Unit.

Littoral barriers are a source of moderate and high stress from Chiefs Point to the St. Clair River. In these Regional Units, the net direction of longshore sediment transport is north to south (except in the Chiefs Point to Point Clark Regional Unit where the net direction varies) and is an important process that maintains coastal ecosystem features. Artificial structures that extend into the lake can impede the natural transfer of sediment and have negative effects down current. Erosion of bluffs can be crucial to the maintenance of large stretches of shoreline. For example, sand that erodes from bluffs south of Goderich replenishes the beaches at the Pinery and Ipperwash Provincial Parks, 75 km south.

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.

Lake Huron's watershed is very large and tributary connectivity is complex. Roughly 29% of the total length of tributaries downstream of a waterfall are disconnected from the nearshore due to the presence of one or more dams. Tributaries upstream of a waterfall are considered naturally disconnected and not included in the overall tributary measure, as it is unlikely that the barrier (i.e. waterfall) would ever be removed. Those naturally disconnected due to a waterfall account for nearly 35% of all Lake Huron tributaries (see Table 2).

In the North Channel, Severn Sound and Chiefs Point to Point Clark Regional Units, tributary connectivity is a source of high stress. Barriers at Blind River, Lauzon Lake and Espanola impede connectivity for a significant portion of tributaries within the North Channel Regional Unit, which has the greatest total length of tributaries downstream of a waterfall. In the Severn Sound Regional Unit, nearly 90% of tributaries are disconnected from the nearshore. A dam on the Saugeen River impedes connectivity for approximately 85% of tributaries downstream of a waterfall in the Chiefs Point to Point Clark Regional Unit.

Regional Units in Georgian Bay – from Killarney to Cognashene and Wasaga Beach to Meaford – are in the moderate stress range as between 25 and 75% of the total length of tributaries are connected to the nearshore. The French River to Parry Sound Regional Unit has almost 25% of all Lake Huron tributaries, but only 36% are connected to the nearshore due to dams at Harris Lake and on the Naiscoot River.

All other Regional Units retain high tributary connectivity and in six Regional Units, 100% of tributaries downstream of a waterfall remain connected to the nearshore.

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 order to better understand tributary connectivity. 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.

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)	Percent of Total Length of Tributaries Connected to the Nearshore (disconnected + connected)
St. Marys River	2,719 km	76 km	657 km	1,986 ha	75%
North Channel	31,044 km	10,053 km	19,577 km	1,414 km	7%
North Manitoulin Island	1,947 km	936 km	298 km	713 km	70%
Cockburn Island	157 km	0 km	0 km	157 km	100%
South Manitoulin Island	885 km	0 km	187 km	698 km	79%
Killarney	1,728 km	14 km	715 km	999 km	58%
French River to Parry Sound	32,103 km	21,303 km	6,950 km	3,850 km	36%
Parry Sound	2,384 km	0 km	1,169 km	1,215 km	51%
Parry Sound to Cognashene	9,255 km	8,043 km	494 km	718 km	59%
Severn Sound	12,343 km	0 km	11,266 km	1,077 km	9%
Christian Island	31 km	0 km	0 km	31 km	100%
Wasaga Beach	4,474 km	110 km	3,218 km	1,146 km	26%

Collingwood to Meaford	2,100 km	267 km	1,005 km	828 km	45%
Owen Sound	939 km	394 km	57 km	488 km	89%
Colpoy's Bay	168 km	0 km	0 km	168 km	100%
Cape Croker to Cabot Head	148 km	0 km	0 km	148 km	100%
Cabot Head to Burnt Point	35 km	0 km	0 km	35 km	100%
Fathom Five	47 km	0 km	0 km	47 km	100%
Cape Hurd to Chiefs Point	619 km	0 km	0 km	619 km	100%
Chiefs Point to Point Clark	8,255 km	1,693 km	5,584 km	978 km	15%
Point Clark to Goderich	4,288 km	0 km	2,757 km	1,531 km	36%
Goderich to Kettle Point	3,157 km	21 km	328 km	2,808 km	90%
Kettle Point to St. Clair River	747 km	0 km	121 km	626 km	84%
TOTAL	**119,600 km**	**42,917 km**	**54,392 km**	**22,291 km**	**29%**

Figure 6. Results of the Coastal Processes category (N/A: the measure does not apply in the Regional Unit).

	St. Marys River	North Channel	North Manitoulin Island	Cockburn Island	South Manitoulin Island	Killarney	French River to Parry Sound	Parry Sound	Parry Sound to Cognashene	Severn Sound	Christian Island	Wasaga Beach	Collingwood to Meaford	Owen Sound	Colpoy's Bay	Cape Croker to Cabot Head	Cabot Head to Burnt Point	Fathom Five	Cape Hurd to Chiefs Point	Chiefs Point to Point Clark	Point Clark to Goderich	Goderich to Kettle Point	Kettle Point to St. Clair River
Tributary Connectivity	75%	7%	70%	100%	79%	58%	36%	51%	59%	9%	100%	26%	45%	89%	100%	100%	100%	100%	100%	15%	36%	90%	84%
Shoreline Hardening	16%	6%	1%	<1%	<1%	<1%	<1%	4%	<1%	32%	12%	24%	45%	35%	25%	6%	<1%	4%	4%	17%	15%	28%	56%
Littoral Barriers	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	3	1	3	1

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 (2015-2018).

Across Lake Huron, water quality is a source of low stress. Environment and Climate Change Canada's 2015-2018 monitoring data was assessed for exceedances in published Federal or Provincial water quality guidelines. In 2017, anthracene (a type of polycyclic aromatic hydrocarbon – PAH) was recorded at a level slightly above the Provincial guideline, putting the North Channel Regional Unit in the moderate stress range, but there were no other exceedances in Regional Units where monitoring data was available.

The parameters analyzed were not standardized at all sampling stations. In twelve Regional Units (LH03, LH04, LH05, LH08, LH11, LH13, LH16, LH17, LH19, LH20, LH21, LH22 [refer to Table 1 for Regional Unit numbers]) the only water quality parameter for which information was available was chloride.

Water quality could not be assessed in the St. Marys River, Parry Sound to Cognashene, Wasaga Beach, Colpoy's Bay and Kettle Point to St. Clair Regional Units as there are no federal monitoring sites.

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 (2009, 2011, 2015).

Across Lake Huron and Georgian Bay, contaminants in sediment are a source of low to high stress (Table 3). Five Regional Units (North Channel, North Manitoulin Island, French River to Parry Sound, Parry Sound and Severn Sound) were assessed as high stress due to the presence of metals (Nickel, Manganese, or Iron) at concentrations above the provincial Severe Effect Level. All five of these Regional Units fall within the North Channel and Georgian Bay, where the watershed is dominated by the Canadian Shield. Metal exceedances may reflect naturally elevated concentrations due to run off from the bedrock rather than a localized source of contaminants. Further investigation would be required to determine the cause.

PCBs were detected in sediment at concentrations above the No Effect Level (NEL) in the Severn Sound Regional Unit. Although the concentration was below the Lowest Effect Level (LEL) and not likely a threat to sediment dwelling organisms, an exceedance of the NEL does indicate a potential risk of bioaccumulation in the food chain.

Sediment quality is a source of moderate stress in the Parry Sound to Cognashene Regional Unit as two PAHs (Indeno(1,2,3-c,d)pyrene and Benzo(k)fluoranthene) were detected at concentrations above the LEL.

In all other Regional Units, no contaminants were detected at levels of concern and sediment quality is a source of low stress.

Seven Regional Units have no provincial monitoring stations and sediment quality could not be assessed.

Table 3. Exceedance of guidelines for the sediment quality measure in each Regional Unit.

Regional Unit Name	Score	Exceedance
St. Mary's River	No Data	no ambient sampling within Regional Unit
North Channel	High Stress	1 metal found above the Severe Effect Level
North Manitoulin Island	High Stress	1 metal found above the Severe Effect Level
Cockburn Island	No Data	no sampling stations within Regional Unit
South Manitoulin Island	Low Stress	no contaminants found in excess of guidelines
Killarney	No Data	no sampling stations within Regional Unit
French River to Parry Sound	High Stress	1 metal found above the Severe Effect Level
Parry Sound	High Stress	1 metal found above the Severe Effect Level
Parry Sound to Cognashene	Moderate Stress	metals and PAHs found at levels above guidelines
Severn Sound	High Stress	metals and PCBs found at levels above guidelines
Christian Island	No Data	no sampling stations within Regional Unit
Wasaga Beach	Low Stress	no contaminants found in excess of guidelines
Collingwood to Meaford	Low Stress	no contaminants found in excess of guidelines
Owen Sound	Low Stress	metals found in sediment but not at levels of concern
Colpoy's Bay	Low Stress	metals found in sediment but not at levels of concern
Cape Croker to Cabot Head	No Data	no sampling stations within Regional Unit
Cabot Head to Burnt Point	No Data	no sampling stations within Regional Unit
Fathom Five	Low Stress	metals found in sediment but not at levels of concern
Cape Hurd to Chiefs Point	Low Stress	metals found in sediment but not at levels of concern
Chiefs Point to Point Clark	Low Stress	no contaminants found in excess of guidelines
Point Clark to Goderich	Low Stress	no contaminants found in excess of guidelines
Goderich to Kettle Point	Low Stress	metals found in sediment but not at levels of concern
Kettle Point to St. Clair River	No Data	no sampling stations within Regional Unit

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 Environment and Climate Change Canada (2010-2014).

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 Huron, benthic community quality varies (Table 4).

In the St. Marys River, Killarney and Cape Croker to Cabot Head Regional Units, the benthic community score indicates high stress as the relative condition of benthic invertebrate communities was low. Sites in the St. Marys River exhibited the lowest taxon richness and evenness and the overall quality of sites was the lowest of all Regional Units.

On the other end of the quality spectrum, the Parry Sound and Colpoy's Bay Regional Units were assessed as being in the top percentile of the range of quality across all sites and sites in Parry Sound had the highest total benthos, richness and evenness.

The North Channel, North Manitoulin Island, French River to Parry Sound, Parry Sound to Cognashene to Wasaga Beach, Owen Sound, Cape Hurd to Chiefs Point and Goderich to Kettle Point Regional Units were assessed as having relatively moderate benthic community quality. With the exception of the site in the Goderich to Kettle Point Regional Unit, which had the second highest total benthos, benthic invertebrate communities at these sites had, generally, low total benthos.

In eight Regional Units there are no monitoring sites and benthic community quality could not be assessed.

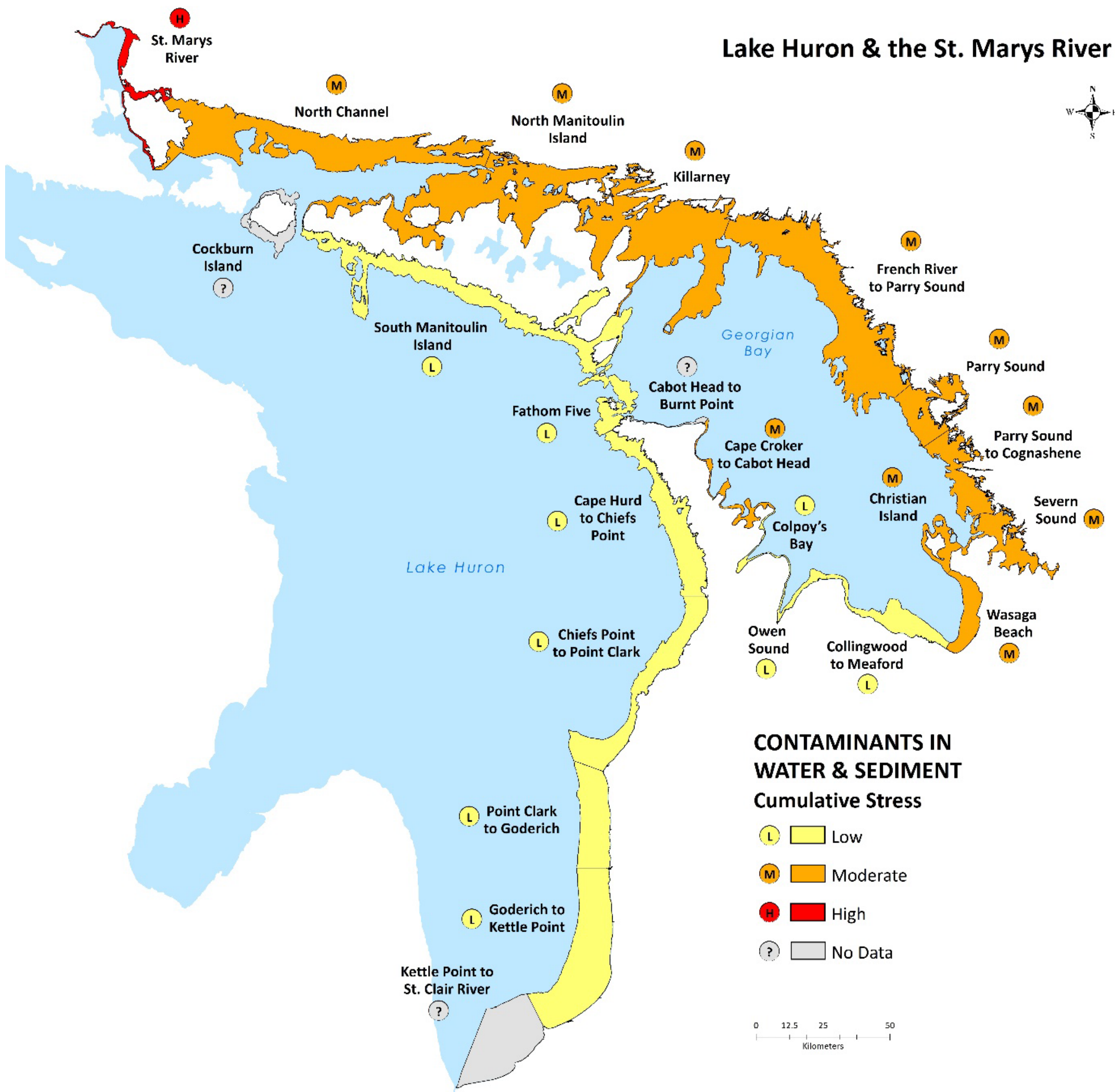
See Appendix A for details on the statistical analysis used to assess Benthic Community.

Table 4. Benthic community quality for Regional Units for ECCC stations, using 2010-2014 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**
St. Marys River	8	High stress	Lowest taxon richness & evenness; taxonomically distinct
North Channel	26	Moderate stress	Low total benthos & richness; high evenness
North Manitoulin Island	12	Moderate stress	Low total benthos & richness
Cockburn Island	0	Data gap	
South Manitoulin Island	0	Data gap	
Killarney	4	High stress	Low total benthos & richness
French River to Parry Sound	4	Moderate stress	Moderate total benthos; high richness & evenness
Parry Sound	2	Low stress	Highest total benthos, richness & evenness
Parry Sound to Cognashene	3	Moderate stress	Low total benthos
Severn Sound	14	Moderate stress	Low total benthos & taxon richness
Christian Island	1	Moderate stress	Moderate total benthos; high richness & evenness
Wasaga Beach	1	Moderate stress	Lowest total benthos
Collingwood to Meaford	0	Data gap	
Owen Sound	3	Moderate stress	High total benthos; low evenness; taxonomically distinct

Colpoy's Bay	1	Low stress	Moderate total benthos & richness; high evenness
Cape Croker to Cabot Head	3	High stress	Low total benthos & taxon richness; taxonomically distinct
Cabot Head to Burnt Point	0	Data gap	
Fathom Five	0	Data gap	
Cape Hurd to Chiefs Point	2	Moderate stress	Moderate total benthos; high richness
Chiefs Point to Point Clark	0	Data gap	
Point Clark to Goderich	0	Data gap	
Goderich to Kettle Point	0	Moderate stress	High total benthos; low evenness
Kettle Point to St. Clair River	0	Data gap	

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



	St. Marys River	North Channel	North Manitoulin Island	Cockburn Island	South Manitoulin Island	Killarney	French River to Parry Sound	Parry Sound	Parry Sound to Cognashene	Severn Sound	Christian Island
Sediment Quality	No Data	Ni > SEL; 5 metals > LEL	Ni > SEL; 7 metals > LEL	No Data	0 exc.	No Data	Ni > SEL; 8 metals > LEL	Mn > SEL; Pb > PEL; 8 metals > LEL	Pb > PEL; 2 PAHs > LEL; 7 metals > LEL	Mn & Fe > SEL; PCBs > NEL; 8 metals > LEL	No Data
Water Quality	No Data	1 exc.	0 exc.	0 exc.	0 exc.	0 exc.	0 exc.	0 exc.	No Data	0 exc.	0 exc.
Benthic Community	Poor Quality	Mod. Quality	Mod. Quality	No Data	No Data	Poor Quality	Mod. Quality	Good Quality	Mod. Quality	Mod. Quality	Mod. Quality

	Wasaga Beach	Collingwood to Meaford	Owen Sound	Colpoy's Bay	Cape Croker to Cabot Head	Cabot Head to Burnt Point	Fathom Five	Cape Hurd to Chiefs Point	Chiefs Point to Point Clark	Point Clark to Goderich	Goderich to Kettle Point	Kettle Point to St. Clair River
Sediment Quality	0 exc.	0 exc.	5 metals > LEL	1 metal > LEL	No Data	No Data	1 metal > LEL	2 metals > LEL	0 exc.	0 exc.	1 metal > LEL	No Data
Water Quality	No Data	0 exc.	0 exc.	No Data	0 exc.	0 exc.	0 exc.	0 exc.	0 exc.	0 exc.	0 exc.	No Data
Benthic Community	Mod. Quality	No Data	Mod. Quality	Good Quality	Poor Quality	No Data	No Data	Mod. Quality	No Data	No Data	Mod. Quality	No Data

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).

Cyanobacteria is a concern to human and ecosystem health and a source of high stress in the Cabot Head to Burnt Point, Chiefs Point to Point Clark, Point Clark to Goderich and Kettle Point to St. Clair River Regional Units. In these areas, cyanobacteria was detected in one seven-day satellite composite. Further in-lake sampling is needed to determine if the bacteria is actively producing toxins.

Episodic blooms are known to occur in some nearshore areas and enclosed embayments, for example in Sturgeon Bay, Deep Cove and in parts of the North Channel, leading to notices issued by local Public Health Units advising against using the water for household use or recreation. In some large embayments in eastern Georgian Bay cyanobacteria was detected, however due to the size of these Regional Units the extent did not exceed 2% of the surface area.

Cladophora

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

Thresholds developed using best professional judgement using 2016-2019 satellite-derived Submerged Aquatic Vegetation (SAV) Mapping from Michigan Tech Research Institute (MTRI).

Nuisance algae has been reported washing ashore in portions of Lake Huron, decomposing into black odourous mats. These can pose a threat to wildlife and human health, as *E.coli* and type e.botulism have been reported amongst algae mats. Nuisance algae can impact industrial processes through clogging water intakes, and smothering the lake bottom impacting fish habitat.

Nuisance algae can be composed of multiple types; in Lake Huron, it is primarily composed of *Cladophora* and *Chara. Cladophora* is a filamentous green algae that grows on hard substrate in the nearshore at depths to approximately 20 m (with adequate water clarity). Chara, a macroscopic algae with a branchlike structure, typically grows along the lake bed at depths of two to three metres. While neither produce toxins, they can both contribute to nuisance conditions in the nearshore. Quantification of nuisance algae growth along the lakebed is at a whole lake scale using satellite imagery that cannot distinguish between types of submerged aquatic vegetation (SAV).

Satellite estimates of SAV were available for the entire lake, however the results could not be verified in any area outside of the south east shore of the main basin, from Tobermory to the St. Clair River. Therefore, the *Cladophora* measure was not assessed in the North Channel and Georgian Bay.

In the five Regional Units where *Cladophora* was assessed, nuisance algae was a source of moderate to high stress. Along the stretch of shoreline from Tobermory to the St. Clair River, nuisance algae has been a known issue for many years. In particular, nuisance algae has been observed where there are local nutrient inputs such as the mouths of drains and streams. The highest extent was in the Kettle Point to St. Clair River Regional Unit with SAV covering 38% of the lake bottom visible to the satellite.

This measure does not apply to Regional Units that are embayments characterized by coastal wetlands (Severn Sound) nor connecting channels (St. Marys River).

Figure 8. Results of the Nuisance & Harmful Algae category (N/A: the measure does not apply in the Regional Unit; 'unable to verify': there was satellite data for the measure, but the results could not be verified through expert consultation or ground-truthing).

	St. Marys River	North Channel	North Manitoulin Island	Cockburn Island	South Manitoulin Island	Killarney	French River to Parry Sound	Parry Sound	Parry Sound to Cognashene	Severn Sound	Christian Island	Wasaga Beach	Collingwood to Meaford	Owen Sound	Colpoy's Bay	Cape Croker to Cabot Head	Cabot Head to Burnt Point	Fathom Five	Cape Hurd to Chiefs Point	Chiefs Point to Point Clark	Point Clark to Goderich	Goderich to Kettle Point	Kettle Point to St. Clair River
Cyanobacteria	<2%	<2%	<2%	<2%	<2%	<2%	<2%	<2%	<2%	<2%	<2%	<2%	<2%	<2%	<2%	<2%	3%	<2%	<2%	4%	4%	<2%	5%
Cladophora	N/A	unable to verify	unable to verify	unable to verify	unable to verify	unable to verify	unable to verify	unable to verify	unable to verify	N/A	unable to verify	unable to verify	unable to verify	unable to verify	unable to verify	unable to verify	unable to verify	unable to verify	28%	24%	26%	34%	38%

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 Smallmouth Bass, Rainbow Trout, Lake Trout, Walleye 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 Lake Huron and Georgian Bay. In the nearshore waters of Lake Huron, fish species most targeted by commercial and recreational fishing include Lake Trout, Rainbow Trout, Yellow Perch, Smallmouth Bass and Walleye. Different fish species are targeted in different regions of the lake due to habitat and life cycle requirements. The consumption advisories considered in each Regional Unit reflect this: Walleye and Yellow Perch were included in all Regional Units; Smallmouth Bass in the North Channel and eastern Georgian Bay; and Rainbow and Lake Trout from southern Georgian Bay around Tobermory and the main basin. The Guide to Eating Ontario Fish[6] provides consumption advisories for specific class sizes and the classes most representative of fish caught and kept for consumption were used to assess this measure (see Table 5).

Across Lake Huron and Georgian Bay, fish consumption advisories represent a source of low to moderate stress (see Table 5). At nine meals per month, average consumption advisories were the least restrictive in Regional Units across southern Georgian Bay from Christian Island to Cabot Head and around Cockburn Island. Average consumption advisories were also a source of low stress in the St. Marys River and Parry Sound to Cognashene Regional Units, with eight meals per month. While average consumption guidelines are more restrictive for the remaining Regional Units, none were found to be high stress. With three meals per month, average guidelines were most restrictive in the Fathom Five Regional Unit, however data was only

[6] 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

available for Lake Trout. Lake Trout generally has the most restrictive consumption advisories of the species considered.

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, Walleye and Smallmouth Bass. In Rainbow Trout and Lake Trout advisories are a result of a combination of PCBs, dioxins/furans, Dioxin-like PCBs and mercury.

Atmospheric deposition and human activities such as mining can be a source of contaminants to Lake Huron. Natural sources of mercury can also enter the lake through surface run off and groundwater. Over the past four decades, binational government intervention and voluntary actions from industry have led to reductions in PCBs and dioxins/furans, however due to their long half-lives and ability to bioaccumulate, these chemicals can result in consumption advisories in fish and represent a risk to human health. Levels of PCBs and mercury in Lake Huron fish improved over the 1970s and 1980s, but decreases have leveled off[7]. Levels of dioxins/furans in Lake Huron fish have also improved, however local/regional concerns remain at some locations[8].

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[9].

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

(**N/A:** the species was not assessed because it is not representative of fish caught and kept for consumption in that Regional Unit; **No Data:** the fish was assessed in the Regional Unit but no consumption advisory data was available)

	Smallmouth Bass		**Rainbow Trout**		**Lake Trout**		**Walleye**		**Yellow Perch**		AVERAGE # OF MEALS/MONTH
	30-50 cm	Contaminant	40-70 cm	Contaminant	45-70 cm	Contaminant	35-60 cm	Contaminant	20-30 cm	Contaminant	
St. Marys River	5	Mercury, PCBs	N/A		N/A		7	Mercury	10	Mercury	**8**
North Channel	5	Mercury, PCBs	N/A		N/A		6	Mercury	8	Mercury	**6**
N. Manitoulin Island	5	Mercury, PCBs	N/A		N/A		8	Mercury	8	Mercury	**7**

7 Turyk ME, Bhavsar SP, Bowerman W, et al. Risks and benefits of consumption of Great Lakes fish. Environ Health Perspect. 2012;120(1):11-18. doi:10.1289/ehp.1003396

8 Gandhi et al., 2019. Dioxins in Great Lakes fish : past, present and implications for future monitoring. Chemosphere. V 222, pages 479-488

9 Ontario Ministry of the Environment, Conservation and Parks. Eating Ontario Fish (2017-18) *Contaminants in fish* Eating Ontario Fish (2017-18) | Ontario.ca

Cockburn Island	6	Mercury	N/A		N/A		No Data		12	Mercury	**9**
S. Manitoulin Island	N/A		9	Dioxin-like PCBs	2	Dioxin-like PCBs	No Data		12	Mercury	**8**
Killarney	5	Mercury	N/A		N/A		9	Mercury	7	Mercury	**7**
French River to Parry Sound	5	Mercury	N/A		N/A		5	Mercury	12	Mercury	**7**
Parry Sound	5	Mercury	N/A		N/A		5	Mercury	12	Mercury	**7**
Parry Sound to Cognashene	4	Mercury	N/A		N/A		6	Mercury	12	Mercury	**8**
Severn Sound	6	Mercury	N/A		N/A		8	Mercury	8	Mercury	**7**
Christian Island	N/A		17	Dioxins/Furans; Mercury	3	Dioxin-like PCBs	8	Mercury	8	Mercury	**9**
Wasaga Beach	N/A		17	Dioxins/Furans; Mercury	3	Dioxin-like PCBs	8	Mercury	8	Mercury	**9**
Collingwood to Meaford	N/A		17	Dioxins/Furans; Mercury	3	Dioxin-like PCBs; Mercury	8	Mercury	9	Mercury	**9**
Owen Sound	N/A		17	Dioxins/Furans; Mercury	3	Dioxin-like PCBs	8	Mercury	8	Mercury	**9**
Colpoy's Bay	N/A		17	Dioxins/Furans; Mercury	3	Dioxin-like PCBs	8	Mercury	8	Mercury	**9**
Cape Croker to Cabot Head	N/A		17	Dioxins/Furans; Mercury	4	Dioxin-like PCBs	8	Mercury	8	Mercury	**9**
Cabot Head to Burnt Point	N/A		No Data		5	Dioxin-like PCBs	No Data		No Data		**5**
Fathom Five	N/A		No Data		3	Dioxin-like PCBs	No Data		No Data		**3**
Cape Hurd to Chiefs Point	N/A		4	Dioxin-like PCBs	2	Dioxin-like PCBs	9	Mercury	8	Mercury	**6**
Chiefs Point to Point Clark	N/A		4	Dioxin-like PCBs	2	Dioxin-like PCBs	9	Mercury	8	Mercury	**6**
Point Clark to Goderich	N/A		13	PCBs; Mercury	0	Dioxin-like PCBs	8	Mercury	6	Mercury	**7**
Goderich to Kettle Point	N/A		10	PCBs; Mercury	0	Dioxin-like PCBs; Mercury	8	Mercury	6	Mercury	**6**
Kettle Point to St. Clair River	N/A		6	Dioxin-like PCBs; PCBs	1	Dioxin-like PCBs; PCBs	8	Mercury	6	Mercury	**5**

Beach Postings

Low Stress	Beaches posted 5% or less of the time during July and August 2016-2020
Moderate Stress	Beaches posted 5-20% of the time during July and August 2016-2020
High Stress	Beaches posted more than 20% of the time during July and August 2016-2020

Thresholds developed using best professional judgement using data from Swim Drink Fish Canada (2016-2020).

This assessment included information on 71 publically monitored beaches on Lake Huron (Figure 9). Overall, beach postings are a low to moderate source of stress. When all Lake Huron beaches are considered, beach water quality is generally very good, with postings for just 6.6% of days in July and August over the 5-year period.

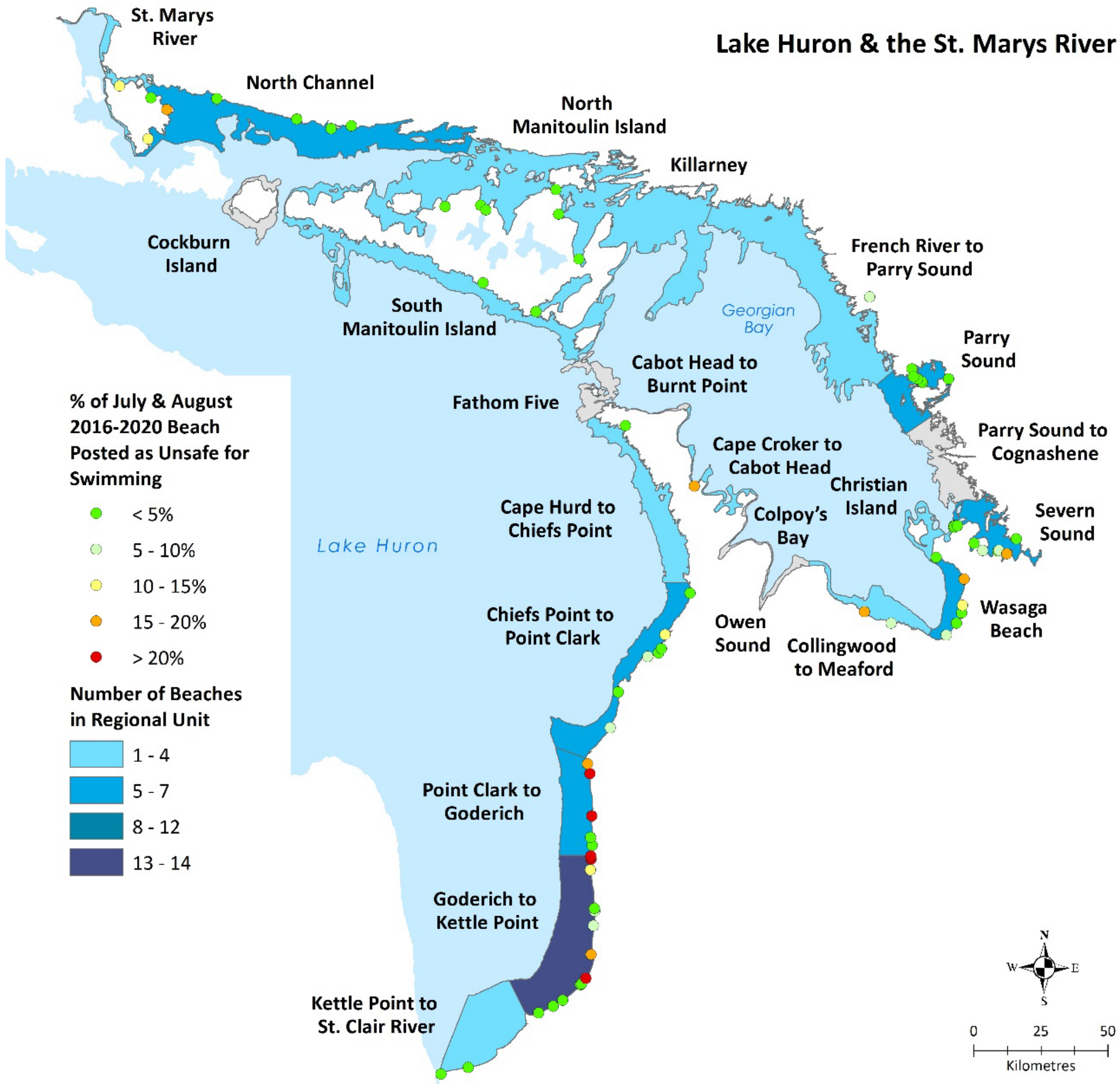
There were no beach postings in the two beaches (Sheguindah Beach and Manitowaning Beach) in the Killarney Regional Unit and the one beach (Singing Sands) in the Cape Hurd to Chiefs Point Regional Unit. In the North Manitoulin Island, South Manitoulin Island, Parry Sound and Christian Island Regional Units beach water quality is good, as beaches were posted for less than 2% of days in July and August 2016-2020.

Individual beaches with the highest average percent of time posted as unsafe for swimming are in the Point Clark to Goderich and Goderich to Kettle Point Regional Units (see Figure 9). The Goderich Main Beach was posted 31% of the time during July and August 2016 – 2020, the most of any beach on Lake Huron. The Goderich to Kettle Point Regional Unit has 14 publically monitored beaches, the most of all Regional Units.

The Cape Croker to Cabot Head Regional Unit had postings for 19% of days – the highest of all Regional Units – with the one beach (Lion's Head) posted as unsafe for swimming 100% of the time in July 2018.

The measure does not apply in the Cockburn Island, Parry Sound to Cognashene, Owen Sound, Colpoy's Bay, Cabot Head to Burnt Point or Fathom Five Regional Units as there are no publically monitored beaches.

Figure 9. The number of publically monitored beaches in each Regional Unit and the percent of time each beach was posted as unsafe for swimming in the 2016-2020 season.



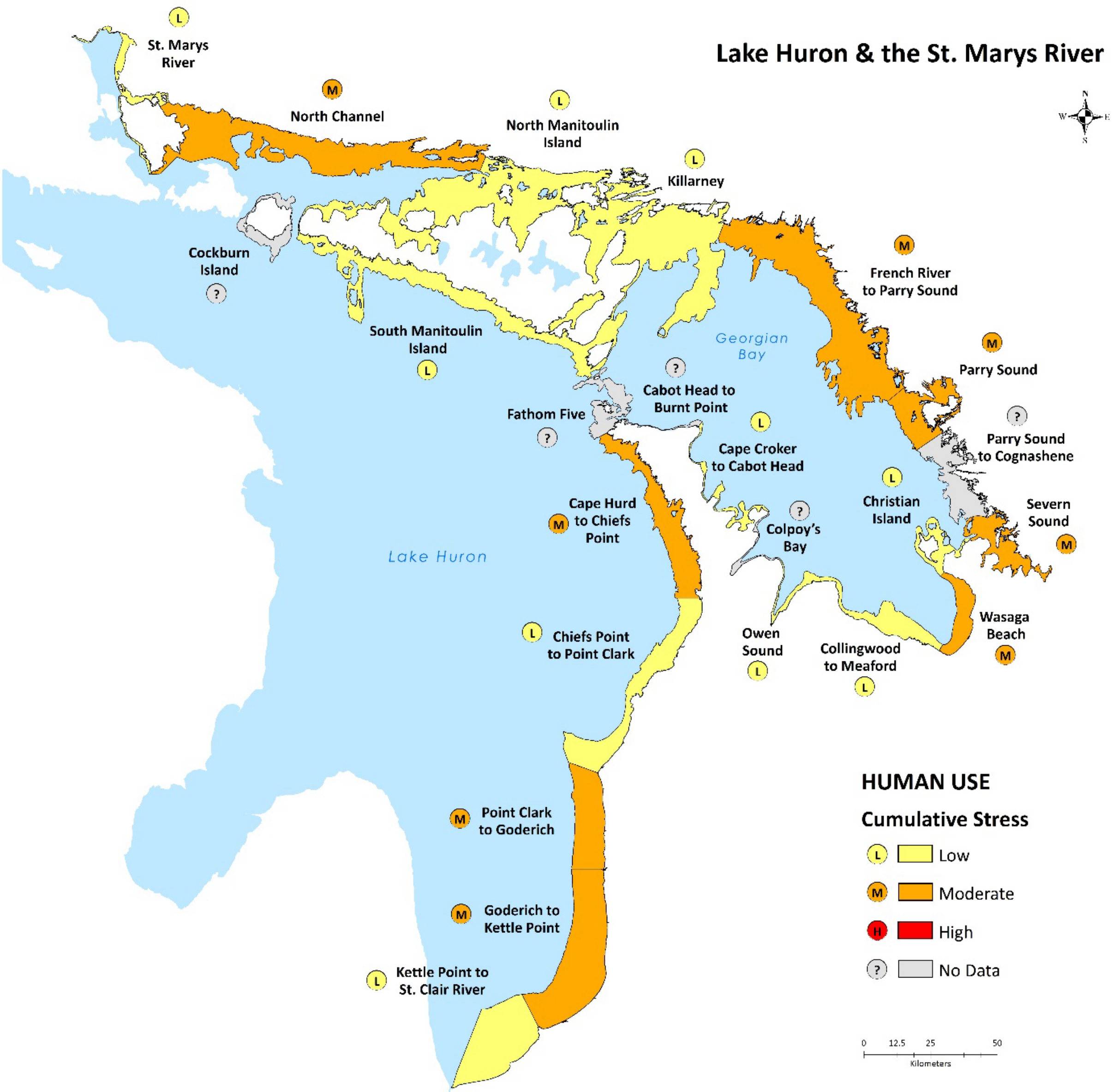
Treated Drinking Water Quality

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 using data from the Ontario Ministry of Environment, Conservation and Parks (2015-2020).

None of the municipal water treatment plants in Lake Huron's Regional Units had adverse water quality incidents (AWQIs) during the years 2015-2020. There are no water treatment plants in the Cockburn Island, French River to Parry Sound, Parry Sound, Parry Sound to Cognashene, Christian Island, Wasaga Beach, Colpoy's Bay, Cabot Head to Burnt Point, Fathom Five, Cape Hurd to Chiefs Point and Point Clark to Goderich Regional Units.

Figure 10. Results of the Human Use category (N/A: the measure does not apply in the Regional Unit).



	St. Marys River	North Channel	North Manitoulin Island	Cockburn Island	South Manitoulin Island	Killarney	French River to Parry Sound	Parry Sound	Parry Sound to Cognashene	Severn Sound	Christian Island	Wasaga Beach	Collingwood to Meaford	Owen Sound	Colpoy's Bay	Cape Croker to Cabot Head	Cabot Head to Burnt Point	Fathom Five	Cape Hurd to Chiefs Point	Chiefs Point to Point Clark	Point Clark to Goderich	Goderich to Kettle Point	Kettle Point to St. Clair River
Treated Drinking Water	0 AWQI	0 AWQI	0 AWQI	N/A	0 AWQI	0 AWQI	N/A	N/A	N/A	0 AWQI	N/A	N/A	0 AWQI	0 AWQI	N/A	0 AWQI	N/A	N/A	N/A	0 AWQI	N/A	0 AWQI	0 AWQI
Fish Consumption	8	6	7	9	8	7	7	7	8	7	9	9	9	9	9	9	5	3	6	6	7	6	5
Beach Postings	13%	5%	1%	N/A	2%	0%	6%	<1%	N/A	7%	1%	7%	13%	N/A	N/A	19%	N/A	N/A	0%	4%	14%	11%	3%

Data Gaps and Limitations in Nearshore Science

Data used in the assessment is obtained from existing monitoring programs, from a range of partners, and varies in type, format, resolution, study design and intended use of the data. 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 Huron 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. 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.

Coastal Processes

The 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 often used for federal monitoring programs 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 are limited data available to assess contaminants in water and sediment at a scale that is regionally appropriate and offers coverage at the lake scale (see Figure 11 and Table 6). 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 well understood. Only a subset of thresholds have been established for safety for PFAS and limited analysis methods have been developed. In addition, concentrations may be so low as to avoid detection with existing laboratory equipment.

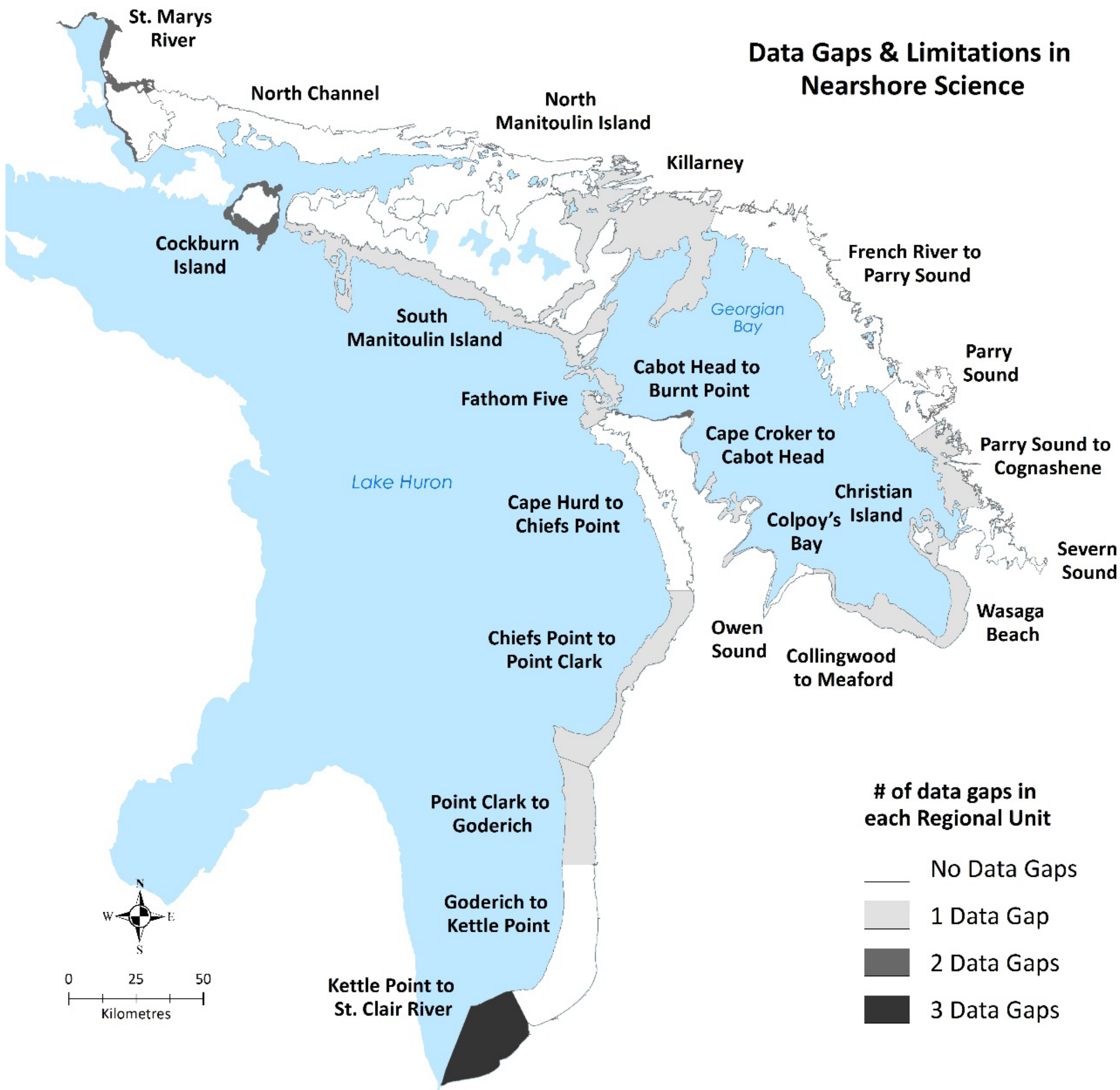
Increased sampling effort at existing long-term monitoring stations would improve results for all of the contaminant measures. Not only would more sites benefit the assessment by adding spatial coverage, but continuing to ensure that site selection occurs in areas where depositional sediment exists may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

Table 6. In Lake Huron, data gaps are associated with the Contaminants in Water & Sediment category.

	Sediment Quality (MECP Great Lakes Nearshore Sediment Chemistry, 2009, 2011, 2015)	**Benthic Community** (ECCC Great Lakes Reference and AOC Sites, 2010-2014)	**Water Quality** (ECCC Great Lakes Water Quality Monitoring and Surveillance Data, 2015-2018)
St. Marys River	Sampling station exists but only available data is related to nutrients, so unable to assess		No sampling station
Cockburn Island	No sampling station	No sampling station	
South Manitoulin Island		No sampling station	
Killarney	No sampling station		
Parry Sound to Cognashene			No sampling station
Christian Island	No sampling station		
Wasaga Beach			No sampling station
Collingwood to Meaford		No sampling station	
Colpoy's Bay			No sampling station

Cape Croker to Cabot Head	No sampling station		
Cabot Head to Burnt Point	No sampling station	No sampling station	
Fathom Five		No sampling station	
Chiefs Point to Point Clark		No sampling station	
Point Clark to Goderich		No sampling station	
Kettle Point to St. Clair River	No sampling station	No sampling station	No sampling station

Figure 11. In Lake Huron, data gaps are associated with the Sediment Quality, Water Quality and Benthic Community measures.



Nuisance and Harmful Algae

The satellite derived Cyanobacteria Index data produced by NOAA was only available for one year (2019) at the time of the assessment. The inclusion of additional years of data would be more reflective of varying climatic factors which can contribute to bloom formation. It is possible that with inter-annual variation in precipitation and temperature blooms could develop in different areas of the nearshore. Considering five years of data could potentially flag incidents of blooms in Regional Units currently assessed to be bloom free. Furthermore where blooms were detected in the satellite imagery there was no corresponding in lake sampling to confirm whether or not the bloom was actively producing toxins. In situ sampling of the bloom would help to better characterize the actual risk to human health.

The satellite-derived mapping product from MTRI used to assess the *Cladophora* measure has spatial coverage for all of Lake Huron. This product uses Landsat 8 satellite composite images from the vegetative growing seasons in 2016 to 2019 in order to classify submerged aquatic vegetation (SAV) in the optically visible portion of the lake. The algorithm used to classify SAV was developed for the lower lakes (Lake Erie and Lake Ontario) and may need to be tuned for the upper lakes (Lake Huron and Lake Superior). In Lake Huron, the results show high extents of SAV in areas where nuisance algae is not currently a known issue (e.g. southern Georgian Bay). There is not currently any in lake sampling data to ground-truth these satellite results. The only area where results could be verified is the south-east shore of the main basin, from Tobermory to the St. Clair River. As such, the *Cladophora* measure was only assessed in five Regional Units.

To verify results elsewhere in Lake Huron, a better understanding of how the optical properties of the lake may be influencing reflectance values is required. For example, being able to differentiate between seasonal variations in algae (including benthic diatoms), the outer limit of the classification (i.e. depth) and detrital deposition would facilitate greater confidence in interpreting the results. Local observations, photographs or other such reports of nuisance algae as well as in-situ sampling and benthic monitoring would help to better characterize this measure.

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 entire 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 Huron’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 from this assessment will be included in the 2022-2026 Lake Huron 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

Huron 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 data for L. Huron Nearshore Framework

Lee Grapentine, Research Scientist, WHERD, WSTD

18 June 2021

A. Benthos data from Environment and Climate Change Canada (ECCC)

Available soft-bottom data for years 2010-2014 from the St. Marys River and Spanish Harbour AOCs and reference sites in Lake Huron were subsetted from the master data file 'AOCs & ref sites benthos (F, LL)+habitat data.xlsx'. (In this document, the terms “site” and “station” are used interchangeably.) These data were collected during multiple surveys of benthic conditions in the Great Lakes to support GLAP-funded assessments of conditions in the 2 AOCs.

The data are on habitat conditions (67 variables) and benthic macroinvertebrate densities identified to the lowest level (LL) possible (297 taxa). Benthos data are densities (number per m^2) for taxa identified to the lowest level possible. Sites were assigned to Nearshore Framework Regional Units (RU) by J. Sherwood. The offshore boundary for the units is at 30 m depth. Sieve mesh size for sample processing was 0.250 mm. In Table 1 the numbers of most recently visited ECCC sites in each Regional Unit and year sampled are tallied.

Table 7. Number of ECCC Sites in Lake Huron sampled by Regional Unit and Year (2010-14).

		Year					
RU ID	**Regional Unit Name**	**2010**	**2011**	**2012**	**2013**	**2014**	**RU Total**
LH01	St. Marys River	8	0	0	0	0	8
LH02	North Channel	0	0	19	7	0	26
LH03	North Manitoulin Island	0	0	9	1	2	12
LH04	Cockburn Island	No Data	No Data	No Data	No Data	No Data	No Data
LH05	South Manitoulin Island	No Data	No Data	No Data	No Data	No Data	No Data
LH06	Killarney	0	0	3	0	1	4
LH07	French River to Parry Sound	0	0	2	0	2	4
LH08	Parry Sound	0	1	0	0	1	2
LH09	Parry Sound to Cognashene	1	1	0	1	0	3
LH10	Severn Sound	7	2	0	0	5	14
LH11	Christian Island	0	1	0	0	0	1

LH12	Wasaga Beach	0	0	0	1	0	1
LH13	Collingwood to Meaford	No Data	No Data	No Data	No Data	No Data	No Data
LH14	Owen Sound	0	2	1	0	0	3
LH15	Colpoy's Bay	0	1	0	0	0	1
LH16	Cape Croker to Cabot Head	1	1	0	1	0	3
LH17	Cabot Head to Burnt Point	No Data	No Data	No Data	No Data	No Data	No Data
LH18	Fathom Five	No Data	No Data	No Data	No Data	No Data	No Data
LH19	Cape Hurd to Chiefs Point	0	1	1	0	0	2
LH20	Chiefs Point to Point Clark	No Data	No Data	No Data	No Data	No Data	No Data
LH21	Point Clark to Goderich	No Data	No Data	No Data	No Data	No Data	No Data
LH22	Goderich to Kettle Point	1	0	0	0	0	1
LH23	Kettle Point to St. Clair River	No Data	No Data	No Data	No Data	No Data	No Data
	Year Total	18	10	35	11	11	85

Figure 12. Map of Lake Huron Regional Units and MECP and ECCC station locations. ECCC stations in the St. Marys River and Spanish Harbour AOCs are not on the map. Map is from J. Sherwood.

Data preparation

Data for years 2010, 11, 12, 13 and 14 were used in the assessment.

- 85 sites in L. Huron (including the St. Marys River) were sampled at least once during 2010-14 from locations within one of 15 Regional Units.
- 3 sites were sampled 2x during this period; only the more recent of the 2 samples were including in the analyses.
- Taxon counts were 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 189 taxa and 85 sites.
- The number of stations per Regional Unit ranges from 0 to 26. Of the 23 units, 8 have no ECCC stations. (In this report, site=station.)
- **Data and Analysis Files:** 'Lake Huron ECCC reference and AOC site data.xlsx', sheet "LLbenth 1"; 'ECCC Huron sites analyses.mpx'

Assessment Methods

Assessing the condition or "health" 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. 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, Ontario and Superior, the data available from the ECCC GLAP projects for Lake Huron were not collected in a design that could characterize reference conditions to compare with Regional Unit conditions.

The benthic invertebrate samples were therefore quantified by 3 commonly used community descriptors:

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

While the first two descriptors are fairly 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 Regional Units based on each of these descriptors. In general, higher values for these descriptors are considered to indicate better condition of the community than lower values. 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 3 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, Regional Unit means were calculated for the descriptors before the PCA.

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 line through the origin whose angle to the x-axis is the mean of the angles for the 3 descriptor loadings in the PCA biplot. Scores for each of the 15 Regional Units were projected perpendicularly onto the quality gradient line. Positions on the line were grouped into 3 classes corresponding to poor, fair and good benthos conditions (corresponding to low, moderate, and high stress) in the Regional Units.

Data Analyses

1. Calculation of benthic community descriptors: total benthos, taxon richness, evenness.

Descriptor values were initial calculated for each of the 85 sites (Table 2). Total Benthos is given by "Sum", Taxon Richness by "S" and Evenness by "E". Also given is Shannon's Diversity (" H′ "), which is used to calculate Evenness, and Simpson's Diversity.

Table 2. Descriptive statistics of L. Huron genus-level ECCC benthos data from 2010-14. Values are for each of 85 sites (rows) from a data set with 189 taxon variables.

Summary of: 85 Locations N = 189 Variables

Number	Name	Mean	Stand.Dev.	Sum	Minimum	Maximum	S	E	H`	D
1	0612	55.846	293.206	10554.8584	0.000	3076.000	18	0.765	2.212	0.8496
2	1207	72.121	422.144	13630.8506	0.000	5367.910	24	0.734	2.333	0.8144
3	1210	23.934	155.599	4523.5200	0.000	1930.040	14	0.742	1.958	0.7723
4	1211	29.359	168.149	5548.8306	0.000	1809.410	13	0.794	2.037	0.8221
5	1213	20.743	114.593	3920.3799	0.000	1206.270	11	0.850	2.037	0.8341
6	1215	27.763	147.799	5247.2700	0.000	1568.150	16	0.807	2.238	0.8456
7	1600	24.115	119.139	4557.7207	0.000	1317.250	58	0.649	2.636	0.8662
8	1603	22.338	109.536	4221.9302	0.000	844.390	16	0.823	2.281	0.8682
9	1606	56.018	333.927	10587.4795	0.000	4329.000	44	0.648	2.452	0.8077
10	0613	52.974	374.396	10012.0498	0.000	4704.460	13	0.690	1.770	0.7318
11	0616	166.261	667.068	31423.3516	0.000	5729.790	32	0.782	2.710	0.9100
12	0701	143.604	960.663	27141.1250	0.000	7961.400	16	0.601	1.666	0.7592
13	0702	136.264	1118.740	25753.8906	0.000	13992.760	17	0.512	1.452	0.6400
14	1203	131.158	658.462	24788.8906	0.000	6513.870	23	0.740	2.320	0.8621
15	1214	60.313	336.675	11399.2480	0.000	3498.190	17	0.747	2.116	0.8307
16	1602	26.487	199.192	5006.0200	0.000	2412.550	11	0.650	1.559	0.6971
17	1605	45.315	231.986	8564.5098	0.000	2050.660	18	0.780	2.256	0.8568
18	1609	83.929	262.276	15862.5098	0.000	1568.150	28	0.911	3.035	0.9433
19	0700	246.360	1378.360	46562.1094	0.000	16646.561	26	0.707	2.303	0.8300
20	1614	27.763	145.823	5247.2500	0.000	1507.840	18	0.787	2.276	0.8495
21	1615	43.400	238.842	8202.6504	0.000	2291.920	18	0.749	2.166	0.8353
22	0615	5.333	31.920	1008.0099	0.000	371.060	16	0.726	2.012	0.8062
23	1201	12.434	54.771	2350.0107	0.000	507.110	27	0.774	2.551	0.8926
24	1206	20.104	158.845	3799.7400	0.000	2050.660	9	0.691	1.518	0.6662
25	1208	20.104	95.161	3799.7400	0.000	844.390	15	0.859	2.326	0.8768
26	1212	11.488	62.386	2171.2500	0.000	723.760	13	0.853	2.187	0.8395
27	1216	67.015	331.540	12665.8047	0.000	3196.620	28	0.734	2.444	0.8659
28	1601	20.743	106.543	3920.3804	0.000	1085.650	16	0.820	2.273	0.8559
29	1604	7.021	38.206	1326.8800	0.000	361.880	9	0.905	1.988	0.8388
30	1611	398.580	1924.982	75331.6953	0.000	23341.369	51	0.691	2.719	0.8719
31	1612	260.082	1089.582	49155.5312	0.000	10554.890	48	0.735	2.845	0.9023

32	1613	20.941	96.371	3957.9102	0.000	958.570	33	0.727	2.542	0.8832
33	0504	218.597	1637.830	41314.8125	0.000	21531.971	25	0.574	1.848	0.6993
34	0602	26.569	108.947	5021.5908	0.000	878.170	39	0.741	2.713	0.9062
35	0601	101.161	647.529	19119.3984	0.000	7539.200	20	0.665	1.992	0.7791
36	1406	76.908	318.716	14535.5693	0.000	3256.940	30	0.817	2.779	0.9043
37	1408	310.503	1026.274	58685.1602	0.000	7780.460	58	0.789	3.205	0.9372
38	1410	91.587	574.971	17309.9883	0.000	7478.890	26	0.693	2.257	0.7873
39	1412	38.932	195.698	7358.2300	0.000	1809.410	20	0.776	2.326	0.8617
40	1414	41.805	204.164	7901.0801	0.000	1869.720	17	0.824	2.336	0.8692
41	1415	104.033	635.104	19662.2285	0.000	6755.130	18	0.665	1.921	0.7986
42	1501	21.062	170.760	3980.6802	0.000	2171.290	9	0.652	1.433	0.6488
43	1502	16.275	108.575	3076.0000	0.000	1145.960	8	0.801	1.665	0.7605
44	1503	10.212	56.432	1930.0302	0.000	482.510	9	0.887	1.949	0.8340
45	1505	7.978	77.160	1507.8301	0.000	1025.330	5	0.631	1.015	0.5024
46	1507	21.381	128.039	4041.0000	0.000	1206.270	8	0.853	1.774	0.8060
47	1509	104.671	656.984	19782.8438	0.000	8564.530	32	0.665	2.304	0.7874
48	1514	336.033	1224.030	63510.2266	0.000	8323.280	37	0.786	2.838	0.9249
49	1515	28.721	198.637	5428.2100	0.000	2533.170	16	0.695	1.927	0.7430
50	2205	10.850	43.520	2050.6499	0.000	361.880	15	0.943	2.552	0.9100
51	2208	101.161	782.315	19119.3906	0.000	8262.970	18	0.522	1.509	0.6800
52	1508	100.522	444.695	18998.7422	0.000	4221.950	28	0.783	2.608	0.8917
53	1413	28.721	131.608	5428.2002	0.000	965.020	18	0.826	2.387	0.8842
54	1500	94.778	444.091	17913.0977	0.000	5066.340	37	0.745	2.689	0.8792
55	1504	2.234	15.701	422.1800	0.000	180.940	5	0.917	1.475	0.7347
56	601DB	14.360	54.638	2714.1101	0.000	422.200	15	0.963	2.607	0.9185
57	609DB	28.402	172.795	5367.8901	0.000	2110.970	16	0.749	2.077	0.7999
58	613DB	13.084	82.776	2472.8503	0.000	965.020	11	0.788	1.889	0.7841
59	67MAB	23.296	117.770	4402.8501	0.000	1025.330	18	0.801	2.314	0.8602
60	67MGI	21.700	188.562	4101.3096	0.000	2533.170	12	0.598	1.485	0.5973
61	67MSI	55.527	245.461	10494.5293	0.000	2231.600	24	0.794	2.524	0.8919
62	67MWC	22.977	125.237	4342.5605	0.000	1387.210	14	0.816	2.154	0.8383
63	67SRC03	7.340	50.193	1387.2000	0.000	603.140	8	0.813	1.690	0.7486
64	67SRC09	135.307	766.795	25572.9902	0.000	6936.070	12	0.787	1.955	0.8257
65	67SRC10	15.637	75.462	2955.3599	0.000	784.080	15	0.871	2.360	0.8721
66	67SRC11	8.935	46.936	1688.7601	0.000	422.200	11	0.882	2.115	0.8495
67	67SRC13	23.615	151.042	4463.1899	0.000	1869.720	15	0.745	2.018	0.7794
68	67SRC16	142.965	1178.901	27020.4648	0.000	15741.850	26	0.522	1.701	0.6368
69	67SRC17	25.529	139.668	4825.0601	0.000	1387.210	17	0.777	2.202	0.8372
70	67SRC26	15.956	83.319	3015.6799	0.000	904.700	14	0.849	2.239	0.8512
71	AI-1	13.084	88.863	2472.8501	0.000	844.390	7	0.816	1.587	0.7519
72	AI-2	9.254	56.769	1749.0902	0.000	542.820	8	0.854	1.777	0.7967
73	AI-3	11.807	46.502	2231.5703	0.000	361.880	19	0.914	2.693	0.9131
74	AI-4	15.956	87.178	3015.6504	0.000	965.020	15	0.815	2.208	0.8376
75	AI-5	22.019	135.567	4161.6201	0.000	1447.530	15	0.735	1.989	0.7952
76	AI-6	29.678	122.793	5609.1602	0.000	1085.650	19	0.878	2.586	0.9046
77	AI-7	28.401	155.465	5367.8701	0.000	1749.100	18	0.788	2.278	0.8370
78	EC47	51.378	554.075	9710.4893	0.000	7418.580	5	0.453	0.730	0.3826
79	EC48	54.569	546.381	10313.6191	0.000	6634.500	4	0.513	0.711	0.4671
80	EC49	145.838	1087.977	27563.3320	0.000	13208.680	9	0.686	1.507	0.7018
81	EC50	126.691	1097.849	23944.5098	0.000	11761.160	11	0.486	1.166	0.5995
82	EC51	72.121	755.878	13630.8672	0.000	10313.630	13	0.407	1.045	0.4166
83	EC52	130.201	969.791	24607.9512	0.000	9348.610	9	0.655	1.439	0.7027
84	EC53	82.971	782.846	15681.5293	0.000	10373.940	12	0.466	1.159	0.5262
85	EC54	138.179	1320.666	26115.7852	0.000	17671.891	16	0.424	1.177	0.5139

S = Richness = number of non-zero elements in row
E = Evenness = H / ln (Richness)
H = Diversity = - sum (Pi*ln(Pi)) = Shannon`s diversity index
D = Simpson`s diversity index for infinite population = 1 - sum (Pi*Pi)
where Pi = importance probability in element i (element i relativized by row total)

Benthic community descriptors are plotted in the following box plots (Figures 2-4), featuring range boxes and mean symbols. Variation among and, for 11 Regional Units within) is shown. Comparisons of among-unit variation should consider differences in the number of sites per unit because this can affect within-unit variability. Looking at the unit mean values to compare among units, LH01 is lowest in Richness and Evenness, while unit LH08 is highest in all 3 descriptors.

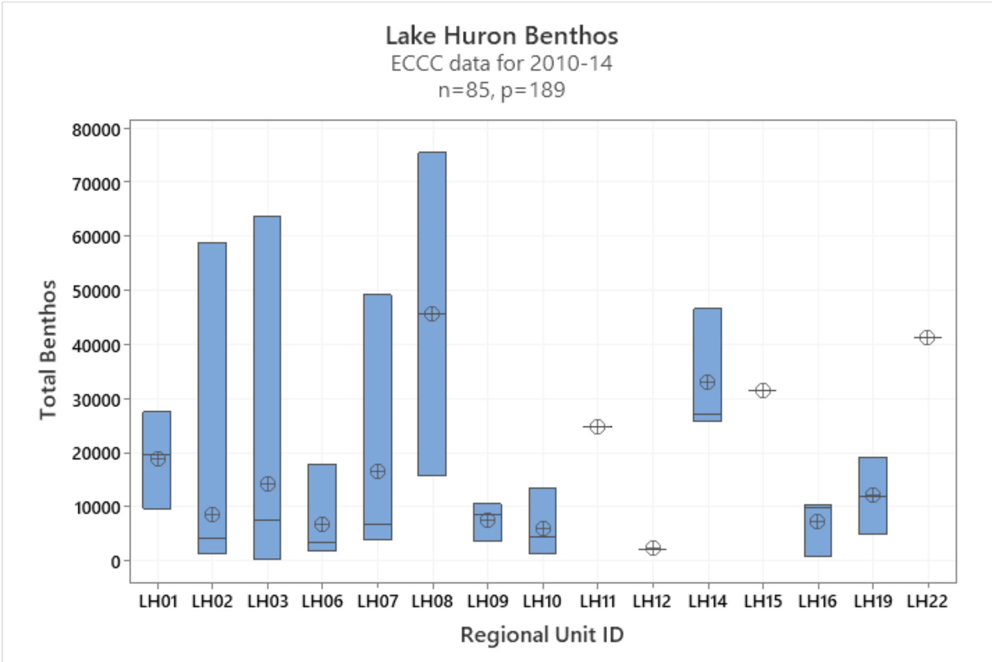


Figure 13. Mean total benthos (number per m^2) for 15 Regional Units. Box plots show range boxes, and mean symbols (circle-cross). Number of sites per Regional Unit ranged from 1 to 26.

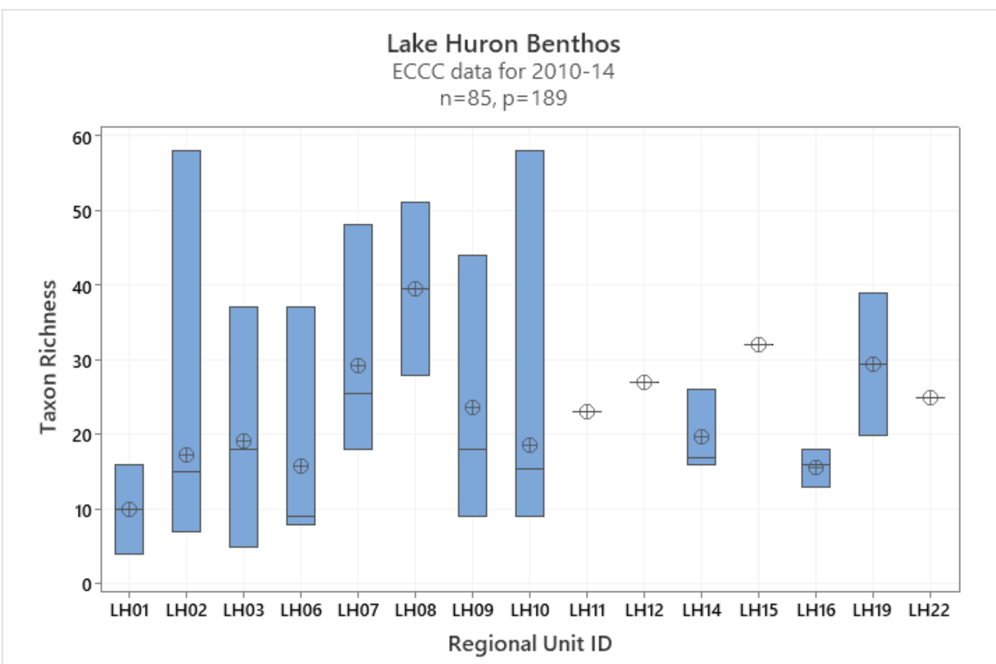


Figure 14. Mean taxon richness (number of genus-level taxa) for 15 Regional Units). Box plots show range boxes, and mean symbols (circle-cross).

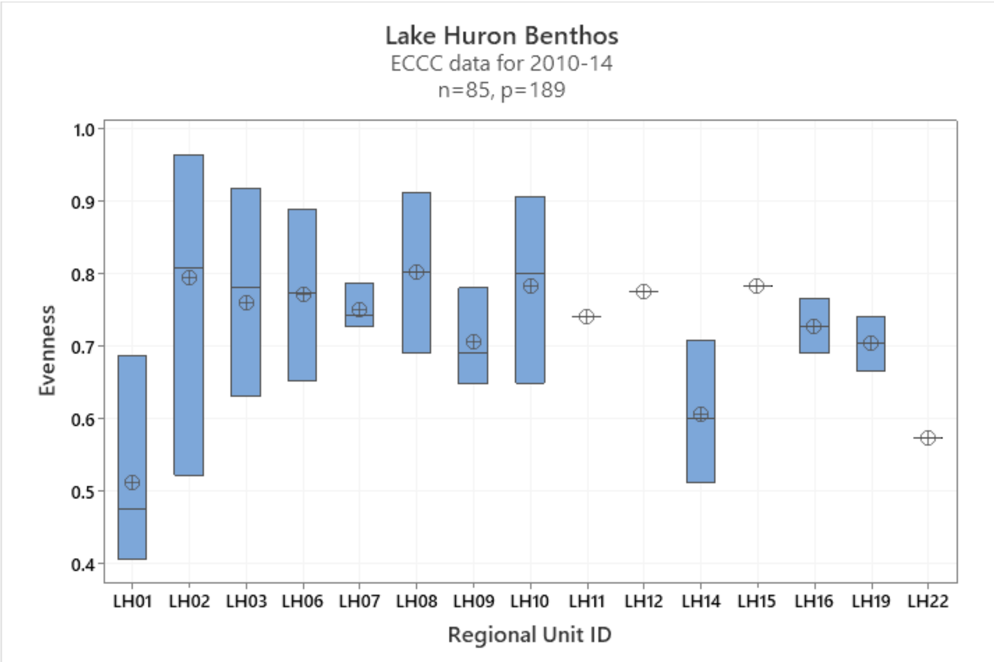


Figure 15. Mean evenness for 15 Regional Units. Box plots show range boxes, and mean symbols (circle-cross).

2. Calculation of Regional Unit means for the 3 descriptors (Table 3). This is done to account for the uneven number of stations in each Regional Unit. Units in which there are many station will influence the quality classification step more than units with few stations. Therefore the benthos descriptors were averaged by Regional Unit before conducting the PCA and quality classification.

Table 3. Benthic community descriptors for ECCC L. Huron sites. Means for Regional Units for data summed to genus, years 2010-14.

RU ID	Regional Unit Name	# of Stations	mean Total Benthos	Mean Richness	Mean Evenness
LH01	St. Marys River	8	18946	9.88	0.511
LH02	North Channel	26	8609	17.31	0.793
LH03	North Manitoulin Island	12	14279	19.17	0.760
LH04	Cockburn Island	No Data	No Data	No Data	No Data
LH05	South Manitoulin Island	No Data	No Data	No Data	No Data
LH06	Killarney	4	6725	15.75	0.771
LH07	French River to Parry Sound	4	16641	29.25	0.750

LH08	Parry Sound	2	45597	39.50	0.801
LH09	Parry Sound to Cognashene	3	7651	23.67	0.706
LH10	Severn Sound	14	5853	18.64	0.783
LH11	Christian Island	1	24789	23.00	0.740
LH12	Wasaga Beach	1	2350	27.00	0.774
LH13	Collingwood to Meaford	No Data	No Data	No Data	No Data
LH14	Owen Sound	3	33152	19.67	0.607
LH15	Colpoy's Bay	1	31423	32.00	0.782
LH16	Cape Croker to Cabot Head	3	7192	15.67	0.727
LH17	Cabot Head to Burnt Point	No Data	No Data	No Data	No Data
LH18	Fathom Five	No Data	No Data	No Data	No Data
LH19	Cape Hurd to Chiefs Point	2	12070	29.50	0.703
LH20	Chiefs Point to Point Clark	No Data	No Data	No Data	No Data
LH21	Point Clark to Goderich	No Data	No Data	No Data	No Data
LH22	Goderich to Kettle Point	1	41315	25.00	0.574
LH23	Kettle Point to St. Clair River	No Data	No Data	No Data	No Data

Total benthos and taxon richness are normally distributed by Anderson-Darling test. Evenness is not normally distributed but is not improved by log(x)-transformation.

3. Principal components analysis was conducted on the correlation matrix calculated from untransformed total benthos, taxon richness, and evenness data. This step reduces the number of dimensions describing the pattern among Regional Units to 2 from 3.

Eigenanalysis of the Correlation Matrix

Eigenvalue	1.5149	1.2878	0.1973
Proportion	0.505	0.429	0.066
Cumulative	0.505	0.934	1.000

Eigenvectors

Variable	PC1	PC2
meanTotBenth	0.588	0.564
meanRichn	0.767	-0.161
meanEvenn	0.257	-0.810

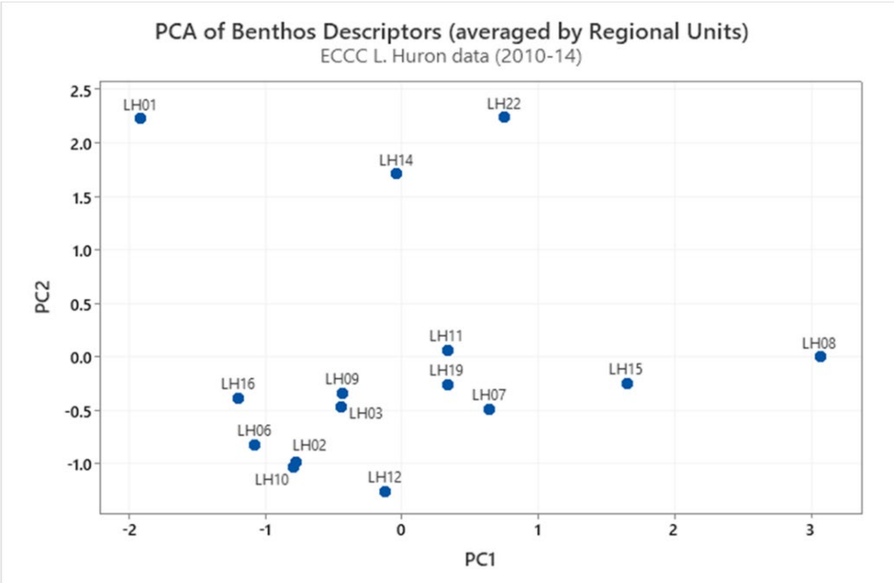


Figure 16. Scores for Regional Units from a PCA of 3 community descriptors for Lake Huron benthos.

The main results of the PCA are shown in Figures 5 and 6. Blue points on the graph are scores for the Regional Units in ordination space. The closer 2 points are to each other the more similar their benthic communities. The 2 axes explain roughly equal amounts of the total variation in the data (51 and 41% for axes 1 and 2, respectively. In Figure 6, loadings for the 3 variables analysed are shown by red lines, which mathematically extend out indefinitely from the origin in both directions. These show the directions of increase of the descriptors through the pattern of Regional Unit scores. (Unit scores and descriptor loading are the same in all the PCA figures, although loading are not shown in Figures 6 and 7.) Perpendicular projections of the scores onto each of the loadings lines (not shown) indicate relative values of the descriptor variables for the Regional Units – the further out from the origin, the higher the relative value of the variable.

4. Determination of Benthos Quality ratings

To derive a 1-dimensional gradient of benthos quality based on the 3 descriptors, a line through the origin corresponding to the direction that best represents the joint decrease/increase of the 3 descriptors was drawn. The angle from the x-axis of this benthic quality line (in green) is the mean of the angles of the 3 descriptors. *(*https://www.calculator.net/right-triangle-calculator.html was used to calculate angles from the lengths of 2 right triangle sides for each descriptor.)

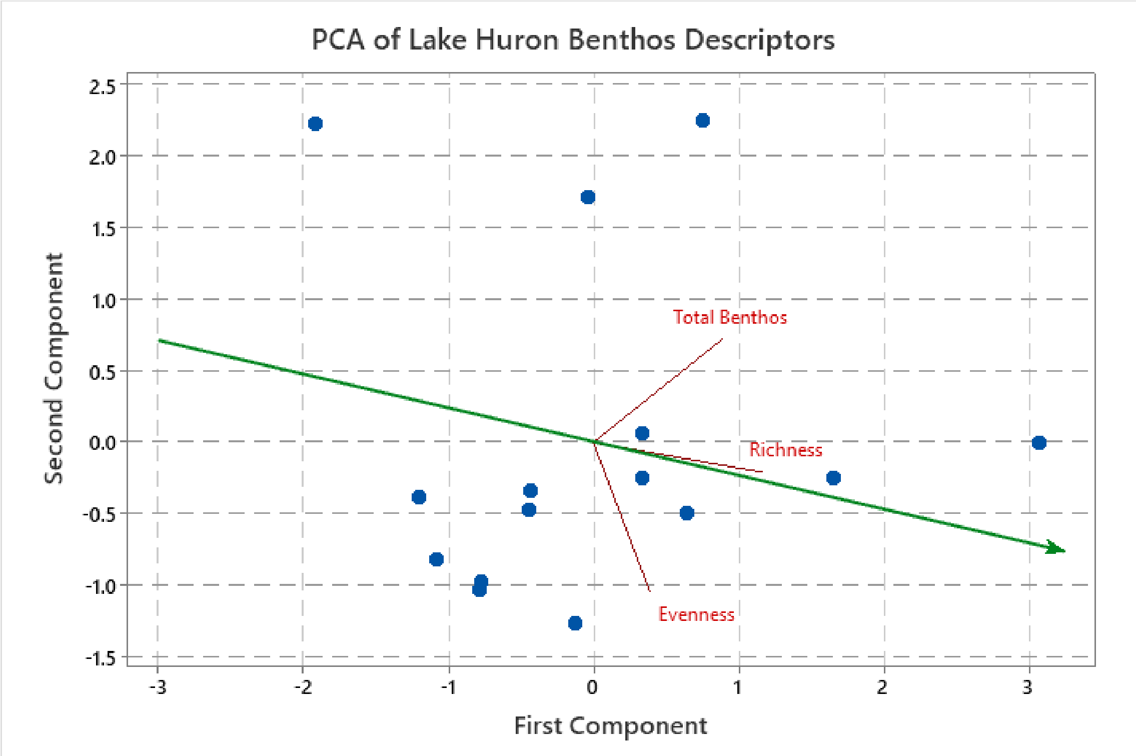


Figure 17. Biplot of Regional Unit scores (blue points) and descriptor loadings (red lines) for a PCA of benthic community descriptor (total benthos, richness, evenness) data from ECCC stations sampled in 2010-14. The station data were averaged by Regional Unit. The angle of the green gradient of quality line at 12.3° clockwise from the x-axis is the mean angle for the 3 descriptor loading lines.

Perpendicular projections of the unit scores onto the quality gradient (Figure 7) determined their relative quality. Quality classes (poor - red, fair - orange, good - green) were designated based on absolute positions of the projections on the quality line, which is divided into 3 equal lengths, marked by blue arrows, within the distance from minimum (LH01) to maximum (LH08).

Regional Unit quality classes could alternatively be determined by order of the projections onto quality gradient line, resulting in 3 groups each with 5 members. Which procedure should be used depends on assumptions about how the line represents the rate of change in benthic quality. The rank order approach seems to require the fewest assumptions, but it also reduces relative distances to ranks thereby losing quantitative information. It is noteworthy that in the middle part of the gradient there is little differences between several units.

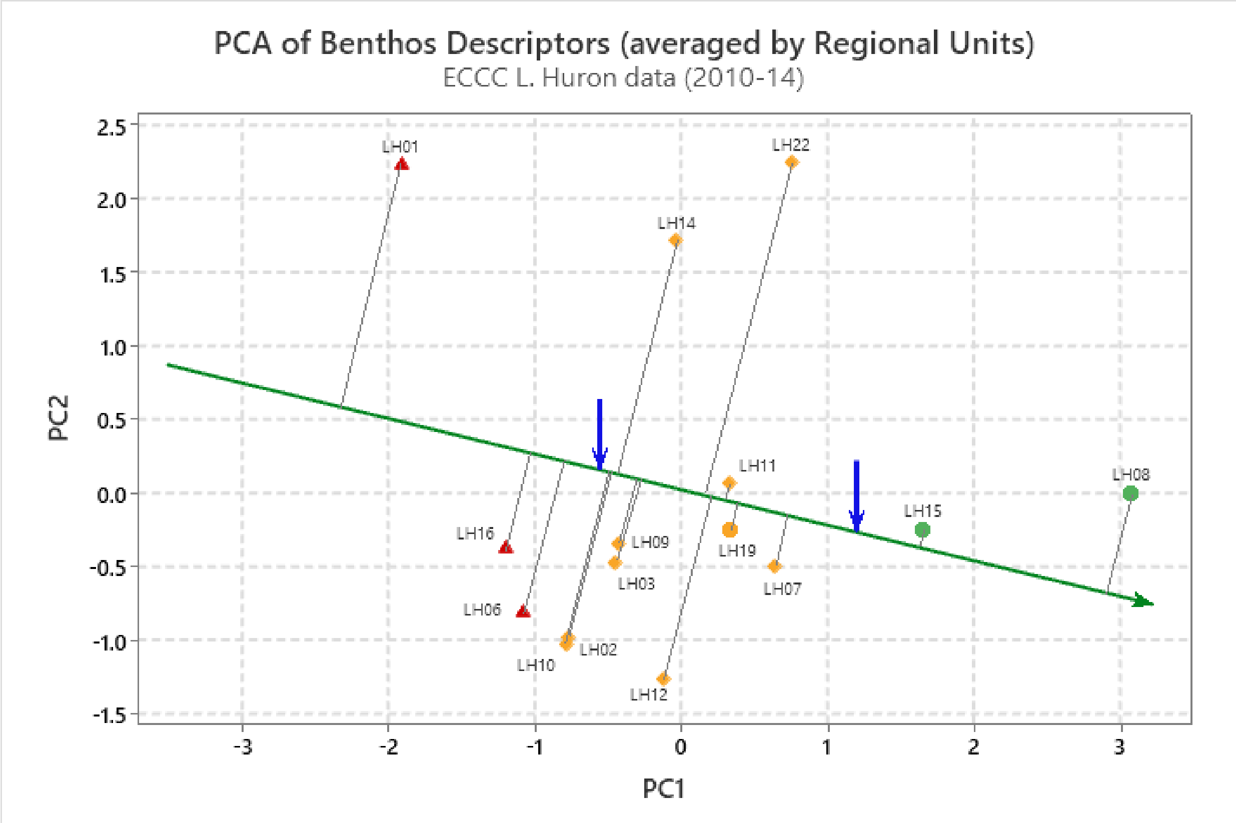


Figure 18. Benthos quality gradient (green line) and quality classes for Regional Units. Quality class is based on perpendicular projection of Regional Unit scores onto the quality line. Quality classes (poor - red, fair - orange, good - green) were designated based on absolute positions of projections on the line, which is divided into 3 equal lengths within the distance from minimum (LH01) to maximum (LH08). Regional Unit quality increases from upper left to lower right. Regional Unit scores are the same as those in Figures 5 and 6. The vertical blue arrows divide the distance from maximum to minimum position (LH01 to LH08) on the green quality gradient into equally sized thirds. (See text for discussion.)

Quality ratings for the 15 Regional Units are listed in Table 4, with comments accounting for the quality rating in terms of the 3 community descriptors and selected individual taxon densities. As with the overall quality rating, these comments are relative to the 15 Regional Units. Comments about a unit's benthos being taxonomically distinct from the benthos in the other Regional Units are supported by an examination and ordination of the genus-level taxonomic data.

Table 4. Benthic community quality of L. Huron Regional Units based on data from ECCC stations sampled in 2010-14. In general, higher quality corresponds to higher but not excessive total benthos, higher taxon richness and higher evenness.

RU ID	Regional Unit Name	No. of Stations	Stress Score	Comments

LH01	St. Marys River	8	High stress	Lowest taxon richness & evenness; taxonomically distinct
LH02	North Channel	26	Moderate stress	Low total benthos & richness; high evenness
LH03	North Manitoulin Island	12	Moderate stress	Low total benthos & richness
LH04	Cockburn Island	0	Data gap	
LH05	South Manitoulin Island	0	Data gap	
LH06	Killarney	4	High stress	Low total benthos & richness
LH07	French River to Parry Sound	4	Moderate stress	Moderate total benthos; high richness & evenness
LH08	Parry Sound	2	Low stress	Highest total benthos, richness & evenness
LH09	Parry Sound to Cognashene	3	Moderate stress	Low total benthos
LH10	Severn Sound	14	Moderate stress	Low total benthos & taxon richness
LH11	Christian Island	1	Moderate stress	Moderate total benthos; high richness & evenness
LH12	Wasaga Beach	1	Moderate stress	Lowest total benthos
LH13	Collingwood to Meaford	0	Data gap	
LH14	Owen Sound	3	Moderate stress	High total benthos; low evenness; taxonomically distinct
LH15	Colpoy's Bay	1	Low stress	Moderate total benthos & richness; high evenness
LH16	Cape Croker to Cabot Head	3	High stress	Low total benthos & taxon richness; taxonomically distinct
LH17	Cabot Head to Burnt Point	0	Data gap	
LH18	Fathom Five	0	Data gap	
LH19	Cape Hurd to Chiefs Point	2	Moderate stress	Moderate total benthos; high richness
LH20	Chiefs Point to Point Clark	0	Data gap	
LH21	Point Clark to Goderich	0	Data gap	
LH22	Goderich to Kettle Point	1	Moderate stress	High total benthos; low evenness
LH23	Kettle Point to St. Clair River	0	Data gap	

B. Benthos data from Ontario Ministry of the Environment, Conservation and Parks (MECP).

The MECP conducted benthic monitoring at 23 stations in Regional Units of L. Huron. Stations were sampled in years 1991, 95, 96, 99, 2002, 05, 09, 11, and 15. Stations sampled in 2009 were all revisited in 2015. Years of samples to include in the assessment were selected to be recent, balanced among units as much as possible, and not liable to confound spatial with temporal variability. Therefore, all samples from years 2011 and 2015, except the August samples from station 604 in 2015, were selected for analyses. All stations were sampled once per year in August or September, except station 604 which was sampled in August *and* September in 2015.

These provide data from one visit per year for 20 stations in 17 Regional Units. Means of station replicates were used for the analyses. Temporal and spatial coverage of the data are similar to those for the ECCC data, although the number of stations per Regional Unit is generally lower for the MECP compared to the ECCC data. 14 Regional Units are represented by 1 station, and 3 Units are represented by 2 stations. 6 Units had no MECP stations within their boundaries (Table 5, Figure 1).

Table 5. MEPC stations in Lake Huron Regional Units with year sampled.

RU ID	Regional Unit Name	Station(s)	Year
LH01	St. Marys River	206, 231	2011
LH02	North Channel	39	2011
LH03	North Manitoulin Island	311	2011
LH04	Cockburn Island	No Data	No Data
LH05	South Manitoulin Island	605	2015
LH06	Killarney	No Data	No Data
LH07	French River to Parry Sound	84, 616	2015
LH08	Parry Sound	615	2015
LH09	Parry Sound to Cognashene	83, 614	2015
LH10	Severn Sound	613	2015
LH11	Christian Island	No Data	No Data
LH12	Wasaga Beach	52	2015
LH13	Collingwood to Meaford	612	2015
LH14	Owen Sound	611	2015
LH15	Colpoy's Bay	610	2015
LH16	Cape Croker to Cabot Head	No Data	No Data
LH17	Cabot Head to Burnt Point	No Data	No Data
LH18	Fathom Five	132	2015
LH19	Cape Hurd to Chiefs Point	608	2015

LH20	Chiefs Point to Point Clark	607	2015
LH21	Point Clark to Goderich	604	2015
LH22	Goderich to Kettle Point	606	2015
LH23	Kettle Point to St. Clair River	No Data	No Data

Stations were sampled and handled using standard MECP methods. These include:

- collecting by Ponar grab of 5 replicate sediment samples per station,
- passing samples through a 0.600-mm mesh sieve and saving material retained on the screen for analysis, and
- identifying benthic invertebrates to lowest possible level.

The MECP and ECCC data were collected by methods that are too different to allow the two data sets to be pooled. The biggest difference is in the mesh size of the sieves used to sort invertebrates from sediment samples. MECP uses a 0.600-mm mesh, whereas ECCC uses a 0.250-mm mesh. As a result smaller organisms such as oligochaetes and some chironomids, which dominant Great Lakes sediment benthos, would not be sampled with the same efficiency.

Benthos data units are number/m^2.

Data preparation

After excerption the from the master data file 'MECP_BenthosQueryHuron.xlsx', 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 112 taxa and 20 stations.

Data and analysis files: ‘Lake Huron MECP benthos data and analyses.xlsx’; ‘MECP Huron sites analyses.mpx’

Assessment Methods

To assess conditions of benthic communities in Lake Huron Regional Units the MEPC benthos data were analysed by the same procedures as those applied to the ECCC data (above). Station means of taxon number per m^2 for all genus-level taxa (and several taxon families and orders that were not identifiable to genus) were compiled. For each station 3 community descriptors – total benthos, taxon richness, and evenness – were calculated and plotted to compare among Regional Units. To adjust for any influence of the unequal number of stations per Regional Unit, Regional Unit means were calculated for the descriptors.

A principal components analysis was then conducted on a correlation matrix calculated from the 3 descriptors. The first 2 axes of the PCA were used to construct a benthos quality gradient aligning with increasing total benthos, increasing taxon richness, and increasing evenness. The gradient line passed through the origin with an angle to the x-axis equalling the mean of the angles for the 3 descriptor loadings in the PCA biplot. Scores for each of the 17 Regional Units were projected perpendicularly onto the quality gradient line. Quality classes corresponding to poor, fair or good benthos conditions of the Regional Units were determined by positions on the line relative to 3 equally size line segments between the minimum and maximum projections on the line.

Data Analyses

1. Calculation of benthic community descriptors: total benthos, taxon richness, evenness.

Descriptor values were initial calculated for each of the 20 stations (Table 6). Total Benthos is given by "Sum", Taxon Richness by "S" and Evenness by "E". Also given is Shannon's Diversity (" H′ "), which is used to calculate Evenness, and Simpson's Diversity.

Table 6. Descriptive statistics of L. Huron genus-level MECP benthos data from 2011 and 2015. Values are for each of 20 stations (rows) from a data set with 112 taxon variables.

Summary of: 20 Locations N = 112 Variables

Number	Name	Mean	Stand.Dev.	Sum	Minimum	Maximum	S	E	H`	D
1	206	12.108	57.623	1356.1000	0.000	530.980	25	0.646	2.081	0.7907
2	231	17.088	76.810	1913.8197	0.000	511.880	21	0.647	1.969	0.8123
3	39	20.567	149.496	2303.4597	0.000	1550.920	17	0.456	1.292	0.5235
4	311	21.044	142.807	2356.9399	0.000	1451.600	16	0.485	1.345	0.5836
5	605	47.648	174.821	5336.5391	0.000	1485.980	45	0.698	2.656	0.8719
6	84	13.336	39.659	1493.6199	0.000	248.300	34	0.797	2.812	0.9128
7	616	18.077	129.094	2024.5999	0.000	1344.640	21	0.453	1.378	0.5398
8	615	39.598	282.480	4435.0190	0.000	2945.220	21	0.442	1.346	0.5408
9	83	14.632	58.123	1638.7800	0.000	359.080	26	0.687	2.238	0.8514
10	614	26.262	142.268	2941.4	0.000	1061.96	14	0.615	1.623	0.7314
11	613	4.673	20.795	523.3401	0.000	183.360	18	0.732	2.115	0.8158
12	52	32.572	138.387	3648.0999	0.000	1088.700	19	0.721	2.123	0.8313
13	612	22.818	92.727	2555.5801	0.000	660.860	15	0.790	2.140	0.8449
14	611	46.727	192.741	5233.3994	0.000	1398.120	19	0.698	2.056	0.8405
15	610	21.794	70.565	2440.9797	0.000	538.620	34	0.762	2.688	0.8983
16	132	87.996	395.787	9855.6006	0.000	3323.400	33	0.629	2.201	0.8121
17	608	34.721	116.992	3888.7600	0.000	878.600	36	0.738	2.645	0.8906
18	607	75.820	590.406	8491.8604	0.000	6203.680	17	0.401	1.135	0.4545
19	604	186.771	1204.558	20918.3223	0.000	12357.700	15	0.542	1.468	0.6230
20	606	8.527	44.957	955.0000	0.000	401.100	15	0.666	1.803	0.7451
Averages		7.64	206.100	4216.0000	0.000	1926.000	23	0.630	1.956	0.7457

Benthic community descriptor values are shown plotted in the box plots below, which show individual values and, for 3 Regional Units, range boxes (Figures 8, 9 and 10).

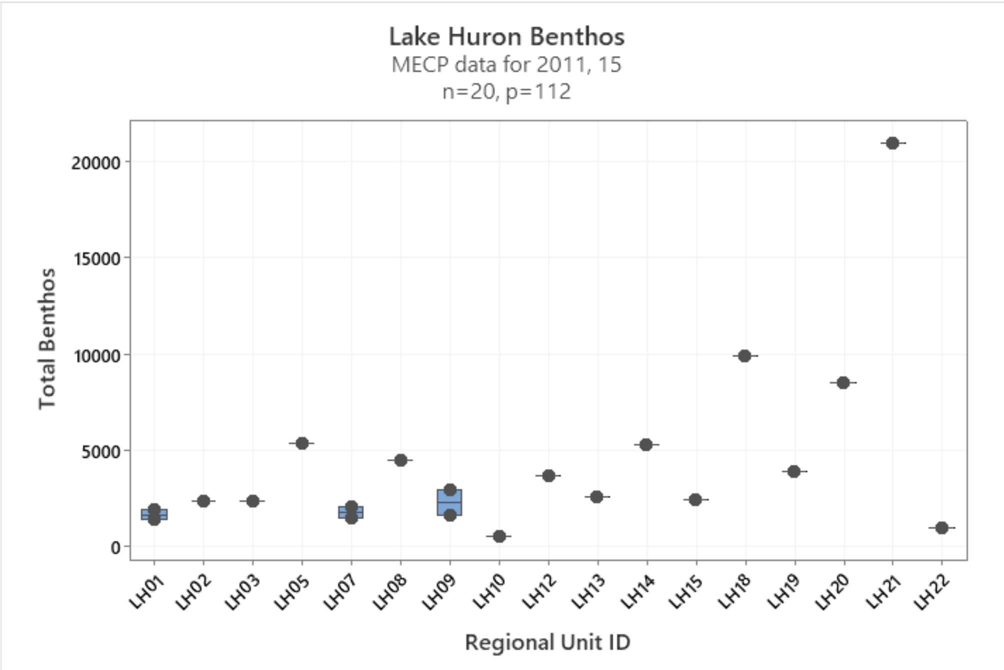


Figure 19. Total benthos (number per m^2) for 17 Regional Units. Box plots show individual values (solid circles) for 20 stations and range boxes for 3 Units having 2 stations. Number of sites per Regional Unit were 1 or 2.

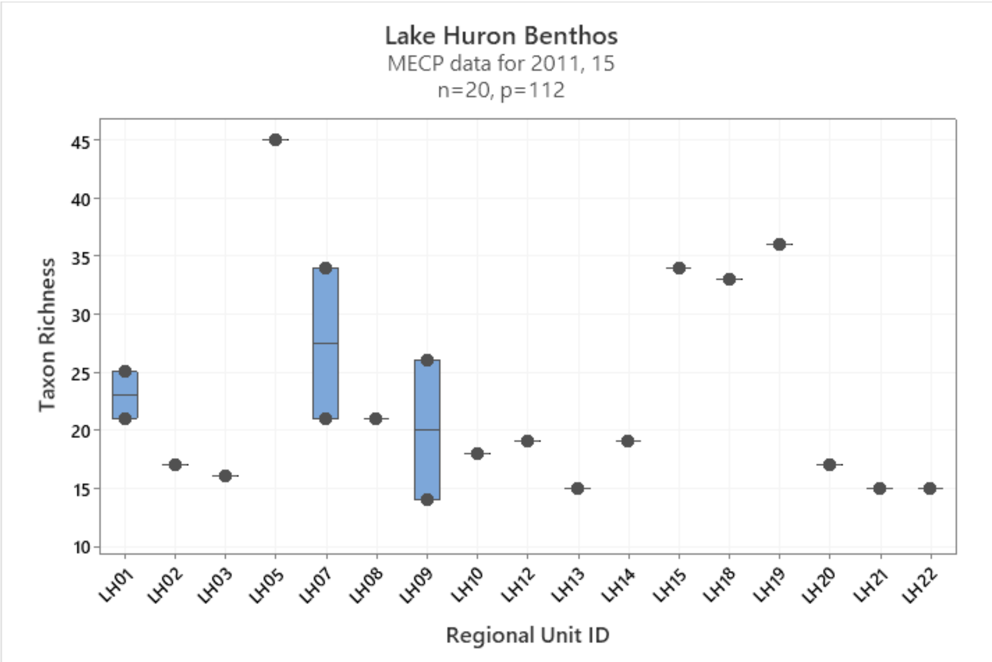


Figure 20. Taxon richness (number of genus-level taxa per m^2) for 17 Regional Units. Box plots show individual values (solid circles) for 20 stations and range boxes for 3 Units having 2 stations. Number of sites per Regional Unit were 1 or 2.

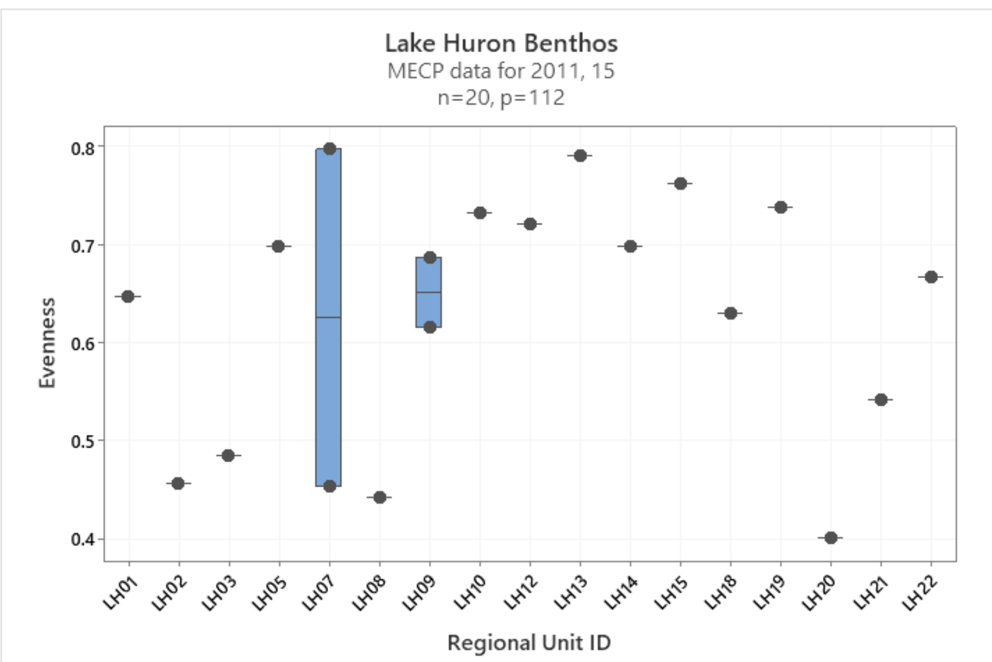


Figure 21. Evenness for 17 Regional Units. Box plots show individual values (solid circles) for 20 stations and range boxes for 3 Units having 2 stations. Number of sites per Regional Unit were 1 or 2.

2. Calculation of Regional Unit means for the 3 descriptors. This is done to account for the uneven number of stations in each Regional Unit.

Table 7. Benthic community descriptors for MECP L. Huron stations are averaged per Regional Unit for data summed to genus, years 2011 and 2015. Values for total benthos and richness were log-transformed to increase normality of the data.

RU ID	Regional Unit Name	Total Benthos	Log(Total Benthos)	Richness	logRichness	Evenness
LH01	St. Marys River	1635	3.214	23	1.362	0.647
LH02	North Channel	2303	3.362	17	1.230	0.456
LH03	North Manitoulin Island	2357	3.372	16	1.204	0.485
LH04	Cockburn Island	No Data	No Data	No Data	No Data	No Data
LH05	South Manitoulin Island	5337	3.727	45	1.653	0.698
LH06	Killarney	No Data	No Data	No Data	No Data	No Data
LH07	French River to Parry Sound	1759	3.245	27.5	1.439	0.625
LH08	Parry Sound	4435	3.647	21	1.322	0.442
LH09	Parry Sound to Cognashene	2290	3.360	20	1.301	0.651
LH10	Severn Sound	523	2.719	18	1.255	0.732
LH11	Christian Island	No Data	No Data	No Data	No Data	No Data
LH12	Wasaga Beach	3648	3,562	19	1.279	0.721
LH13	Collingwood to Meaford	2556	3.407	15	1.176	0.790
LH14	Owen Sound	5233	3.407	19	1.279	0.698
LH15	Colpoy's Bay	2441	3.388	34	1.531	0.762
LH16	Cape Croker to Cabot Head	No Data	No Data	No Data	No Data	No Data
LH17	Cabot Head to Burnt Point	No Data	No Data	No Data	No Data	No Data
LH18	Fathom Five	9856	3.99433	33	1.519	0.629
LH19	Cape Hurd to Chiefs Point	3889	3.590	36	1.556	0.738
LH20	Chiefs Point to Point Clark	8492	3.929	17	1.230	0.401
LH21	Point Clark to Goderich	20918	4.321	15	1.176	0.542
LH22	Goderich to Kettle Point	955	2.980	15	1.176	0.666
LH23	Kettle Point to St. Clair River	No Data	No Data	No Data	No Data	No Data

Total benthos and taxon richness were not normally distributed by Anderson-Darlington test. Therefore these 2 descriptors were log(x)-transformed.

3. Principal components analysis was performed on the correlation matrix calculated from log(x)-transformed total benthos, log(x)-transformed taxon richness, and untransformed evenness data.

Eigenanalysis of the Correlation Matrix

Eigenvalue	1.4140	1.1400	0.4460
Proportion	0.471	0.380	0.149
Cumulative	0.471	0.851	1.000

Eigenvectors

Variable	PC1	PC2
logTotalBenthos	-0.446	-0.721
logRichness	0.478	-0.693
Evenness2	0.756	0.012

Figure 11 shows the results of the PCA.

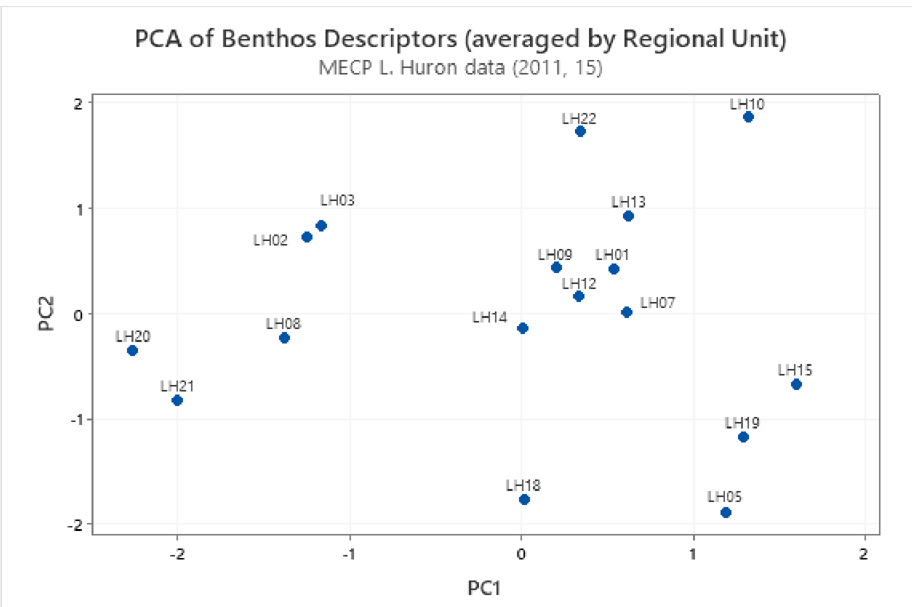


Figure 22. Scores for Regional Units from PCA of 3 community descriptors for Lake Huron benthos.

4. Determination of Benthos Quality ratings

To derive a 1-dimensional gradient of benthos quality based on the 3 descriptors, a line through the origin corresponding to the direction that best represents the joint decrease/increase of the 3 descriptors was drawn (Figure 12). The angle from the x-axis of this benthic quality line (in green) is the mean of the angles of the 3 descriptors. (https://www.calculator.net/right-triangle-calculator.html was used to calculate angles from the lengths of 2 right triangle sides for each descriptor.)

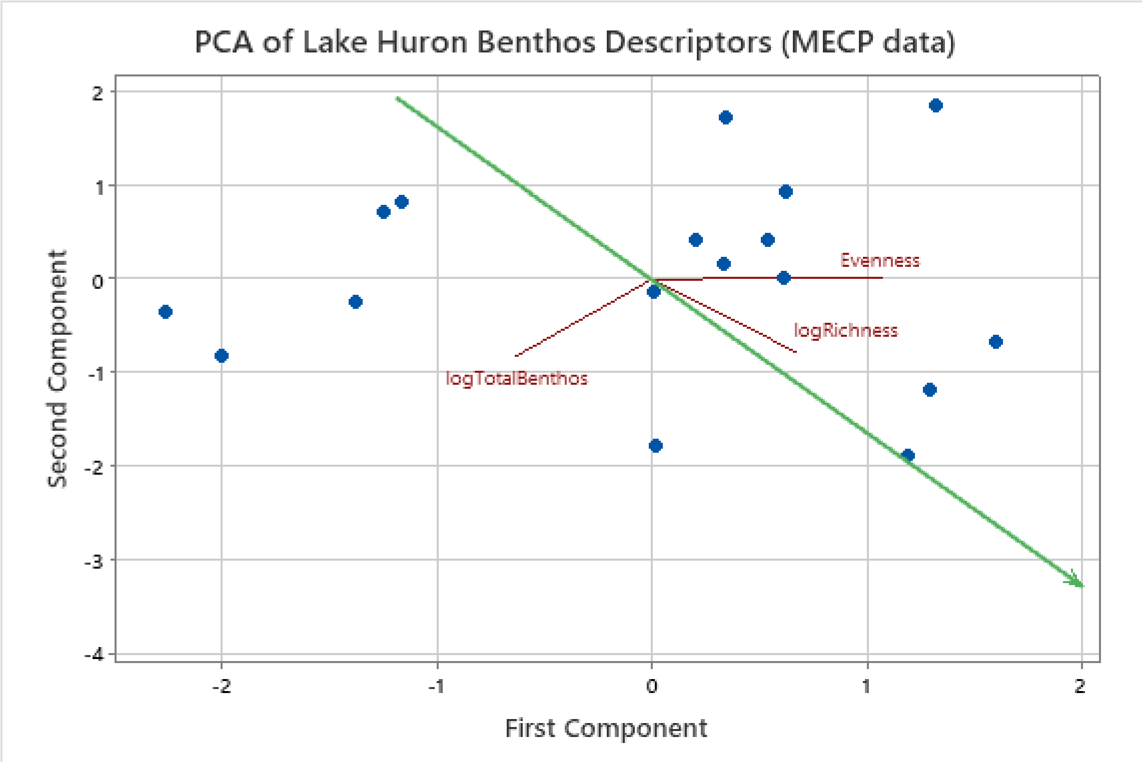


Figure 23. Biplot of Regional Unit scores (blue points) and descriptor loadings (red lines) for a PCA of benthic community descriptor (total benthos, richness, evenness) data from MECP stations sampled in 2011 and 2015. The station data were averaged by Regional Unit. The angle of the green gradient of quality line at 58.8° clockwise from the x-axis is the mean angle for the 3 descriptor loading lines.

Perpendicular projections of the unit scores onto the quality gradient (Figure 13) determined their relative quality. Quality classes (poor - red, fair - orange, good - green) were designated based on absolute positions of the projections onto the quality line, which is divided into 3 equal lengths, marked by blue arrows, within the distance from minimum (LH03) to maximum (LH05).

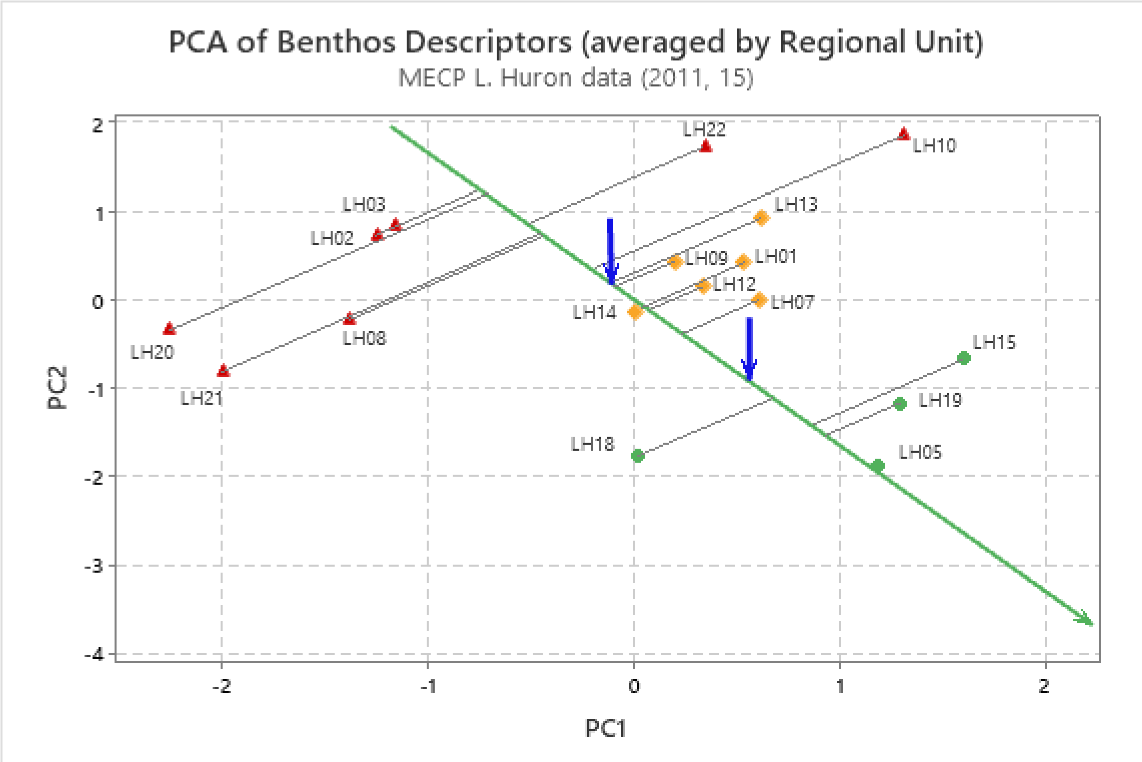


Figure 24. Benthos quality gradient (green line) and quality classes for Regional Units. Quality class is based on perpendicular projection of Regional Unit scores to the quality line. Quality classes (poor - red, fair - orange, good - green) were designated based on absolute position of projection on the line, which is divided into 3 equal lengths within the distance from minimum (LH03) to maximum (LH05), marked by blue arrows. Regional Unit quality increases from upper left to lower right. Regional Unit scores are the same as those in Figures 11 and 12. The vertical blue arrows divide the distance from maximum to minimum position (LH03 to LH05) on the green quality gradient into equally sized thirds. Note that scales of x- and y-axes are not the same.

<u>Notes re MECP results:</u>

Regional Units LH01, LH02 and LH03 were sampled in 2011; all other Units were sampled in 2015. Could sampling year be a factor in quality rating?

LH01 is in St. Marys River area. LH02 and LH03 in Spanish Harbour area. These AOCs would be expected to adversely affect quality.

Taxonomic composition of the MECP data set (not presented) suggests a spatial pattern to the distributions of poor and good quality units.

Comparisons of MECP and ECCC results should consider (a) differences in station locations, (b) differences in sampling methods (particularly sieve mesh sizes), and (c) number of stations per Regional Unit. (ECCC data are from more than 4× as many stations as the MECP data, on average).

Table 8. Benthic community quality of L. Huron Regional Units based on data from MECP stations sampled in 2011 and 2015. In general, higher quality corresponds to higher but not excessive total benthos, higher taxon richness, and higher evenness.

RU ID	Regional Unit Name	No. of Stations	Stress Score	Comments
LH01	St. Marys River	2	Moderate	Low total benthos
LH02	North Channel	1	High	Low total benthos richness, and evenness
LH03	North Manitoulin Island	1	High	Low total benthos, richness, and evenness
LH04	Cockburn Island	0	No Data	
LH05	South Manitoulin Island	1	Low	High richness; high evenness
LH06	Killarney	0	No Data	
LH07	French River to Parry Sound	2	Moderate	Low total benthos; moderate to low evenness
LH08	Parry Sound	1	High	Low evenness
LH09	Parry Sound to Cognashene	2	Moderate	Moderate to low total benthos, richness, and evenness
LH10	Severn Sound	1	High	Lowest total benthos
LH11	Christian Island	0	No Data	
LH12	Wasaga Beach	1	Moderate	Moderate total benthos, richness, and evenness
LH13	Collingwood to Meaford	1	Moderate	Low richness; highest evenness
LH14	Owen Sound	1	Moderate	High total benthos
LH15	Colpoy's Bay	1	Low	High richness and evenness
LH16	Cape Croker to Cabot Head	0	No Data	
LH17	Cabot Head to Burnt Point	0	No Data	
LH18	Fathom Five	1	Low	High total benthos and richness
LH19	Cape Hurd to Chiefs Point	1	Low	High richness and evenness
LH20	Chiefs Point to Point Clark	1	High	High total benthos; lowest richness
LH21	Point Clark to Goderich	1	High	Outlyingly high total abundance (especially for naidids and other olgiochaetes); low richness and evenness
LH22	Goderich to Kettle Point	1	High	Low total benthos and richness
LH23	Kettle Point to St. Clair River	0	No Data	