
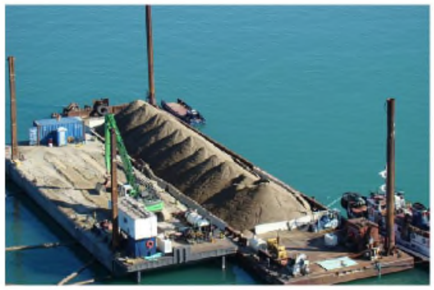


STATUS REPORT
2020

PENINSULA HARBOUR

AREA OF CONCERN

REMEDIAL ACTION PLAN

Canada

Ontario

CLEANING UP AREAS OF CONCERN

Canada and Ontario work together to restore Areas of Concern. This work relies on collaboration with conservation authorities, municipalities, First Nation communities, Métis communities, environmental groups, industry and the public. Working together, communities and governments develop and implement Remedial Action Plans.

For more information on Areas of Concern visit: https://www.canada.ca/en/environment-climate-change/services/great-lakes-protection/areas-concern.html

ACKNOWLEDGEMENTS

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RAP NORTH SHORE OF LAKE SUPERIOR REMEDIAL ACTION PLANS

The success of the Peninsular Harbour RAP has been possible through the collaborative efforts of Environment and Climate Change Canada, Ontario Ministry of the Environment, Conservation and Parks, Ontario Ministry of Natural Resources and Forestry, Town of Marathon, Métis Nation of Ontario, Pic River First Nation and Lakehead University.

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ACRONYMS AND ABBREVIATIONS

AOC	Area of Concern
BEAST	Benthic Assessment of Sediment
BOD	Biological Oxygen Demand
BUI	Beneficial Use Impairment
CLC	Community Liaison Committee
COA	Canada-Ontario Agreement on Great Lakes Water Quality and Ecosystem Health
DFO	Fisheries and Oceans Canada
ECCC	Environment and Climate Change Canada
ERA	Environmental Risk Assessment
FCIN	Fish Community Index Netting
GLWQA	Great Lakes Water Quality Agreement (between Canada and United States)
IJC	International Joint Commission
LEL	Lowest Effect Level
LTM	Long-term Monitoring
MECP	Ontario Ministry of the Environment, Conservation and Parks (formerly MOECC)
MeHg	Methyl-mercury
MNRF	Ontario Ministry of Natural Resources and Forestry
PAC	Public Advisory Committee
PCB	Polychlorinated biphenyl
PSPC	Public Services and Procurement Canada
RAP	Remedial Action Plan
RFA	Requires further assessment
SEL	Severe Effect Level
SMART	Specific, Measurable, Achievable/feasible, Realistic, and Time-bound
SWAC	Spatially Weighted Average Concentrations
TOC	Total Organic Carbon
TSS	Total Suspend Solids
WPCP	Water Pollution Control Plan

EXECUTIVE SUMMARY

The purpose of this Status Report is to summarize the remedial and monitoring activities undertaken over the history of the Peninsula Harbour Remedial Action Plan (RAP), and to present an update on the status of beneficial use impairments within the Area of Concern (AOC). The Status Report discusses what study findings are indicating about the current state of the environment, and propose Not Impaired status for beneficial use impairments (BUIs) where evidence supports improved conditions and delisting criteria having been met.

Updates to this report will continue as more information is made available to assist the assessment of remaining BUIs. This report has been reviewed by the federal and provincial researchers who led the monitoring work, and Canada and Ontario will be engaging community members and stakeholders on the results, conclusions, and proposed re-designations of certain beneficial use impairments.

Environment and Climate Change Canada (ECCC) and the Ministry of the Environment, Conservation and Parks (MECP) co-lead the RAP for the Peninsula Harbour AOC, with support from the Ministry of Natural Resources and Forestry (MNRF). Lakehead University helps with community outreach and engagement.

Peninsula Harbour is located at the Town of Marathon, Ontario on the northeastern shore of Lake Superior. It was listed as an AOC under the 1987 *Protocol to the Great Lakes Water Quality Agreement between Canada and the United States*. At the time, environmental issues were caused by the discharge of wastewater from the municipal sewage treatment plant, and the former pulp mill (closed in 2009), and its associated chlor-alkali chemical plant (closed in 1977) and log booming operations. As a result of these environmental issues, five beneficial use impairments and one problem requiring further assessment were identified for the AOC under the 1991 Stage 1 RAP report. Table 1 lists the original problems identified in that report, their status in the subsequent Stage 2 RAP report (2012), and the current status and recommended re-designations.

Table 1: Status of Beneficial Use Impairments in the Peninsula Harbour AOC.

BENEFICIAL USE IMPAIRMENT	1991 STATUS (STAGE 1 RAP)	2012 STATUS (STAGE 2 RAP)	2020 STATUS
Restrictions on Fish Consumption	Impaired	Impaired	Impaired
Degradation of Fish Populations	Impaired	RFA	Proposed for Re-designation
Fish Tumours or Other Deformities	RFA	Not Impaired	Not Impaired
Degradation of Benthos	Impaired	Impaired	Proposed for Re-designation
Restrictions on Dredging Activities	Impaired	Not Impaired	Not Impaired
Loss of Fish and Wildlife Habitat	Impaired	RFA	Proposed for Re-designation

RFA = requires further assessment

Fish Tumours or Other Deformities and *Restrictions on Dredging Activities* were officially re-designated to Not Impaired under the Stage 2 RAP report (2012) due to the following:

- *Fish Tumours or Other Deformities:* Instances of tumours or deformities in Peninsula Harbour fish had never been reported from fisheries personnel or the public since the beneficial use was identified as requiring further assessment under the Stage 1 RAP report (1991).
- *Restrictions on Dredging Activities:* No dredging operations had been undertaken in the harbour since the AOC designation in the late 1980s. Any future dredging in the area is subject to existing provincial dredging and disposal restrictions and regulations that are applied like anywhere else on the Great Lakes, and which discourage open water disposal.

Under the Stage 2 RAP report (2012) two beneficial uses remained impaired (*Restriction on Fish Consumption* and *Degradation of Benthos*), because of elevated mercury and polychlorinated biphenyls (PCBs) within AOC sediment, particularly Jellicoe Cove. Two beneficial uses that had been designated impaired were changed to requires further assessment (*Degradation of Fish Populations* and *Loss of Fish Habitat*), because monitoring was needed to confirm the belief fish communities were restored and no longer impaired.

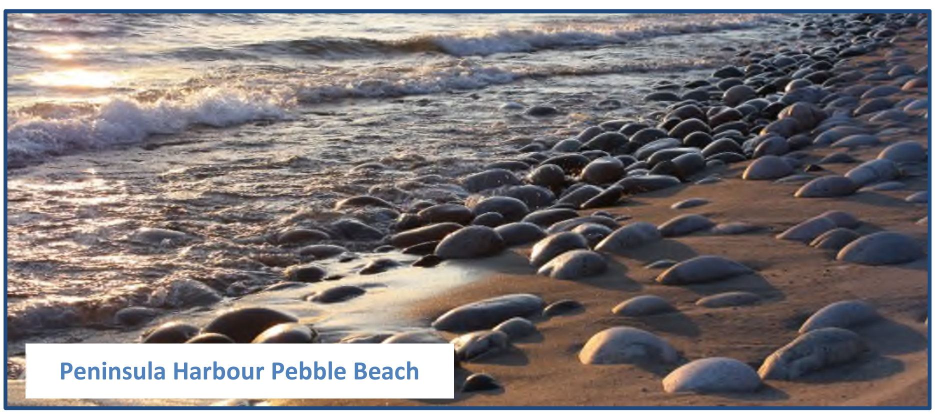
There has been a concerted effort to address the mercury and PCBs-contaminated sediment in the AOC. Following an environmental risk assessment in 2008 and a thorough review of sediment management options with the municipality, area First Nations, Métis and the public, Canada and Ontario selected the “hot spot-based” sediment management option to construct a thin-layer cap on top of the most contaminated sediment in Jellicoe Cove. In 2012, at a cost of $7.3 million, a cap consisting of medium-grade and course-grade sand was placed on top of the most contaminated sediment in Jellicoe Cove. The cap with over 216,400 m³ in material covers approximately one-quarter of Jellicoe Cove, or about 2.5% of the AOC overall. This sediment management project was the last management action remaining for the Peninsula Harbour AOC, and it was designed to reduce the risk from, and spread of, contaminated sediment from Jellicoe Cove, expedite natural recovery in Jellicoe Cove, and facilitate ecosystem recovery of the AOC.

A Long-Term Management Plan for the thin-layer cap was developed in 2011 to monitor and evaluate the effectiveness of the cap every five years over a 20-year period. The first assessment completed in 2017 shows the thin-layer cap has been effective at reducing the concentrations of mercury and PCBs in surficial sediment across the AOC.

Assessments of environmental conditions post-cap also indicate improved conditions for fish populations, fish habitat and benthos. This report presents a discussion recommending re-designation to Not Impaired status for *Degradation of Fish Populations*, *Degradation of Fish Habitat* and *Degradation of Benthos* for the following reasons:

- *Degradation of Fish Populations*: MNRF's Fish Community Index Netting program findings conclude species composition within the Peninsula Harbour AOC is similar to that outside of the AOC, and is dominated by native species.
- *Loss of Fish Habitat:* MNRF's study results indicate that, when compared to reference sites, fish habitat in Beatty Cove in Peninsula Harbour is relatively unimpaired except for minor organic enrichment from remaining wood debris leftover from log-booming that stopped in the 1980s, which is expected to dissipate over time. Habitat concerns in Jellicoe Cove were addressed by 2012 capping remediation project.
- *Degradation of Benthos*: ECCC's findings show:
    - Benthic communities outside of Jellicoe Cove in Peninsula Harbour have long been similar to Great Lakes reference locations, and benthic communities inside Jellicoe Cove are re-emerging post-cap construction showing increasing benthic species diversity.
    - Spatially weighted average concentrations (SWACs) for the AOC (based on 2017 sampling) show levels of Total PCBs (0.0509 mg/kg) meet the delisting criteria target of less than 0.060 mg/kg, and levels for methylmercury (0.0019 mg/kg) meet the delisting criteria target of less than 0.002 mg/kg.

The *Restrictions on Fish Consumption* BUI will remain impaired, but improving conditions have been documented. A recent (2019) analysis of fish contaminant data shows fish collected from Peninsula Harbour have declining levels of PCBs and mercury. However, the contaminants are still at levels resulting in advisories against consuming more than 8 meals per month, which is considered restrictive, for both general and sensitive populations. In 2020, ECCC commissioned the collection of forage and young-of-the-year fish to aid in MECP's updated assessment of contaminant levels in fish, and MECP will conduct a community survey on fish consumption in 2021 to assist with the full assessment of this BUI. Consumers are always advised to consult the *Ontario Guide to Eating Fish*[1] to help minimize exposure to contaminants within AOC-caught fish.


Peninsula Harbour Pebble Beach

[1] Visit: https://www.ontario.ca/environment-and-energy/eating-ontario-fish

1.0 INTRODUCTION

1.1 OVERVIEW OF REMEDIAL ACTION PLANS FOR AREAS OF CONCERN

Under the 1987 Protocol to the *Great Lakes Water Quality Agreement* (GLWQA) between Canada and the United States, the two countries identified 43 degraded areas on the Great Lakes known as Areas of Concern (AOCs). In 2012, the GLWQA was updated and the countries reaffirmed their commitment to address environmental issues within AOCs.

The environmental issues originally identified in the 1991 Stage 1 Remedial Action Plan (RAP) report for the Peninsula Harbour AOC (Peninsula Harbour RAP Team, 1991) included high levels of contaminants in fish and sediment, loss of fish habitat, and degraded fish and benthic communities. These historical environmental issues were caused primarily by discharges from the pulp mill and associated chlor-alkali plant, log booming debris, and discharges of wastewater from the municipal sewage treatment plant.

Remedial Action Plans have been developed for each AOC through a collaborative, methodical, and scientific approach. RAPs define the nature, extent, and causes of environmental problems and recommend actions to restore and protect the environment. Canada and Ontario work together with conservation authorities, municipalities, Indigenous communities, environmental groups, industry and the public to develop and implement the plans. There are several components common to all RAPs. These are often undertaken in sequence starting with identifying the relevant beneficial use impairments (BUIs) and their causes; then developing criteria for restoration and identifying the remedial measures to be taken to restore the beneficial uses; and eventually confirming that these actions have been effective in restoring water quality and ecosystem health through evidence gathered in monitoring efforts.

The GLWQA identifies a suite of 14 potential impairments to beneficial uses that may have one or more environmental, human health, or economic impact through a change in the chemical, physical, and biological integrity of the AOC ecosystem. Of the 14 potential BUIs, five were identified for the Peninsula Harbour AOC under the Stage 1 RAP report (further detail provided in section 1.2).

In 1971, the first *Canada-Ontario Agreement* (COA) *Respecting the Great Lakes Basin Ecosystem* was signed by the provincial and federal governments, and since then, COA has been renewed and modified several times to coordinate provincial and federal efforts and commitments for Great Lakes environmental protection and restoration, including in Areas of Concern. Commitments in the 2014 COA specific to Peninsula Harbour include implementing a monitoring plan and completing assessments of beneficial use impairments to determine the environmental status of the AOC. This Status Report presents the outcome of these assessments.

1.2 THE PENINSULA HARBOUR REMEDIAL ACTION PLAN

The Stage 1 RAP report (1991) was produced to document the environmental conditions at the time. Relying on data and information collected since the 1980s, the report provided a definition and detailed description of the environmental problems within the AOC, and identified five BUIs applicable to Peninsula Harbour (Table 2). The Stage 1 RAP report was reviewed by various experts in federal and provincial agencies and submitted to the International Joint Commission (IJC) in 1991.

Table 2: Impaired Beneficial Uses in Peninsula Harbour Area of Concern (Stage 1 RAP Report, 1991).

IMPAIRED BENEFICIAL USE	HISTORICAL CAUSE FOR IMPAIRMENT (STAGE 1 RAP REPORT)
Restrictions on Fish and Wildlife Consumption	Identified as impaired due to consumption advisories based on mercury and polychlorinated biphenyl (PCB) concentrations. (No restrictions were found to exist for consuming wildlife).
Degradation of Fish and Wildlife Populations	Identified as impaired due to decline in Lake Trout populations from extensive commercial fishing and the introduction of Sea Lamprey and other invasive species, and the damage to Lake Trout spawning grounds in Jellicoe and Beatty Coves through mill effluent and accumulation of wood debris from log booming. (No evidence of impairment was noted for wildlife).
Degradation of Benthos	Benthic community structure was identified as impaired due to contaminated sediment within the AOC causing degraded water quality. Pollution-tolerant benthos were the type most often found. Benthos are aquatic macroinvertebrates (insects and worms) that live in the lake sediment for all or part of their lifecycle.
Restrictions on Dredging Activities	Identified as impaired due to contaminated sediment in the AOC, particularly in Jellicoe Cove, as a result of previous activities at the former pulp mill and chlor-alkali plant. The contaminant levels exceeded provincial open water disposal guidelines at the time (i.e. 1991), meaning dredging would have required treatment or containment for disposal. This BUI was re-designated to Not Impaired status in the Stage 2 RAP report (2012) as it was not applicable to the AOC (see section 5.1).
Loss of Fish and Wildlife Habitat	The loss of fish habitat was attributed to accumulation of wood fibre and bark along bottom sediments. (Wildlife habitat was not considered to be impaired).

The Stage 1 RAP report (1991) also identified *Fish Tumours or Other Deformities* as “requiring further assessment” (RFA) because of the potential for impairment due to industrial effluent at the time. Until 2012, when the Stage 2 RAP report was produced, there had been no reports from fisheries personnel or the public to indicate the presence of tumours or deformities in AOC fish, and therefore the status was changed to “Not Impaired” (see section 5.2 for more detail).

In the Stage 2 RAP report (2012), two beneficial uses that had been impaired were changed to RFA (*Degradation of Fish Populations* and *Loss of Fish Habitat*), because monitoring was needed to confirm the belief fish communities were restored and no longer impaired. The *Restriction on Fish Consumption* and *Degradation of Benthos* BUIs remained impaired due to elevated mercury and PCBs within AOC sediment, particularly Jellicoe Cove.

The Stage 2 RAP report identified delisting criteria[2] for all BUIs and was finalized when a preferred management strategy for contaminated sediment was determined. Contaminated sediment required investigation as to whether management actions were needed, and if so, which methods would be most suitable for the AOC. Between the Stage 1 and Stage 2 RAP reports, a number of monitoring and sediment studies were completed. This included an environmental risk assessment (ENVIRON 2008a) and a sediment management options report (ENVIRON 2008b), which provided valuable information to help determine what remedial actions were required to rehabilitate the environment and subsequently delist Peninsula Harbour as an AOC. The Stage 2 RAP report described the assessment of remedial options and related monitoring in order to complete implementation of the RAP, and provided a recommendation for a preferred sediment management strategy: thin-layer capping.

1.2.1 Role of Agencies

Implementation of the RAP and monitoring the AOC for ecosystem recovery is the responsibility of Canada and Ontario, with the support and involvement of the local community. The development and implementation of the RAP has been led by ECCC and MECP, with support from MNRF and DFO. Through COA and the GLWQA, the provincial and federal governments are committed to working with municipal governments, First Nations, Métis, local stakeholders and the public to restore environmental conditions and remove Peninsula Harbour from the list of Great Lakes AOCs.

1.2.2 Public Involvement and Committees

The federal and provincial governments recognize the importance of community involvement in RAP decision making. The combination of local knowledge and community-based goals with scientific data and expertise has resulted in a pragmatic approach to restoring the environment. Lakehead University supports Canada and Ontario in their community engagement efforts.

The Peninsula Harbour Public Advisory Committee (PAC) was formed in 1989 and was comprised of representatives from the Town of Marathon, James River-Marathon Ltd. (last owner, Marathon Pulp Inc.), Friends of Pukaskwa National Park, Buchanan Forest Products, Ontario Federation of Anglers and Hunters, Marathon District Chamber of Commerce, Marathon Rod and Gun Club, and members of the public (Peninsula Harbour RAP Team 1991). The PAC helped to evaluate the BUIs and develop water use goals for the AOC that provided community-based guidance for the RAP. The PAC provided input throughout the 1990s in the drafting of the Stage 2 RAP report. The PAC successfully completed their objectives and subsequently disbanded.

[2] Locally-developed, AOC-specific goals used to measure progress and assess the condition of each of the BUIs of an AOC. The delisting criteria should be specific, measurable, achievable/feasible, realistic, and time-bound (i.e., “SMART”)

Public involvement continued to play an important role in the development of the contaminated sediment management plan for the AOC. In the first half of 2008, meetings were held with the Town of Marathon, Biigtigong Nishnaabeg (formerly Ojibways of the Pic River First Nation) Band Council, and Marathon Pulp Inc. This was followed by three community open houses in June 2008, two in Marathon and one at Biigtigong Nishnaabeg. The purpose of the open houses was to review information related to the RAP, and in particular, contaminated sediment within the AOC. This included options for management of contaminated sediment, proposed delisting criteria, and the results of an ecological risk assessment and sediment stability study. Additional public open houses were held in 2011 at the Biigtigong Nishnaabeg and the Town of Marathon to update residents and community members on the detailed engineering design and accompanying environmental assessment for the sediment management approach. The Métis Nation of Ontario was also engaged in the process in 2011.

Following these open houses and the selection of the preferred sediment management option by ECCC and the MECP in 2008, the Peninsula Harbour Community Liaison Committee (CLC) was formed to facilitate public involvement in the sediment management plan and other RAP related decisions. The CLC provided input to the RAP and assisted with information sharing within the communities of Marathon and the Biigtigong Nishnaabeg. The CLC has been comprised of representatives from the Town of Marathon, Biigtigong Nishnaabeg, Superior Greenstone District School Board, Conseil Scolaire De District Catholique Des Aurores Boreales, and local residents, including members of the previous PAC. The group was kept informed and updated throughout the thin-layer cap installation process in 2012.

The most recent meeting with the CLC and Biigtigong Nishnaabeg occurred in October 2016, where ECCC and MECP presented and discussed plans for their 2017 fieldwork to evaluate the thin-layer cap and assess AOC restoration five years post-cap installation. MNRF presented preliminary results from its Fish Community Index Netting program, which was showing positive results for AOC fish populations.

1.3 DESCRIPTION OF THE AOC

A detailed description of the Peninsula Harbour ecosystem including information on climate, sediment, geology, and land and water uses is included in the Stage 1 RAP report (Peninsula Harbour RAP Team 1991). The following section summarizes the background information and provides recent and additional information relevant to this Status Report.

1.3.1 Physical Description

Peninsula Harbour is located at the Town of Marathon on the northeastern shore of Lake Superior approximately 290 kilometres east of the City of Thunder Bay. The AOC is roughly bounded by the harbour to the north of the peninsula and Pebble Beach to the south, and extends outward approximately four kilometres from the peninsula into Lake Superior to the west (Figure 1). Within Peninsula Harbour there are a number of small bays/coves including Jellicoe Cove, Carden

Cove, and Beatty Cove. Two small creeks, Shack Creek and another unnamed watercourse, drain into the harbour just north of Jellicoe Cove and the Town of Marathon. The average water depth is approximately 30 metres and offshore from the peninsula there are maximum depths up to 65 metres (Peninsula Harbour Remedial Action Plan, 1991).

Figure 1: *Map of Peninsula Harbour Area of Concern*

1.3.2 Water Use

Water from Peninsula Harbour was used primarily for the pulp mill process until the mill closed in 2009. The most recent Permit to Take Water was issued by the MECP in 2008 (7270-7CMP7B) and allowed for a maximum amount of water taken as 98,064,000 L/day or 98,000 m^3/day. In 2007, the mill had a total annual flow of 16,037,389 m^3 which equated to an average of 43,938 m^3/day. In 2009 the mill closed following the bankruptcy of Marathon Pulp Inc.

During mill operation, Peninsula Harbour was an active shipping channel from mid-April to mid-December. Between 10 and 12 ships per season arrived at the mill dock with supplies, and left with pulp. Until 1983, Jellicoe Cove was historically used as a log booming area in the winter months when shipping was not possible. Log booming was officially discontinued in 1983; however, Buchanan Forest Products used the harbour temporarily for log rafting in 1987 and 1988.

Lake Superior is not the source of potable water for the Town of Marathon. The municipal water supply is provided by five wells, which intercept a nearby sandy aquifer.

1.3.3. Land Use

The only urban settlement within the AOC is the Town of Marathon (population of 3,273 based on the 2016 Canadian Census). Current land use in the town is primarily residential, with some commercial. The Canadian Pacific Railway, constructed in the 1880s, passes through Marathon along the harbour shoreline. The Trans-Canada Highway, completed in 1960, returns to the north shore of Lake Superior. A hydro corridor also extends through this region.

Forestry was an important industry in the community. Marathon Pulp Inc. and its predecessors were licensed to harvest timber from the Big Pic River Forest Management Unit and used the timber as raw material for the production of pulp. Waterfront property immediately north of the peninsula, in the Jellicoe Cove area, was zoned industrial for the operation of the bleached kraft pulp mill. The mill operated from 1944 until its closure in 2009 with the bankruptcy of Marathon Pulp Inc. The shoreline was used for storing softwood chips, and for storing and occasionally debarking hardwood logs. A wood waste disposal site, located near the shoreline north of the mill was utilized between 1945 and 1990. The site has been closed, with a closure plan initiated in 2003. There is ongoing monitoring of the closed wood waste site with reporting of results to the MECP. Adjacent to the mill, a chlor-alkali plant operated from 1952 until 1977 and manufactured caustic soda, chlorine, sodium chlorate and sodium hypochlorite for use in the mill's pulp bleaching process.

1.4 SOURCES OF POLLUTION – CURRENT

The Town of Marathon's water pollution control plant (WPCP) is the only remaining point source discharging into the Peninsula Harbour AOC. The facility's effluent quality has improved significantly since the application of secondary treatment in 1982 (Jardine and Simpson, 1990). The facility operates in the 95-98% removal efficiency range for biological oxygen demand (BOD) and total suspended solids (TSS). Effluent is consistently below the MECP guideline of 25 mg/L for BOD and TSS at the secondary treatment facilities (MECP, 1994). The Stage 2 RAP report provides a summary of discharges from the WPCP from 1992 to 2010, which demonstrates a declining trend in concentration of BOD and TSS discharged from the WPCP over that time period. A review of effluent data from 2011 to 2017 continues to show discharges are consistently in compliance with the facility's provincial discharge limit of 15 mg/L.

Other non-point sources of pollution (which are diffuse inputs that reach the water from multiple points of origin through natural and constructed delivery channels) include atmospheric deposition, groundwater flow, runoff from adjacent areas, and release from sediment. Atmospheric deposition is considered to be a lakewide issue caused by the production of airborne pollution outside of the AOC. Heavy metals, polychlorinated biphenyls (PCBs) and toxaphene are contaminants known to be transported via long-range atmospheric processes (Bashkin, 2008);

however, actual loadings are difficult to quantify and release from the most contaminated sediment is mitigated through the thin-layer cap; as detailed in later sections of the Status Report.

1.5 SOURCES OF POLLUTION – PAST

1.5.1 Former Kraft Mill (decommissioned 2009)

The mill began operations in 1946 and discharged its effluent via four outfalls directly to the harbour as wastewater, and through spills, leaks, and vapour loss (Peninsula Harbour RAP Team, 1991). Wood fibre, bark waste and wood processing by-products were released from the mill into Jellicoe Cove and contributed to the contamination of Peninsula Harbour. The Stage 2 RAP report provides a summary of discharges from the mill from 1990 to 2008, which shows improvements to effluent quality following a number of process changes. The treatment system was upgraded to include secondary treatment in 1995. From December 1995 until its closure in March 2009, treated effluent from the mill was discharged through a submerged diffuser (added in 1995) into Lake Superior southeast of the mill (Figure 1 above). The addition of the secondary treatment system and a number of process changes, such as switching to an elemental chlorine free bleaching process in 1991, improved effluent quality.

1.5.2 Former Chlor-Alkali Plant (decommissioned 1977)

The former chlor-alkali plant associated with the pulp mill was the primary source of mercury contamination to Peninsula Harbour from 1952 to 1977 when it was decommissioned. When in operation, the plant used a mercury-cell method to produce sodium hydroxide (caustic soda) and chlorine for use by the Kraft pulp mill during the chemical pulping and chlorine bleaching process, respectively. Effluent from the plant was discharged into Jellicoe Cove and contributed to elevated levels of mercury in the sediment (BEAK 2000). Mercury loadings from the plant occurred through poorly treated wastewater, spills, leaks, and vapour loss and contributed to elevated levels of mercury in sediment and fish (Peninsula Harbour Remedial Action Plan, 1991). When the chlor-alkali plant was decommissioned in 1977, mercury-contaminated materials were removed and disposed of at the Georgia-Pacific[3] mercury disposal site. The disposal site is now owned and operated by Fort James Fiber Canada Corporation (a subsidiary of Georgia-Pacific). The site is capped and operating under a provincial Environmental Compliance Approval that includes requirements for monthly site inspections, signage and security, an annual groundwater monitoring program, and triannual reporting to the MECP.

[3] Lot 19 and 20, Concession 8, Town of Marathon, District of Thunder Bay.

2.0 THE MANAGEMENT PLAN FOR CONTAMINATED SEDIMENT (Jellicoe Cove)

Jellicoe Cove was the contaminated hot spot with highest contaminant concentrations in Peninsula Harbour AOC, and thus contaminated sediment in the Cove has been the most significant environmental issue for the AOC for many years. The sediment has elevated levels of mercury, PCBs, and wood fibre. A reconnaissance survey conducted in 1999 (Richman, 2004) indicated the highest zones of contamination occur within Jellicoe Cove (Table 3).

Table 3: Sediment mercury and PCB concentrations in 1999

	Total Hg (mg/kg)	Total PCB (mg/kg)
Jellicoe Cove	3.0 – 21	0.02 – 0.24
Outside Jellicoe Cove	0.04 – 1.3	0.02 – 0.18
Lowest Effect Level (LEL)	0.2	0.07
Severe Effect Level (SEL) (mg/kg OC)[a]	2	Jellicoe Cove: 17.1 Outside Jellicoe Cove: 11.8

[a]530 mg/kg x % Total Organic Carbon (TOC). Since SEL depends on TOC, PCB SEL values in the provincial guidelines (530 mg/kg) have to be adjusted for TOC content up to a maximum of 10%. TOC values were difference for inside and outside Jellicoe Cove, hence the SEL values are presented for both inside and outside the Cove. LEL does not depend on TOC level.

The 1999 survey showed, overall, total mercury concentrations in Jellicoe Cove sediment ranged from 3.0-21 mg/kg[4], with all the sites having concentrations that exceeded the provincial sediment Lowest Effect Level[5] of 0.2 mg/kg and the Severe Effect Level[6] (SEL) of 2 mg/kg. Outside of Jellicoe Cove, but still within the Harbour, total mercury concentrations in sediment were lower, ranging from 0.04 – 1.3 mg/kg, with the maximum concentrations being less than the provincial SEL and three sites being below the provincial LEL. For PCBs, Richman (2004) found sediment PCB concentrations ranged from 0.02 mg/kg to 0.24 mg/kg in Jellicoe Cove and 0.02 mg/kg to 0.18 mg/kg outside Jellicoe Cove, with higher concentrations detected in Jellicoe Cove. PCB concentrations did not exceed the provincial SEL of 17.1 mg/kg in Jellicoe Cove or 11.8 mg/kg in the Harbour.

In 2008, ECCC and MECP commissioned ENVIRON (now called Ramboll Group) to conduct an environmental risk assessment (ERA) to evaluate the ecological and human health risks posed by PCBs and mercury in the sediment and biota in the AOC, particularly Jellicoe Cove (ENVIRON, 2008a). Following the assessment of human and environmental risks, ENVIRON also conducted an evaluation of sediment management options with the input from local First Nations, area

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[4] Milligram per kilogram (mg/kg) = (concentration of metals x volume of sample) / (sample weight). A milligram is one parts per million (ppm) of a kilogram, therefore, 1 mg/kg is the same as 1 ppm, which is a unit of measurement that is the mass of a chemical or contaminant per unit volume of water (Scatterfield, 2004).

[5] Under the Provincial Sediment Quality Guidelines for Ontario, the Lowest Effect Level indicates a level of contamination that can be tolerated by the majority of sediment-dwelling organisms. Sediments meeting the LEL are considered clean to marginally polluted (MECP, 2019).

[6] Under the Provincial Sediment Quality Guidelines for Ontario, the Severe Effect Level indicates a level of contamination that is expected to be detrimental to the majority of sediment-dwelling organisms. Sediments exceeding SEL are considered heavily contaminated (MECP, 2019).

stakeholders and the public concerning those options (ENVIRON, 2008b). The 2008 sediment management options study identified and evaluated various management options for the most effective and feasible option to address PCB and mercury contaminated sediment in Jellicoe Cove. From the sediment management options presented in the study, ECCC and the MECP selected a thin-layer cap as the preferred method to manage contaminated sediment in the AOC. The hot spot-based sediment management (thin-layer cap) satisfied the criteria established in the sediment management options analysis (effectiveness, feasibility, and cost), and it was supported by the community. In 2011, an environmental assessment was carried out with the input from area First Nations, Métis, and local stakeholders and the public.

Together, the ERA and sediment management options study led to a sediment management plan for the most contaminated sediment in Jellicoe Cove, and in 2012, a thin-layer cap was placed to cover areas where the levels of mercury in sediment was equal to or greater than 3 mg/kg of total mercury. Completing the cap fulfilled the last remedial action required for the AOC.

2.1 IMPLEMENTATION OF THE THIN-LAYER CAP

To implement the thin-layer capping project to address the historical mercury and PCB contamination, Public Services and Procurement Canada (PSPC) served as the contracting authority for the project. PSPC contracted AECOM Canada Ltd. to prepare Detailed Engineering Design, Construction Oversight, and Environmental Assessment pursuant to the *Canadian Environmental Assessment Act*.

The capping project was implemented in summer 2012 at a cost of $7.3 million. The former owners of the pulp mill contributed $3 million as a result of a settlement negotiated with the Government of Ontario to uphold the polluter pays principle. The Government of Canada contributed $2.7 million, and the Province of Ontario contributed $1.6 million along with a commitment to cover the cost of a 20 year long term monitoring program (estimated at $1.1 million).

The objectives of the sediment remediation project were to:

- reduce risk to animals and plants from contaminated sediment in Jellicoe Cove;
- reduce the spread of contaminated sediment from Jellicoe Cove to the rest of Peninsula Harbour;
- expedite the natural recovery of Jellicoe Cove; and
- facilitate ecosystem recovery in Peninsula Harbour contribute to its “delisting” as an AOC.

To complete the project, 49,600 tonnes of locally sourced medium-grade sand and 36,000 tonnes of coarse-grade sand from Manitoulin Island were used. Approximately 15-20 cm of sand was placed over the cap, with 67% of the cap covered with medium-grade sand, and the remaining 33% covered with coarse-grade sand. The coarse-grade sand was specifically used to reduce the movement of the cap material in areas with strong currents or wave action.

Capping was completed in two phases: a test phase and a production phase. The one-week test phase fine-tuned placement techniques for both medium and coarse sand to optimize these techniques while meeting the criteria for cap thickness and water quality. In the production phase, the methodology selected during the test phase was implemented.

The sand cap was mechanically placed using a long reach excavator with a clamshell bucket that was supported by a material barge with a global positioning system for electronic positioning (Figure 2). Cells were established over the footprint of the capping area, and sand was released through the water column in each specified cell until the 15 – 20 cm thickness was achieved. This operation was repeated over the entire capping site.

Figure 2: *Clamshell bucket (green) placing sand from the supply barge to its right into designated cells to its left*

Physical water quality control measurements during cap construction included: a turbidity curtain box (a mesh barrier measuring 3 metres on all sides that was suspended in the water column by floating rods attached to the barge) surrounded the barge to contain suspended solids; and silt curtains (floating mesh barriers) to prevent sand from depositing in nearshore fish habitat areas.

The capping process was completed in 48 days between June 5 and August 5, 2012. Overall, the total area capped in Jellicoe Cove was 234,000m² with the cap covering approximately one-quarter of Jellicoe Cove, or about 2.5% of the Peninsula Harbour AOC.

2.2 MONITORING DURING PLACEMENT OF THE THIN-LAYER CAP

2.2.1 Water Quality Monitoring

Prior to cap installation, baseline monitoring was conducted where turbidity, TSS, suspended solids, dissolved oxygen, temperature, and specific conductance readings were collected to establish background conditions at the project site which would help assess the amount of TSS resulting from the capping operation itself. Samples were collected at the following locations: Shack Creek (which flows into the harbor), Control Site (located outside of Jellicoe Cove), three Background Stations (located outside the capping area), and three Inside Cap Surface Stations (Figure 3).

During the placement of the thin-layer cap, water samples were collected over three depths (surface, mid, and bottom) for areas where the water depth was >= 4m. For areas with less than 4m water depth, samples were taken from surface and mid depth. For areas with less than 2m, surface samples were taken. The samples were analyzed for TSS and the samples collected from the bottom were analyzed for mercury and PCBs in addition to TSS. Sampling locations were selected according to the location of capping operations. In addition, *in situ* measurements of turbidity, temperature and dissolved oxygen were taken.

The primary water quality criterion is 150 TSS or 50 Nephelometric Turbidity unit (NTU) above background levels at 100 metres from the capping barge. 100 metres from the capping barge was designated as the work area. Samples were collected two times per day (AM and PM), two days per week. Real-time measurements of turbidity, TSS, temperature, specific conductance and dissolved oxygen were taken at 100 metres from the capping barge. In addition, samples were taken from Shack Creek, the Control Site and the three Background Stations. Shack Creek was sampled to measure TSS loading from the creek, the control station was sampled to measure the turbidity away from capping activity and background locations were sampled to measure turbidity caused by the capping activity. When monitoring indicated site specific criteria were not met, operational changes were made and conditions were monitored until the criteria were met.

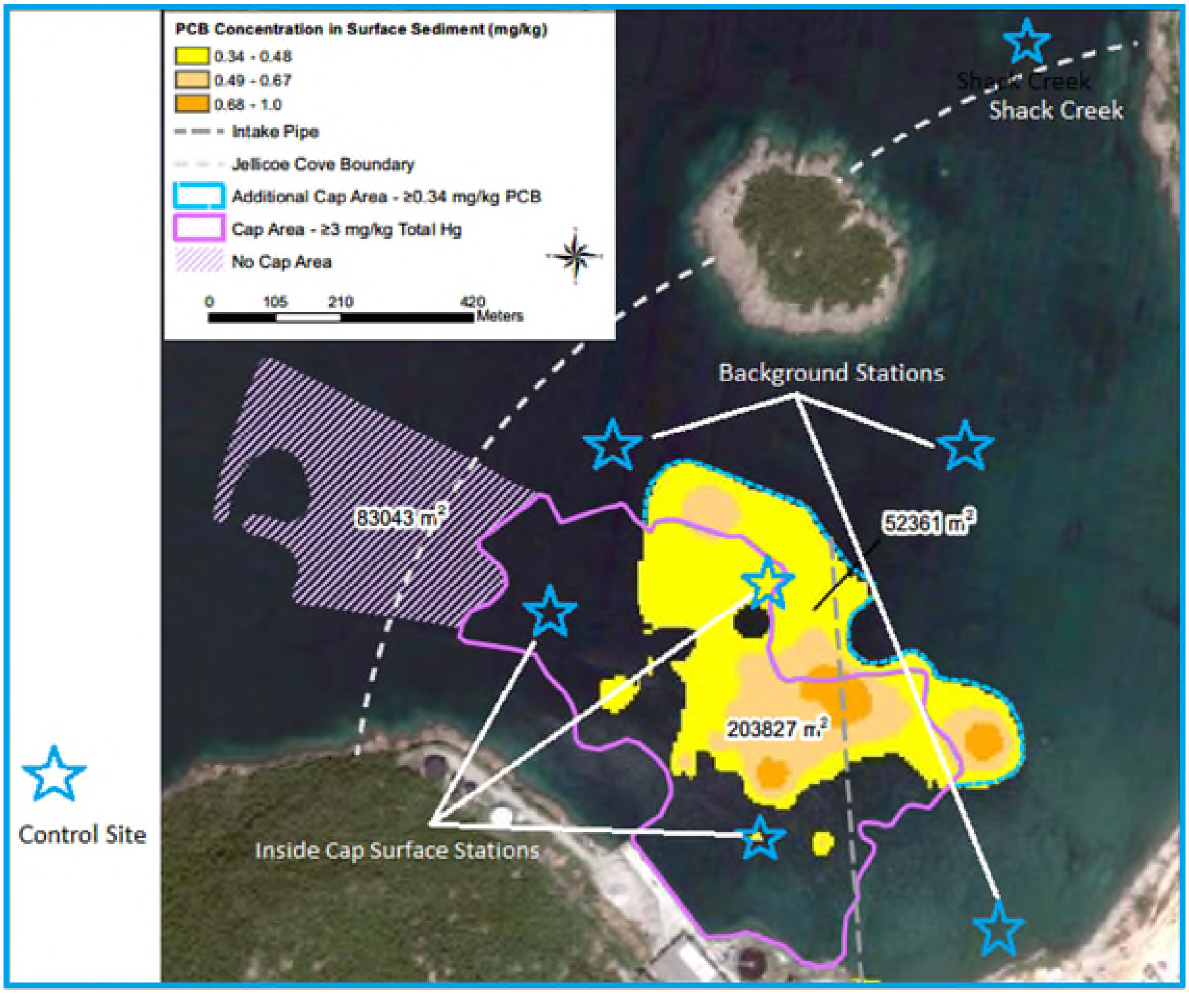

Figure 3: *Sampling locations (blue stars) for water quality monitoring.*

Data collected through the water quality monitoring helped establish background levels and ensured that the project adhered to the project design. At the 100-metre compliance boundary from the capping barge, turbidity and TSS readings were mostly in compliance during the standard monitoring, with the exception of three instances where excess turbidity was caused by:

- propeller wash from the tugboat that towed the barge,
- the turbidity curtain dragging on the lake bottom in shallow water, and
- capping without a full turbidity curtain.

Operational changes were quickly made to reduce turbidity in each of these instances.

2.2.2 Cap Thickness Assessment

Cap thickness was monitored for accuracy throughout the implementation of the thin-layer cap. Cores were taken using a coring device to ensure that cap thickness criteria were met. Five cores were collected per each grid (100m x 100m) (refer to Appendix D for coring stations on the cap).

2.3 MONITORING THIN-LAYER CAP POST-PLACEMENT

2.3.1 Long Term Monitoring Plan for the Thin-layer Cap

As previously mentioned, MECP committed to leading the long-term monitoring (LTM) of the thin-layer cap over a 20 year period, with support from ECCC.

In 2011, a post-construction LTM plan was developed (AECOM, 2011) with the objective of advising MECP and ECCC on monitoring efforts to evaluate the effectiveness of the thin-layer cap over the 20-year period. In 2017, five-years after cap installation, the first full LTM assessment was completed by MECP with the goal of assessing targets with regard to cap stability, cap effectiveness, and ecological recovery (George, 2019). Overall, results from the first LTM assessment provide clear evidence that the cap is effective and meets the goals of the remedial effort. The following is a summary of the LTM assessment results:

- *Cap Stability:*
  - The thin-layer cap is stable, and sediment from areas surrounding the cap is depositing on the cap.
- *Cap Effectiveness:*
  - The thin-layer cap is effective in reducing total mercury concentrations in surficial sediment below the remedial target of <3 mg/kg.
  - The thin-layer cap is effective in reducing exposure and flux of mercury to the overlying waters.
  - The thin-layer cap reduced concentrations of methylmercury (MeHg) and PCBs.
- *Ecological Recovery:*
  - The thin-layer cap has been colonized with benthic invertebrates.
  - Patches of submerged aquatic vegetation continue to increase over time on top of the cap.
  - Mercury and PCB levels in fish tissue have decreased on both long and short term temporal scales, but continue to be elevated above fish consumption advisory benchmarks (more detail covered in Section 3.2.1 *Restrictions on Fish Consumption*).

The results from the first LTM assessment show that conditions in Jellicoe Cove have improved in response to the remedial effort of 2012. MECP will continue to monitor the effectiveness of the cap under the 20-year LTM plan, with the second LTM assessment anticipated for 2023.

2.3.2 Spatially Weighted Average Concentrations

In 2017, sediment samples were collected throughout the AOC to determine the "spatially weighted average concentrations" (SWACs) for the entire AOC following the cap installation five years earlier. The samples were collected by ECCC and MECP, and data analysis was completed by ECCC. The purpose was to determine if the delisting criteria for the *Degradation of Benthos* BUI was met, and specifically if the AOC average concentrations for total PCBs and MeHg met the target levels established by the 2008 ERA at the beginning of the sediment remediation process. Details on the SWAC analysis are presented under section 3.1.3 *Degradation of Benthos*.

3.0 STATUS OF BENEFICIAL USE IMPAIRMENTS

Table 4 below provides the status of all beneficial uses in Peninsula Harbour AOC at the time of the Stage 1 RAP report (1991), as well as in the subsequent Stage 2 RAP report (2012). It also provides the status and recommended re-designations as of 2020.

Table 4: Status of Beneficial Use Impairments in the Peninsula Harbour AOC.

BENEFICIAL USE IMPAIRMENT	1991 STATUS (STAGE 1)	2012 STATUS (STAGE 2)	2020 STATUS
Restrictions on Fish and Wildlife Consumption	Impaired (for fish only)	Impaired (for fish only)	Impaired (for fish only)
Tainting of Fish and Wildlife Flavour	Not Impaired	Not Impaired	Not Impaired
Degradation of Fish and Wildlife Populations	Impaired (for fish only)	RFA (for fish only)	Proposed for Re-designation
Fish Tumours or Other Deformities	RFA	Not Impaired	Not Impaired (see Appendix A)
Bird or Animal Deformities or Reproduction Problems	Not Impaired	Not Impaired	Not Impaired
Degradation of Benthos			
♦ Population	Impaired	Impaired	Proposed for Re-designation
♦ Body Burden	RFA	Impaired	Proposed for Re-designation
Restrictions on Dredging Activities	Impaired	Not Impaired	Not Impaired (see Appendix A)
Eutrophication or Undesirable Algae	Not Impaired	Not Impaired	Not Impaired
Restrictions on Drinking Water Consumption, or Taste and Odour Problems	Not Impaired	Not Impaired	Not Impaired
Beach Closings	Not Impaired	Not Impaired	Not Impaired
Degradation of Aesthetics	Not Impaired	Not Impaired	Not Impaired
Added Costs to Agriculture or Industry	Not Impaired	Not Impaired	Not Impaired
Degradation of Phytoplankton and Zooplankton Populations	Not Impaired	Not Impaired	Not Impaired
Loss of Fish and Wildlife Habitat	Impaired	RFA (for fish only)	Proposed for Re-designation

3.1 PROPOSED BUI RE-DESIGNATION TO NOT IMPAIRED

3.1.1 Degradation of Fish and Wildlife Populations (RFA)

Re-designation Recommendation

It is recommended that this beneficial use be re-designated to Not Impaired, as outlined below.

Historical Reason for Impairment

Fish populations had been designated impaired in the Stage 1 RAP report (1991) because of a decline in Lake Trout populations due to habitat destruction from industrial effluent and log booming, the introduction of Sea Lamprey (*Petromyzon marinus*), and over-exploitation through commercial fishing. Log booming (a practice that ended in the 1980s) had resulted in wood debris contamination in Jellicoe and Beatty Coves that reduced traditional (prior to 1955) Lake Trout spawning habitat.

In the Stage 2 RAP report (2012), this beneficial use was changed from impaired to requires further assessment. This applies to the fish component only; wildlife populations were never deemed impaired for the Peninsula Harbour AOC.

Evaluation/Delisting Criteria

As per the Stage 2 Remedial Action Plan (2012), the BUI was changed to “requires further assessment”. Thus, instead of delisting criteria, the RAP uses evaluation criteria[7] to verify the current status. It is:

Fish populations will be considered not impaired when the fish community has the following structure:

- *The Peninsula Harbour AOC fish community should be similar to near shore (0 – 80 m deep) fish communities adjacent to the AOC as measured by relative abundance and species composition of the community.*
- *The near shore fish community should be dominated by self-sustaining populations of native fishes*
- *Lake Trout populations have the following characteristics:*
  - ⇒ *Mean age greater than eight years*
  - ⇒ *Populations are dominated by wild Lake Trout (greater than 50% wild)*
  - ⇒ *Length-at-age of age seven Lake Trout is stable and greater than 430 mm*
  - ⇒ *Populations are dominated by mature fish and many age classes present*

Evidence in support of achieving the target

Following process changes and upgrades to mill effluent treatment, and the passing of time since log booming ended, the ecosystem started to recover. In 2010, MNRF initiated a Lake Superior Fish Community Index Netting (FCIN) Program to obtain 5 years of data for Lake Superior AOCs.

[7] As a Party to the GLWQA, ECCC has deemed appropriate to use the term “evaluation criteria” for beneficial uses requiring further assessment. Impaired beneficial uses continue to use “delisting criteria” for BUI status assessment.

The FCIN program establishes a fishery independent trend over time of the abundance and diversity of the fish community in these AOCs.

Results from the Peninsula Harbour AOC index netting from 2010-2018 have been tracked for changes over time and compared to results from areas within and adjacent to the AOC to evaluate the status of this beneficial use. MNRF's recent analysis of these results shows a healthy, self-sustaining population of primarily native fish species (MNRF, 2019) (Appendix F).

MNRF's evidence, collected from 2010-2018, in support of the delisting criteria is:

- The relative abundance and species composition[8] of the AOC fish community has been consistently higher inside the AOC compared to outside. Also, species richness (number of species) and species evenness (proportion of species) has remained relatively consistent, with a long-term average of eight species caught inside the AOC and nine species outside the AOC.

- Self-sustaining populations of native fishes: the Lake Superior fish community is composed of 86 species, 70 of which are native fishes.

- More than 95% of the Lake Trout sampled in the FCIN surveys from 2010-2018 both inside and outside the AOC have been identified as wild fish.

- The mean age of Lake Trout in FCIN samples collected from 2010 to 2017 within the AOC ranged from 4 to 11 years, with an average of 9 years, exceeding the index value of 8 years.

- Between 2010 and 2017 Lake Trout averaged 403 mm to 589 mm in total length at age-7 inside the AOC and were consistently larger than the baseline value of 430 mm since 2011.

- The age structure of Lake Trout sampled inside and outside of the AOC is near identical, with an average of 15-year classes of Lake Trout spanning 2 to 39 years observed in FCIN samples collected from 2010 to 2017. This is a characteristic of a healthy, robust population that is experiencing regular annual recruitment. On average, 64% of the fish in the FCIN samples are mature.

Based on this evidence collected under the FCIN program from 2010-2018, the criteria have been met, and therefore it is recommended that *Degradation of Fish Populations* be re-designated to a Not Impaired status. The MNRF will continue to monitor the fish community as part of an ongoing assessment program, emphasizing the importance of fishery independent trend-through-time data to guide management decisions.

[8] The relative abundance and species composition is expressed as the catch-per-unit-effort, which is the abundance per kilometre of net (#/km) and the landed weight in kilograms per kilometre of net set (kg/km) (MNRF, 2019).

3.1.2 Loss of Fish and Wildlife Habitat (RFA)

Re-designation Recommendation
It is recommended that this beneficial use be re-designated to Not Impaired, as outlined below.

Historical Reason for Impairment
In the Stage 2 RAP report (2012), this beneficial use was changed from impaired to requires further assessment for the fish component (wildlife habitat was never impaired for the AOC).

Fish habitat in the AOC was deemed impaired in the Stage 1 RAP report (1991) due to the loss of fish spawning areas. Goodier (1981 and 1982) documented historic spawning areas (prior to 1955) for Lake Trout and Cisco in Peninsula Harbour; however, Lake Trout spawning grounds along the shorelines of Jellicoe and Beatty Coves had been degraded through the accumulation of organic materials from pulp mill activities, namely log booming and effluent discharge.[9]

At the time of the Stage 2 RAP report (2002), the levels of organic matter entering the harbour had greatly reduced due to the end of log booming activities in the 1980s, upgrade to the municipal wastewater treatment plant to secondary treatment in 1982, and upgrades to the pulp mill and its wastewater treatment plant to secondary treatment in 1995, and then the closure of the pulp mill in 2009 and subsequent decommissioning.

With the ecosystem recovering, an assessment of the extent of quality habitat within the AOC was conducted by Northern Bioscience Ecological Consulting in 2010 to support the environmental assessment of the sediment management project (Foster and Harris, 2011). Overall, the Foster and Harris (2011) study found historical Lake Trout spawning habitat along Ypres Point and west of Beatty Cove in relatively good condition. In Beatty Cove, the study determined some Lake Trout habitat may have been impaired in the deeper waters as a result of wood debris from log booming activities, whereas along the shoreline the impairments were minor. The study concluded spawning habitat west of Beatty Cove and along the north shore of Peninsula Harbour was relatively unimpacted, however conditions along the western shoreline of Beatty Cove had yet to be confirmed. Due to this lack of data, the status of this BUI was deemed to “require further assessment” in the Stage 2 RAP report (Peninsula Harbour Remedial Action Plan, 2012) so that further monitoring could be conducted in Beatty Cove.

Evaluation/Delisting Criteria
As per the Stage 2 Remedial Action Plan (2012), the BUI was changed to “requires further assessment”. Thus, instead of delisting criteria, the RAP uses evaluation criteria to verify the current status. It is:

[9] Note that In the case of Beatty Cove, it is organic matter from log booming, not mill operations, that may have impacted spawning grounds (Foster and Harris, 2011).

This beneficial use will no longer be impaired when the amount and quality of physical, chemical, and biological habitat within the AOC has been established and protected and is not an impediment to achieving Lake Superior Fish Community Objectives.

- *The aquatic habitat is capable of supporting a biologically diverse fish community*
- *The desired fish and benthic communities are showing signs of sustainable recovery post sediment remediation*
- *Monitoring and reporting systems are in place to track and guide recovery*

Evidence in support of achieving the target

In 2012, MNRF undertook a targeted study of Beatty Cove to assess whether the waste from the historic log booming activity continued to impair fish habitat (Deacon and Lavoie, 2013). The study used aquatic benthic macroinvertebrates[10] for this assessment. The study found that fish habitat in Beatty Cove is relatively unimpaired except for minor organic enrichment from the remaining wood debris. With log booming operations having ended in the 1980s, the residual woody debris should continue to dissipate from year-to-year; therefore, conditions within the cove should continue to improve. The study concluded there is a high density of aquatic benthic macroinvertebrates in the Cove, and that this should provide abundant forage for fish.

In February 2020, MNRF prepared an assessment report (Appendix G) containing a detailed analysis of various studies, some of which are captured in the discussion above, to assess the status of fish habitat in the AOC. The assessment report provides evidence in support of achieving the delisting criteria for the *Loss of Fish and Wildlife Habitat BUI (fish component)*:

The aquatic habitat is capable of supporting a biologically diverse fish community

- The FCIN program (mentioned in section 3.1.1 above) shows that aquatic habitat within the AOC is supporting a diverse and healthy fish community. The relative abundance and species composition of the AOC fish community has been consistently higher inside the AOC compared to outside.

- The capping of contaminated sediment, which ultimately reduces the availability of contaminants to the fish community, aligns with the Fish Community Objectives[11] that provide guiding principles for aquatic habitats and for individual fish species.

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[10] Aquatic benthic macroinvertebrates are insects and worms that live at the bottom of the water column, in the lake sediment, for all or part of their lifecycle. They respond to ecosystem changes faster than other members of the aquatic community, such as fish, because of their shorter lifecycle. For this reason, these benthic macroinvertebrates are commonly used as indicator species to provide information about the health of aquatic ecosystems.

[11] MNRF is mandated to follow the Fish Community Objectives for Lake Superior. The goal for aquatic habitat is: "*Achieve no net loss of the productive capacity of habitat supporting Lake Superior fishes. Where feasible, restore habitats that have been degraded and have lost their capacity for fish production. Reduce contaminants so that all fish are safe to eat. Develop comprehensive and detailed inventories of habitats" (MNRF, 2020).*

The desired fish and benthic communities are showing signs of sustainable recovery post sediment remediation.

To assess whether aquatic communities show sings of recovery post the thin-layer cap sediment remediation in 2012, the assessment report looked at changes in habitat (substrate changes and growth of submerged aquatic vegetation) on and adjacent to the capped area in Jellicoe Cove from various studies. Surveys conducted in 2013, 2014 and 2017 show that*:*

- Coverage of submergent vegetation has increased since the installation of the thin-layer cap.
- In 2017, the aquatic vegetation was still sparse within the capped area; however continued natural sedimentation is expected to improve substrate conditions for aquatic macrophytes, enabling recovery to continue.

In addition, MECP's LTM plan (more detail discussed in section 3.1.3 below) found benthic invertebrates inhabiting the cap; the number of organisms was low but the diversity was high. The type of invertebrates was similar to pre-cap conditions.

Monitoring and reporting systems are in place to track and guide recovery

- MECP's LTM Program, designed to assess improvements in sediment and biological communities post remediation. It includes a schedule of the work to be completed, with the collected data compared to baseline conditions where appropriate. Monitoring started in 2017 and will continue every 5 years for the next 20 years, with reports made public.
- The MNRF will continue to monitor fish community as part of the ongoing FCIN program. Sampling effort will be increased in the Peninsula Harbour AOC during the Cooperative Science and Monitoring Initiative years (Note: five year rotational cycle on the Great Lakes; next survey year for Lake Superior is 2021).

Based on the analysis conducted by MNRF in the assessment report, it is evident that aquatic habitat in the AOC is supporting a diverse and healthy fish community and the evaluation/ delisting criteria have been met. MNRF will continue to monitor the fish community as part of an ongoing program, and MECP will continue its long-term monitoring of the cap, ensuring any changes to environmental conditions will be identified and met with appropriate action. Therefore, it is recommended that *Loss of Fish Habitat* be re-designated to Not Impaired status.

3.1.3 Degradation of Benthos (Impaired)

Re-designation Recommendation

It is recommended that this beneficial use impairment be re-designated to Not Impaired, as outlined below.

Historical Reason for Impairment

Benthic community structure was identified as impaired in the Stage 1 RAP report (1991) due to contaminated sediment within the AOC having elevated concentrations of mercury and PCBs. Since benthos live in (or in close proximity to) the lake bottom sediment for some or all of their lifecycles, the organisms are highly exposed and potentially most sensitive to contaminants in sediment (Milani and Grapentine, 2005).

The original case for impairment used studies going back decades. In 1969, the densities of pollution tolerant sludgeworms *(Tubifex tubifex*) were found to increase closer to the main sump overflow of the kraft mill (Peninsula Harbour RAP Team, 1991). In 1976, these sludgeworms were found to be the dominant species in Peninsula Harbour to the west and southwest of the main mill outfall (Peninsula Harbour RAP Team, 1991). However, by 1991 when the Stage 1 report was released, a study by Sibley *et al*. (1990) demonstrated that benthic community diversity and population had increased in the AOC, suggesting improvement in water quality. That being said, the study also found that water quality remained impaired to some degree based on the absence of species common to pristine bays in Lake Superior, such as *Ephemeroptera*, *Plecoptera* and *Trichoptera* (Sibley *et al*., 1990 and Peninsula Harbour Remedial Action Plan, 1991).

The Degradation of Benthos BUI had two elements in the Stage 1 RAP report: a) benthic community populations, which were deemed impaired due to there being mostly pollutant-tolerant species; and b) benthic body burdens, which required further assessment, as the effects of contaminants in water and bottom sediments to the benthos community were unknown (Peninsula Harbour Remedial Action Plan, 1991). Both benthic populations and benthic body burdens continued to be impaired in the Stage 2 RAP report released in 2012.

Delisting Criteria

As per the Stage 2 Remedial Action Plan (2012), the BUI delisting criteria is:

> ***Dynamics of benthic populations (assessed via community structure):***
> *This beneficial use will no longer be impaired when acute and chronic toxicity and benthic community composition and abundance (outside the shipping channel) are comparable to suitable reference sites.*
>
> ***Benthic invertebrate contaminant body burdens:***
> *This beneficial use will no longer be impaired when invertebrate tissue concentrations are below levels associated with adverse impacts (such as potential effects in predator species due to biomagnification).*
>
> NOTE: For Peninsula Harbour, this is hypothesized to occur when **average sediment concentrations are less than 0.060 mg/kg PCB and 0.002 mg/kg methylmercury** within the AOC. This is based on locally derived risk-based tissue residue guidelines from the environment risk assessment for Peninsula Harbour (ENVIRON, 2008a).

Invertebrate tissue concentration data was not collected for the Peninsula Harbour AOC, and thus, contaminant body burdens in benthic invertebrates are assessed using average PCB and MeHg sediment concentrations (as indicated in the delisting criteria note above), along with evidence from other studies. Assessment for this criterion is presented below.

Evidence in support of achieving the target

Evidence in support of achieving delisting criteria targets for the *Degradation of Benthos* BUI is presented in five different studies conducted over the years, and is summarized in this report:

1. Milani and Grapentine, 2005: Before the thin-layer cap was installed in 2012, ECCC conducted a BEAST (BEnthic Assessment of SedimenT) study in 2000 to evaluate the potential effects from contaminated sediment to benthic invertebrates in the AOC. The assessment found that within Peninsula Harbour AOC, **the benthic communities were most impaired in Jellicoe Cove, and benthic communities outside Jellicoe Cove were similar to reference sites.**

2. Deacon and Lavoie, 2013: An assessment of benthic macroinvertebrate community composition in Beatty Cove concluded that **Beatty Cove is relatively unimpaired**, with a high density of benthic macroinvertebrates comprising mostly of crustacea.

3. ENVIRON, 2008: As discussed above under section 2.0, an ecological risk assessment (ERA) concluded that hot-spot management was the preferred remedial approach to manage contaminated sediment in Jellicoe Cove. **The resulting thin-layer cap was intended to allow for the re-establishment of a benthic community in clean lake bottom material within Jellicoe Cove.** The ERA also identified **risk-based sediment management**

goals for MeHg and PCBs, from which the delisting criterion targets were based to protect fish and mink.

4. George, 2019: In order to evaluate the success of the thin-layer cap in Jellicoe Cove with regards to cap stability, cap effectiveness, and ecological recovery, a long-term monitoring (LTM) plan for the AOC was established; to be conducted every 5 years for 20 years. In 2017, the first full long-term monitoring assessment was completed by the MECP showed the **cap to be stable, effective at reducing total Hg, MeHg and PCB surficial concentrations on the thin-layer cap footprint, and was recolonized by benthic invertebrates.**

5. Graham *et al*., 2019: To measure the average concentrations of mercury and PCBs for the entire AOC following the thin-layer cap installation in 2012, and determine if the average levels meet the BUI delisting criteria and targets established by the 2008 ecological risk assessment, ECCC and MECP collected sediment samples in 2017. The resulting analysis by ECCC produced **spatially weighted average concentrations (SWACs) that show declines in average concentrations for MeHg and PCBs in surficial sediment of the AOC, meeting the ERA risk-based sediment management goals on which the delisting criteria is based.**

The results of these studies are discussed below.

a) Dynamics of benthic populations

The 2000 BEAST study evaluated several different parameters to evaluate the potential effects from contaminated sediment to benthic invertebrates in the AOC, one of which included benthic community structure (Milani and Grapentine, 2005). The study assessed 33 sites in Peninsula Harbour, with 12 located outside of Jellicoe Cove and 21 located inside. To evaluate benthic community structure, the study compared benthic invertebrate communities in Peninsula Harbour to Great Lakes reference sites from Lake Superior, Lake Huron (including Georgian Bay and the North Channel), Lake Michigan, and Lake Ontario, and found benthic communities at sites located in the AOC outside of Jellicoe Cove to be similar to Great Lakes reference sites.

In addition, in 2012, a study analysed the composition of benthic macroinvertebrate communities at three sites within Beatty Cove and found that when compared to relatively unimpaired sites from Lake Nipigon and an impounded area of the Black Sturgeon River, Beatty Cove was relatively unimpaired with a relatively high density of benthic macroinvertebrates (Deacon and Lavoie, 2013). However, Milani and Grapentine (2005) reported benthic communities within Jellicoe Cove – the site subject to the 2012 thin-layer cap – to be very different from Great Lakes reference sites, indicating that benthic communities only within Jellicoe Cove were impaired in the AOC. With benthic communities outside of Jellicoe Cove being similar to reference sites, and thus not impaired, the evaluation of criterion a) *dynamics of benthic populations* is thereby applied only to benthic communities inside Jellicoe Cove, where benthic populations were impaired. Thus, the following discussion focuses primarily on assessments conducted within Jellicoe Cove.

Prior to cap installation, benthic invertebrate communities in Jellicoe Cove had greater diversity and abundance of taxa compared to reference sites as a result of enrichment from high organic matter in the sediment (Milani and Grapentine, 2005). In other words, the existing abundance and diversity of benthos found in the area of the elevated contaminated sediment were different from the naturally occurring benthic communities at Great Lakes reference sites. Through cap installation, the affected benthic community in Jellicoe Cove was covered and essentially destroyed as a result of the smothering affect by the cap, which was a necessary measure for the management of contaminated sediment in the Cove. With the legacy contamination now covered, it is expected that over time, as new sediment continues to deposit over the cap, substrate material and conditions necessary for benthic invertebrates will likely re-establish. An aquatic vegetative study (Foster and Radcliff, 2018) observed submergent vegetation had increased since the installation of the thin-layer cap from 3% in 2013 to 5% in 2018, and reported there to be sparse patches of stonewort and other submerged aquatic vegetation.

Although a direct comparison of benthic community structure cannot be made pre- and post-cap due to differences in sampling methodologies, the 2017 LTM assessment did report benthic invertebrate re-colonization on the cap. The diversity of benthos was calculated to be fairly high on the cap, with 102 species from 24 families identified on the thin-layer cap in 2017, including more sensitive taxa like amphipods (George, 2019). Note that natural recovery on the thin-layer cap will continue to be tracked under the LTM program, regardless of BUI re-designation to Not Impaired status.

b) Benthic invertebrate contaminant body burdens

ENVIRON (2008) developed several management goals in the ERA that intended to be protective of receptors exposed to contaminated sediment in Jellicoe Cove. Through bioaccumulation, contaminants stored within benthic invertebrates (termed "body burdens") can be passed on and accumulate up the food chain; going from benthos to fish/wildlife (benthic invertebrates form part of the diet of some fish), and then to other animals that eat the fish/wildlife. MeHg is the form of mercury that bioaccumulates the most and is the most toxic, and PCBs can contribute to these contaminants being present in fish.

The ERA concluded that MeHg and PCB levels in Peninsula Harbour may have impaired the reproductive success of individual Lake Trout, Lake Whitefish, and Longnose Suckers; three fish species for which information on MeHg and PCBs is primarily available (ENVIRON, 2008a). The ERA also found that levels of MeHg and PCBs may pose a risk to humans (discussed under Fish Consumption section, below), and to some wildlife consuming fish from the harbour. Mink were selected to represent fish-eating wildlife (i.e., piscivorous mammal populations) as they are known to be highly sensitive to the toxicological effects of MeHg and PCBs. Therefore, it was believed that conclusions regarding mink would be protective of other, less sensitive species (ENVIRON, 2008a).

In order to evaluate the impact of MeHg and PCBs in benthic invertebrates, the ERA locally derived sediment targets were based on the potential for MeHg and PCBs to cause adverse effects on the reproductive success of mink consuming Lake Trout, Lake Whitefish, and Longnose Sucker, and on the reproductive success of fish within the AOC. The PCB and MeHg risk-based sediment management goals for the protection of specified receptors identified in the ERA were:

- AOC average sediment concentration for total PCBs is 0.060 mg/kg (*no adverse effects on mink consuming Lake Trout, Lake Whitefish and Longnose Sucker*).

- AOC average sediment concentration for MeHg is 0.002 mg/kg (*no adverse effects on fish*) (ENVIRON, 2008a).

These risk-based protective levels, as identified in the ERA, were incorporated into the *Degradation of Benthos* BUI delisting criteria. The delisting criteria calls for AOC average sediment concentrations to be ***less than*** 0.060 mg/kg for total PCBs and ***less than*** 0.002 mg/kg for MeHg. It should be noted that the ERA risk-based protection levels have been identified as being "overly protective" by the author of the ERA, Miranda Henning (Henning, 2020). Although they are based on the ERA risk-based management goals, the delisting criterion targets have extended the protection limit for fish and mink beyond the already conservative targets identified in the ERA by requiring total PCB and MeHg concentrations to be *less than* 0.060 and 0.002 mg/kg, respectively, as opposed to equalling them.

To assess if MeHg and PCB sediment concentrations met the delisting criterion for benthic invertebrate contaminant body burdens, a spatially weighted average concentration (SWAC) survey was conducted in 2017 (Graham *et al*., 2019; see full report in Appendix E). Sediment samples were collected throughout the AOC and analysed to calculate SWACs that could be compared with both the delisting criteria targets and the ERA 2008 pre-remediation sediment SWACs. The SWACs were calculated using Theissen polygons, and quantify actual exposure to contaminants by mobile species (Figure 4). Given that the target species, mink and fish, are not limited to Jellicoe Cove where the thin-layer cap was installed, SWACs allow for a more accurate and realistic estimation of MeHg and PCB exposure to varying concentrations throughout the AOC.

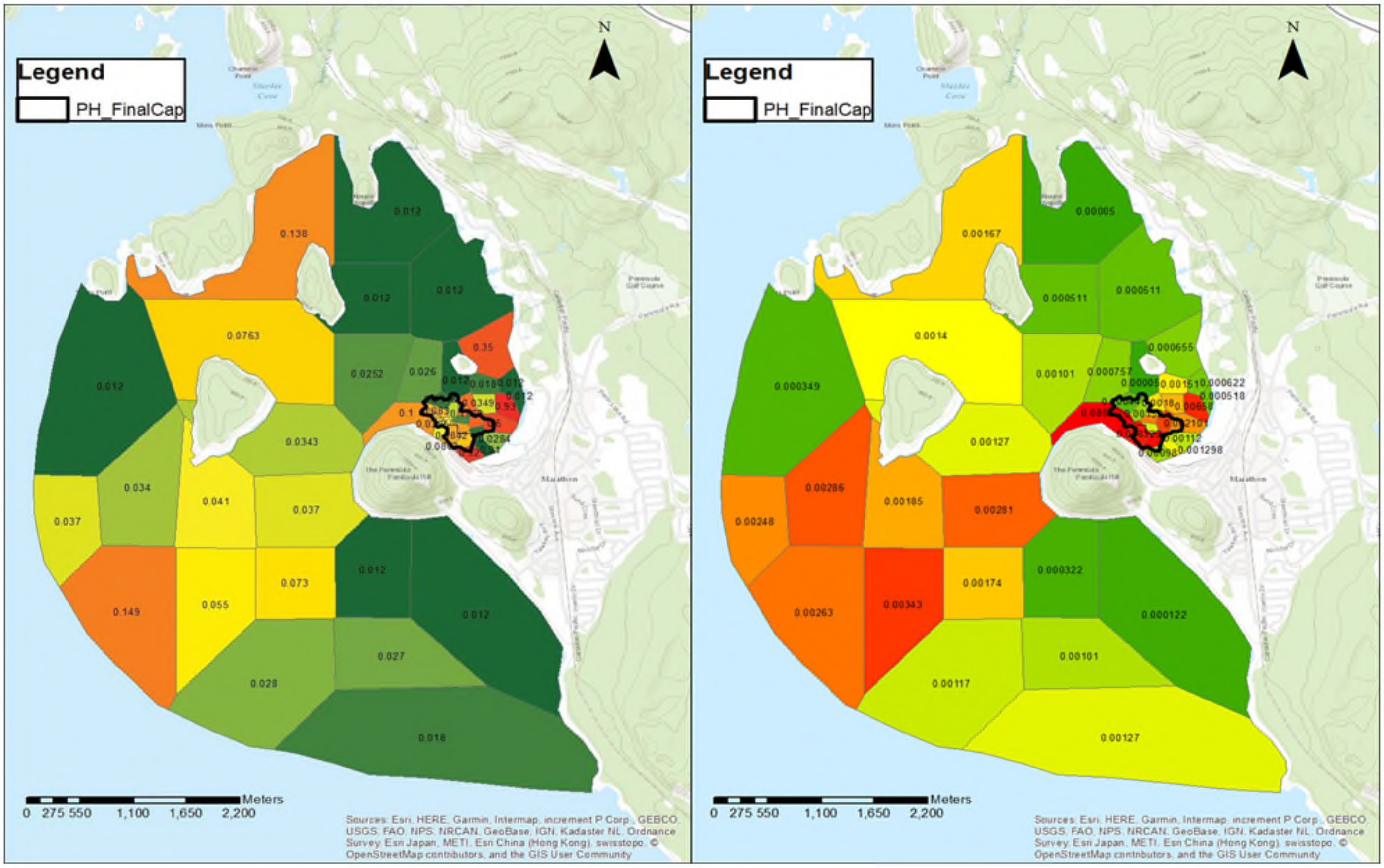

Figure 4: *Thiessen Polygons and concentrations (mg/kg) used for calculating SWACs for Total PCBs (left) and MeHg (right). Colours represent concentrations ranging from lowest (green) to highest (red). Concentrations in mg/kg are shown in each polygon.*

The ERA risk-based target concentrations, delisting criteria, ERA pre-remediation SWACs, and the post-remediation SWACs are presented in Table 5:

Table 5: Spatially Weighted Average Concentrations of total PCBs and MeHg in surficial sediment of the Peninsula Harbour AOC.

	ERA RISK-BASED GOAL	DELISTING CRITERION TARGET (mg/kg)	2008 PRE-REMEDIATION SWACS (mg/kg)	2017 POST-REMEDIATION SWACS (mg/kg)
Total PCBs	0.060	<0.060	0.11	0.0509
MeHg	0.002	<0.002	0.0029	0.0019

Note that SWACs calculated for the 2008 ERA (pre-remediation SWACs) and those calculated post-remediation in 2017 in the Graham et al. (2019) study used different AOC boundaries likely based on data availability. The ERA used an area that is about half the extent of the AOC boundary. The SWACs calculated from the 2017 data on the other hand used a larger area that more accurately represents the AOC boundary, as specified by the BUI delisting criteria.

Results of the survey (Graham *et al.,* 2019) in Table 5 show a reduction in the levels of PCBs and MeHg throughout the AOC following the thin-layer cap sediment remediation in 2012 (Table 5 above). Based on the 2017 sediment sampling, the AOC average SWACs for both total PCBs and MeHg meet their respective delisting criterion targets:

- The AOC average SWAC for total PCBs is 0.0509 mg/kg, which meets the delisting criterion target of less than 0.060 mg/kg total PCBs; and
- The AOC average SWAC for MeHg is 0.0019 mg/kg, which meets the delisting criterion target of less than 0.002 mg/kg MeHg.

As a point of reference, the post-remediation total PCBs concentration (0.0509 mg/kg) not only meets the delisting criterion target (<0.060 mg/kg), and is lower than the ERA risk-based target (0.060 mg/kg), it is also lower than the provincial SEL of 17.1 mg/kg (for inside Jellicoe Cove), and the provincial LEL of 0.07 mg/kg (see Table 3 on page 17) (Fletcher *et al*., 2008). Similarly, for MeHg, the post-remediation concentration (0.0019 mg/kg) also meets the delisting criterion target (<0.002 mg/kg) and is lower than the ERA risk-based target (0.002 mg/kg), provincial SEL of 2 mg/kg and the provincial LEL of 0.2 mg/kg.

As for conditions on the cap, prior to cap installation, baseline data was collected in 2009 and 2011 to measure the future success of the cap in reducing concentrations of Hg and PCBs in the tissue of benthos (ECCC, unpublished data). Post cap installation, MECP analysed the surficial sediment on the cap that resulted from natural sedimentation since construction of the cap in 2012, and compared that data to the 2009 and 2011 baseline data (George, 2019). Overall, the 2017 LTM assessment showed the thin-layer sediment cap to be stable and effective in reducing total Hg surficial sediment concentrations well below the remedial target of 3 mg/kg. The median SWAC for the capped area was 0.37 mg/kg, which was much lower than the Hg surficial cap 2009 and 2011 SWACs of 7.69 and 6.37 mg/kg, respectively (Table 6). Similarly, concentrations of MeHg and PCBs on the surficial sediment of the cap were also reduced compared to levels measured in pre-remediation 2009 and 2011 (Table 6).

Table 6: Median SWACs for total Hg, MeHg and PCBs on the thin-layer cap footprint in 2009, 2011, 2017

	2009 SWACS (mg/kg)	2011 SWACS (mg/kg)	2017 SWACS (mg/kg)
Total Hg	7.69	6.37	0.37
MeHg	0.0078	0.00511	0.00302
PCBs	N/A	0.372	0.053[b]-0.196[c]

[b] SWAC based on minimum concentration of replicates at each station

[c] SWAC based on maximum concentration of replicates at each station

These declining levels of Hg, MeHg, and PCBs are an indication that recovery is underway in Jellicoe Cove. Results from the LTM assessment assist with understanding changing conditions specifically on the thin-layer cap, versus the AOC-average SWACs as presented by Graham *et al*. (2019) that examine changes across the AOC as a whole that are used in the BUI delisting criteria. Hg, MeHg and PCB concentration reductions in Jellicoe Cove have high implications for the rest of the Peninsula Harbour since Jellicoe Cove was identified as being the most heavily impacted area in the AOC (see section 2.0). Therefore, continued improvements in Jellicoe Cove will mean improvements in the rest of the AOC because of the reduced spread of contaminants into the harbour from the Cove.

Overall, results from various studies discussed above indicate improving conditions within the AOC with declining contaminant concentrations. The 2017 post-cap sample collections and analysis by Graham *et al*. (2019) shows AOC average concentrations for MeHg and PCBs meet the delisting criterion, as well as the protective, risk-based targets established in the ERA to protect fish and mink.

In addition, the thin-layer cap has been effective at reducing the total Hg surficial concentration well below the 3 mg/kg remediation target within Jellicoe Cove. MECP will continue to monitor the effectiveness of the cap under the 20-year LTM plan, but based on the evidence provided for AOC-wide sediment concentration averages (Table 5) and averages on the thin-layer cap footprint (Table 6) over time, it is clear that recovery is underway. Also, following the 2012 remediation project, there is evidence of benthic re-colonization and the emergence of submerged aquatic vegetation on the cap, and AOC benthic populations outside the Jellicoe Cove area have long been found to be similar to Great Lakes reference sites. Therefore, it is recommended that the *Degradation of Benthos* BUI be re-designated to a Not Impaired status.

3.2 BUIs CONTINUED TO BE DESIGNATED AS IMPAIRED

3.2.1 Restrictions on Fish and Wildlife Consumption (Impaired)

Historic Reason for Impairment

This BUI continues to be impaired for the fish component only; wildlife consumption has always been designated Not Impaired. The Stage 1 RAP report (1991) first identified the BUI as impaired because restrictions were advised on eating fish due to elevated concentrations of mercury and polychlorinated biphenyls (PCBs).

- Hg concentrations in larger sizes of Lake Trout (*Salvelinus namaycush*), White Sucker (*Catostomus commersonii*), Longnose Sucker (*Catostomus catostomus*) and Redhorse Sucker (*Moxostoma carinatum*) exceeded the then Health and Welfare Canada guideline of 0.5 mg/kg.
- PCB concentrations in White Sucker (*Catostomus commersonii*) from 35 to 45 cm in length exceeded the guideline of 2.0 mg/kg.

The status remained Impaired in the Stage 2 RAP report (2012).

As with all AOCs, the Peninsula Harbour RAP has aligned this BUI with the provincial Fish Contaminants Monitoring Program and the Stage 1 fish concentrations applied to the fish consumption advice issued under the MECP's *Guide to Eating Ontario Fish* (MECP, 2019)[12].

Delisting Criteria

In 2017, ECCC and MECP conducted an evaluation of delisting criteria for the remaining BUIs in all Canadian AOCs. The objective of the evaluation was to identify delisting criteria that do not appear to be measureable or feasible, and to develop specific recommendations and/or suggestions to update the problematic delisting criteria. For the *Restrictions of Fish Consumption* BUI, generic language for a revised delisting criteria is suggested by scientific experts for consideration by all Canadian AOCs, and is presented below along with the original delisting criteria for the *Restrictions on Fish Consumption* BUI as adopted under the Stage 2 RAP report:

ORIGINAL DELISTING CRITERIA (2012)	REVISED DELISTING CRITERIA (2017)
A comparison study of fish tissue contaminant levels demonstrates that there is no statistically significant difference in fish tissue concentrations of contaminants causing fish consumption advisories in the AOC compared to suitable Lake Superior reference sites.	*Consumption advisories for fish of interest in the AOC are non-restrictive or no more restrictive than the advisories for suitable reference areas due to contaminants from locally controllable sources.*

The revised delisting criteria is being adopted in several Canadian AOCs, and it will evaluate the beneficial use impairment based on a three-tiered assessment framework (Bhavsar et al., 2018). Note that the current Status Report formalises the revised criteria as the official criteria for the Restriction on Fish consumption BUI in Peninsula Harbour AOC.

The framework sets out the order in which the three tiers are examined and evaluated to assess the status of the beneficial use impairment against the delisting criteria: advisory criteria, reference comparisons, and lines of evidence (Figure 5). Based on the outcomes of the tiered evaluation(s), a recommendation is made to either maintain the 'Impaired' beneficial use impairment status or to pursue the re-designation to 'Not Impaired' given the evidence used in the assessment framework.

[12] https://www.ontario.ca/environment-and-energy/sport-fish-consumption-advisory?id=48448625: MECP advisory table for Peninsula Harbour, presented through an interactive map.

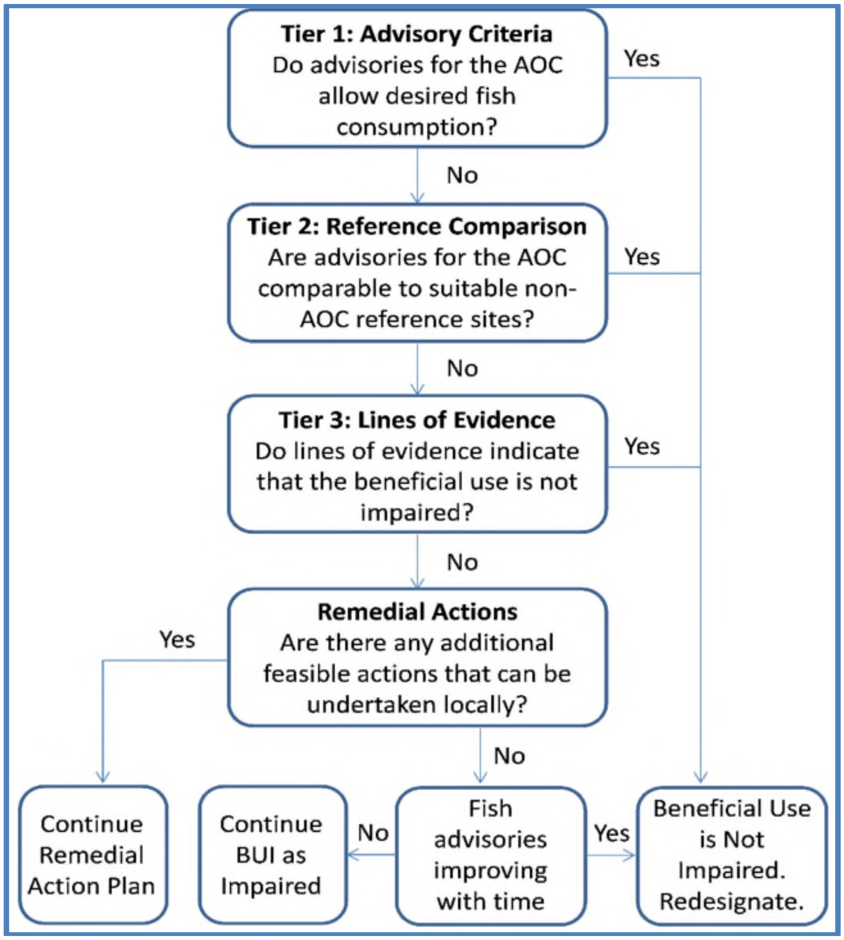

Figure 5: *Three-Tier Assessment Framework (Bhavsar et al., 2018)*

Tier 1 examines if contaminant levels in fish at an AOC are resulting in restrictions for eating fish at a frequency that are below a desired level determined by consumption surveys of people fishing at the AOC. If the Tier 1 criterion is met, then the RAP Team may suggest proceeding with the BUI's status re-designation to 'Not Impaired' and the other tiers are not assessed.

Tier 2 examines the advisories for the fish of interest (from local survey of anglers) compared to a suitable Great Lakes reference site. The advisories given for he AOC should be no more restrictive (no worse) than the appropriate reference sites. If the Tier 2 criterion is met, then the RAP Team may suggest proceeding with the BUI's status re-designation to 'Not Impaired' and the other tier is not assessed.

Tier 3 analysis is conducted if Tier 1 and Tier 2 fail. Tier 3 assessment considers other quantitative and qualitative lines of evidence along with professional judgement to understand the current status of contaminants related to fish consumption restrictions in the AOC. The multiple lines of evidence suggested are temporal trends of fish contaminant levels, trends in young-of-the-year or forage fish in an AOC compared to a reference site (e.g., the nearby connecting Great Lakes), trends of the contaminant levels in sediments or water. Professional judgement could also include examining the ecological aspects of the fish of interest (such as their feeding ecology, growth, condition, and spatial movements) because these can be factors in how/where contaminants bioaccumulate and may confound cause-effect linkages between cleanup activities and the status of the BUI or of AOC-specific issues.

If the multiple lines of evidence indicate that conditions are improving over time and there are no additional, feasible remedial actions that can be undertaken locally to improve fish consumption, then the RAP Team may suggest proceeding with the BUI's status re-designation. However, if more actions can be implemented to address local contaminant sources, then those should be identified and implemented through the RAP with the BUI remaining 'Impaired' until the delisting criteria can be met.

Evidence in support of achieving the target

The delisting criteria for the *Restrictions on Fish Consumption* BUI has not yet been met.

The elevated levels of mercury and PCBs in the fish were caused by the contaminated sediment in Jellicoe Cove, which was the result of historical inputs from the former pulp mill and chlor-alkali plant, and historical log booming within the harbour. In 2012, a thin-layer cap was installed on top of the most contaminated sediment in the AOC, which placed 15-20 cm of clean sand over an area in Jellicoe Cove to reduce exposure of benthos to contaminants. With the benthos' exposure to contaminants reduced, the level of contaminants in fish that results from ingesting these insects and worms is also reduced.

In 2019, a preliminary study commissioned by ECCC examined trends in contaminant levels in fish collected from Peninsula Harbour (Drouillard, 2019 – see Appendix H). The study was a Tier-1 level analysis (of the three-tier Assessment Framework) using MECP's Fish Contaminant Monitoring Program's monitoring data collected between 1973 and 2017. The study analysed levels of total PCBs and Hg in fish from the harbour, with a focus on the status post-thin layer cap construction in 2012. Short-term (2012 – 2017) and long-term (1970s – 2017) temporal comparisons were conducted for Lake Whitefish and Lake Trout caught within the AOC. Longnose Suckers were also collected in 2017, but there was no pre-remediation collection, and therefore a short-term temporal comparison was not possible. The comparisons were conducted for each species using fish that were in the same size class.

The Tier 1 evaluation of the three-tier Fish Consumption BUI assessment showed substantial declines in levels of both PCBs and Hg, since the 1970s (long term), in Lake Trout, Lake Whitefish and Longnose Sucker.

Long-term analysis (Table 8) showed (for changes that happened even before the thin-layer cap):

- 85% or greater declines in levels of total PCBs in all three fish species between 1973 to 2017; and
- Greater than 80% decline in levels of Hg in Lake Whitefish and Longnose Sucker, and by 69% in Lake Trout from the 1970s.

Table 8: Long-term trend analysis of total PCB and Hg concentration in Lake Trout, Lake Whitefish and Longnose Sucker from 1973-2017.

	% DECREASE IN TOTAL PCBs	% DECREASE IN Hg
Lake Trout	85	69
Lake Whitefish	98	90
Longnose Sucker	95	80

Short-term analysis (Table 9) showed (for changes following thin-layer cap installation in 2012):

- About 85% decline in levels of total PCBs in both Lake Trout and Lake Whitefish from 2012 to 2017;
- Decline by 50% and 26% in levels of Hg in Lake Trout and Lake Whitefish, respectively, from 2012 to 2017.

Table 9: Short-term trend analysis of total PCB and Hg concentration in Lake Trout and Lake Whitefish from 2012-2017.

	% DECREASE IN TOTAL PCBs	% DECREASE IN Hg
Lake Trout	84	50
Lake Whitefish	85	26

Note: Longnose Sucker was only sampled once, thus not considered in the short-term analysis.

Drouillard's study also analysed toxaphene, dioxins/furans and dioxin-like PCB compounds (twelve PCBs that interact with organisms in the same mechanism as the most toxic dioxin compounds). However, in the context of the Areas of Concern program, toxaphene, dioxins/furans and dioxin-like PCB compounds were not identified as contaminates of local concern in the Peninsula Harbour AOC Stage 1 RAP report.

The Government of Ontario has been monitoring fish contaminant levels and issuing fish consumption advisories for the Canadian waters of the Great Lakes since the 1970s, and in doing so, looks for a number of contaminants, including PCBs and Hg (Bhavsar *et al.*, 2018). When compared to the fish advisory benchmarks for at least 8 meals per month advisory set by Ontario (MECP, 2019) results from Drouillard's analysis show that PCB and Hg levels measured in recent years (2017) may still pose a potential health risk to human consumers. Although concentrations have declined since the 1970s, current Hg and PCB levels continue to be elevated above the fish consumption advisory benchmarks of 8 meals/month in all three fish species.

Using the most recent data from 2017, Drouillard simulated fish consumption advisories for the Peninsula Harbour AOC in order to help understand the health risk to consumers of AOC caught fish due to contaminants present in the fish. The advisories were derived assuming a sole presence of total PCBs and Hg irrespective of the presence of other contaminants. And the Ontario method of applying a power series regression of fish length vs. contaminant concentration for each species was used. The simulated advisories were:

- Total PCBs: *fairly restrictive*, meaning about 0-2 meals per month for Lake Trout and Longnose Sucker for all populations;
- Hg: *fairly lenient* for the general population and have only minor restrictions, meaning 4 meals per month for the sensitive population.

Overall, Drouillard's study noted PCBs to be the primary and Hg to be the secondary contaminant of concern for consuming AOC fish. The simulated advisories highlight that current total PCB concentrations continue to drive fish consumption restrictions, and it is still a concern from the Fish Consumption BUI perspective. However, declining levels of both Hg and total PCBs observed over the long-term and short-term, as a result of the 2012 thin layer cap remedial effort as well as operational changes to the Marathon mill in the 1990s, are encouraging. Drouillard's anticipates further decreases in contaminant concentrations in fish, especially in response to the sediment remediation effort of 2012 (Drouillard, 2019).

Currently, as a result of this, the *Restrictions on Fish Consumption BUI* use remains impaired. Diligence will continue under the provincial Fish Contaminants Monitoring Program. Consumers are advised to consult the *Guide to Eating Ontario Fish*[13] to help minimize exposure to contaminants in fish caught in the AOC.

To continue efforts in evaluating the *Restrictions on Fish Consumption* BUI, ECCC and MECP will assess forage fish (born after the thin-layer cap was constructed) in 2020-2021 to better understand the effectiveness of the 2012 sediment remediation project in the ecological recovery of the AOC. Including forage fish is important, because analysing individual fish born after the installation of the thin-layer cap will give an indication of the level of contaminants accumulated by fish post-cap installation, in addition to the older, larger bodied fish that may have a legacy body burden. In addition, MECP will conduct a community survey on fish consumption in 2021 to gather updated information from area residents on the popularity and frequency of eating fish caught from the AOC. This will be an update to a community survey conducted in 2008 undertaken as part of the human health risk assessment by ENVIRON (2008a). In that past survey, residents of Marathon and the Biigtigong Nishnaabeg were canvassed about whether they fish within Peninsula Harbour, and if they eat the catch. The majority response indicated most people do not consume the number of fish from Peninsula Harbour that would be associated with adverse impacts (ENVIRON, 2008a). While 17% of the survey respondents indicated that they consume fish caught in Peninsula Harbour, the report concluded avid anglers do not target Peninsula Harbour as a fishing destination; instead showing the majority of fish consumed were caught outside of the AOC. The new 2021 survey will provide updated insight and help supplement data collected during the survey in 2008. It will provide information on the popularity of fish for consumption as well as eating frequency by the local community over a decade later.

[13] Visit: https://www.ontario.ca/environment-and-energy/eating-ontario-fish

Together, the past studies and those planned for the future are consistent with the new comprehensive three-tiered approach adopted to evaluate the revised delisting criteria. The assessment of *the Restrictions on Fish Consumption* beneficial use impairment based on the three-tiered assessment framework may look like:

TIER	INFORMATION TO SUPPORT ASSESSMENT
1	**Fish Consumption Survey** **(Completed - 2008)** In 2008, as part of the ecological risk assessment to help determine the management of contaminated sediment in the AOC, a community survey was commissioned to canvass residents of Marathon and the Biigtigong Nishnaabeg about whether they fish within Peninsula Harbour, and if they eat the catch. The majority response indicated most people do not consume the amount of fish from Peninsula Harbour that would be associated with adverse impacts. **Updated Fish Consumption Survey** **(Planned for 2021)** Since the 2008 survey is now over a decade old, a follow-up is planned to provide current representation of fish consumption habits by area residents. MECP will conduct a new community survey to gather updated information on the popularity and frequency of eating AOC-caught fish. **Contaminants in Peninsula Harbour Fish: A Short-Term and Long-Term Analysis** **(Completed: 2019)** In 2019, a preliminary study examined contaminant levels in select AOC fish using data collected between 1973 and 2017. The short-term and long-term trend comparison shows a significant reduction in contaminant levels in AOC fish; however levels continue to drive fish consumption restriction advisories and a fuller assessment, based on more AOC fish (not just a few select species), is required. **Contaminant Analysis in Peninsula Harbour Forage Fish** **(Underway in 2020 and 2021)** In summer 2020, there was a collection of forage fish born after the installation of the thin-layer cap. These will be examined by the MECP for contaminants to advance the assessment of the BUI. Results from this assessment will supplement results from the 2019 Drouillard assessment to provide a fulsome assessment of contaminant levels in the AOC using more fish.
2	**Pending review of Tier 1**
3	**Pending review of Tier 2**

Once completed, the forage fish contaminant analysis and the updated community fish consumption survey will provide a fuller assessment of the *Restrictions on Fish Consumption* BUI under Tier 1 of the assessment framework. Results from the Tier 1 analysis will determine the need for further assessment of the beneficial use impairment under Tier 2. The current assessment shows that declining levels of mercury and total PCBs observed over the long-term and short-term analysis from the 2019 study are encouraging, and further decreases in response to the sediment remediation effort of 2012 can be expected in the future analysis.

Along with these future initiatives, MECP's 20-year LTM plan for the thin-layer cap will also help determine whether contaminant tissue concentrations are decreasing through time. The second LTM assessment is anticipated for 2023.

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APPENDIX A: BUIs ALREADY RE-DESIGNATED TO NOT IMPAIRED

1. Restrictions on Dredging Activities

Reason for Impairment

The *Restrictions on Dredging* activities beneficial use was considered impaired due to contaminated sediment in the AOC. The sediment, particularly in Jellicoe Cove, contains levels of mercury, PCBs, chromium, copper, iron, nickel and total phosphorus as a result of previous discharges from the former pulp mill and chlor-alkali plant. In addition, there were high levels of organic materials in the Jellicoe and Beatty Coves from historic log booming practices. The levels of these parameters in Peninsula Harbour sediment exceed MECP's open water disposal guidelines, meaning that dredging this sediment would have required treatment or proper containment for disposal.

Completed Actions and Monitoring

As mentioned, contaminated sediment was the driver behind the designation of the *Restrictions on Dredging* BUI. Originally, the BUI was meant to address large-scale commercial navigational dredging of contaminated sediments, which challenged its applicability to several AOCs where navigational dredging was not undertaken. In the case of Peninsula Harbour AOC, dredging operations have not been undertaken in the area during the lifetime of the AOC designation. In addition, the primary sources of contamination – log booming, the pulp mill and chlor-alkali plant have all ceased operation. In 1998, MECP and ECCC produced a technical memorandum to the Steering Committee overseeing the *Canada-Ontario Agreement on the Great Lakes*, which recommended that *Restrictions on Dredging Activities* should not be considered an impairment in several AOCs, including Peninsula Harbour, because it was determined not to have navigational dredging requirements.

Without the demand for navigational dredging, contaminated sediments should be considered in the context of other categories of ecosystem impairment (Krantzberg *et al*., 1996) and are better represented by the *Degradation of Benthos*, *Restrictions on Fish and Wildlife Consumption* and *Fish and Wildlife Populations* BUIs, discussed above. In the case that dredging is required for navigational or other development purposes in the future, dredging needs were considered in the sediment management plan (ECCC and MECP, 2011).

Moreover, the BUI had intended to address the additional *financial costs* associated with taking special precautions when dredging and disposing the material on land, instead of freely in the open waters of the Great Lakes. Open water disposal is now largely discouraged in Ontario. Any future dredging activities in this area, for development or navigational purposes, are subject to existing provincial dredging and disposal restrictions and regulations, which requires proof that it will not cause an adverse effect to the lake ecosystem. With no dredging operations undertaken in its history as an AOC, contaminated sediment being more effectively addressed under the benthos beneficial use impairment, and any future dredging being subject to existing administrative controls, this beneficial use was determined to no longer be a concern in the Stage 2 RAP report (Peninsula Harbour Remedial Action Plan, 2012).

2. Fish Tumours or Other Deformities

Reason for Impairment

Although this BUI was never designated as impaired, the Stage 1 RAP report identified the *Fish Tumours or Other Deformities* beneficial use as Requires Further Assessment (Peninsula Harbour Remedial Action Plan, 1991) because of the potential carcinogen effects from pulp mill effluent on fish.

Completed Actions and Monitoring

The Stage 2 RAP report noted there had been no reports from fisheries personnel or the public to indicate the presence of liver tumours or other deformities in Peninsula Harbour fish (Peninsula Harbour Remedial Action Plan, 2012). The potential for impairment based on the discharge of chlorinated organics was addressed when the pulp mill began using 100% chlorine dioxide in place of chlorine in the bleaching process in 1991 and, together with the implementation of the secondary treatment in 1995 and its closure in 2009, has effectively reduced and then eliminated the discharge of chlorinated organics and dioxins and furans. This beneficial use, therefore, was considered Not Impaired for this AOC in the Stage 2 RAP report (Peninsula Harbour Remedial Action Plan, 2012).

APPENDIX B: LONG TERM MONITORING AND SURVEILLANCE

1. Long Term Monitoring Plan (MECP)

A Long Term Management Plan for the thin-layer cap was developed by AECOM in 2011 for a period of 20 years to monitor and evaluate the effectiveness of the cap. The LTM assessment is to be conducted by MECP every five years, with the first assessment completed in 2017 (results discussed in the report above). MECP's LTM is a separate initiative from the RAP and the projected timeline for the upcoming assessments is presented in Table 10 below.

Table 10: Sediment Management Project Long Term Monitoring Plan Timeline.

YEAR	YEARS POST-CAP	ACTIVITY
2012	0.2	Multi-beam bathymetry survey
		Baseline - Submerged aquatic vegetation survey
		Baseline - Cap movement survey
2013	1	Substrate aquatic vegetation survey
		Cap movement survey
		Cap thickness study
2015	3	Submerged aquatic vegetation survey
		Cap movement survey
2017	5	Submerged aquatic vegetation survey
		Fish tissue survey
		Sediment characterization
		Cap movement survey
2022	10	BEAST study and benthic tissue
		Fish tissue survey
		Sediment characterization
		Cap movement survey
2027	15	BEAST study and benthic tissue
		Fish tissue survey
		Sediment characterization
		Cap movement survey
2032	20	BEAST study and benthic tissue
		Fish tissue survey
		Sediment characterization
		Cap movement survey

2. Sportfish Contaminant Monitoring Program (MECP)

The Sportfish Contaminant Monitoring Program of the MECP has been monitoring various contaminants in Ontario fish since the late 1960s. Fish are collected and analyzed for a variety of substances, including mercury, PCBs and dioxins, and the data gathered is used to inform fish-eating guidelines in Ontario in the Guide to Eating Ontario Fish. The guide provides information to anglers regarding the types and amounts of fish that are safe to eat from Ontario lakes and rivers. The Sport Fish Contaminant Monitoring Program is the largest testing and advisory program of its kind in North America.

3. Fish Community Index Netting (MNRF)

In 2010, MNRF initiated a Lake Superior Fish Community Index Netting (FCIN) Program to obtain 5 years of data for each of the four Lake Superior Areas of Concern (Thunder Bay, Nipigon Bay, Peninsula Harbour and Jackfish Bay). It is a standardized annual fisheries independent gillnet survey that is carried out from June through August in Ontario waters of Lake Superior. The FCIN program aims to establish a fishery independent trend over time of the relative abundance and diversity of fish species, particularly of Lake Trout and Lake Whitefish, and serves as a monitoring tool to track the dynamics of fish populations and their recovery within the Peninsula Harbour AOC. Data collected during the FCIN are the Upper Great Lakes Management Unit's primary sources of information for fisheries stock assessment and are used to inform commercial and recreational fisheries management.

APPENDIX C: COMMUNITY ENGAGEMENT

The assessment results and proposed BUI re-designations presented in this Status Report will be discussed with the AOC community in 2020-2021. Following community outreach and engagement, the Status Report will be submitted to the government of Canada and Ontario for formal agency approval for the BUIs recommended for Not Impaired status.

The following groups of experts have been or will be involved in the technical review process for the proposed BUI re-designations in the Peninsula Harbour AOC:

1) The RAP Coordinating Committee, which coordinates implementation of the Peninsula Harbour Remedial Action Plan and examines whether the science behind the work supports a recommendation to change the status of a BUI;
2) Members of the former RAP Public Advisory Committee and CLC, which provides local expertise and values that inform progress and plans for the Remedial Action Plan.

Outcomes of the technical review, as well as Indigenous and public engagement for the proposed BUI re-designations, will be recorded in a future edition of this Status Report under this Appendix.

APPENDIX D: THIN-LAYER CAP CORING STATIONS

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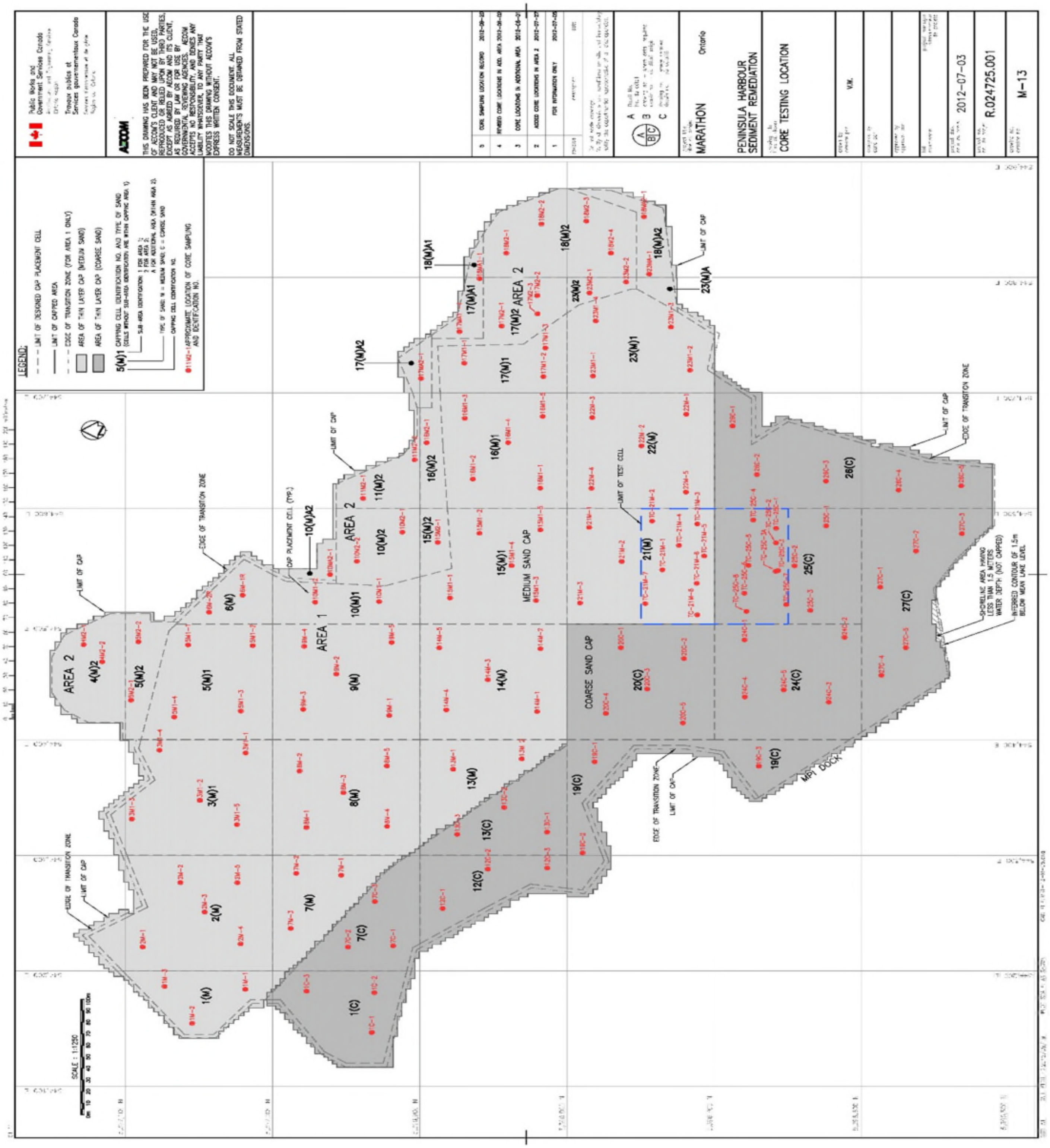

APPENDIX E: 2017 Spatially Weighted Average Concentration of MeHg and Total PCBs (ECCC)

APPENDIX F: Degradation of Fish and Wildlife Populations Assessment Report (MNRF)

APPENDIX G: Loss of Fish and Wildlife Habitat Assessment Report (MNRF)

APPENDIX H: Contaminants in Peninsula Harbour Fish

Appendix E

Environment and Climate Change Canada
Environnement et Changement climatique Canada

2017 SPATIALLY WEIGHTED AVERAGE CONCENTRATION OF METHYLMERCURY AND TOTAL PCBS FOR THE PENINSULA HARBOUR AREA OF CONCERN

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Great Lakes Areas of Concern Section
Sediment Remediation Unit
May 22, 2019

Canada

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2017 SPATIALLY WEIGHTED AVERAGE CONCENTRATION OF METHYLMERCURY and TOTAL PCBs FOR THE PENINSULA HARBOUR AREA OF CONCERN

FINAL REPORT

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Date: May 22, 2019

1 BACKGROUND

Prior to the management of the contaminated sediment in the Peninsula Harbour (PH) Area of Concern (AOC), Environment and Climate Change Canada (ECCC) commissioned an ecological and screening level human health risk assessment (ERA) that placed into context the potential risk of contaminated sediment on higher piscivorous receptors (i.e., mink, birds and anglers) and human health (Environ, 2008). The conclusion of the risk assessment was that a hot spot remediation approach would effectively reduce concentrations of total mercury (Hg), methyl-mercury (MeHg) and total polychlorinated biphenyls (PCBs) in the sediment to a level that would be protective of the target receptors, as well as prevent further spreading of contaminated sediment to the rest of PH.

The highest concentrations of Hg and the PCBs were found to be in the area of Jellicoe Cove, a 97 hectare area adjacent to the shoreline of the former pulp mill. The mill closed in 2009 and the site has been decommissioned. To establish the area and volume of sediment warranting management, spatially weighted average concentrations (SWAC) for MeHg and total PCBs were calculated. The PCBs hotspots were co-located with total Hg hot spots and as such, managing Hg contaminated areas would also manage PCB contaminated areas. Total Hg was selected as the focal contaminant for the hot spot remedial approach.

In 2012, a thin layer cap (TLC) was placed over a portion of Jellicoe Cove, covering areas that exceeded 3 mg/kg Hg, which was the clean-up target. Approximately 23 hectares were covered with 15-20 cm of clean sand to cap hotspots. Contaminated sediment that exceeded the target in water greater than 25 m deep was left to recover naturally.

In 2017, five years post-cap, sediment samples were collected from the entire AOC to assess the Degradation of Benthos beneficial use impairment (BUI). Beneficial use impairments are assessed against local delisting criteria that are outlined in the AOC's Remedial Action Plan. The sediment sampling for this study also corresponded to the first monitoring survey of the twenty year long-term monitoring (LTM) plan to assess the effectiveness of the cap and to monitor the ecological recovery of the area.

There are two elements of the delisting criteria for the Degradation of Benthos BUI; this report addresses one, as follows: "*this beneficial use will no longer be impaired when invertebrate tissue concentrations are below levels associated with adverse impacts (such as potential effects in predator species due to biomagnification). This is hypothesized to occur when average sediment concentrations in the AOC are less than: 0.06 mg/kg PCBs and 0.002 mg/kg methylmercury.*" (Peninsula Harbour Remedial Action Plan Team, 2012).

These locally derived targets were based on the human health and environmental risk assessments (Environ, 2008). The absence of adverse effects on mink (consuming longnose suckers, lake trout, and lake whitefish), were hypothesized to occur when average sediment PCB concentrations were less than 0.06 mg/kg. For MeHg, the protection of fish within the AOC required sediment concentrations less than 0.002 mg/kg. MeHg is the form of Hg that is available to receptors.

These sediment targets will be used as a measure to determine whether the Degradation of Benthos BUI delisting criterion has been met.

The pre-remediation SWACs provided in the ERA were established for three areas: Jellicoe Cove, the rest of Peninsula Harbour (RPH), and the AOC (JC + RPH) (Figure 1). Jellicoe Cove, as described above, is the area adjacent to the former pulp mill. The RPH is illustrated in the inset of Figure 1. For the purposes of the ERA, the AOC was described as JC and RPH combined, and not the entire AOC which is shown in Figure 2. The 2008 ERA established the following SWACs for the area:

MeHg:

- Jellicoe Cove – 0.0051 mg/kg
- Rest of Peninsula Harbour – 0.0019 mg/kg
- AOC (Jellicoe Cove + Rest of PH) – 0.0029 mg/kg

Total PCBs:

- Jellicoe Cove – 0.14 mg/kg
- Rest of Peninsula Harbour – 0.12 mg/kg
- AOC (Jellicoe Cove + Rest of PH) – 0.11 mg/kg

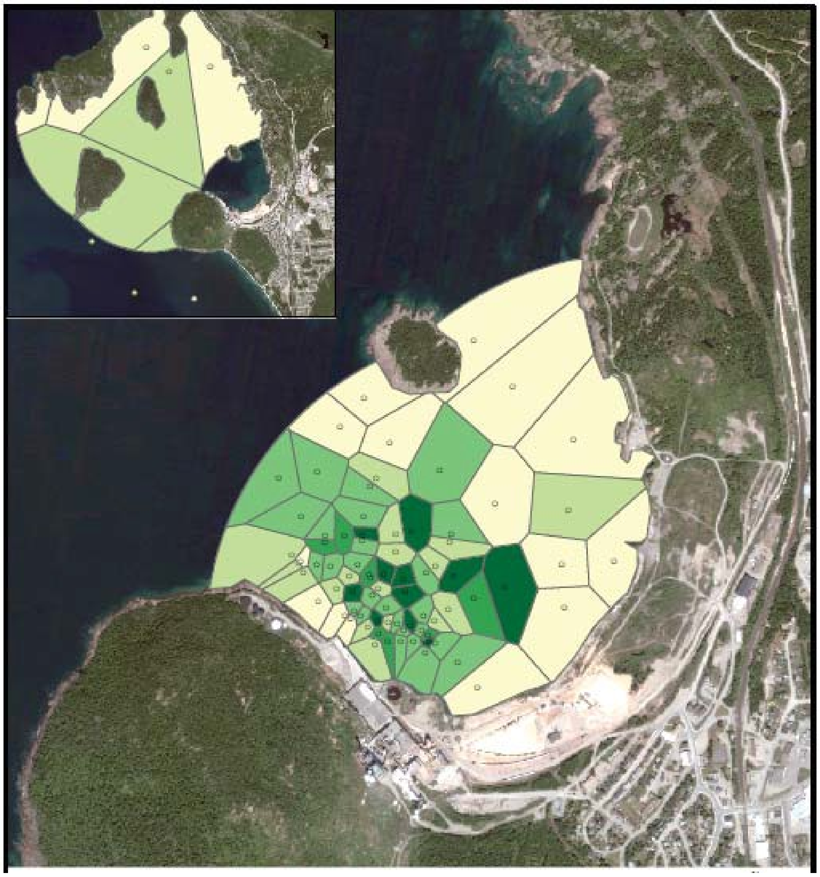

Figure 1. Spatially weighted average concentration (SWAC) polygons in Jellicoe Cove and the rest of Peninsula Harbour (inset) from the 2008 Ecological Risk Assessment (Environ, 2008).

2 OBJECTIVE

The objective of this study was to produce post-remediation SWACs that could be compared to Degradation of Benthos delisting criterion in order to help assess whether this BUI could be re-designated as 'not impaired'.

3 SCOPE OF WORK

Data for this study was collected jointly by Environment and Climate Change Canada (ECCC) and the Ontario Ministry of the Environment, Conservation and Parks (MECP).

The 2017 sampling included the ERA's defined area of Jellicoe Cove and the rest of Peninsula Harbour. In addition, the samples covered the entire AOC (area in orange in Figure 2) with a higher sample density within Jellicoe Cove.

Figure 2. Peninsula Harbour AOC water lot boundary (orange) with smaller sub-divided areas representing what was presented in the 2008 ERA (Areas 1 and 2).

1. Jellicoe Cove

Jellicoe Cove is shown as area #1 in Figure 2. Figure 3 shows the sample density from a 200m grid used to select locations in the cove, outside of the capped area (outlined in pink.) This resulted in twelve stations in Jellicoe Cove, not including the capped area.

As part of the 2017 Long-term monitoring plan (LTM), MECP collected surficial sediment from nine stations on the cap. This LTM data was also used in this SWAC assessment (Figure 4).

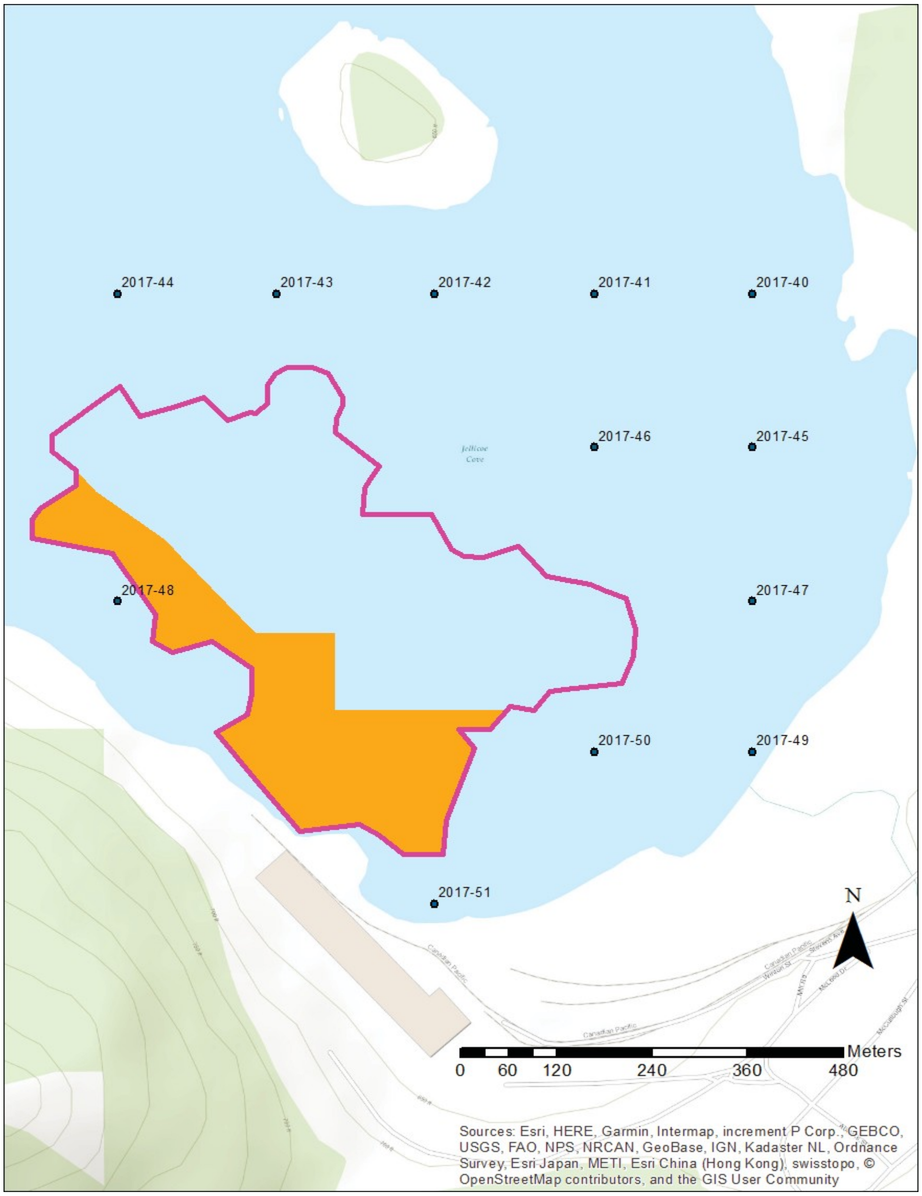

Figure 3. ECCC and MECP's 2017 Sampling locations in Jellicoe Cove, outside of the capped area. Capped area outlined in pink; Orange area is the coarse-grained cap area while the remaining part of the cap was medium-grained sand.

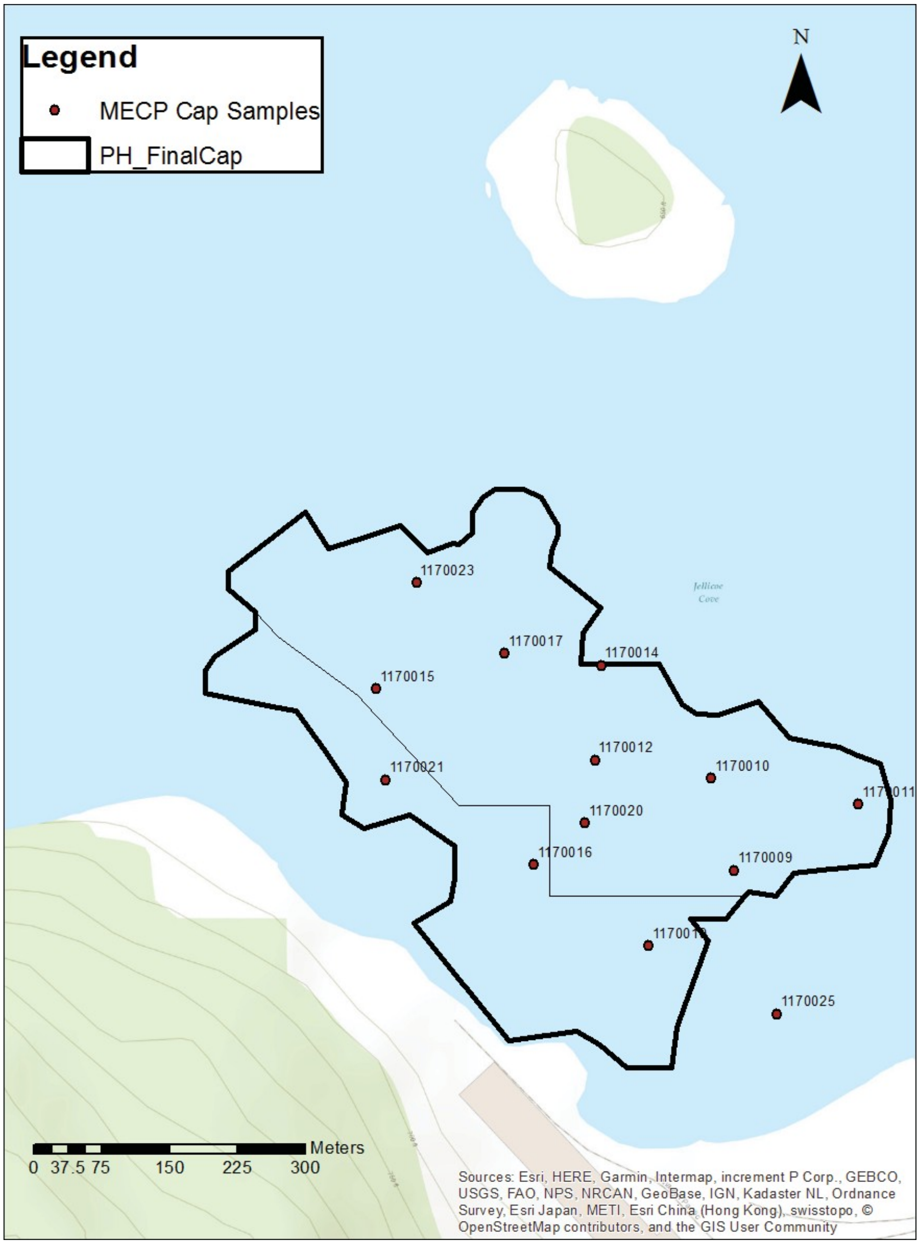

Figure 4. MECP's 2017 Sampling locations within the capped area.

2. RPH and AOC

The RPH, or rest of Peninsula Harbour, was a designation used in the ERA (Environ 2008) to describe the portion of the AOC outside Jellicoe Cove, but still within the ERA boundary (Area 2 in Figure 2). However, to assess against the delisting criterion for the *Degradation of Benthos* BUI, the entire AOC (outlined in orange in Figure 2) was sampled since the BUI applies to the AOC, and not just the area that was remediated. Given the larger area of the RPH and AOC, an 800 m grid was used to identify twenty sampling locations (Figure 5). Samples were taken from most of the grid intersects and provided good coverage of the AOC.

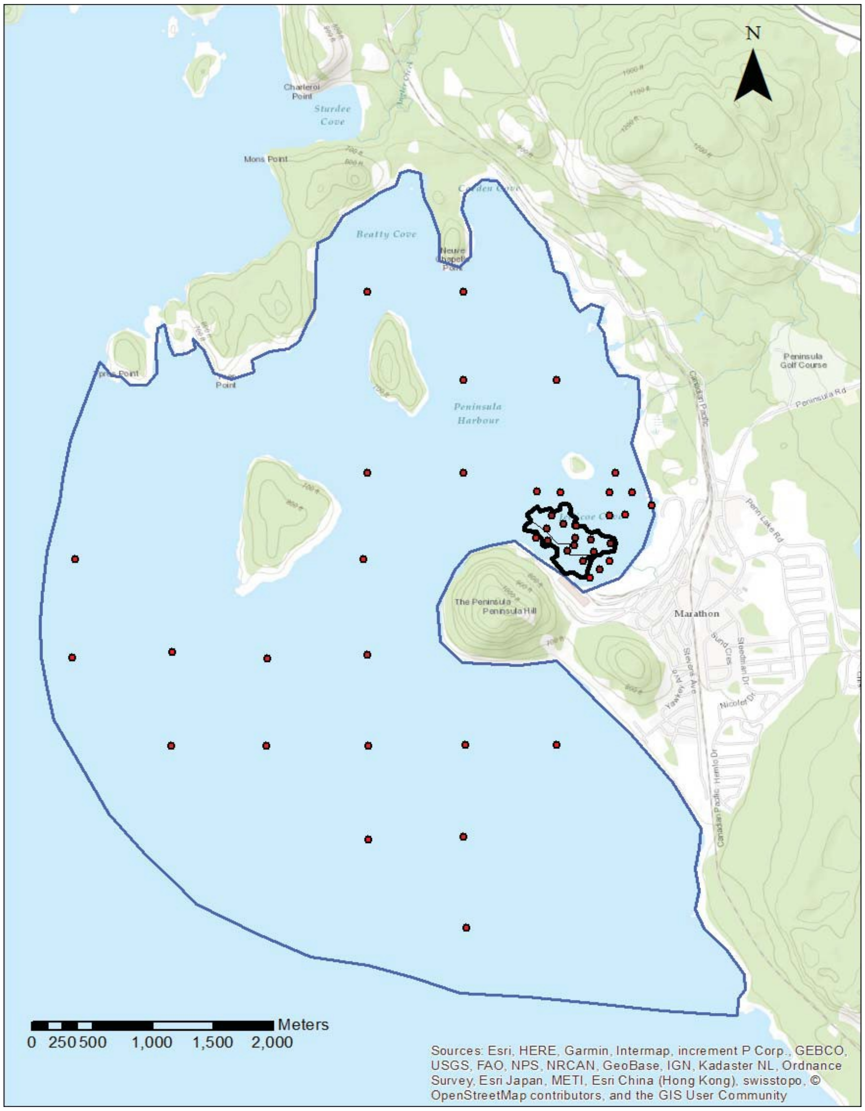

Figure 5. ECCC and MECP's 2017 Sample locations for the RPH / AOC.

4 METHODS

Field Collection

Sampling was coordinated between ECCC and the MECP in order to cover the entire AOC. ECCC used a 7 m aluminum vessel with a winch that was capable of retrieving samples up to a depth of 50m. The MECP's Great Lakes Guardian was a larger vessel capable of collecting samples in greater than 50 m water depth. Sampling on the actual cap was overseen by MECP, but the physical sample collection was conducted, by hand, by ECCC divers. As a result of all this, slight differences in sampling apparatus and positioning occurred. In addition, some of the MECP samples were collected for a separate monitoring program where replicates were required, whereas the ECCC samples were used solely for this SWAC project. Replicate samples by the MECP were averaged to produce a single number for the SWAC calculations. Other than diver collected samples, all samples were collected with a grab sampler and the top 3 cm was removed for the analysis of total mercury, methylmercury, total PCBs, particle size and total organic carbon (TOC).

The top 3 cm sediment was homogenized in a glass or stainless steel sampling tray before placing sediment into respective jars. Between stations, sampling equipment was cleaned with soap, water, acid or solvent, followed by a lake water rinse.

On the cap, surficial sediment was quite thin (<1 cm – 3 cm) and therefore divers collected the thin layer of sediment directly into glass jars.

Station ID, and coordinates, are presented in Table 1.

Samples collected by ECCC were sent to a private lab (ALS Environmental) and were analyzed using the following methods:

- Mercury in soil by EPA 200.2/1631E(mod)
- Methylmercury in soil by Dewild et al. (2004), Dewild, Olund, Olsen and Tate (2004) US Geological Survey (Techniques and Methods 5a-7)
- PCBs to meet CCME Sediment Criteria by the EPA testing method SW846 8270

Samples collected by MECP were sent to the University of Western Ontario, Analytical Services for methylmercury following US EPA method 1630. Total mercury and PCBs were analyzed by the MECP's Laboratory Services Branch using MECP method PCBC3487 and HG3059, respectively.

For quality assurance and control, duplicate samples were collected from four randomly selected sites (stations 2017-17, 2017-51R, 2017-15 and 2017-25).

Calculation of SWACs

The surface sediment samples collected in 2017 were analyzed for MeHg, total Hg and total PCBs. The MeHg and total PCB results were used to estimate SWACs for the entire AOC by compiling the MeHg and total PCBs data in ArcGIS 10.2 and creating Thiessen polygons based on the concentrations of each contaminant. The Thiessen method is based on the assumption that the measured concentration at any location can be applied halfway to the next station where a concentration is present. The method divides the subject area into polygons, where the concentration at the center point is applied across the area of that particular polygon. The polygon areas and associated concentrations can be summed and used to create a spatially weighted average for the area of interest.

For samples with results that were reported as less than detection limits, the detection limit was used as a conservative assumption.

Equation 1 below demonstrates how SWACs were calculated, where C_i is the concentration of a compound, and A_i is the area of the polygon.

$$SWAC = \frac{\Sigma(C_i * A_i)}{\Sigma A_i} \qquad (1)$$

SWAC = Surface weighted average concentration

C_i = Concentration i

A_i = Area of polygon i

5 RESULTS

5.1 Sampling Results

The concentrations of Hg, MeHg and total PCBs (tPCBs) are presented in Table 1. Blanks in the table indicate the absence of data for replicate samples. It should be noted that the replicates shown in this table were subsequently averaged to produce one value for SWAC calculation.

It should be noted that the duplicates for 2017-17 and 2051R were taken by ECCC and the laboratory certificates record these samples as 2017-19 and 2017-18 respectively. At the time of sampling the boat crew were not aware that these names were the same as future samples to be taken by the MECP. As a result, the corrected labels will appear in this report in order to differentiate; but official laboratory certificates will have the original sample names.

Table 1. Station positions and sediment contaminant concentrations used in the SWACs.

Sample Location ID	UTM Coordinates (m)		Concentration (mg/kg)			Source	Location
	Easting	Northing	Hg	MeHg	tPCBs		
2017-40	545021	5397247	0.0833	0.000622	<0.012	EC	JC
2017-41	544830	5397249	0.111	0.00151	0.0180	EC	JC
2017-43	544424	5397245	0.0103	0.00005	<0.012	EC	JC
2017-44	544226	5397251	0.0831	0.000757	0.0260	EC	RPH
2017-48	544224	5396848	11.0	0.0863	0.1000	EC	JC
2017-50	544828	5396648	0.914	0.00112	0.0284	EC	JC
2017-51R	544665	5396496	0.679	0.000700	0.4110	EC	JC
2017-46	544827	5397046	0.149	0.00180	0.0349	EC	JC
2017-4	544390	5398233	0.0759	0.000511	<0.012	EC	RPH
2017-5	543621	5398231	0.246	0.000511	<0.012	EC	RPH
2017-2	543622	5399001	0.0187	0.00005	<0.012	EC	RPH
2017-3	542825	5399001	0.312	0.00167	0.1380	EC	RPH
2017-17	540403	5396665	0.184	0.000768	0.0180	EC	AOC
2017-17 Dup	540403	5396665	0.246	0.000349	<0.012	EC	AOC
2017-22	544391	5395033	0.0438	0.000122	<0.012	EC	AOC
2017-11	542819	5397417	1.19	0.00140	0.0763	EC	RPH
2017-10	543622	5397415	0.317	0.00101	0.0252	EC	RPH
2017-51R Dup	544665	5396496	9.27	0.00126	1.4400	EC	JC
2017-52- at BL	545184	5397133	0.0266	0.000518	<0.012	MECP	JC
2017-53-BTW BL & Skin Is	544962	5397051	0.247	0.00658	0.9300	MECP	JC
2017-54	544878	5397415	0.143	0.000655	0.3500	MECP	JC
2017-15SPLIT 1/2	542789	5396660	0.248	0.00122	0.0257	MECP	RPH
2017-15-SPLIT 2/2	542789	5396660	0.250	0.00127	0.0343	MECP	RPH
2017-34	543642	5393437	0.323	0.00127	0.0180	MECP	AOC
2017-25-SPLIT 1/2	541982	5395027	0.968	0.00345	0.0696	MECP	AOC
2017-25-SPLIT 2/2	541982	5395027	0.860	0.00343	0.0550	MECP	AOC
2017-20	541202	5395849	0.614	0.00286	0.0340	MECP	AOC
2017-21	540376	5395796	0.394	0.00248	0.0370	MECP	AOC
2017-27	539808	5396771	0.870	0.00166	0.0450	MECP	N/A
2017-19	541991	5395796	0.468	0.00185	0.0410	MECP	AOC
2017-26	541195	5395027	1.20	0.00263	0.1490	MECP	AOC
2017-31	539968	5394351	1.41	0.00333	0.0870	MECP	N/A
2017-30	539854	5389895	0.471	0.00215	0.0180	MECP	N/A
2017-36	542134	5392209	0.466	0.00218	0.0260	MECP	N/A
2017-29	542833	5394209	0.473	0.00117	0.0280	MECP	AOC
2017-28	543621	5394230	0.293	0.00101	0.0270	MECP	AOC
2017-23	543634	5395036	0.0663	0.000322	<0.012	MECP	AOC
2017-24	542828	5395027	0.583	0.00174	0.0730	MECP	AOC
2017-18	542822	5395824	0.699	0.00281	0.0370	MECP	AOC
1170010	544679	5396830	0.34	0.00283	0.140	MECP	JC
1170010	544679	5396830	0.43	0.00321	0.140	MECP	JC
1170010	544679	5396830	0.24	0.00313	0.160	MECP	JC
1170010	544679	5396830	0.28	0.00397	0.310	MECP	JC
1170014	544557	5396955	0.08	0.00211	0.091	MECP	JC

Table 1 Continued

Sample ID	Easting	Northing	Units	Hg	MeHg	tPCBs	Source	Location
1170014	544557	5396955	mg/kg	0.17	0.00163	0.067	MECP	JC
1170014	544557	5396955	mg/kg	0.14	0.00085	0.520	MECP	JC
1170014	544557	5396955	mg/kg			0.029	MECP	JC
1170016	544483	5396734	mg/kg	0.78	0.00464	0.069	MECP	JC
1170016	544483	5396734	mg/kg	1.5	0.01675	0.033	MECP	JC
1170016	544483	5396734	mg/kg	1.5	0.01424	0.033	MECP	JC
1170016	544483	5396734	mg/kg	0.78	0.00255	0.130	MECP	JC
1170016	544483	5396734	mg/kg	1.1	0.00344	0.140	MECP	JC
1170016	544483	5396734	mg/kg			0.100	MECP	JC
1170017	544450	5396968	mg/kg	0.2	0.00125	0.010	MECP	JC
1170017	544450	5396968	mg/kg	0.07	0.00050	0.012	MECP	JC
1170017	544450	5396968	mg/kg	0.07	0.00046	0.029	MECP	JC
1170017	544450	5396968	mg/kg	0.14	0.00105	0.059	MECP	JC
1170017	544450	5396968	mg/kg			0.062	MECP	JC
1170019	544609	5396644	mg/kg	2.1	0.01214	0.047	MECP	JC
1170019	544609	5396644	mg/kg			0.082	MECP	JC
1170019	544609	5396644	mg/kg			0.044	MECP	JC
1170019	544609	5396644	mg/kg			0.024	MECP	JC
1170019	544609	5396644	mg/kg			0.240	MECP	JC
1170019	544609	5396644	mg/kg			0.045	MECP	JC
1170020	544539	5396780	mg/kg	0.17	0.00126	0.250	MECP	JC
1170020	544539	5396780	mg/kg	0.21	0.00126	0.041	MECP	JC
1170020	544539	5396780	mg/kg			0.024	MECP	JC
1170020	544539	5396780	mg/kg			0.040	MECP	JC
1170023	544353	5397047	mg/kg	0.08	0.00057	0.010	MECP	JC
1170023	544353	5397047	mg/kg	0.06	0.00042	0.025	MECP	JC
1170023	544353	5397047	mg/kg	0.06	0.00033	0.010	MECP	JC
1170023	544353	5397047	mg/kg			0.014	MECP	JC
1170025	544751	5396569	mg/kg	0.48	0.00089	0.010	MECP	JC
1170025	544751	5396569	mg/kg	0.61	0.00124	0.010	MECP	JC
1170025	544751	5396569	mg/kg	0.56	0.00163	0.010	MECP	JC
1170025	544751	5396569	mg/kg	0.56	0.00143	0.010	MECP	JC
1170025	544751	5396569	mg/kg			0.010	MECP	JC
1170012	544550	5396850	mg/kg	0.36	0.00373	0.260	MECP	JC
1170012	544550	5396850	mg/kg	0.2	0.00130	0.210	MECP	JC
1170012	544550	5396850	mg/kg			0.140	MECP	JC
1170011	544841	5396801	mg/kg	0.21	0.00210	0.660	MECP	JC
1170011	544841	5396801	mg/kg			0.570	MECP	JC
1170011	544841	5396801	mg/kg			0.540	MECP	JC
1170011	544841	5396801	mg/kg			0.230	MECP	JC
1170021	544319	5396828	mg/kg			0.045	MECP	JC
1170021	544319	5396828	mg/kg			0.010	MECP	JC
1170021	544319	5396828	mg/kg			0.079	MECP	JC
1170021	544319	5396828	mg/kg			0.018	MECP	JC
1170015	544309	5396929	mg/kg			0.083	MECP	JC
1170015	544309	5396929	mg/kg			0.110	MECP	JC
1170015	544309	5396929	mg/kg			0.056	MECP	JC
1170009	544705	5396728	mg/kg			0.014	MECP	JC

N/A = Outside of area of interest.

5.2 Quality Assurance/Quality Control

To assess variability between duplicates and the original samples, the relative percent difference (RPD) was calculated using equation 2 below.

RPD = 100% x ((sample – duplicate) / ((sample + duplicate)/2)) (2)

An RPD of 40% (BC MOE, 2009) can often be applied to values greater than 5 times the method detection limits (MDL) to identify significant differences between the original and the duplicate. Sample 2017-51R and its duplicate have high RPDs. During sample collection, the samples were actually from different grabs and it was noted that the sample matrix between the original and the duplicate was different, and that is likely the reason for the difference in concentrations.
Regardless, while they do not represent true duplicate samples, they do represent the variable conditions of the AOC. In the calculation of the SWAC, the two values were averaged to produce one number.

Table 2 - Relative Percent Difference (RPDs)

	2017-51R	2017-51R-Dup	RPD
Mercury (Hg)	0.679	9.27	-172.70%
PCBs	0.411	1.44	-111.18%
MeHg	0.0007	0.00126	-57.14%
	2017-17	**2017-17-Dup**	
Mercury (Hg)	0.184	0.246	-28.84%
PCBs	0.018	0.012	40.00%
MeHg	0.000768	0.000349	75.02%
	2017-15 Split1/2	**2017-15 Split2/2**	
Mercury (Hg)	0.248	0.25	-0.80%
PCBs	0.0257	0.0343	-28.67%
MeHg	0.00122	0.00127	-4.02%
	2017-25Split1/2	**2017-25Split2/2**	
Mercury (Hg)	0.968	0.86	11.82%
PCBs	0.0696	0.055	23.43%
MeHg	0.00345	0.00343	0.58%

5.3 Sample Locations and Thiessen Polygons

The Thiessen polygons used in the calculation of the SWACs for MeHg and total PCBs are shown in Figures 7-10. Colours represent concentrations ranging from lowest (green) to highest (red). Concentrations in mg/kg are shown in each polygon.

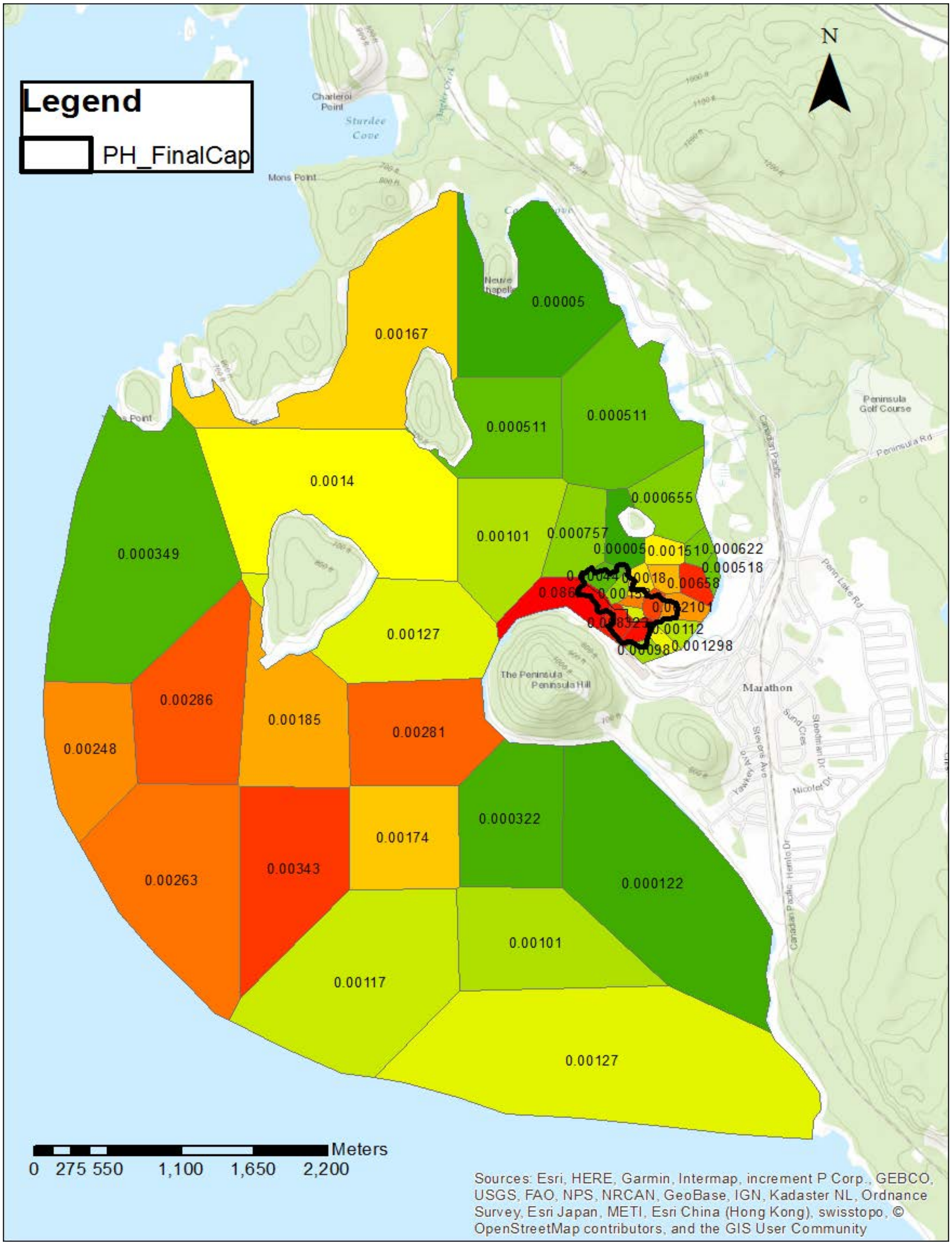

Figure 7. Thiessen Polygons and concentrations (mg/kg) used for calculating the MeHg SWAC.

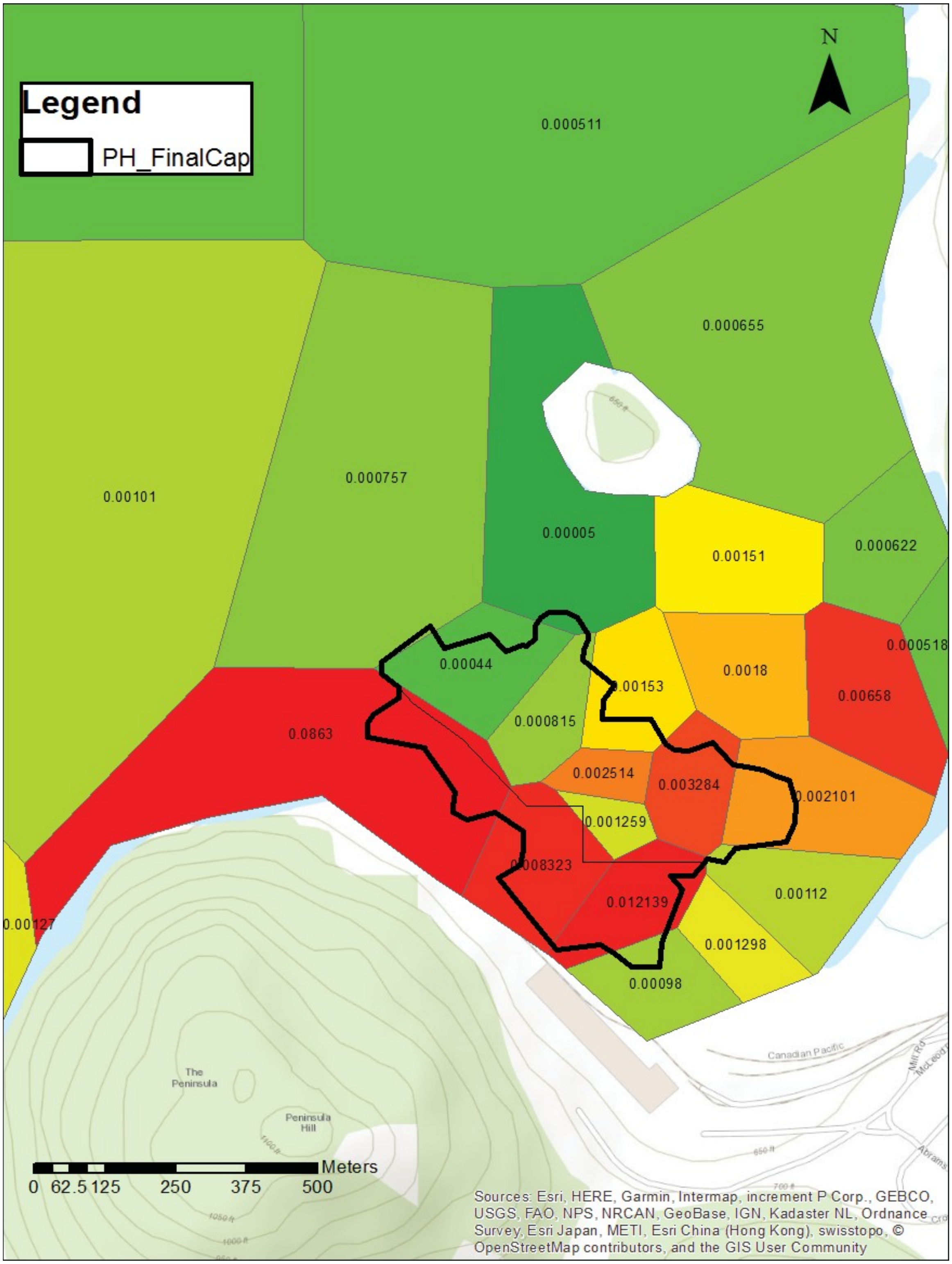

Figure 8. Thiessen Polygons and concentrations (mg/kg) used for calculating the MeHg SWAC (zoomed to Jellicoe Cove).

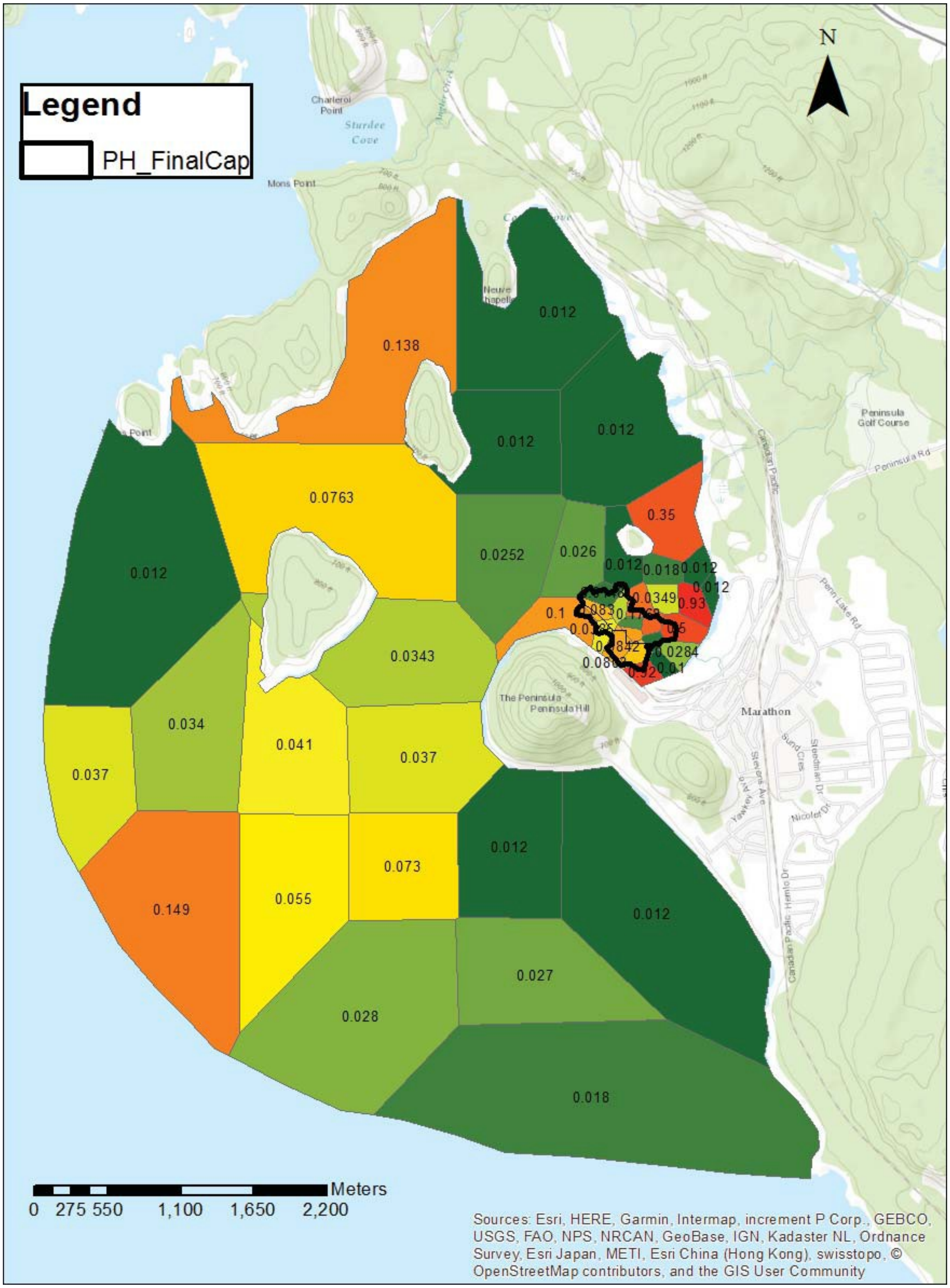

Figure 9. Thiessen Polygons and concentrations (mg/kg) used for calculating the total PCBs SWAC.

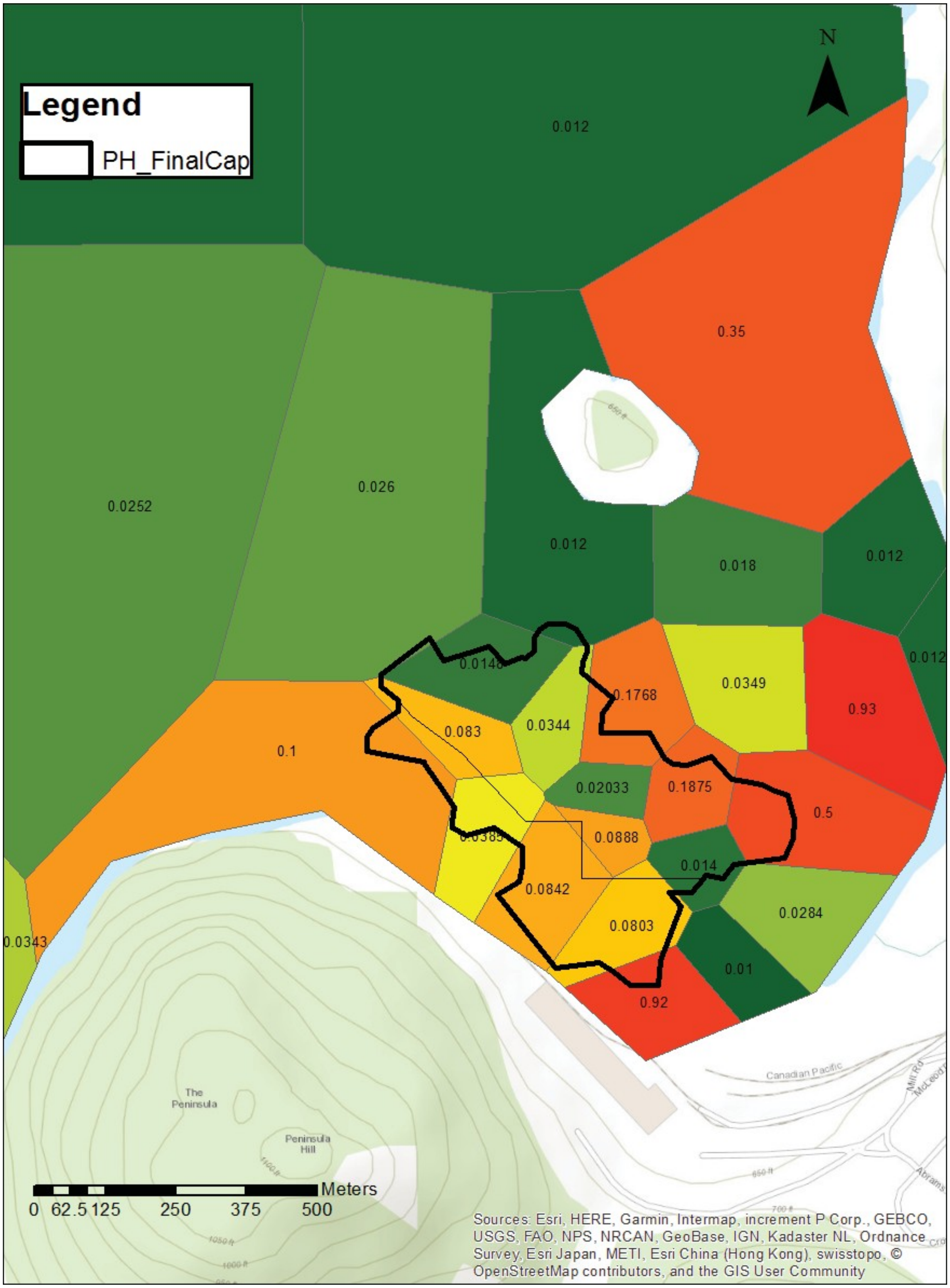

Figure 10. Thiessen Polygons and concentrations (mg/kg) used for calculating the total PCBs SWAC (zoomed to Jellicoe Cove).

5.4 SWAC

The polygon areas and contaminant concentrations used in the calculation of the SWACs for MeHg and total PCBs are provided in Tables 2 and 3, respectively. Using Equation 1, the post-remediation SWAC for the PH AOC for MeHg is 0.0019 mg/kg, and for total PCBs, 0.0509 mg/kg. The Remedial Action Plan target established in the delisting criterion is an AOC average sediment concentration of less than 0.002 mg/kg MeHg and 0.06 mg/kg total PCBs based on some specific but conservative assumptions in the 2008 ERA.

Table 3. Polygon areas for SWAC calculation for MeHg.

Easting	Northing	MeHg (mg/kg)	Polygon Area (m^2)
541195.4	5395027	0.00263	1475389
542832.6	5394209	0.00117	1689725
544391.1	5395033	0.000122	2023136
544665.1	5396496	0.00098	33594.97
542822.3	5395824	0.00281	836220.8
541201.7	5395849	0.00286	1008389
542819.4	5397417	0.0014	1702815
544877.5	5397415	0.000655	262136.5
542825.4	5399001	0.00167	1417520
541982.3	5395027	0.00343	996334.5
542828.4	5395027	0.00174	666436.2
543633.5	5395036	0.000322	826143.8
543621.4	5394230	0.00101	939471.6
543641.9	5393437	0.00127	2782549
544841	5396801	0.002101	60779.66
544550	5396850	0.002514	13933.2
544751	5396569	0.001298	25210.34
544539	5396780	0.001259	11566.58
544609	5396644	0.012139	34489.6
544483	5396734	0.008323	47835.13
544679	5396830	0.003284	31006.41
544827.6	5396648	0.00112	44036.74
544223.7	5396848	0.0863	191689.8
542789.3	5396660	0.00127	892284.4
541990.8	5395796	0.00185	832207.6
540376.5	5395796	0.00248	674223.7
540403	5396665	0.000349	2120681
543622.4	5397415	0.00101	678905.5
543621.3	5398231	0.000511	608297.2
544353	5397047	0.00044	44547.88
544450	5396968	0.000815	28515.01
544557	5396955	0.00153	38160.26
544962.2	5397051	0.00658	57864.65
545184.2	5397133	0.000518	26518.03
544390	5398233	0.000511	927169.3
544827.4	5397046	0.0018	46840.96
544226.4	5397251	0.000757	263076.8
544424.4	5397245	0.00005	124868.1
544829.5	5397249	0.00151	59749.46
545021.4	5397247	0.000622	46602.43
543622.3	5399001	0.00005	1138453

Table 4. Polygon Areas for SWAC Calculation for total PCBs.

Easting	Northing	tPCBs (mg/kg)	Polygon Area (m^2)
541195.4	5395027.177	0.149	1475389
542832.6	5394208.786	0.028	1689725
544391.1	5395033.2	0.012	2023136
544665.1	5396496.1	0.92	33676.85
542822.3	5395823.692	0.037	836220.8
541201.7	5395848.608	0.034	1008389
542819.4	5397416.5	0.0763	1702815
544424.4	5397244.7	0.012	124864.4
542825.4	5399001	0.138	1417520
541982.3	5395026.834	0.055	996334.5
542828.4	5395027.054	0.073	666436.2
543633.5	5395036.346	0.012	826143.8
543621.4	5394230.302	0.027	939471.6
543641.9	5393436.864	0.018	2782549
544751.1	5396569.22	0.01	24462.33
544609.2	5396644.34	0.0803	29613.4
544827.6	5396648.2	0.0284	40576.03
542789.3	5396660.27	0.0343	892284.4
541990.8	5395795.79	0.041	832207.6
540376.5	5395796.289	0.037	674223.7
540403	5396664.8	0.012	2120681
543622.4	5397414.7	0.0252	678905.5
543621.3	5398230.6	0.012	608297.2
544704.6	5396727.75	0.014	17010.19
544309.2	5396929.39	0.083	23682.4
544318.6	5396828.47	0.0385	30761.76
544841.1	5396800.56	0.5	59281.86
544550	5396850	0.02033	13945.16
544352.5	5397047.1	0.0148	35086.14
544538.5	5396779.47	0.0888	11398.77
544450	5396968.1	0.0344	22681.48
544483	5396733.65	0.0842	38204.68
544557	5396955.21	0.1768	38194.99
544679.2	5396829.85	0.1875	24546.9
544877.5	5397414.615	0.35	262136.5
544962.2	5397050.914	0.93	57885.47
545184.2	5397132.986	0.012	26518.03
544390	5398233.1	0.012	927169.3
544827.4	5397046.3	0.0349	46857.92
544223.7	5396847.7	0.1	162341.8
544226.4	5397250.8	0.026	262945.5
544829.5	5397248.9	0.018	59747.61
545021.4	5397247	0.012	46602.43
543622.3	5399000.5	0.012	1138453

6 CONCLUSIONS

The risk-based management goals from the ERA (Environ, 2008) hypothesized that when average sediment concentrations within the AOC are less than 0.06 mg/kg total PCBs and 0.002 mg/kg MeHg, the risk to target receptors will be acceptable. These targets were established as the delisting criteria within the AOC's Remedial Action Plan. Based on the 2017 sampling, the AOC SWACs of 0.0509 mg/kg PCBs and 0.0019 mg/kg MeHg, meet the risk based management criteria.

It is important to note that sediment environments are not static and this sampling represents a snap shot of the concentrations from the time of sampling.

7 REFERENCES

BC MOE (Ministry of Environment). 2009. British Columbia Environmental Laboratory Manual. Available at: http://www.env.gov.bc.ca/edp/wamr/labsy/lab-man-09/index.htm

Environ International Corporation. 2008. Environmental Risk Assessment for Peninsula Harbour Area of Concern, Final Report, September 2008. Project Number 21-16548C.

Peninsula Harbour Remedial Action Plan Team. 2012. Stage 2: Remedial Strategies for Ecosystem Restoration.

PENINSULA HARBOUR AREA OF CONCERN

Degradation of Fish and Wildlife Populations Beneficial Use Impairment

RE-DESIGNATION REPORT

Ministry of Natural Resources and Forestry
2020

Peninsula Harbour Area of Concern

Degradation of Fish and Wildlife Populations Beneficial Use Impairment

Recommended Beneficial Use Status: Not Impaired

Background

The Peninsula Harbour Area of Concern (AOC) is roughly bounded by the harbour to the north of the peninsula and Pebble Beach to the south and extends outward approximately four kilometres from the peninsula into Lake Superior (Figure 1). The AOC boundary is based on the extent of Ministry of the Environment, Conservation and Parks (MECP) water and sediment sampling surveys in 1984-85; not necessarily on the extent of contamination.

There are a number of small embayments within Peninsula Harbour including Jellicoe, Beatty and Carden Coves. Two small creeks, Shack Creek and another unnamed watercourse, pass through former wood waste storage sites before discharging into the harbour just north of Jellicoe Cove and the Town of Marathon. The average water depth within the AOC is approximately 30 metres with maximum depths of up to 65 metres offshore from the peninsula.

Reason for Impairment

Peninsula Harbour fish populations were designated impaired in the Stage 1 Remedial Action Plan Report (RAP) because of a decline in Lake Trout (*Salvelinus namaycush*) populations. Lake Trout, the dominant species for the AOC, declined as a result of habitat destruction due to industrial effluent and log booming, the introduction of Sea Lamprey (*Petromyzon marinus*), and exploitation through extensive commercial fishing. Log booming resulted in organic (wood debris) contamination in Jellicoe and Beatty Coves that reduced traditional (prior to 1955) Lake Trout spawning habitat. The Stage 2 RAP report (Peninsula Harbour RAP Team 2012) stated that the fish community within Peninsula Harbour was comparable to reference sites adjacent to the AOC. For this reason, the status of the beneficial use impairment was considered Requires Further Assessment (RFA) so that further monitoring could be conducted to confirm these results.

Figure 1. Peninsula Harbour Area of Concern.

Delisting Criteria

Fish populations within the AOC will no longer be impaired when the fish community has the following characteristics, as observed by the Ministry of Natural Resources and Forestry (MNRF) Fish Community Index Netting (FCIN) program:

- The Peninsula Harbour AOC fish community should be similar to near shore (0 – 80 m deep) fish communities adjacent to the AOC as measured by relative abundance (catch-per-unit-effort) and species composition of the community;
- The near shore fish community should be dominated by self-sustaining populations of native fishes;
- Lake Trout populations have the following characteristics:
  - ⇒ Mean age greater than eight years
  - ⇒ Length-at-age of age seven Lake Trout is stable and greater than 430 mm
  - ⇒ Populations are dominated by mature fish and many age classes present
  - ⇒ Populations are dominated by wild Lake Trout (greater than 50% wild)

FCIN is a standardized annual fisheries independent gillnet survey that was first implemented in 2009 and is carried out from June through August in Ontario waters of Lake Superior. Data collected during the FCIN are the Upper Great Lakes Management Unit's primary sources of information for fisheries stock assessment and are used to inform commercial and recreational fisheries management. The FCIN program is also used to monitor population recovery and rehabilitation efforts at a lake-wide scale and was expanded to include sampling within the Peninsula Harbour AOC starting in 2010.

Methods

FCIN uses a stratified random sampling design that ensures sampling coverage based on the surface area across four predetermined depth strata: 0-30 m, 30-60 m, 60-90 m, and >90 m. The FCIN program consists of overnight sets using graded-mesh (a combination of different mesh sizes) monofilament gillnets, 305 m in length, and set perpendicular to the depth contour to maximize catch and reduce the variability between catches. These nets catch a wide variety of sizes, ages, and species of fish. All fish caught are counted and recorded. Biological information is collected from the catch and includes length (mm), round weight (g), age, sex, and maturity. Otoliths were collected for age analysis and gender and maturity assessments were completed through internal examination. Age was determined from otolith samples for Lake Trout, Lake Whitefish (*Coregonus clupeaformis*), Cisco (*Coregonus artedi*) and Yellow Perch (*Perca flavescens*).

The presence and type of fin clips for Lake Trout were recorded in order to produce an estimate of the percentage of native fish in the catch.

Catch-per-unit-effort serves as an index of relative abundance and was calculated for each species as the abundance per kilometre of net (#/km) and as landed weight in kilograms per kilometre of net set (kg/km) for both inside and outside the AOC as well as for the entire sample area.

Evidence in support of achieving the target

Fish Community – relative abundance and species composition

The delisting criteria for fish communities require that species composition and relative abundance expressed as the catch-per-unit-effort (# fish/km of gillnet) in waters less than 80 m in depth, be similar in areas within and adjacent to the AOC. This was determined by examining catches collected from 2010 to 2018 as part of MNRF's FCIN program (Table 1; Figure 2). Samples were weighted proportionally to area and depth within the AOC.

Table 1. Number of sites sampled inside and adjacent to the Peninsula Harbour Area of Concern between 2010-2018.

Number of sampling sites			
Year	Inside AOC	Outside AOC	Total
2010	9	23	32
2011	7	17	24
2012	6	6	12
2013	5	7	12
2014	5	5	10
2015	4	2	6
2016	3	7	10
2017	3	12	15
2018	1	14	15
Total	43	93	136

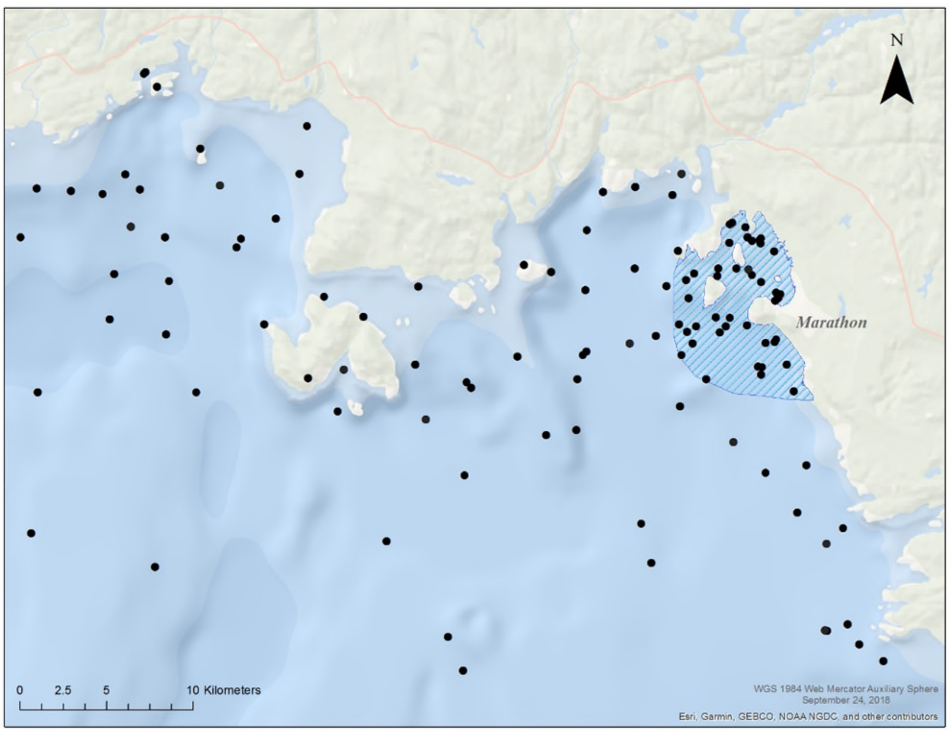

Figure 2. Fish community index netting sites within and adjacent to the Peninsula Harbour Area of Concern (AOC) (hatch-marked area) from 2010-2018.

The catch-per-unit-effort of all fish species combined from 2010 to 2018 has been consistently higher inside the AOC compared to outside (Figure 3); however, there is a difference between the contributions of individual species (Figure 4). The catch outside of the AOC is dominated by Lake Trout, Lake Whitefish, various Coregonid species (including Bloater (*Coregonus hoyi*), Cisco, Kiyi (*C. kiyi*) and

Shortjaw Cisco (*C. zenithicus*)), as well as Longnose Sucker (*Catostomus catostomus*) and Round Whitefish (*Prosopium cylindraceum*). Longnose Sucker is the dominant species within the AOC, with Lake Trout, Lake Whitefish, Bloater, Round Whitefish and Cisco contributing significantly to the catch.

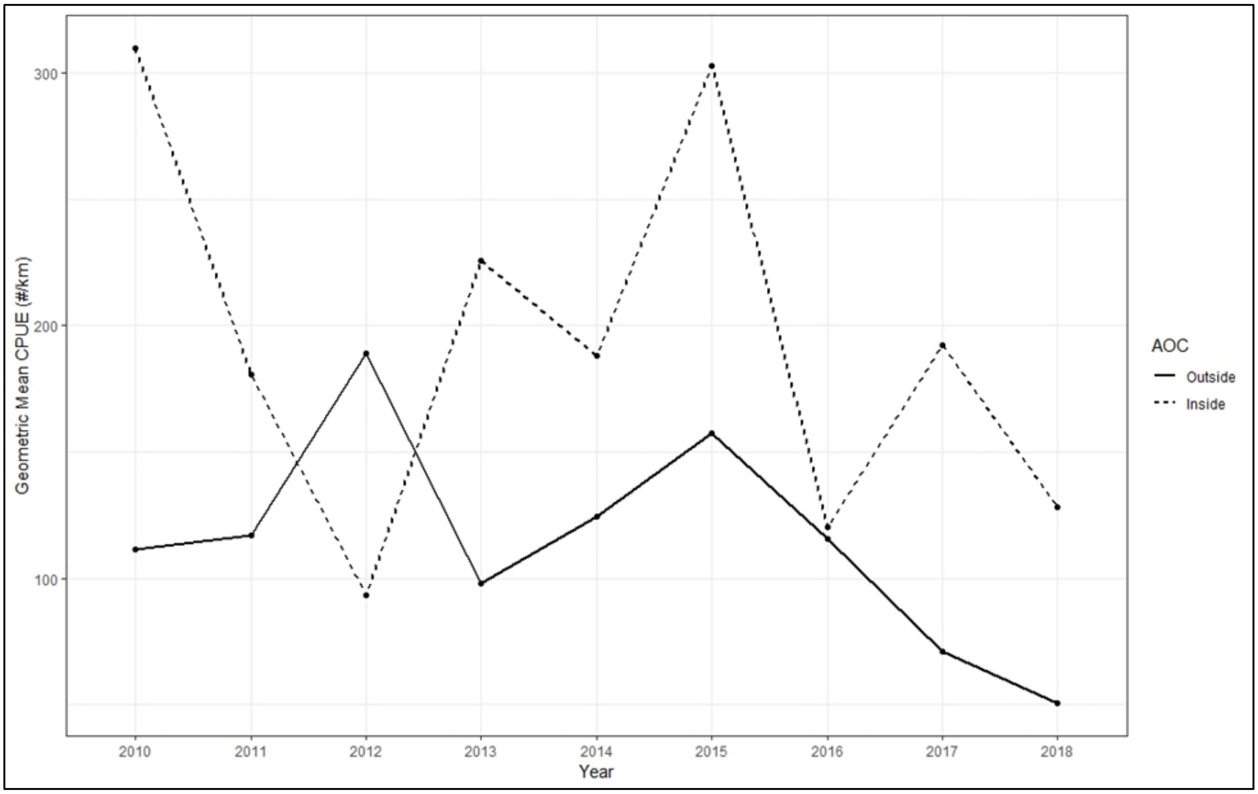

Figure 3. Relative abundance of all fish species combined, from inside (dashed line) and reference sites outside (solid line) the Peninsula Harbour Area of Concern (AOC); expressed as the geometric mean catch-per-unit-effort (CPUE; number of fish caught/km of gillnet) in Fish Community Index gillnets from 2010 to 2018, in waters less than 80m in depth. (Note: Thin layer capping operation took place in 2012).

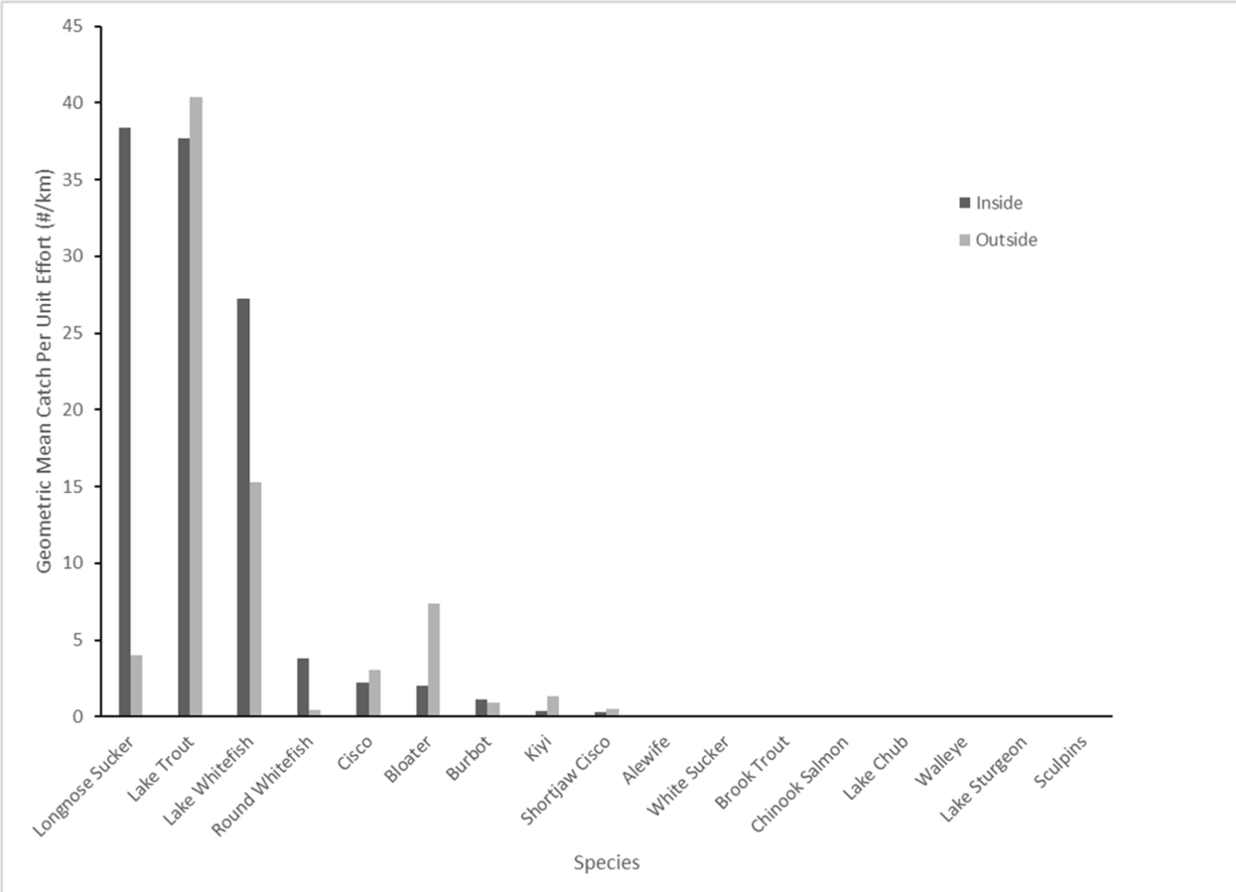

Figure 4. Relative abundance of individual fish species from 2010-2018 expressed as the geometric mean catch-per-unit-effort (number of fish /km of gillnet) from Fish Community Index Netting, inside (black bars) and outside (grey bars) the Peninsula Harbour Area of Concern. (Note: all species listed in the figure were captured however some were below the one fish per kilometre threshold and therefore not depicted on the graph).

Fish community: self-sustaining populations of native fishes

The Lake Superior fish community is composed of 86 species, 70 of which are native fishes (Horns et al. 2003). Foster and Harris (2011) summarized the number of species caught from previous surveys in Peninsula Harbour (Table 2). Catches from the FCIN program have been added to this list; recognizing that while other fish species may have been present in Lake Superior and in Peninsula Harbour in particular, during the FCIN sampling years they may not have been susceptible to the sampling gear due to fish size or time of year.

Table 2. Documented fish species (N = native; I = introduced) and life stages* for the Peninsula Harbour Area of Concern and adjacent Lake Superior waters. Table taken from Foster and Harris (2011) with the addition of fish captured during the Fish Community Index Netting (FCIN) program from 2010-2018.

Common name	Scientific name	FCIN	Lake Superior	Peninsula Harbour	Jellicoe Cove	Shack Creek
Alewife (I)	*Alosa pseudoharengus*	A		U[4]	A[5]	
Emerald Shiner (N)	*Notropis atherinoides*			U[4]		
Lake Chub (N)	*Couesius plumbeus*	A		U[4] J[5]	J[5]	J[5]
Longnose Dace (N)	*Rhinichthys cataractae*			U[4] J[5]	J[5] A[5]	J[5] A[5]
Spottail Shiner (N)	*Notropis hudsonius*			U[4]		
Longnose Sucker (N)	*Catostomus catostomus*	A	J[3]	J[3,5] A[5]	J[3,5] A[5]	S[6]
White Sucker (N)	*Catostomus commersoni*	A		J[3] A[5]	J[3]	S[6]
Northern Pike (N)	*Esox lucius*			U[4]	A[5]	
Rainbow Smelt (I)	*Osmerus mordax*			J[3]	J[3]	
Brook Trout (N)	*Salvelinus fontinalis*	A				S[6] J[5] A[5]
Chinook Salmon (I)	*Oncorhynchus tshawytscha*	A	J[3]			S[6]
Cisco (Lake Herring) (N)	*Coregonus artedi*	A	S[1]		J[5]	
Coho Salmon (I)	*Oncorhynchus kisutch*				J[5] A[5]	J[5]
Lake Trout (N)	*Salvelinus namaycush*	A	S[1,2]	S[1]	J[5] A[5]	
Lake Whitefish (N)	*Coregonus clupeaformis*	A		J[3,5] A[5]	J[3]	
Round Whitefish (N)	*Prosopium cylindraceum*	A		J[5] A[5]	J[5] A[5]	
Pink Salmon (I)	*Oncorhynchus gorbuscha*				J[5]	S[6]
Rainbow Trout (I)	*Oncorhynchus mykiss*			U[4] J[5] A[5]		J[5]
Burbot (N)	*Lota lota*	A	A[3]	J[5]	J[5]	
Sticklebacks	Unknown			U[4]		
Threespine Stickleback (I)	*Gasterosteus aculeatus*				A[5]	
Mottled Sculpin (N)	*Cottus bairdi*			J[5] A[3]	J[5] A[5]	A[5]
Slimy Sculpin (N)	*Cottus cognatus*		J[3]		J[5] A[5]	J[5] A[5]
Johnny Darter (N)	*Etheostoma nigrum*			U[4]		
Walleye (N)	*Zander vitreus*	A		U[4]		
Yellow Perch (N)	*Perca flavescens*			U[4]	J[5]	
Bloater (N)	*Coregonus hoyi*	A				
Kiyi (N)	*Coregonus kiyi*	A				
Shortjaw Cisco (N)	*Coregonus zenithicus*	A				
Lake Sturgeon (N)	*Acipenser fulvescens*	A				

*S = spawning; J = nursery (presence of young-of-the-year or juveniles based on total length range); A = adult; U = unknown life stage

[1] (Goodier 1981, 1982); [2] Goodyear et al. (1982); [3] Hamilton (1986); [4] Suns pers. comm. in Hamilton (1986); [5] Beak (2001); [6] AECOM (2009).

Although the relative abundance of individual species caught inside and outside the AOC varies, species richness (number of species) and species evenness (proportion of species) has remained relatively consistent over the eight-year time series; with a long term average of eight species caught inside the AOC and nine species outside the AOC (Figure 5) and relatively stable level of community evenness (Figure 6).

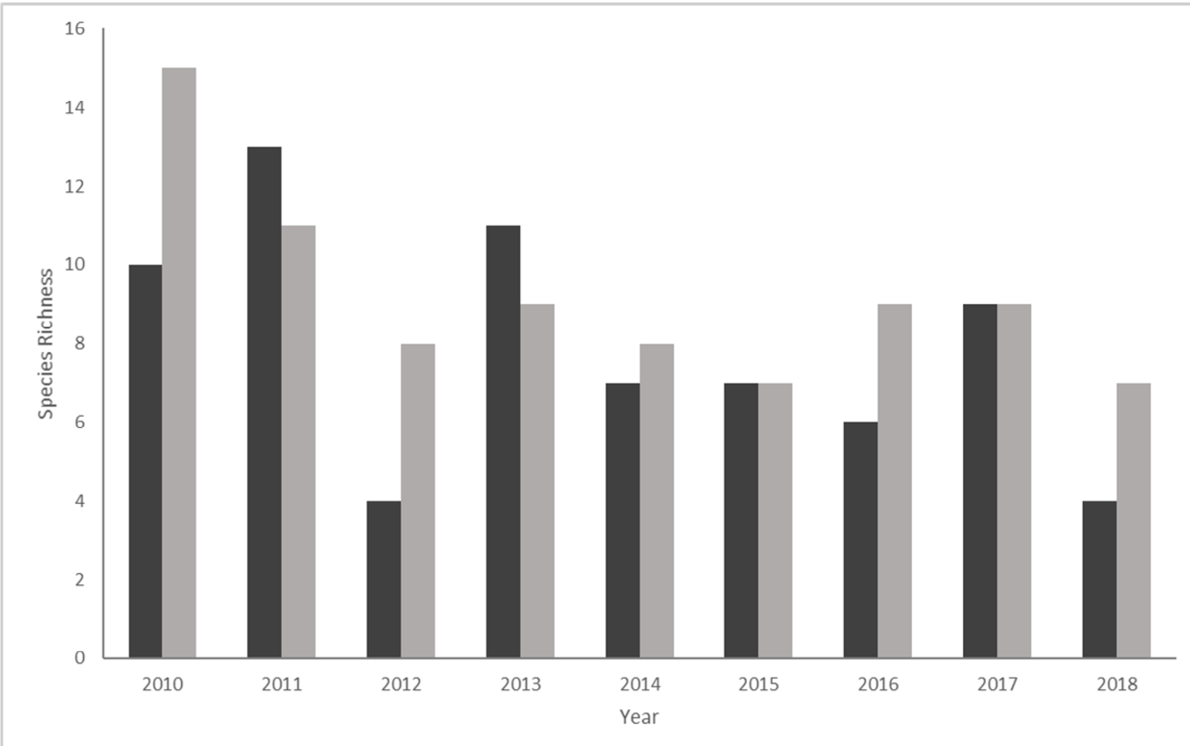

Figure 5. Species richness inside (black bars) and outside (grey bars) the Peninsula Harbour Area of Concern from 2010-2018, based on catches from the Ministry of Natural Resources and Forestry Fish Community Index Netting.

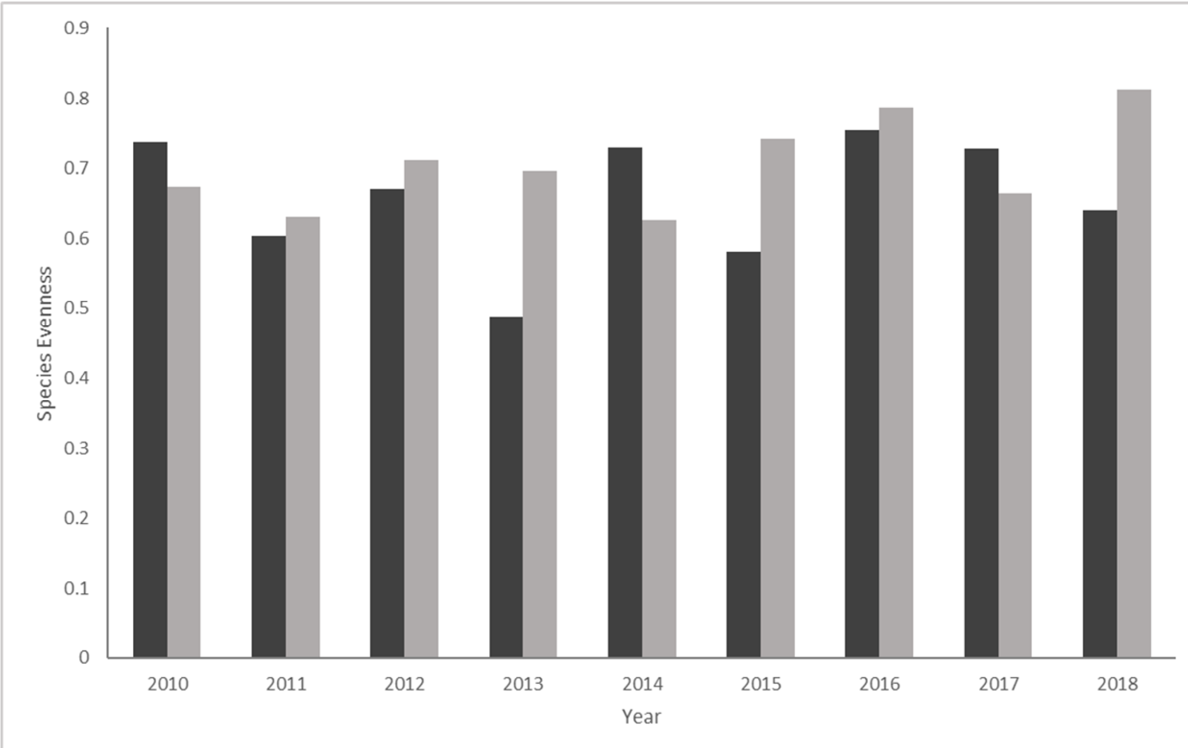

Figure 6. Species evenness inside (black bars) and outside (grey bars) the Peninsula Harbour Area of Concern from 2010-2018, based on catches from the Ministry of Natural Resources and Forestry Fish Community Index Netting.

Lake Trout (population characteristics):

The delisting criteria include four specific measures of Lake Trout health:

- Mean age greater than eight years
- Length-at-age of age seven Lake Trout is stable and greater than 430 mm
- Populations are dominated by mature fish and many age classes present
- Populations are dominated by wild Lake Trout (greater than 50% wild)

The first of these is a measure of the longevity of the population, described in terms of mean age; with a minimum index value of 8-years. The mean age of Lake Trout in FCIN samples collected from 2010 to 2017 within the AOC ranged from 4 to 11 years, with an average of 9 years, exceeding the index value of 8-years (Table 3).

The second criterion examines the growth rate of Lake Trout, which is commonly expressed as size at a given age (Figure 7). The total length at age seven is used as a growth standard in Lake Superior with 430 mm used as baseline value (Hansen 1996). Results show that between 2010 and 2017 Lake Trout averaged 403 mm to 589 mm in total length at age-7 inside the AOC and were consistently larger than the baseline value of 430 mm since 2011 (Table 3).

The third criterion is related to Lake Trout recruitment and maturity (Table 3). The age structure of Lake Trout sampled inside and outside of the AOC is near identical (Figure 8). An average of 15 year classes of Lake Trout spanning 2 to 39 years old have been observed in FCIN samples collected from 2010 to 2017. This is a characteristic of a healthy, robust population that is experiencing regular annual recruitment. On average, 64% of the fish in the FCIN samples are mature (Table 3).

Table 3. Statistics related to delisting criteria for Lake Trout from the annual Fish Community Index Netting program (2010-2017) within the Peninsula Harbour Area of Concern.

Year	Mean Age (yr)	Length at Age 7 (mm)	Number of Age Classes	Percent Mature
2010	11	403	22	57
2011	10	466	18	23
2012	10	446	21	51
2013	9	508	14	78
2014	9	432	15	45
2015	9	472	12	91
2016	9	499	15	100
2017	4	589	8	70

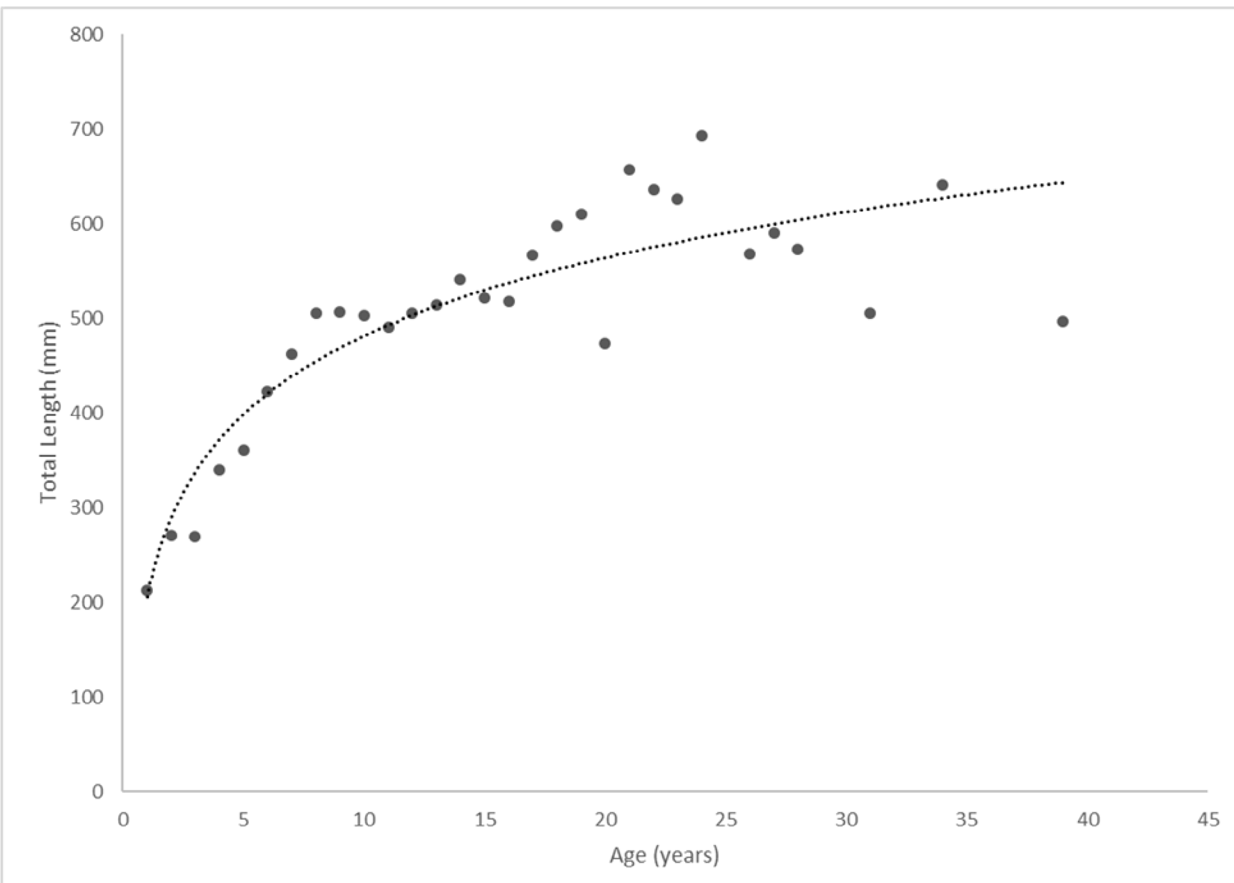

Figure 7. Lake Trout mean length at age relationship from Fish Community Index Netting samples collected inside the Peninsula Harbour Area of Concern between 2010-2017.

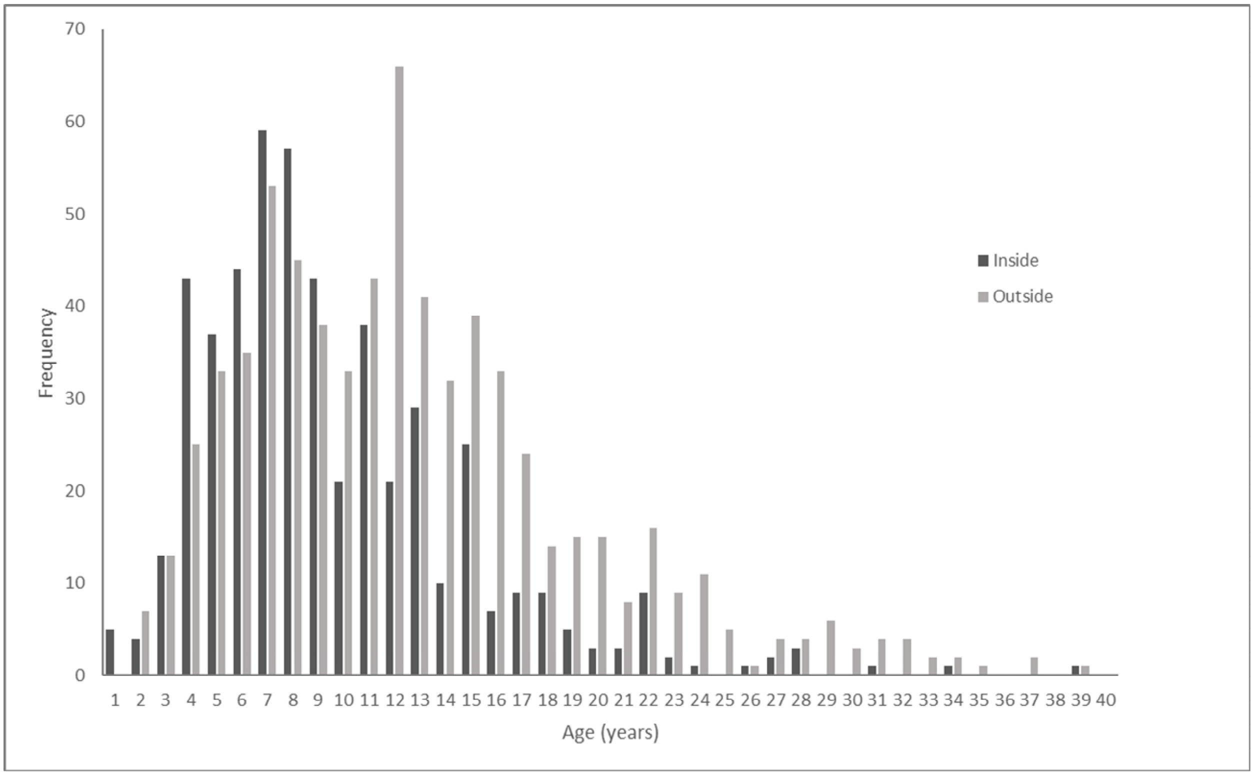

Figure 8. Age frequency histogram for Lake Trout sampled inside (black bars) and outside (grey bars) of the Area of Concern in Fish Community Index Netting (2010-2017).

The fourth and final criterion specific to Lake Trout is based on the relative number of wild fish in the population. More than 95% of the Lake Trout sampled in FCIN surveys from 2010-2018 both inside and outside the Peninsula Harbour AOC have been identified as wild fish (Figure 9).

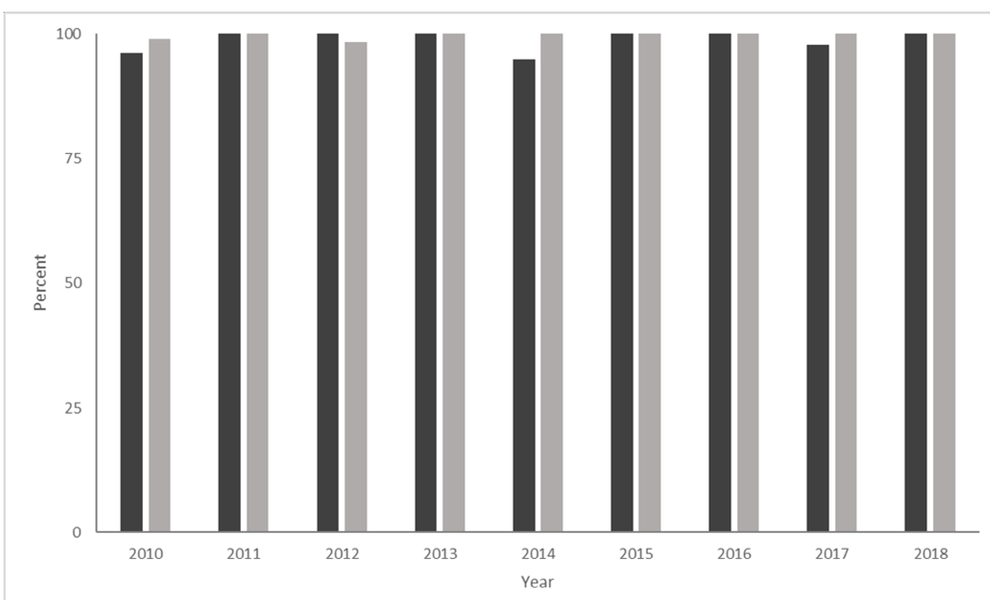

Figure 9. Percentage of wild Lake Trout caught in MNRF Fish Community Index netting inside (black bars) and outside (grey bars) the Peninsula Harbour Area of Concern between 2010 and 2018.

Conclusions

Results of the FCIN program from 2010-2018 within the Peninsula Harbour AOC and adjacent waters of Lake Superior indicate a healthy, self-sustaining population of primarily native fish species. Monitoring data shows the delisting criteria has been met, and it is recommended the beneficial use status be changed to Not Impaired. The MNRF will continue to monitor the fish community as part of an ongoing assessment program, emphasizing the importance of fishery independent trend-through-time data to guide fisheries management decisions.

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PENINSULA HARBOUR AREA OF CONCERN

Loss of Fish and Wildlife Habitat Beneficial Use Impairment

RE-DESIGNATION REPORT

Ministry of Natural Resources and Forestry
2020

Peninsula Harbour Area of Concern

Loss of Fish and Wildlife Habitat Beneficial Use Impairment

Recommended Beneficial Use Status: Not Impaired

Background

The Peninsula Harbour Area of Concern (AOC) is roughly bounded by the harbour to the north of the peninsula and Pebble Beach to the south and extends outward approximately four kilometres from the peninsula into Lake Superior (Figure 1). There are a number of small embayments within Peninsula Harbour including Jellicoe, Beatty and Carden Coves. Two small creeks, Shack Creek and another unnamed watercourse, pass through former wood waste storage sites before discharging into the harbour just north of Jellicoe Cove and the Town of Marathon.

Waterfront property immediately north of the peninsula, in the Jellicoe Cove area, is zoned industrial and was the site of a former bleached kraft pulp mill. The mill operated from 1944 until it closed in 2009. The shoreline was used for storing softwood chips, and for storing and occasionally debarking hardwood logs. A wood waste site was located near the shoreline north of the mill. Jellicoe, Carden and Beatty Coves were also used for log storage for over forty years. Historically, Peninsula Harbour was used for building log rafts to be transported by water to Ashland, Wisconsin (Boultbee 1967). Pulpwood logs were stored in the harbour for use in winter months when shipping was not possible. Log storage was discontinued in 1983; however, the harbour was again used for log rafting in 1987-88 when logs were transported to Thunder Bay.

Figure 1. Peninsula Harbour Area of Concern.

The Peninsula Harbour AOC watershed is characterized by rugged, hilly bedrock terrain typical of the Canadian Shield. With the exception of Jellicoe Cove, water depth generally increases abruptly from the rugged shorelines. As a result, littoral areas form extremely narrow bands along the shoreline and wetlands are not present in the AOC. Nearshore fish spawning and nursery habitat is restricted to isolated pockets.

Reason for Impairment

Fish habitat was designated impaired in the Stage 1 Remedial Action Plan (RAP) because of the loss of fish spawning areas (Peninsula Harbour RAP Team 1991). Goodier (1981 and 1982) had documented historic spawning areas (prior to 1955) for the major commercial fish species in the Peninsula Harbour area (Figure 2). Lake Trout (*Salvelinus namaycush*) spawning grounds were identified along the south shore of Yser Point, along the western shore of Beatty Cove and in Jellicoe Cove. Cisco (*Coregonus artedi*) spawning grounds were located along the shoreline of Lake Superior adjacent to Peninsula Harbour. Lake Trout spawning grounds along the shorelines of Jellicoe and Beatty Coves, however, were degraded through the accumulation of organic materials from mill activities such as log booming and effluent discharge from the mill.

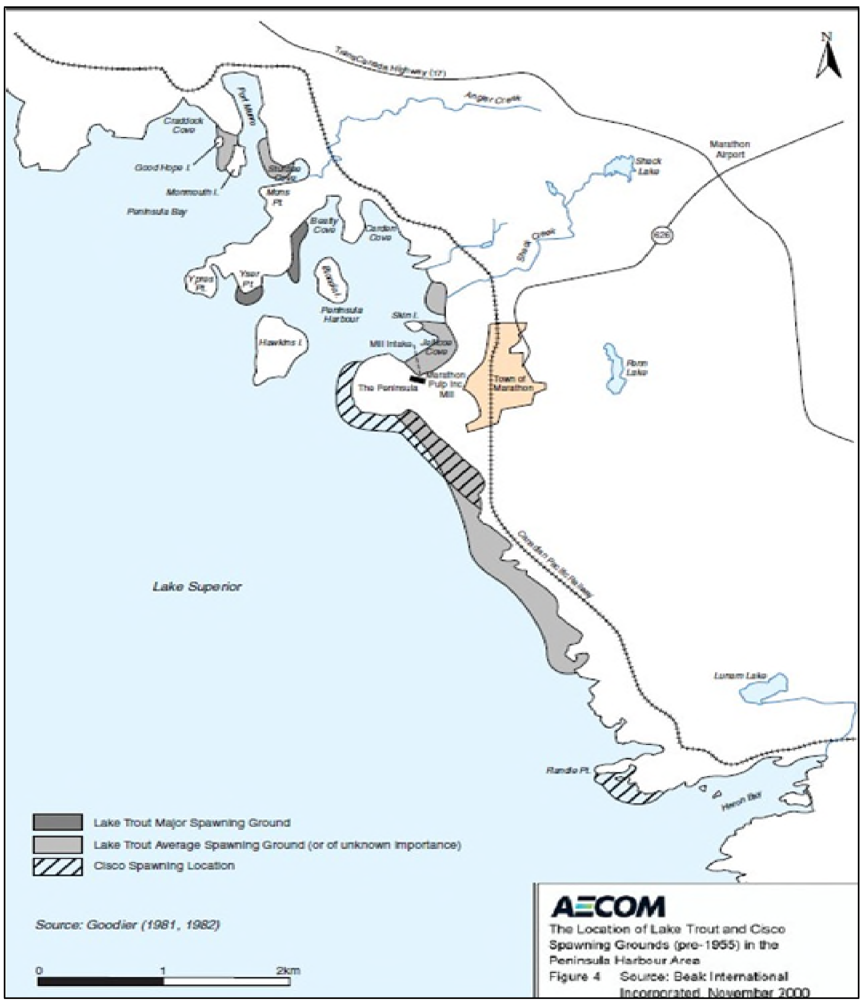

Figure 2. Lake Trout and Cisco spawning grounds prior to 1955 based on Goodier (1981, 1982) (Foster and Harris 2011).

Sediment in Peninsula Harbour is contaminated with mercury, polychlorinated biphenyls (PCBs), and wood fibre. The highest zones of contamination occur within Jellicoe Cove, and represent the most significant non-point source of contamination to the AOC. In 2012, approximately 23ha of Jellicoe Cove was capped with approximately 15 to 20 cm of medium to coarse sand in order to enhance natural recovery and reduce exposure of organisms to contaminated sediments. Even though the capping process covered potential benthic habitat it did mitigate exposure risks to fish and wildlife species, provided clean material for benthic recolonization, and limited the transport of contaminated sediments to other areas of the harbour. While the capping activity addressed habitat concerns in Jellicoe Cove, conditions in Beatty Cove had yet to be confirmed. For this reason, the status of the beneficial use impairment was considered Requires Further Assessment (RFA) in the Stage 2 RAP (Peninsula Harbour RAP Team 2012) so that further monitoring could be conducted.

There was no evidence of impairment for wildlife populations and wildlife habitat under the Stage 1 RAP report. The report states, “because of the natural absence of wetlands, wildlife populations such as waterfowl and shore birds are not abundant or considered impaired.” In addition, “incidents of bird or animal deformities have not been reported in the AOC nor have reproductive problems been reported. Lakewide pollutant sources are dominant on transient birds. There are minimal local populations exposed due to the lack of wetlands with which wildlife would be associated. Also, due to the location of the outfalls, there is a high rate of dilution” (Peninsula Harbour RAP team 1991).

Summary of the delisting target

This beneficial use will no longer be impaired when the amount and quality of physical, chemical, and biological habitat within the AOC has been established and protected and is not an impediment to achieving Lake Superior Fish Community Objectives.

- The aquatic habitat is capable of supporting a biologically diverse fish community
- The desired fish and benthic communities are showing signs of sustainable recovery post sediment remediation
- Monitoring and reporting systems are in place to track and guide recovery

Evidence in support of achieving the delisting target

Northern Bioscience Ecological Consulting was contracted in 2010 to review existing fish community and habitat reports, mapping, underwater video, and geospatial data for Peninsula Harbour to support an environmental assessment of the sediment management project in Jellicoe Cove (Foster and Harris 2011; Appendix A). The purpose of this analysis was to determine the impact of thin-layer capping on available fish habitat and therefore required looking at all available fish habitat within the AOC.

The following information and reports were used in their assessment:

- Goodier (1981, 1982) conducted interviews with experienced commercial fishermen and compiled other historical evidence on the location of historic (pre-1955) spawning and fishing grounds for Lake Trout and other species in Lake Superior.

- Hamilton (1987) used electrofishing surveys to assess nearshore spawning and nursery habitat in AOCs.

- Beak (2001) was commissioned by the Town of Marathon to look at the feasibility of combining the remediation of contaminated sediment in Jellicoe Cove with the development of a marina in Carden Cove. The assessment included mapping potential fish habitat in both areas.

- AECOM (2009) was contracted to complete an environmental assessment report for the sediment management project in Jellicoe Cove.

- BioSonics (2011) conducted a hydroacoustic survey in Peninsula Harbour to classify the types of substrate and for the identification of potential fish habitat. Underwater video was also taken to verify bottom substrate types.

- Northern Bioscience reviewed underwater video files, taken by Environment and Climate Change Canada (ECCC; 2005 and 2007), Ministry of the Environment, Conservation and Parks (MECP; formerly Ministry of the Environment and Climate Change), and BioSonics (2011), to confirm existing habitat mapping.

An additional survey was conducted using benthic macroinvertebrates as an indicator of habitat health in Beatty Cove (Deacon and Lavoie 2013; Appendix B). Together, these reports were used to determine the current habitat conditions in the AOC.

Current Conditions:

Beatty Cove

Using the available information, Foster and Harris (2011) concluded that historical Lake Trout spawning habitat along Yser Point and west of Beatty Cove is in relatively good condition. Underwater video indicates that clean cobble exists out to a depth of at least 14 m along portions of this shoreline, which is consistent with preferred spawning habitat for Lake Trout. The exposed aspect and deeper waters help keep the cobble free of silt and fine sediments that would reduce suitability as spawning substrate for Lake Trout and other fish. Fish community monitoring by the Ministry of Natural Resources and Forestry (MNRF) from 2010 to 2018 confirms that Lake Trout continue to inhabit this area (E. Berglund, pers. comm.). Silty sediments predominate in deeper water, and at least some woody debris is present.

A subsequent survey of habitat conditions in Beatty Cove was completed using benthic macroinvertebrates (Deacon and Lavoie 2013). Invertebrates respond to ecosystem changes faster than other members of the aquatic community. Trends and changes in aquatic invertebrate populations and community structure can serve as indicators of short-term, action-required stresses that may ultimately influence the aquatic community of Lake Superior.

The methodology for this assessment was patterned after the aquatic macroinvertebrate biomonitoring network for Ontario's lakes, streams and wetlands (OBBN: Ontario Benthos Biomonitoring Network) using the Reference Condition Approach as outlined in the OBBN Protocol Manual (Jones *et al.* 2005). Relatively unimpaired sites from Lake Nipigon (Deacon 2011) and an impounded area of the Black Sturgeon River (Deacon 2013) were used for comparison with the sites from Beatty Cove. The following results have been taken from the report *Aquatic Benthic Macroinvertebrate Communities in Beatty Cove, Lake Superior, 2012* (Deacon and Lavoie, 2013).

Three sites in Beatty Cove were sampled in 2012 according to lake methodology as outlined in the protocol manual. The OBBN biotic indices used to analyze the samples provide an insight into present and past conditions experienced by the aquatic macroinvertebrate communities. Each biotic index provides a separate insight into the quality of the habitat. The combination of several indices makes it possible to evaluate the relative, long-term health of the site and the overall suitability of the site to support a healthy fishery.

Analysis of the composition of macroinvertebrate communities indicates that Beatty Cove is relatively unimpaired except for minor organic enrichment from woody debris. Crustacea comprise a large component of the macroinvertebrate communities probably because of the favourable habitat provided by the woody debris and the high dissolved oxygen in the cove. Overall, the relatively high density of aquatic benthic macroinvertebrates in Beatty Cove should provide abundant forage for fish. Woody debris should continue to dissipate from year-to-year; therefore, conditions within the cove should continue to improve.

Carden Cove

In the late 1980's, the Town of Marathon explored waterfront development opportunities in the region extending from the edge of the former mill property to Carden Cove (Moore/George Associates Inc. 1993). The proposed development was to consist of a marina, boat launch, docking facilities, hiking trails, and the construction of a breakwater creating a sheltered harbour area. Carden Cove was selected as the preferred site for marina construction in the town's waterfront development plan and an access road was constructed as the initial phase of the project (circa 1994).

Beak (2001) conducted fisheries and habitat surveys in Peninsula Harbour that included an assessment of Carden Cove in preparation for the marina development. While further development did not occur, the information from these surveys is used in this report.

Generally, Carden Cove is a shallow, protected environment with a maximum water depth of 7 m. Nursery habitat for Round Whitefish (*Prosopium cylindraceum*) and rearing habitat for Longnose Sucker (*Catostomus catostomus*) occurs in Carden Cove as evidenced by the large numbers of young-of-the-year and juveniles collected during the Beak (2001) assessment. Adult habitat for these species occurs in the offshore waters of the cove.

The substrate in Carden Cove is primarily fine sand with a band of clay running east-west across the middle of the bay (Beak 2001). A sandy beach is located at the head of the cove and patches of detritus are scattered in shallow water, presumably bark from past booming operations. Bedrock shorelines are common along the northern portions of Peninsula Harbour and video observations show bedrock and cobble in shallow water on the west side of Carden Cove (Foster and Harris 2011).

Beak (2001) also sampled the benthic macroinvertebrate community in Carden Cove and found low densities of macroinvertebrates, which likely reflected the low productivity and lack of diverse benthic habitat in the area (substrate is dominated by fine sand). The results were similar to previous surveys (MOE 1972 and 1978 as reported in Sibley et al. 1991); however, no recent assessment of the benthic community has been completed.

Tributary Streams

Habitat surveys (along with fisheries assessments) were conducted by Beak (2001) at four stations on Shack Creek. Each station was found to have a wide variety of substrates, ranging from boulders to sand and clay with stream velocities ranging from medium to fast. Electrofishing surveys indicated that Shack Creek provided spawning, nursery and rearing habitat in its lower reaches that were inhabited by migratory pacific salmonids; Rainbow Trout (*Oncorhynchus mykiss*) and Coho Salmon (*O. kisutch*). The middle reaches of Shack Creek supported healthy densities and various life stages (young-of-year, juveniles and adults) of Brook Trout (*Salvelinus fontinalis*). The presence of Brook Trout is an indicator that Shack Creek is relatively clean and capable of supporting coldwater fish species.

The small unnamed tributary north of Shack Creek was determined to be intermittent in nature (Beak 2001). It may provide some fish habitat in years with higher spring flows; however, no surveys have been conducted.

Both tributaries lie outside the AOC boundary and may still provide habitat for migratory fish. Recent assessments however have not been completed.

Jellicoe Cove

Approximately 23 ha of Jellicoe Cove in the Peninsula Harbour AOC was capped during the summer of 2012 with approximately 15 to 20 cm of medium to coarse sand in order to enhance natural recovery and reduce exposure of organisms to contaminated sediments. The cap covers about ¼ of Jellicoe Cove or about 2.5% of Peninsula Harbour. Prior to this remediation work, Foster and Harris (2011) provided a description of the substrate and presence of viable fish habitat in Jellicoe Cove using visual observations, bottom sampling, underwater video, and existing reports.

Historical records (pre-1955) noted the presence of Lake Trout spawning habitat in Jellicoe Cove (Goodier 1981, 1982); however, habitat conditions undoubtedly changed with the construction of the mill in 1944. Modifications to the shoreline and nearshore areas included the construction of a shipping wharf and the addition of coarse riprap adjacent to the mill property.

Log piles and rock cribs occur throughout the area from log booming activities. Foster and Harris (2011) found that very little Lake Trout spawning habitat exists in Jellicoe Cove (<1 % of the cap area). They suggested that the historic spawning habitat is now covered by riprap and the wharf. Lake Trout may have spawned over the coarser sands and gravel in the shallower waters of the cove provided there was enough wave energy to prevent siltation of the eggs (Foster and Harris 2011). A few (<5) eggs were observed on the underwater video footage from the cap area; however, it is unknown if they were deposited in the area or were swept in from outside the cap area. The species of fish and viability of the eggs cannot be determined from these images. Restoring spawning habitat in this portion of Jellicoe Cove will have little effect on the population as habitat is not limiting Lake Trout production in Lake Superior (Horns, et al. 2002). Fisheries data would suggest that Lake Trout have been rehabilitated in western Lake Superior, including Peninsula Harbour, mostly as a result of stocking efforts and a reduction in Sea Lamprey.

No aquatic vegetation or nursery habitat was found in Peninsula Harbour during an initial fishery survey that included Jellicoe Cove (Hamilton 1987); however, Beak (2001) found aquatic macrophytes along the southeast shore of Jellicoe Cove covering an area of approximately 5 ha. Upon examination of underwater video taken by ECCC in 2005 and 2007, Foster and Harris (2011) noted a much larger area of aquatic vegetation; approximately 10 ha within the cap area. The most significant negative impact from the capping may be the potential reduction in aquatic macrophyte abundance in the cap area, which could reduce the habitat suitability for fish, particularly Longnose Suckers, Northern Pike (*Esox lucius*), and Yellow Perch (*Perca flavescens*). The long-term benefit however, of reducing exposure to contaminated sediments by capping it with a layer of sand probably outweighs any potential short-term negative impacts to fish habitat within this portion of the AOC. Foster and Harris (2011) concluded that the cap area does not provide critical fish habitat and similar littoral habitat is available elsewhere in Peninsula Harbour.

Determination of Beneficial Use Status

Delisting Criteria:

The aquatic habitat is capable of supporting a biologically diverse fish community

Fish populations in Lake Superior are assessed using the MNRF's Fish Community Index Netting (FCIN) program. This survey has been executed in Peninsula Harbour since 2010, in order to assess the dynamics (variety of species, sizes, ages, etc.) of the fish community. The catch-per-unit-effort of all fish species combined from 2010 to 2018 has been consistently higher inside the AOC compared to outside (Figure 3); however, there is a difference between the contributions of individual species (Figure 4). The catch outside of the AOC is dominated by Lake Trout, Lake Whitefish, various Coregonid species (including Bloater (*Coregonus hoyi*), Cisco, Kiyi (*C. kiyi*) and Shortjaw Cisco (*C. zenithicus*)), as well as Longnose Sucker (*Catostomus catostomus*) and Round Whitefish (*Prosopium cylindraceum*). Longnose Sucker is the dominant species within the AOC, with Lake Trout, Lake Whitefish, Bloater, Round Whitefish and Cisco contributing significantly to the catch.

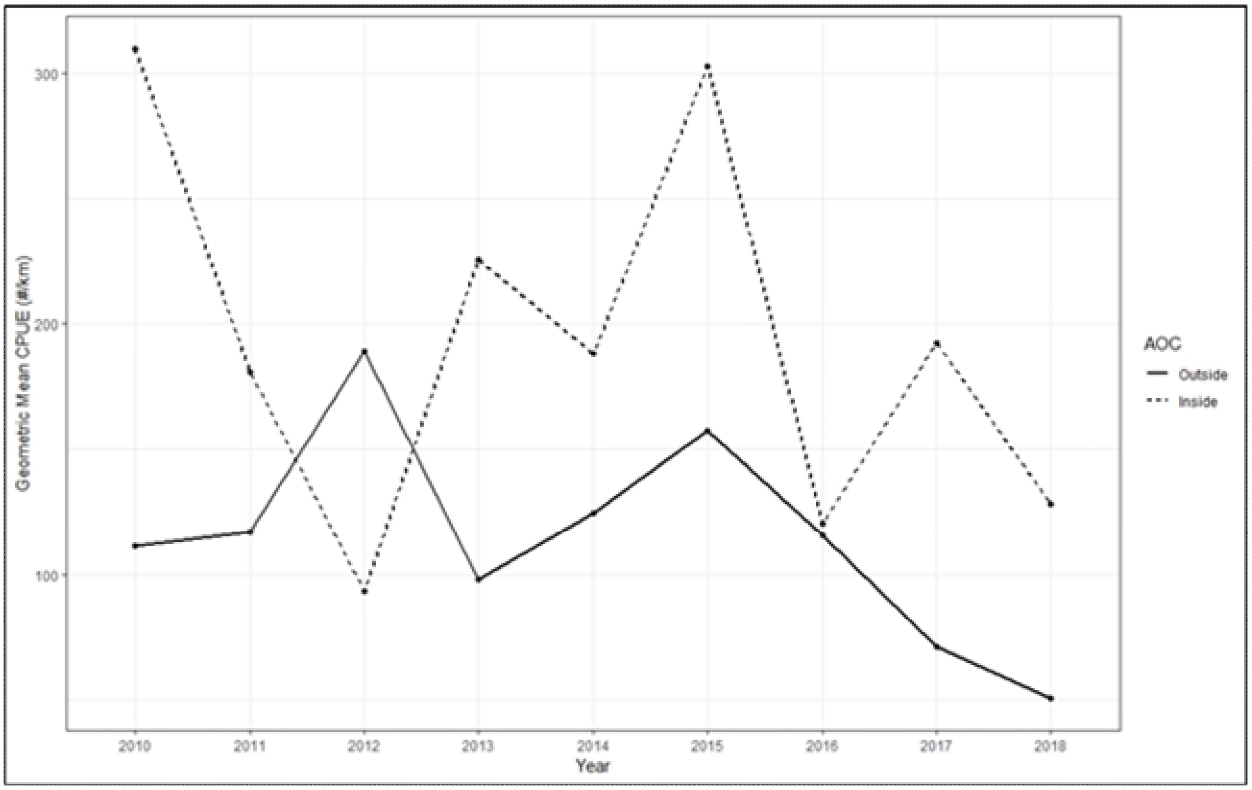

Figure 3. Relative abundance of all fish species combined, from inside (dashed line) and reference sites outside (solid line) the Peninsula Harbour Area of Concern (AOC); expressed as the geometric mean catch-per-unit-effort (CPUE; number of fish caught/km of gillnet) in Fish Community Index gillnets from 2010 to 2018, in waters less than 80m in depth. (Note: Thin layer capping operation took place in 2012).

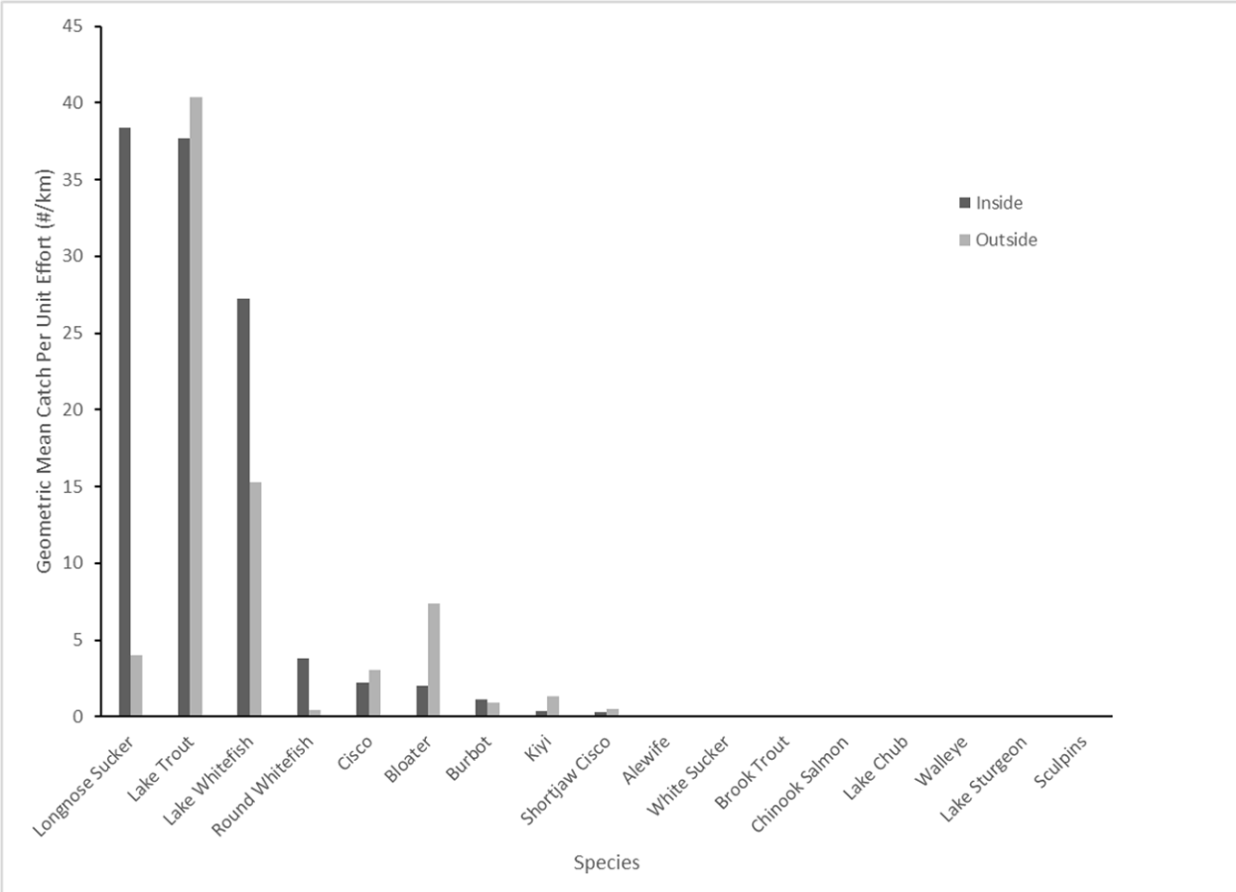

Figure 4. Relative abundance of individual fish species from 2010-2018 expressed as the geometric mean catch-per-unit-effort (number of fish /km of gillnet) from Fish Community Index Netting, inside (black bars) and outside (grey bars) the Peninsula Harbour Area of Concern. (Note: all species listed in the figure were captured however some were below the one fish per kilometre threshold and therefore not depicted on the graph).

In addition to monitoring the fish community through the FCIN program, the MNRF is mandated to follow the Fish Community Objectives (FCO's) for Lake Superior (Horns et al. 2002). The FCO's provide guiding principles and objectives for aquatic habitats, as well as for individual fish species. The goal for aquatic habitat is to:

> *"Achieve no net loss of the productive capacity of habitat supporting Lake Superior fishes. Where feasible, restore habitats that have been degraded and have lost their capacity for fish production. Reduce contaminants so that all fish are safe to eat. Develop comprehensive and detailed inventories of habitats."*

Based on results and information collected from the FCIN survey, the aquatic habitat within the Peninsula Harbour AOC is supporting a diverse and healthy fish community. The capping of contaminated sediment, which ultimately reduces the availability of contaminants to the fish community, aligns with habitat objectives outlined in the FCO's.

The desired fish and benthic communities are showing signs of sustainable recovery post sediment remediation

For aquatic communities to show signs of recovery post remediation we looked at changes in habitat – substrate changes and growth of submerged aquatic vegetation – in the cap area. No aquatic macrophytes were observed in Hamilton's (1987) rudimentary survey of select locations in the AOC. The substrate in Jellicoe Cove consisted of sand, rubble, rock-cribs and sawdust (Hamilton 1987). A subsequent survey by Beak (2001) noted the presence of aquatic vegetation along the southern shoreline of Jellicoe Cove adjacent to the cap area and in a small embayment ~500 m east of the cap. The aquatic macrophytes, in addition to cobble and gravel substrate, may have provided suitable habitat for some fish species.

A pre-remediation survey was conducted by Foster and Harris (2011) to get a more recent representation of habitat conditions. Examination of ECCC video files from 2005 and 2007 showed a greater distribution and density of aquatic vegetation than what was noted in the Beak (2001) survey (Foster and Harris 2011). The videos also showed an accumulation of bark and logs in Jellicoe Cove similar to other areas in Peninsula Harbour. While woody debris may have allowed for the growth of aquatic vegetation and provided cover for fish and benthic invertebrates, Foster and Harris (2011) still concluded that the cap area did not provide suitable fish spawning habitat prior to the remediation project.

Foster and Ratcliff (2013, 2014, and 2018) looked at the recovery of submerged aquatic vegetation in the cap and adjacent areas immediately after the rehabilitation was complete, one year later, and again five years post-cap. This was part of the long-term monitoring plan, which included assessment of the distribution and potential movement of the cap. Five years post sediment remediation, and the aquatic vegetation is still sparse within the cap area; however, Foster and Ratcliff (2018) surmised that continued natural sedimentation will improve substrate conditions for aquatic macrophytes and recovery will continue.

A 20-year long-term monitoring plan (LTM) was developed by AECOM in 2011 to assess, in part, improvements in biological communities after thin layer capping was completed. As part of this plan, MECP looked at ecological recovery five years post-cap, including the recolonization of the area by benthic invertebrates (George 2019). George (2019) found benthic invertebrates inhabiting the cap and even though the number of organisms was low the diversity was high. The type of invertebrates was similar to pre-cap conditions (George 2019).

Monitoring and reporting systems are in place to track and guide recovery

The LTM mentioned above was designed to assess improvements in sediment and biological communities following construction of the thin layer cap in Jellicoe Cove. The plan includes a schedule of the work to be completed with the information collected compared to baseline conditions where appropriate. George (2019) outlined some necessary changes to the sampling protocol during the first year of monitoring; however, these modifications do not detract from the intention of the LTM.

The MNRF will continue to monitor the fish community as part of an ongoing FCIN assessment program, emphasizing the importance of fishery independent trend-through-time data to guide fisheries management decisions. Sampling effort will be increased in the Peninsula Harbour AOC during the Cooperative Science and Monitoring Initiative years (Note: five year rotational cycle on the Great Lakes; next survey year for Lake Superior is 2021).

Conclusions

The status of this beneficial use impairment was considered Requires Further Assessment (RFA) in the Stage 2 RAP (Peninsula Harbour RAP Team 2012) so that further monitoring could be conducted in Beatty Cove and then combined with monitoring data collected in the rest of the AOC. Targeted surveys in the area indicate that the aquatic habitat supports a high density of benthic macroinvertebrates, which in turn provide abundant forage for fish (Deacon and Lavoie 2013).

The aquatic habitat in the AOC is capable of supporting a diverse and healthy fish community. The delisting criteria have been met and it is recommended that the beneficial use status be change to not impaired. The LTM plan will ensure that any changes to environmental conditions will be identified and met with appropriate action.

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Appendix A

Peninsula Harbour
Fish Habitat Assessment

April 26, 2011

Prepared for:
Environment Canada

Prepared by:
Dr. Robert F. Foster
Allan G. Harris

NORTHERN BIOSCIENCE
ECOLOGICAL CONSULTING

Executive Summary

Existing fisheries and habitat reports, mapping, underwater video, and geospatial data were reviewed for the Peninsula Harbour Area of Concern on Lake Superior near Marathon, Ontario. This review is to support an environmental assessment of proposed capping of mercury and PCB contaminated sediments in the Jellicoe Cove "hotspot". A list of 26 species of fish that have been confirmed from Peninsula Harbour was compiled, including 18 that have been found in Jellicoe Harbour. Approximately 80 fish species are known from Lake Superior, additional species may use Jellicoe Cove and the proposed cap area given the very limited fisheries assessment has been conducted in Peninsula Harbour.

Underwater video and ponar grabs indicate that the proposed 25 ha cap area is comprised of soft sediments, primarily fine sands and silts, with some clay. Coarser sands, limited patches of cobble, and some rip rap is found in a narrow nearshore band along the western portion of the proposed cap, but represents a small fraction of the total cap area (likely <5%). Although there were historic accounts of lake trout spawning prior to 1955, there is very little suitable (<2000 m^2) cobble or gravel substrate in the proposed cap that appears suitable for lake trout spawning and there are no contemporary accounts of spawning fish. Suitable clean cobble substrate in 2-16 m of water is found along the shoreline west of Beatty Cove near Yser Point where significant historical lake trout spawning grounds were mapped by Goodier (1981).

Approximately 10 ha of the southeastern portion of the proposed cap have sparse to dense aquatic macrophytes dominated by the stonewort (*Chara*), Canada waterweed, and pondweeds. Submergents are densest in approximately 4-10 m water depth and provide cover for larval and adult fish. A few fish eggs and larval fish of unknown species were observed on underwater video in or immediately adjacent to the proposed cap. Yellow perch are known to spawn over submerged vegetation and young-of-the-year (YOY) were caught in Jellicoe Cove. The nearshore zone in and near the proposed cap is used by larval fish including longnose suckers, rainbow trout, and salmon. These likely originated from Shack Creek on the eastern shore of Peninsula Harbour. Other larval or juvenile fish such as round whitefish and rainbow smelt may have come from potential spawning grounds over coarse sand, gravel and cobble/rip rap along the periphery of the proposed cap or elsewhere in Peninsula Harbour.

Recognizing the limitations of the existing data, the proposed cap area does not appear to be critical fish habitat. Less than 2% of the cap is in shallow (<2 m) water preferred by many YOY fish including salmonids and suckers, and relatively similar littoral habitat is abundant elsewhere in Peninsula Harbour along more natural shorelines. The unvegetated portion of the proposed cap in deep water over fine-textured substrate is likely used by adult longnose

suckers and round whitefish in particular. The proposed capping will cover silt substrate with sand; this may benefit slightly species that prefer sand compared to silt and vice versa, but will probably not have a significant effect on fish habitat use. Furthermore, deepwater silt habitat is common in elsewhere in Peninsula Harbour.

Available evidence suggests that the most significant impact will be the potential reduction in aquatic macrophyte abundance in the proposed cap area, which could reduce the habitat suitability for foraging adult longnose suckers and northern pike. Although data are lacking, yellow perch and small fish species in various life stages could also be affected by a reduction in submergent density. The response of submergents to disturbances such as the proposed capping is poorly understood for oligotrophic systems like Peninsula Harbour. Various lines of evidence suggest however that the plant species present in Jellico Cove are will be able to recover in the short to medium term.

Finally, the long-term benefit of reducing exposure to contaminated sediments by capping it with a layer of sand probably outweighs the any potential short-term negative impacts to fish habitat. Although the proposed cap area provides habitat for a number of species of fish, in various life stages, it does not represent ideal foraging habitat due to contaminated sediments with mercury that bioaccumulates and can impair fish health and reproduction.

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1 Introduction

Peninsula Harbour, a large embayment adjacent to the town of Marathon on Lake Superior, was identified as an Area of Concern in 1985 as part of the review by the Water Quality Board of the International Joint Commission (; Stage 1 RAP 1991). Jellicoe Cove encompasses approximately 97 ha of Peninsula Harbour south of Skin Island (Figure 1, Figure 2). It has been the focus of numerous studies due to elevated concentrations of mercury and polychlorinated biphenyls (PCDs) in sediment and fish as the result of industrial contamination (e.g., Biberhofer and Dunnet 2005; Golder 2005; Richman 2004).

The objectives of Thin layer capping (AECOM 2009a) are:

- To reduce risk to biota from contaminated sediment in Jellicoe Cove thus reducing bioaccumulation into the food chain;
- To reduce the spread of contaminated sediment from Jellicoe Cove to the rest of Peninsula Harbour;
- To expedite the natural recovery of Jellicoe Cove; and
- To facilitate ecosystem recovery in Peninsula Harbour which will contribute to "delisting" as an Areas of Concern (AOC) identified in the *Great Lakes Water Quality Agreement between Canada and the United States*).

The proposed cap would cover approximately 25 ha, or about ¼ of Jellicoe Cove or about 2.5% of Peninsula Harbour (approximately 1000 ha) and even less of the Peninsula Harbour AOC, which extends further out into Lake Superior. The 33% design build specifies proposes a 15-20 cm capping layer of medium sand, with coarse sand in nearshore areas less than 5 m water depth.

Northern Bioscience has been engaged to independently review existing fish community and fish habitat data for Peninsula Harbour. Existing fish and fish habitat information has been synthesized, and its significance assessed based on these data. Potential short and longer term impacts of the proposed capping and remediation are also discussed.

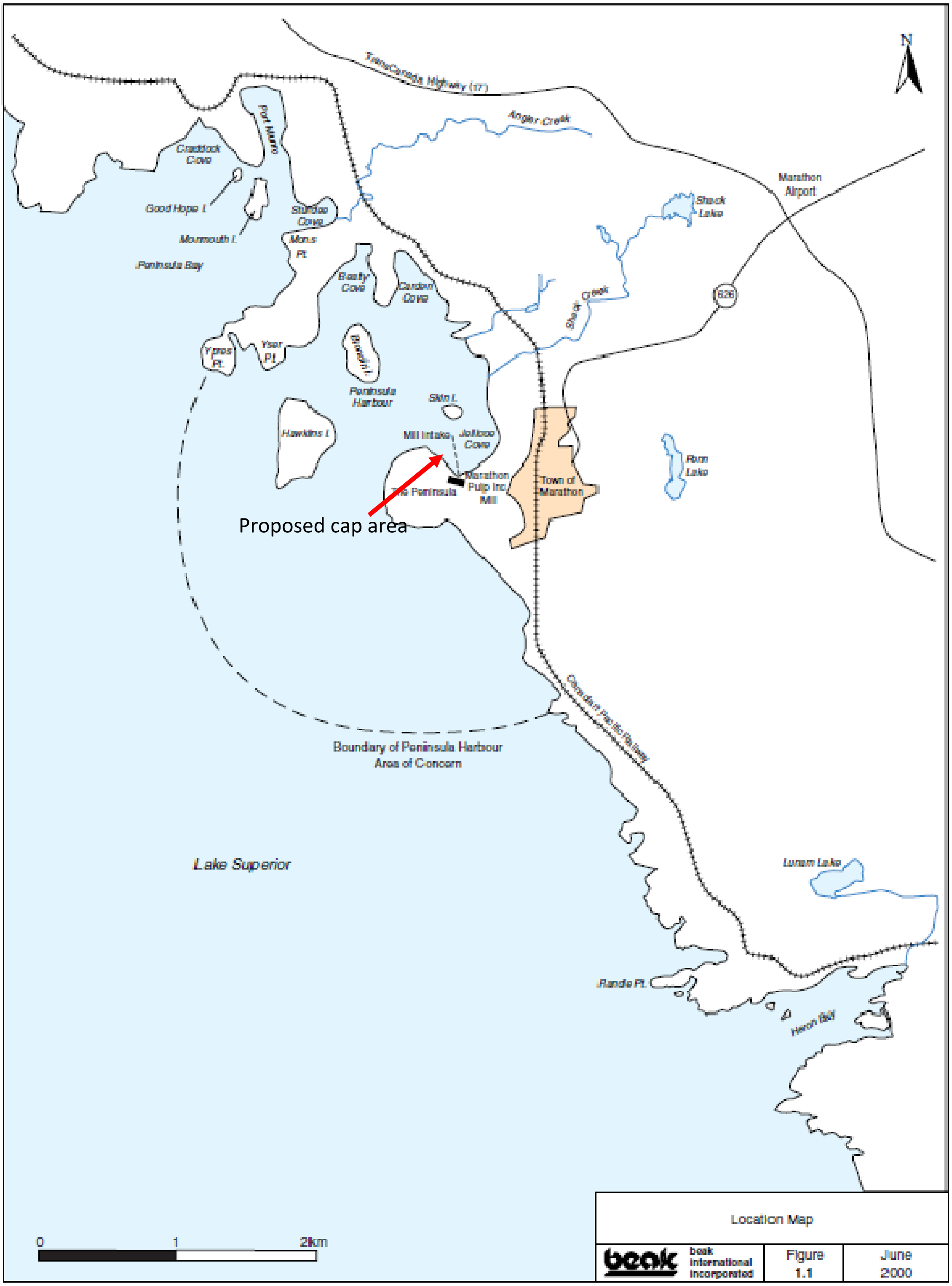


Figure 1. Map of Peninsula Harbour Area of Concern near town of Marathon (Beak 2001).

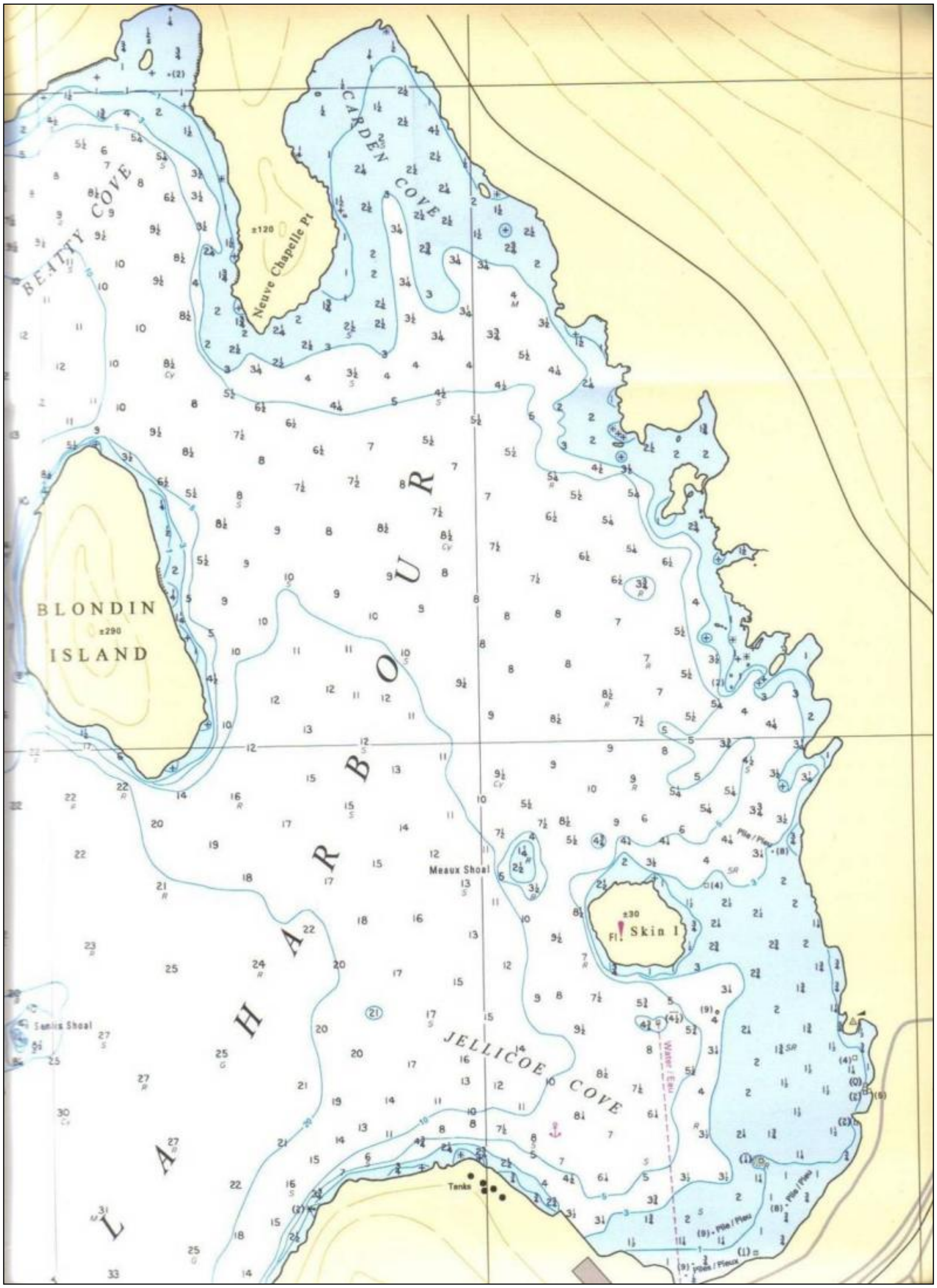


Figure 2. Detail of Canadian Hydrographic Service Chart 2306 Peninsula Harbour and Port Munro showing Jellicoe Cove and surrounding waters.

2 Fisheries

Limited information on fish and fish habitat use is available for Peninsula Harbour and Jellicoe Cove.

2.1 Historic Documentation

Goodier (1981, 1982) conducted interviews with experienced commercial fishermen and compiled other historical evidence on the location of historic (pre-1955) spawning and fishing grounds for lake trout and other species in Lake Superior. The spawning grounds identified for Jellicoe Cove were identified as “average or not known” meaning that they did not stand out in commercial fisherman interviewed as either particularly significant or relatively minor (Goodier 1981)(Figure 4). Significant historic (pre-1955) lake trout spawning shoals were also mapped along the north shore of Peninsula Harbour at Yser Point and along the western shore at the mouth of Beatty Cove. Although mapped, there was no text describing use of Peninsula Harbour by lake trout. Goodier (1981) suggest that there existed many discrete and semi-discrete stocks with Lake Superior prior to their collapse in the 1950s. Goodier (1981) stated that many of the original spawning grounds are now deserted in the fall (the status of the Peninsula Harbour was unknown at the time of his thesis). Goodier’s historical observations are the only available supporting documentation for the statement in AECOM’s (2009b, p. 1-1) 33% design brief that “Historical lake trout spawning grounds along the shorelines of Jellicoe and Beatty Coves, have been destroyed through the accumulation of organic matter from mill operations.” In the case of Beatty Cove, it is organic matter from log booming, not mill operations, that may have impacted spawning grounds.

Goodier (1982) stated that “Peninsula Harbour continues to receive herring in November, although effluent and debris from the American Can paper mill is undoubtedly deleterious.” The location of spawning grounds is very roughly depicted with the symbol overlapping The Peninsula (Figure 3). No historic spawning or fishing grounds for chub (*Coregonus* spp.), lake whitefish, walleye, northern pike, yellow perch, and lake sturgeon were identified for Peninsula Harbour in Goodier (1982). These historic spawning grounds from Goodier (1981, 1982) were reproduced in Beak (2001) and AECOM (2009)(Figure 5,Figure 6).

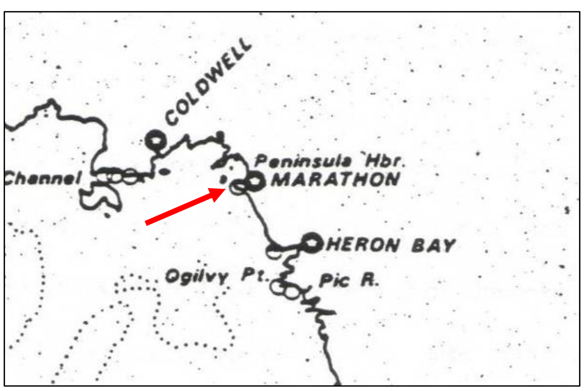


Figure 3. Detail of lake herring spawning locations (open circles) from Goodier (1982) northeastern Lake Superior including Peninsula Harbour (red arrow).

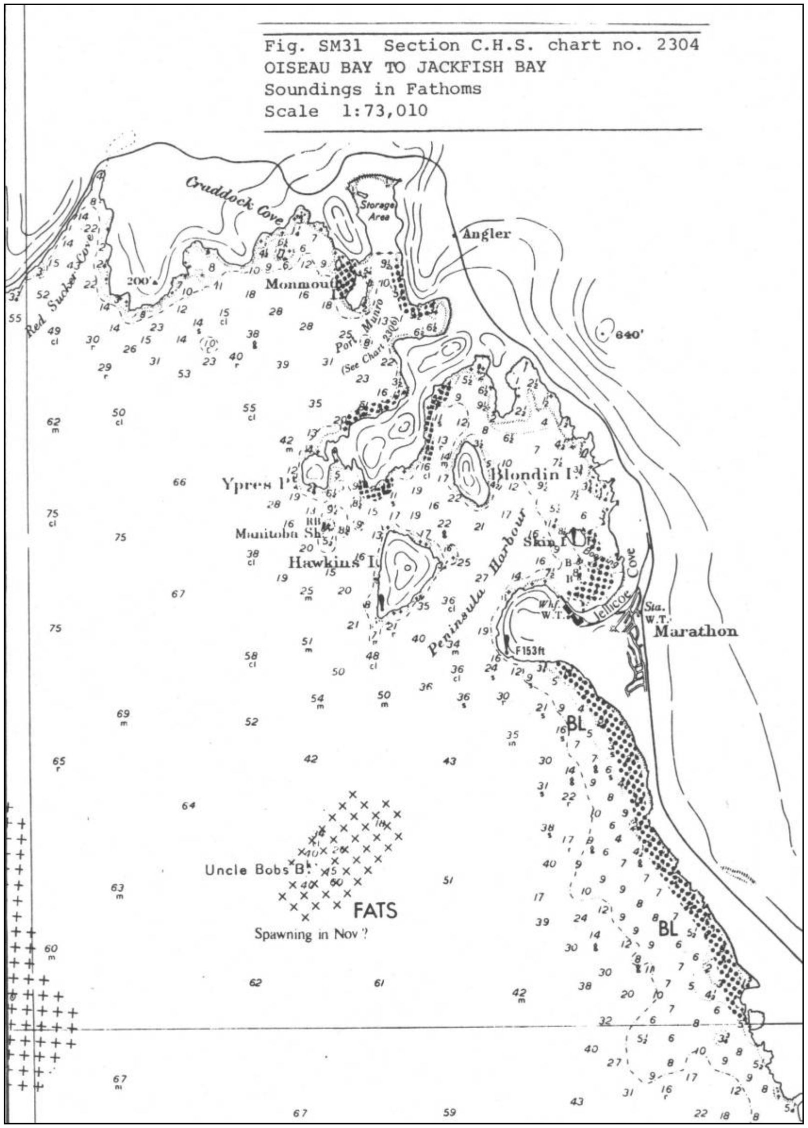


Figure 4. Summary of spawning grounds (stippled) and fishing grounds (hatched) for native lean lake trout stocks prior to 1955 (Goodier 1981, Fig. SM31).

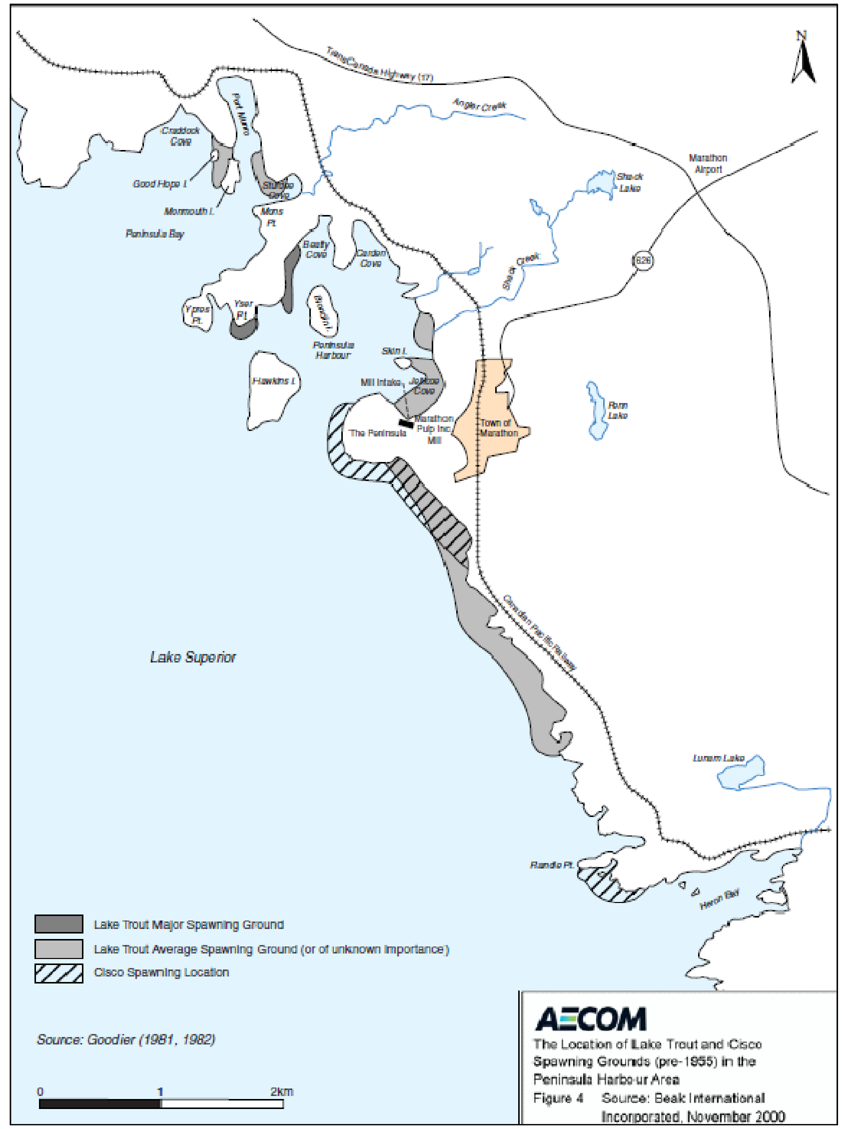


Figure 5. AECOM map of lake trout and cisco spawning ground prior to 1955 based on Goodier (1981-1982).

Spawning and nursery habitat for a number of economically important fish species were mapped by Goodyear et al. (1982) for Lake Superior based on a variety of existing sources (Figure 6). For Peninsula Harbour, Goodier (pers. comm. 1979) was the cited source:

> "Spawning occurred at Port Munro (48°46', 86°26'), Ypres Point(48°44', 86°27'), Peninsula Harbor (48°44', 86°24'), along shore around Craig's Pit (48°41, 86°22'), Randle Point (48°39', 86°21'), Heron Bay(48°38', 86°20'), Ogilvy Point (48°36', 86°21'), and the points outside Playter Harbour (Goodier, pers. comm. 1979)."

Although mapped, there was no supporting text for Peninsula Harbour in Goodyear et al. (1982). No spawning or nursery grounds for other lake-spawning fish species (including lake herring) are depicted for the Peninsula Harbour in Goodyear et al. (1982). Spawning habitat for rainbow trout in Lake Superior tributaries is mapped in Goodyear et al. (1982), but Shack Creek is not specifically listed.

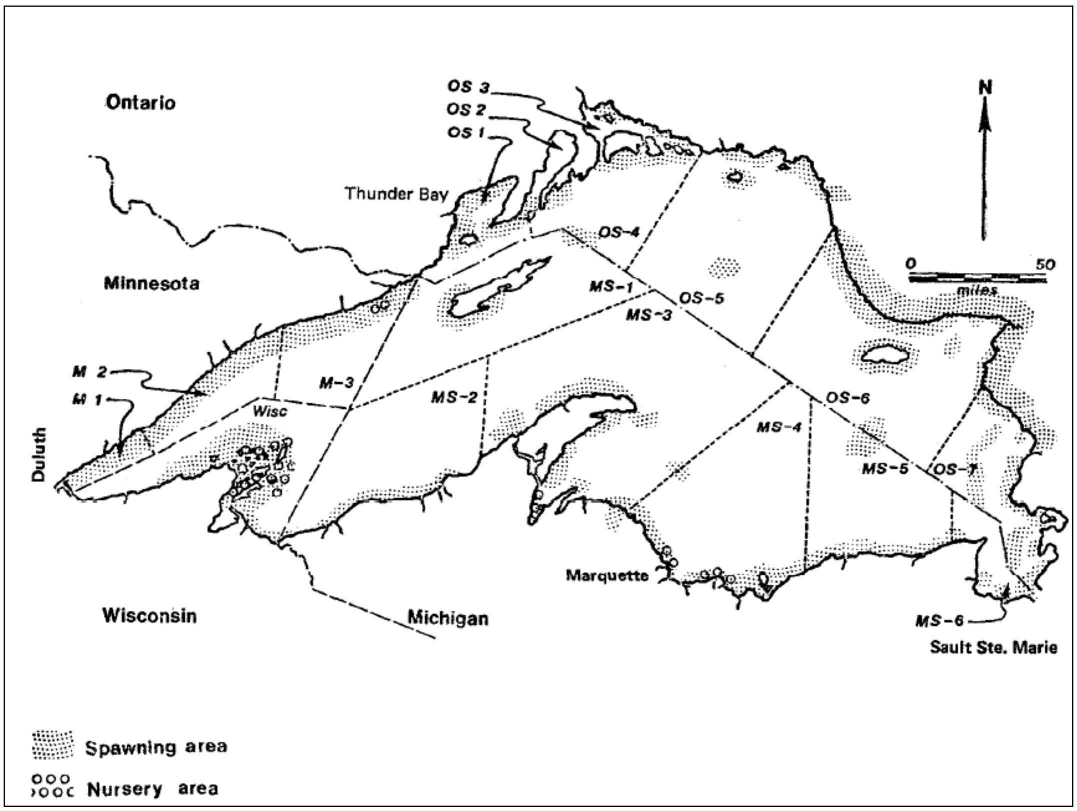
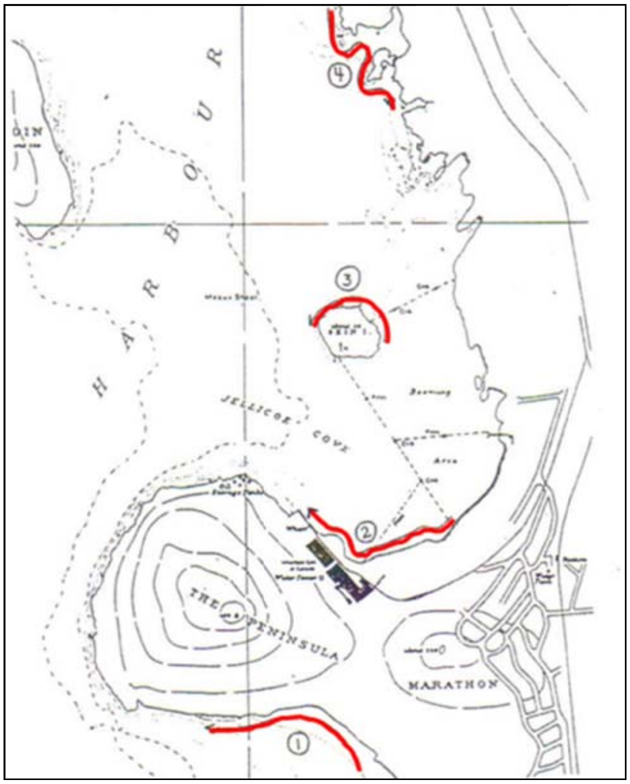


Figure 6. Lake trout spawning and nursery areas mapped by Goodyear et al. (1982)

2.2 Contemporary Fisheries Assessments



The first documented fisheries assessment for Peninsula Harbour appears Hamilton (1987). Four, night-time, boat-based electrofishing runs (3889 seconds total) in 1-4 m of water of Jellico Cove, Peninsula Harbour and adjacent Lake Superior (Figure 7) yielded 73 fish of 8 species (Table 1). An additional 11 species were noted from a personal communication with Suns (Table 1). No aquatic macrophytes were observed and no nursery habitat was identified. Substrate for Jellico Cove electrofishing run was described as sand/rubble, old cribs, and sawdust.

Figure 7. Location of four electrofishing runs (red lines), August 27-28, 1986 (Hamilton 1986).

Beak conducted sampling in Peninsula Harbour (Figure 8a) on August 22-27 , 2000, consisting of 5 overnight gillnet sets (1½"-5" mesh), beach seining (36 x 4 bag seine with ¼" mesh) at four locations (50-150 m distance), and backpack electrofishing (total 1299 seconds) in Jellicoe Cove (Figure 8). Slightly less effort was used in Carden Cove (Figure 9a.). Gill-netting catch per unit effort (CUE) by Beak (2001) was three times higher in Carden Cove compared to Jellicoe Cove, but CUE for backpack electrofishing and beach seining were similar.

Based on this sampling, maps of sensitive fish habitat in Jellicoe Cove were prepared by Beak (Figure 8b, Figure 9b). Nursery habitat was mapped along the southwest shoreline of Jellicoe Cove adjacent to the proposed cap (rainbow trout and coho salmon) and in the small embayment along the eastern shore approximately 500 m east of the cap (yellow perch and longnose sucker). Sensitive fish habitat was only delineated for areas that were sampled; other areas that were not sampled may or may not contain sensitive habitat. Areas with YOY large fish species were called nursery habitat, but small fish species were not considered. Similar criteria were used for the longnose sucker and round whitefish nursery habitat mapped for Carden Cove.

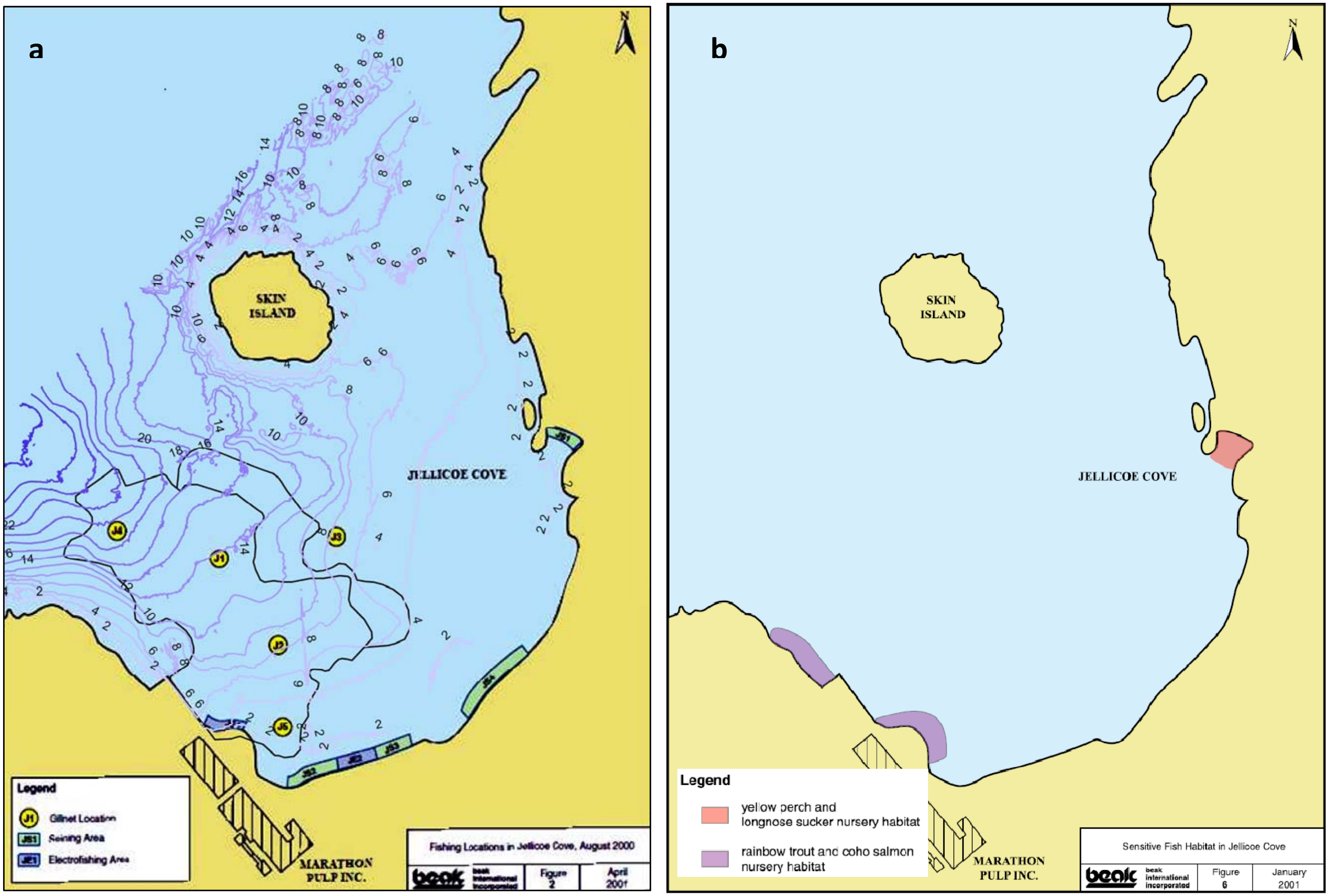


Figure 8. Beak (2001) fisheries assessment locations in Jellicoe Cove, August 22-27, 2000 modified to show proposed cap area and bathymetry (a) and identified sensitive fish habitat (b).

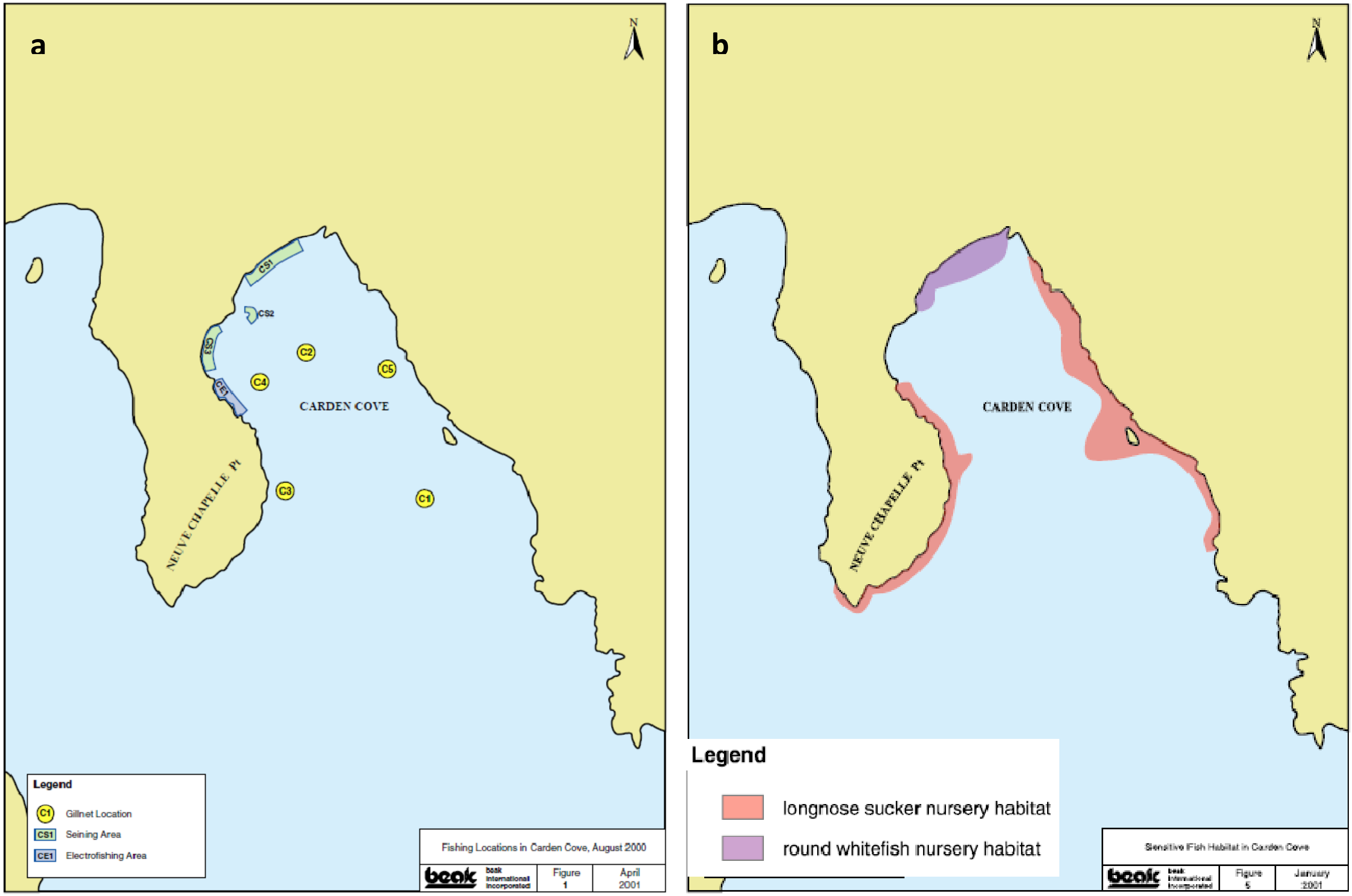


Figure 9. Beak (2001) fisheries assessment locations in Carden Cove, August 22-27, 2000 and identified sensitive fish habitat.

2.3 Video Interpretation

During examination of Environment Canada videos recorded for substrate analysis (see 3.1.1.5), fish eggs and/or larval fish were observed at several locations. What appears to be a single fish egg was observed on video at two locations within the proposed cap (these are difficult to see on still photographs but are more evident in the video). At location #1, a single egg was observed on silty sand substrate with scattered stonewort at approximately 10 m depth. Egg #2 was observed on silt with abundant bark deposits in 14 m of water depth. At the west end of the cap (Location #3), a small school of larval fish and several fish eggs were observed in approximately 21 m of water. It appears that at least 2 cm of silt overlays bedrock where the fry and egg were observed (Figure 11). At 3:21 of video run time, several fish eggs can be seen rolling about on the surface of the substrate. Approximately 300 m west of Skin Island, another small school of small larval fish were observed on video (Figure 12). The water depth was 21 m and the substrate was silty as well.

It is not known if the eggs were laid in the locations observed on video, if they were viable or not, or what species they are. Similarly, the larval fish are too small to positively identify. Both are difficult to pick out in still photos, but are more readily distinguished in the video.

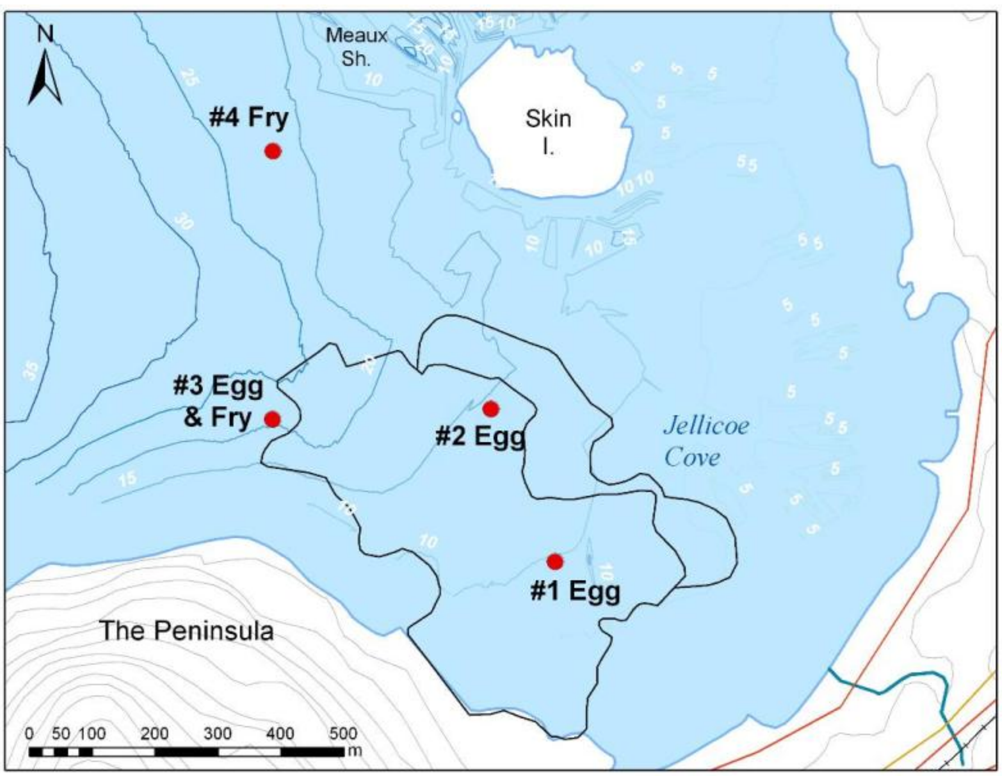


Figure 10. Location of apparent fish eggs and fry observed in Environment Canada videos.

Figure 11. Silty sediment at 21 m depth west of proposed cap with larval fish (red arrow) and fish egg (black arrow)(Photo 36b).

Figure 12. Silty sediment at 21 m depth west of Skin Island with larval fish (arrow) near bottom.

2.4 Fish Community

According to Beak (2001) and Peninsula Harbour RAP Team (1991), Peninsula Harbour supports a fish community which includes at least 31 species, citing Scott and Crossman (1973), Lawrie (1978), Goodyear *et al.* (1982); and Mandrak and Crossman (1992). Species lists were not provided. A total of 20 species were confirmed in Peninsula Harbour by Hamilton (1986) and Beak (2001), with another 6 species from personal communications. Based on these sources, Beak (2000), and AECOM (2009), a total of 26 species has been compiled in Table 1, of which 18 have been recorded from Jellicoe Cove.

Approximately 80 species of fish are documented from Lake Superior and other species not found during sampling may potentially utilize Peninsula Harbour at some point in their life cycle such as trout-perch (*Percopsis omiscomaycus*) and cyprinid (minnow) species. Young of the year (YOY) and juvenile longnose sucker and round whitefish were the most abundant species sampled by Beak (2001) in Peninsula Cove, followed by rainbow trout and longnose dace in the lower reaches of Shack Creek. However, relative abundance of larval fish can be very variable depending on the time of year, type of sampling gear used, and time of day that the sampling was conducted (e.g. night vs. daytime sampling, particularly for habitats with little or no cover such as beaches). For example, no offshore areas were mapped as nursery areas by Beak (2001) since all seining and electrofishing was done along the shoreline or in tributary streams.

The significance of fish populations is difficult to determined based on published fisheries assessments given the paucity of available data i.e., only two, limited effort, point-in-time sampling sessions in 1986 and 2001. Hamilton’s (1986) observation that Peninsula Harbour has the lowest species diversity in Lake Superior must be considered in the context of the limited sampling effort and that is was only being compared to other Areas of Concern (AOC) that were sampled on Canadian Lake Superior.

2.5 Species at Risk

Several aquatic Species At Risk (SAR) are known from Lake Superior and could potentially use Peninsula Harbour at some point in their life cycle. In particular, lake sturgeon are known to spawn and reside in the Pic and Black rivers (e.g., Foster and Tost 2010) and it is conceivable that they could forage in Peninsula Harbour. There is no evidence of their use of the Peninsula Harbour (AECOM 2009a), but no assessment sampling with appropriate gear (e.g., large mesh gill net) has been there. Great Lakes populations of lake sturgeon is considered Threatened in Ontario and protected under the Endangered Species Act (ESA) 2007.

Shortjaw cisco (*Coregonus zenthicus*) is also Threatened under SARA and Ontario's ESA and could potentially use Peninsula Harbour since there is a single record in Mandrak and Crossman (1992) near Marathon. However, the species typically inhabits deeper water i.e., 55 to 144 m, and shows seasonal differences, moving into shallower water to spawn (COSEWIC 2003). In Lake Superior, spawning probably occurs in 37-73 m over a clay bottom (Scott and Crossman 1998). There is no evidence that it is found in Peninsula harbour however.

The upper Great Lakes population of kiyi (*Coregonus kiyi kiyi*) is listed as Special Concern federally and is known from Lake Superior as well. This cisco species lives in the deepest part of Lake Superior and is rarely collected in waters less than 108 m deep (COSEWIC 2005). It lives in a clear, poorly lit, coldwater environment year round and spawning occurred at a depth of 108 m (Parker 1989; Scott and Crossman 1998). It is highly unlikely to be found in Jellicoe Cove.

Northern brook lamprey (*Ichthyomyzon fossor*) is a non-parasitic lamprey that is resident in a number of Lake Superior tributaries. It is considered Threatened in Ontario and nationally. There are no records of it from Shack Creek or the other unnamed tributary in Peninsula Harbour, though it is known from the nearby Pic River (Schuldt and Goold 1980; COSEWIC 2007). Shack Creek is not listed as a tributary treated by the Sea Lamprey Control Centre, so it is unlikely there has been any recent targeted surveys. As this species does not live in Lake Superior itself, it would not be impacted by the proposed capping in Jellicoe Cove.

The deepwater sculpin (*Myoxocephalus thompsonii*) is a Special Concern species that is known from Lake Superior (COSEWIC 2006a). In Lake Superior, deepwater sculpin are most common at depths greater than 70 m and have been found as deep as 407 m (Selgeby 1988). None have been recorded within 100 km of Peninsula Harbour (Mandrak and Crossman 1992) and it is highly unlikely that they are present in Jellicoe Cove due to the comparatively shallow water depths.

Table 1. Documented fish species and life stages* for Jellicoe Cove, Peninsula Harbour, Shack Creek and adjacent Lake Superior (taxonomic order).

Common Name	Scientific Name	Lake Superior	Peninsula Harbour	Jellicoe Cove	Shack Creek
Alewife	*Alosa pseudoharengus*		U[4]	A[5]	
Emerald Shiner	*Notropis atherinoides*		U[4]		
Lake Chub	*Couesius plumbeus*		U[4], N[5],U7	N[5]	N[5]
Longnose Dace	*Rhinichthys cataractae*		U[4], N[5]	N[5], A[5]	N[5], A[5]
Spottail Shiner	*Notropis hudsonius*		U[4]		
Longnose Sucker	*Catostomus catostomus*	N[3]	N[3], N[5], A[5]	N[3], N[5], A[5]	S[6]
White Sucker	*Catostomus commersoni*		N[3], A[5]	N[3]	S[6]
Northern Pike	*Esox lucius*		U[4]	A[5]	
Rainbow Smelt	*Osmerus mordax*		N[3]	N[3]	
Brook Trout	*Salvelinus fontinalis fontinalis*				S[6], N[5], A[5]
Chinook Salmon	*Oncorhynchus tshawytscha*	N[3],U[7]			S[6]
Cisco (Lake Herring)	*Coregonus artedi*	S[1]		N[5]	
Coho Salmon	*Oncorhynchus kisutch*			N[5], A[5]	N[5]
Lake Trout	*Salvelinus namaycush*	S[1,2]	S[1]	N[5], A[5]	
Lake Whitefish	*Coregonus clupeaformis*		N[3], N[5], A[5]	N[3]	
Round Whitefish	*Prosopium cylindraceum*		N[5], A[5]	N[5],A[5]	
Pink Salmon	*Oncorhynchus gorbuscha*			N[5]	S[6]
Rainbow Trout	*Oncorhynchus mykiss*		U[4], N[5], A[5]		N[5]
Burbot	*Lota lota*	A[3]	N[5]	N[5]	
Sticklebacks	Unknown		U[4]		
Threespine Stickleback	*Gasterosteus aculeatus*			A[5]	
Mottled Sculpin	*Cottus bairdi*		N[5], A[3]	N[5], A[5]	A[5]
Slimy Sculpin	*Cottus cognatus*	N[3], U[7]		N[5], A[5]	N[5], A[5]
Johnny Darter	*Etheostoma nigrum*		U[4]		
Walleye	*Zander vitreus*		U[4]		
Yellow Perch	*Perca flavescens*		U[4]	N[5]	

*S=Spawning; N=Nursery (presence of YOY or Juveniles based on total length); A=Adult; U=unknown life stage

[1] (Goodier 1981, 1982); [2] Goodyear et al. (1982);
[3] Hamilton (1986); [4] Suns pers. comm. in Hamilton (1986)
[5] Beak (2001) [6] AECOM (2009)
[7] (GBIF 2011)

3 Aquatic Environment

3.1 Substrate

3.1.1 Existing Studies

3.1.1.1 Beak 2001

Initial habitat mapping was conducted by Beak (2000) in conjunction with fisheries assessment. Visual assessment of substrate, aquatic vegetation, bedrock outcroppings, in-water structure and shoreline features were recorded on base maps. According to Beak (2000), the lake bed was visible to a depth of approximately 6 m due to clear water and sunny skies. Substrate types were verified at "numerous" locations (no map or coordinates were provided) in Carden and Jellicoe coves with the aid of a petite Ponar grab and visual/manual inspection in the field. Samples of aquatic macrophytes were collected for species determination and photographs of representative habitat features were taken. The resulting habitat map prepared by Beak is shown in Figure 13.

3.1.1.2 Environment Canada Reports

Numerous toxicological studies examined sediments in the Peninsula Harbour AOC on behalf of Environment Canada, and have included particle size analysis. Reports by Milani et al. (2001) and Grapentine et al. (2005) included tables with particle size distributions, depths, and geographic coordinates. These have been compiled (Appendix 1) and are portrayed in Figure 15. These are the only particle size data from laboratory analysis that was readily available for the current review.

3.1.1.3 AECOM 2009

The Beak habitat map was largely reproduced by AECOM (Figure 14) with new bathymetry and some minor refinements i.e., a small area of silt/mud was delineated based on a couple of substrate grab samples from Grapentine et al. (2005) and Milani et al. (2002)(Figure 15). No new field sampling was conducted for this revised habitat map.

Based on several other previous studies, AECOM 2009 summarized sediment quality in Jellicoe Cove as the following:

> "Substrates in the area of the proposed capping were described as having coarse sand over gravel (Burt and Fitchko 2001), and photographs indicate material consists predominantly of a soil matrix (*i.e.,* clay, silt, sand, gravel spectrum) with occasional layers of darker organic matter resembling peat. Eakins and Fitchko (2000) have also reported that substrate in Jellicoe Cove is generally a silty sand in the shallows becoming mud offshore in deeper waters with areas of exposed glacial clay also present. The "hotspot" area that contains the highest mercury concentrations overlies two types of hard uncontaminated substrate comprised of either glacial till (*i.e.,* light gray

compacted fine sand with clay) or light gray glaciolacustrine clay (Burt and Fitchko 2001, Beak 2000), and occupying approximately 3 and 2 ha, respectively (Dainty 2003)."

3.1.1.4 BioSonics 2011

Contracted through EcoSuperior Environmental Programs, BioSonics (2011) conducted a hydroacoustic survey in 2010 to map the substrate in Peninsula Harbour for the identification of fish habitat. Submersible video and ponar grabs used for spot confirmation, with substrate determination from ponar grabs done visually in the field (Mike Burger, BioSonics, pers. comm.). The substrate classes could be roughly compared to those used Beak (2001) and AECOM (2009).

3.1.1.5 Northern Bioscience

The following underwater video coverage was reviewed by Northern Bioscience to confirm existing habitat mapping:

1. October 21-22, 2005 Environment Canada (VTS_01_1, VTS_01_02, VTS_01_03, VTS_01_04)
2. September 18, 2007 Environment Canada (Transects 1, B, C, C1, C2, D, E, F, F1)
3. BioSonics 2010 video from acoustic mapping (Cardin Cove, inside Beatty Cove entrance, middle Beatty Cove, outside entrance to Beatty Cove, Outside Blondin I., Skin I. Beatty shoreline, Yser Pt)
4. Ministry of the Environment (VTS_01_1, VTS_01_02, VTS_01_03, VTS_01_04) with audio.

The Environment Canada and BioSonics videos have global positioning system (GPS) coordinates overlain with the image, allowing the video images to be georeferenced. Environment Canada personnel interpreted their 2005 and 2007 videos and created two georeferenced databases (point ArcGIS shapefiles) with 372 and 552 data points respectively. At each these 924 locations, the substrate, woody debris, aquatic vegetation, and other notable features were described. Due to limitations of video interpretation, substrate were identified as fine sediments (<2 mm), gravel (2-64 mm), cobbles and boulders (>64 mm) and bedrock (Environment Canada 2007). For this study, the Environment Canada shapefiles were reviewed in ArcGIS concurrently with georeferenced videos (where available) to assess their accuracy.

Environment Canada videos CPS01 to CPS13, HDT1, HDTD2, and NC02 to NC04 were not provided but point shapefiles interpreted from them were available for this review. Not all BioSonics videos were available for review, but their 2011 draft report provides descriptions of the results from 42 spots with video and/or ponar grabs (Figure 17).

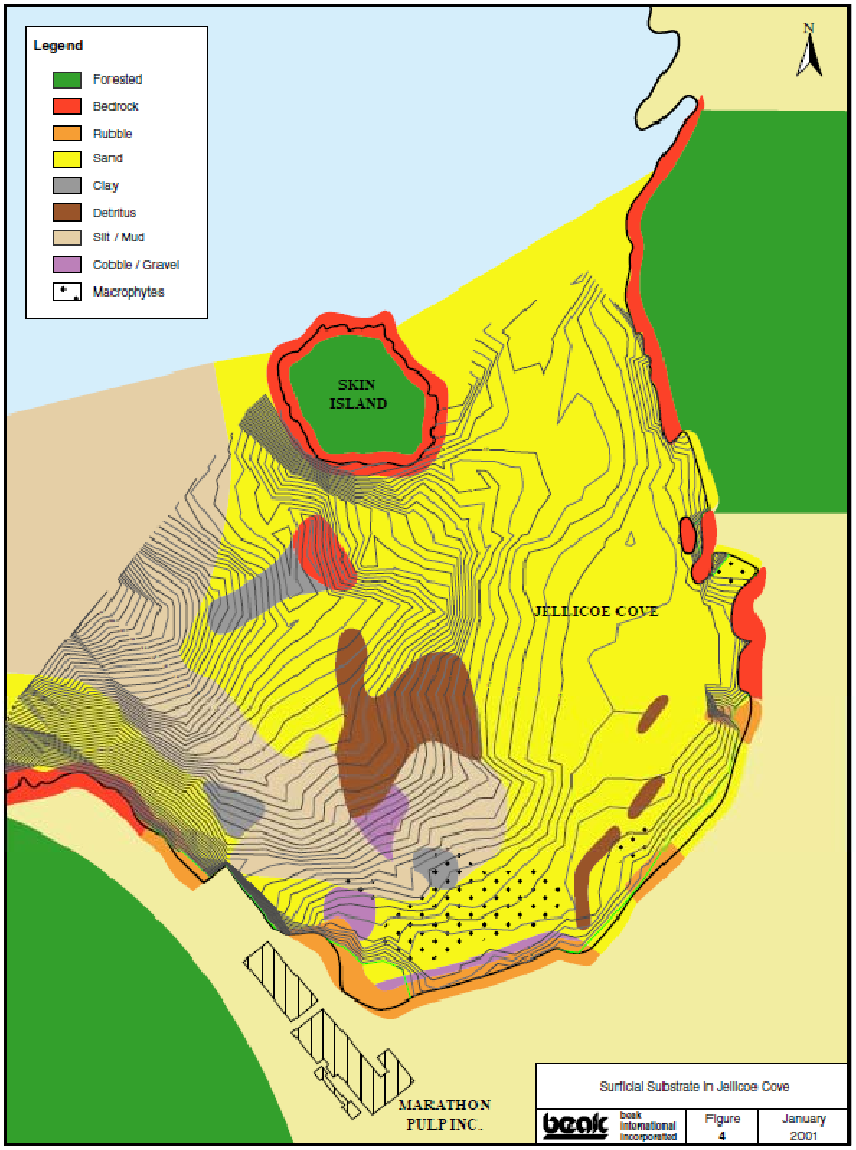


Figure 13. Beak (2001) habitat map for Jellicoe Cove.

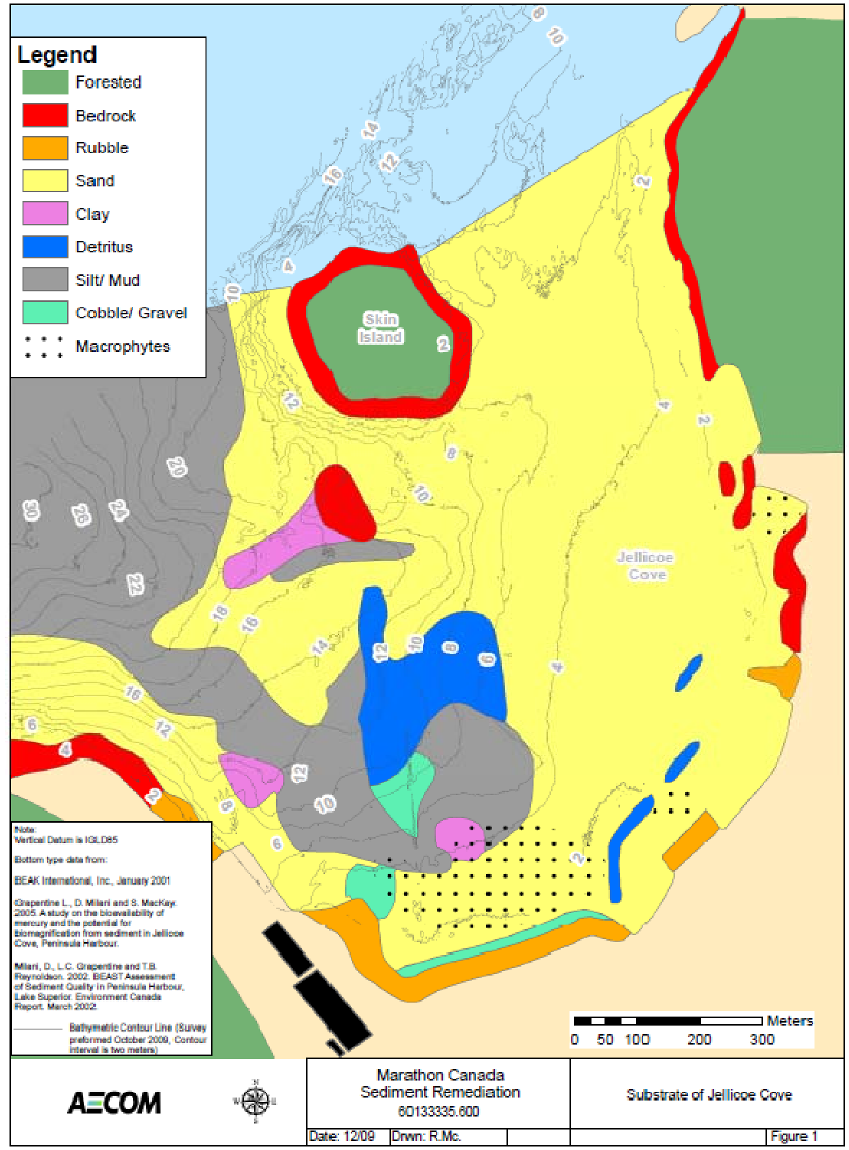


Figure 14. AECOM habitat map for Jellicoe Cove based on Beak (2001).

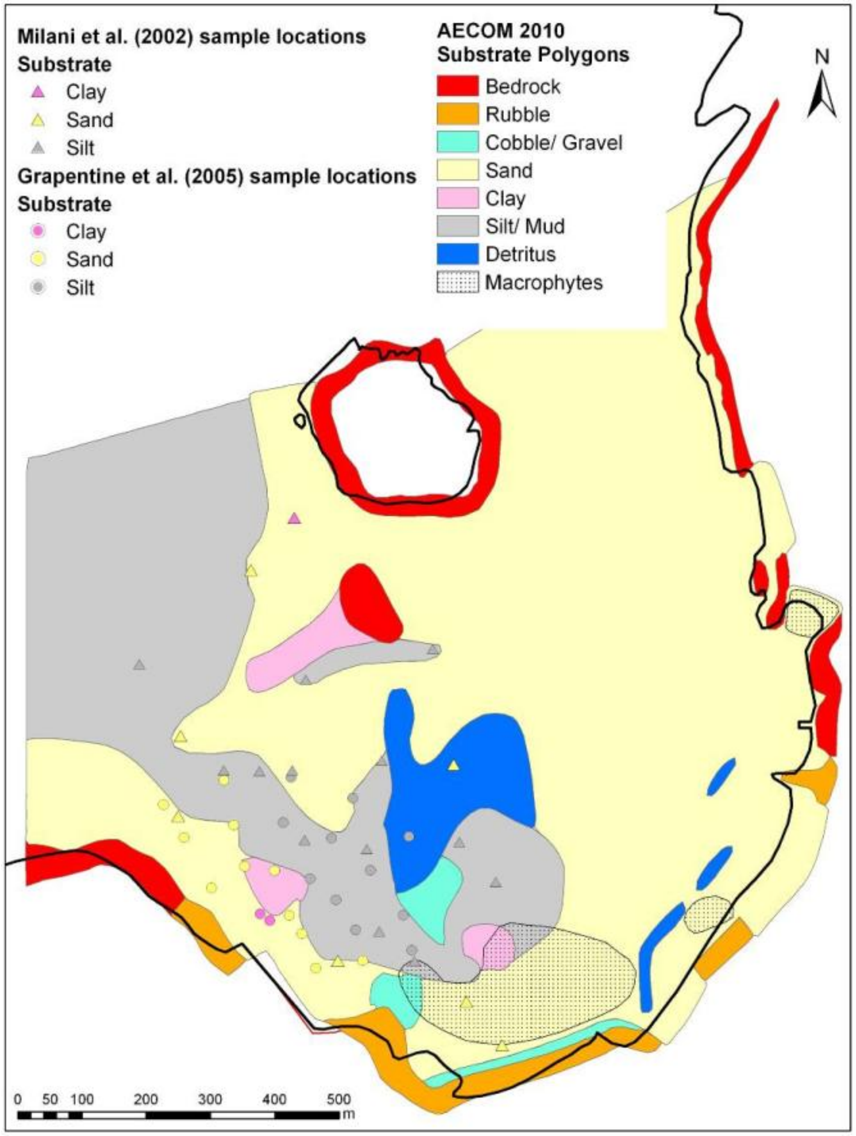


Figure 15. Substrate polygons (AECOM 2009a) overlain with substrate samples from Milani et al. (2002) and Grapentine et al. (2005).

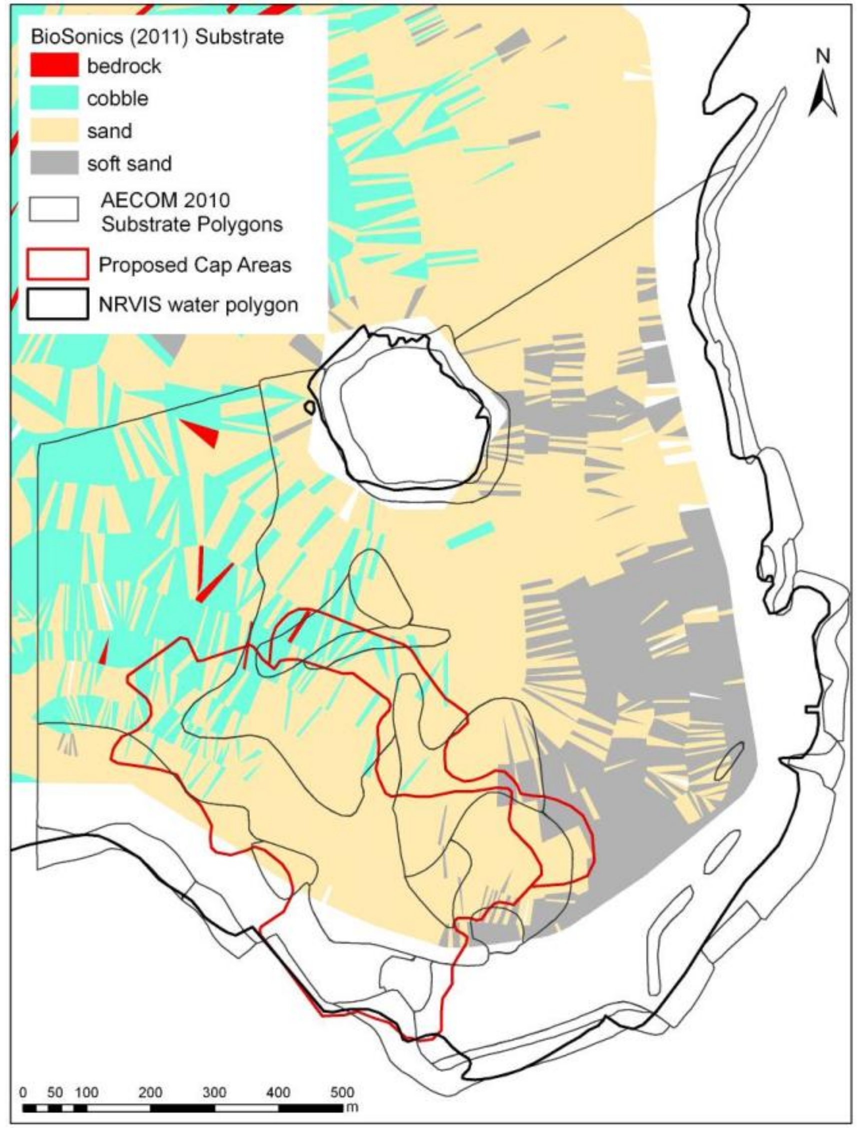


Figure 16. Substrate mapping from BioSonics (2011) overlaid with substrate polygon boundaries from AECOM (2009) in relation to proposed cap area.

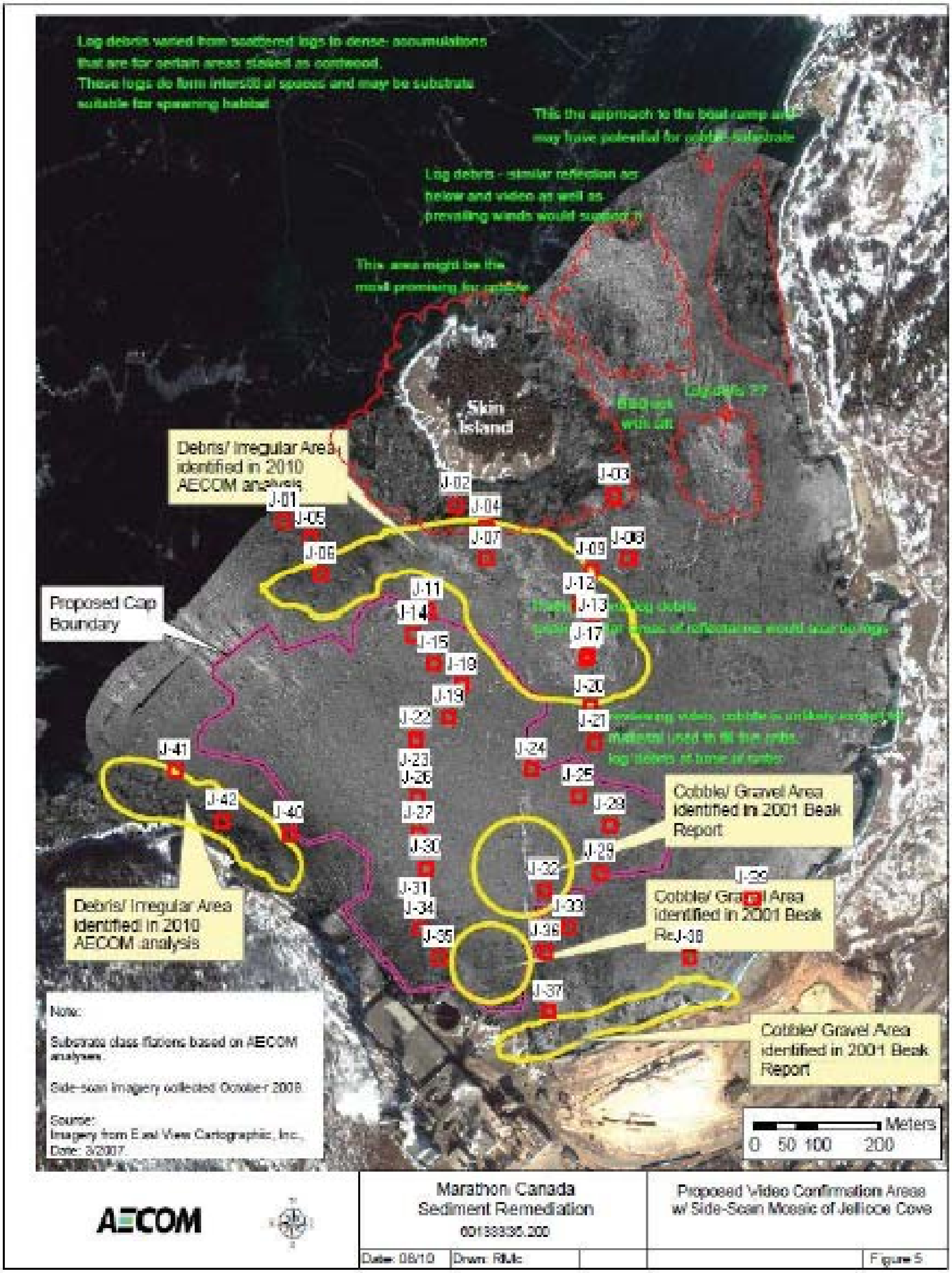


Figure 17. Site locations (red squares) for BioSonics video and ponar confirmation for their 2010 hydroacoustic survey (BioSonics 2011).

3.1.2 Substrate Synthesis

3.1.2.1 Jellicoe Cove and Proposed Cap Area

Based on sediment sampling, acoustic analysis, and review of underwater video, the proposed cap area is predominantly soft sediments. Laboratory particle analyses of Environment Canada samples from the proposed cap area indicated they were a mixture of sand and silt; samples from shallower water tended to have a higher proportion of sand, with offshore samples from greater water depth have more silt (Appendix 1; Figure 26). Of the 576 points in or within 100 m of the proposed cap that were interpreted by Environment Canada from their 2005 and 2007 videos, 78% were visually classified as soft sediments and 18% as mixed substrates (Figure 18). Review of these videos confirmed this interpretation; see Appendix 2 for representative video images and key map for the proposed cap area and elsewhere in Peninsula Harbour. Most of the mixed substrate was located in shallow water near the shoreline (Figure 26), and appeared to be predominately sand, with patches of overlying gravel and the occasional cobble (Figure 19).

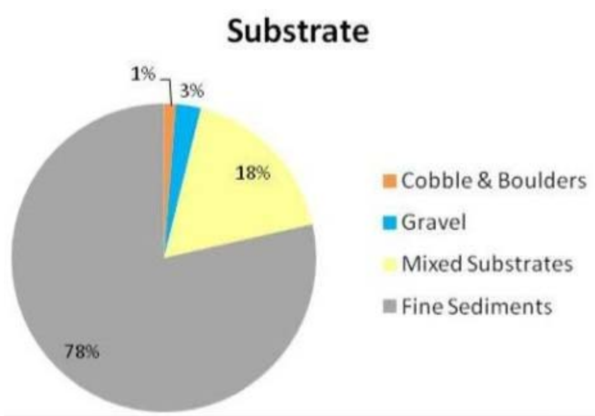


Figure 18. Substrate composition based on 568 interpreted Environment Canada 2005 &2007) video points within the proposed cap area and 100 m buffer.

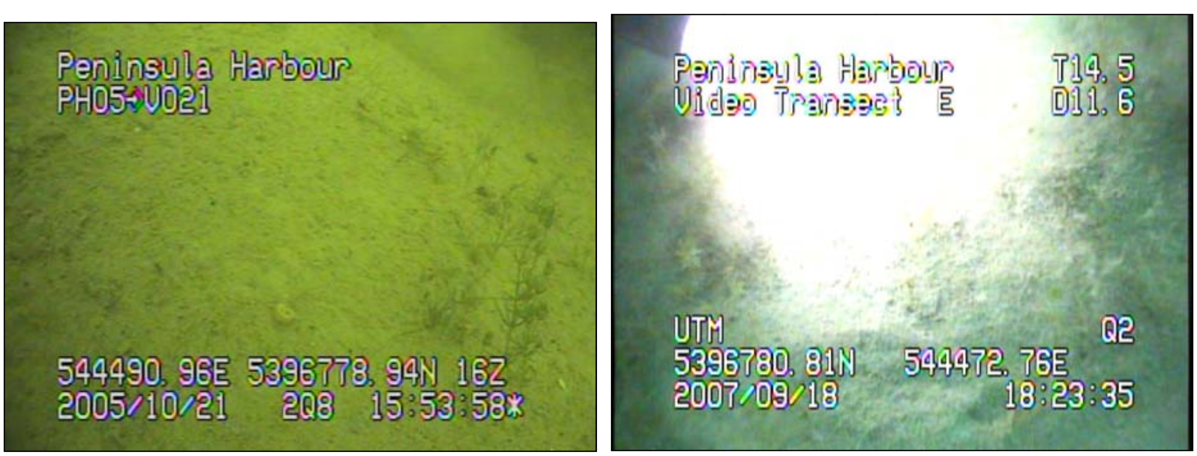


Figure 19. Centre of proposed cap area with soft sediment and sparse macrophytes (note dead planorbid snail in photo on left).

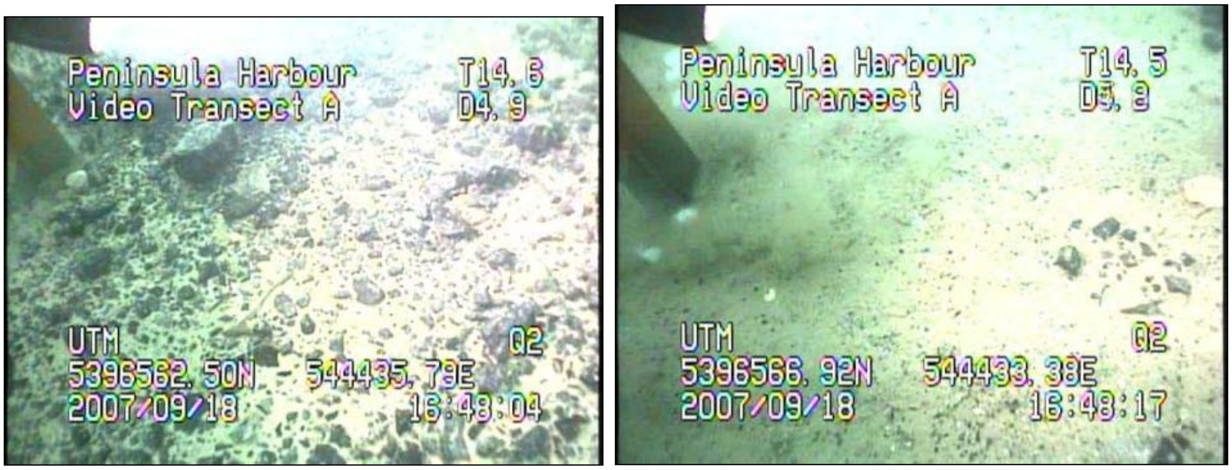


Figure 20. Mixed substrate in shallow water along southwest margin of proposed cap.

The original mapping by Beak (2001) correctly shows that the majority of the proposed cap is soft sediments (e.g., either sand or silt), but maps the northern and eastern portions of the cap as sand, rather than as silt. These areas, in 6-16 m of water and more than 200 m from the shoreline, are predominately silt, rather than sand based on sediment samples and video interpretation. The silt polygon added by AECOM (2009) at the northern edge of the cap (Figure 15) is accurate based on grab samples and video interpretation, but the surrounding area should be silt rather than sand. AECOM (2009b) characterized the surficial sediments on the eastern side of the cap area and near the existing dock as predominantly silty sands (SM and SP-SM), while the remainder of the surficial sediments in the cap area as low plasticity silts, based on their 11 bore holes and sampling by Terraprobe (2008). The characterization of the northern portion of the cap as cobble by the BioSonics hydroacoustic survey (Figure 16) therefore appears erroneous.

Figure 21. Bark overlying silty substrates at northwest edge of proposed cap.

Beak (2001) mapped two polygons within the proposed cap as cobble. Video analysis showed that the 6800 m^2 polygon approximately 200 m from shore near the centre of the cap was not cobble, but rather silty deposits, typically vegetated (Figure 22). Ponar grabs around the polygon were predominantly silt as well. The field observations of cobble may have been of rip rap used in association with cribbing found in the mapped polygon (Figure 23). Unfortunately, the type of substrate could not be confirmed for the other smaller (5000 m^2) polygon near the southern edge of the cap that was mapped as cobble by Beak (2001) since no video or ponar grabs were taken at that location. BioSonics (2011) observed cobble in video and ponar grabs at samples J36 and J37 approximately 50 m to the east, just outside the cap. This cobble is likely associated with the effluent pipe and associated cribbing that runs north approximately 700 m from the shore near this location. Beak (2001) also mapped some long, narrow polygons of cobble in shallow water (<3m water depth) along the eastern shore of Jellicoe Cove. Two BioSonics video and ponar stations (J38, J39) targeted these polygons, but instead of cobble, they were actually sand.

Figure 22. Soft sediments with dense stonewort with boot for scale in southern portion of proposed cap.

Figure 23. Cribbing in cap area mapped as cobble by AECOM/Beak within the proposed cap area.

At least in the area of the cap for which video was available, there is a narrow band (perhaps 10-20 m) of coarser sediments close to shore in shallower (<5 m approximately) water where there is too much wave energy for finer silts to settle out, at least during the ice-free season. The substrate consists of patches of rounded, natural–looking cobble and larger, darker, angular, rocks that are presumably rip rap used for fill and shoreline armouring. There are also areas of coarse sands rippled from wave action and mixed substrates. Farther west along The Peninsula was an area along the shore mapped as bedrock by Beak/AECOM (Figure 15). Although too shallow for a hydroacoustic survey, three video and ponar stations were conducted there by BioSonics (Figure 17) which confirmed that is was gravel and sand over bedrock, as well as cobble and rubble. East of the proposed cap, at the head of Jellicoe Cove is a beach, with coarse sand and gravel (ENVIRON 2008a, b).

Figure 24. Angular rocks (upper right) and rounded cobbles in shallower water along margin of proposed cap.

Beak (2001) mapped several polygons in the cap area as clay, including one adjacent to the AECOM silt polygon at the northern edge of the cap. There were no grab samples or video in the adjacent clay polygon mapped by Beak at the northern edge of the cap, so the substrate could not be confirmed. The one BioSonics ponar grab (J33; Figure 17) in the polygon mapped as clay at the southern edge of the cap in 4 m of water indicated that it was "sand, plants and some cobble"(BioSonics 2011). On the southwest edge of the cap in 7-11 m of water, a Grapentine et. al. (2005) ponar grab in the polygon mapped as clay by Beak (2001), indicated that the sediment composition as 55% sand, 31% silt and only 13% clay. It appears that clay is a minor component of the surficial substrate in the proposed cap zone, although it is possible that it may be more predominant deeper in the sediment profile.

The AECOM (2009a) Peninsula Harbour 33% Design Report (p. 6) identifies a couple of isolated rock outcrops at location #28 and #29 (relabelled as #34 and #35 on AECOM CAD plot MRT-030m002.dwg but with the same plotted location and UTM coordinates) in the proposed cap area, adjacent to silty deposits to the south and east. No sediment grabs or video footage was available for this area, but the contours derived from hydroacoustic mapping suggest some bottom irregularities and hydroacoustic survey by BioSonics (2011) also characterized that area as bedrock (Figure 25). These locations are in approximately 17 m of water, and if not bedrock, are likely another substrate with similar acoustic properties such as hardpan clay.

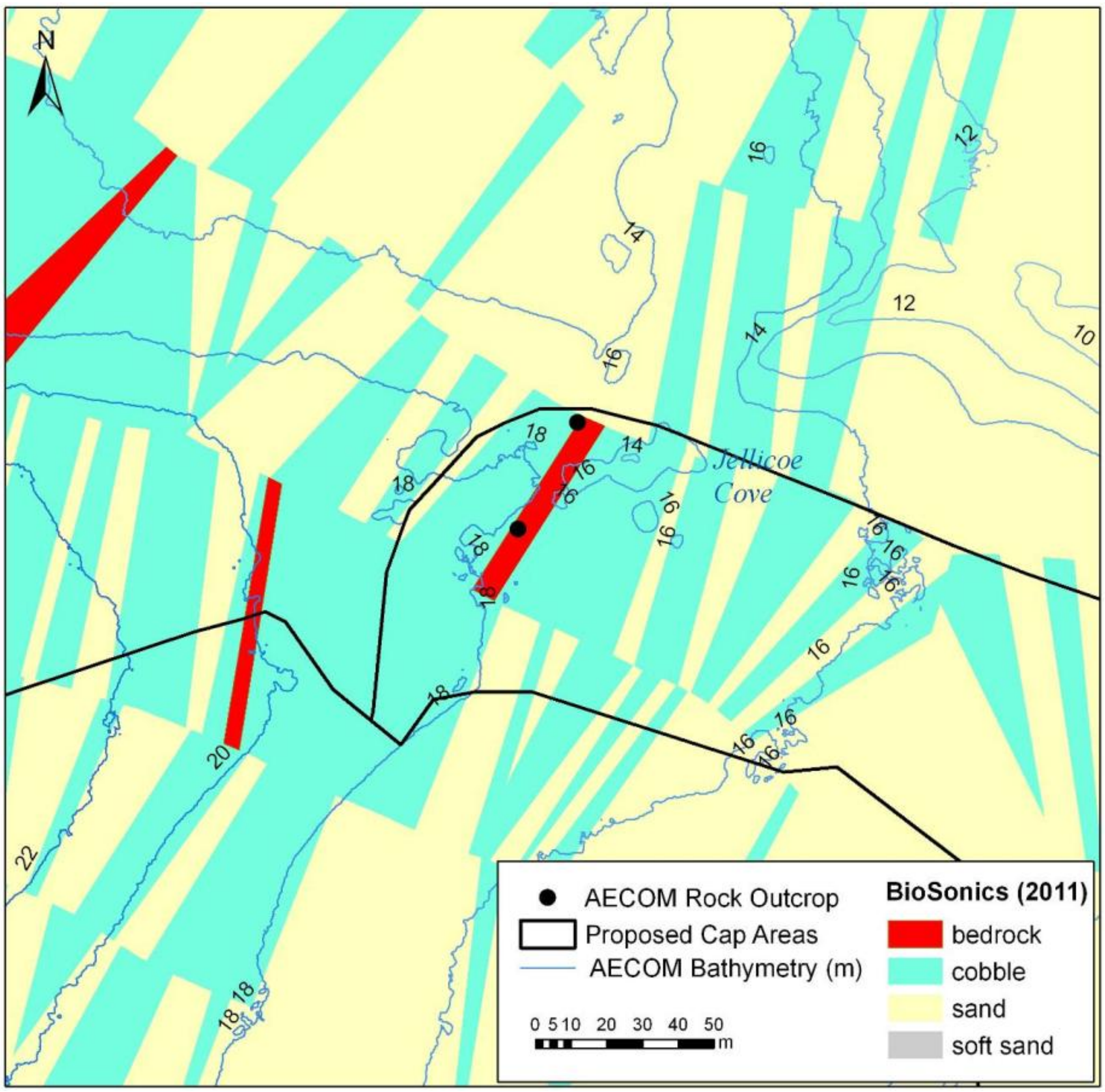


Figure 25. Location of rock outcrops identified in AECOM (2009a) 33% Design Build at locations 28 and 29 at the northern edge of the proposed cap.

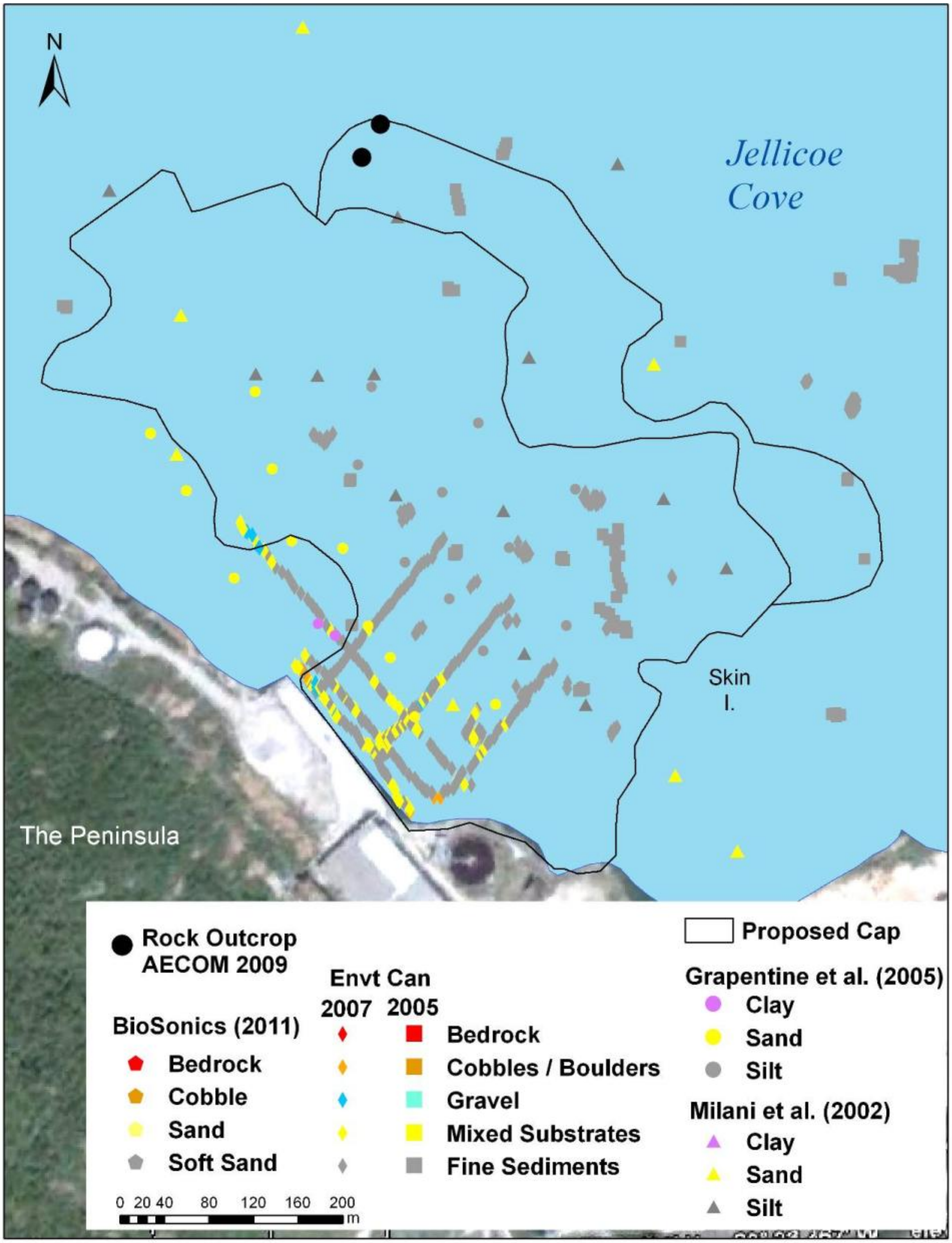


Figure 26. Detail of substrate verification points for proposed cap area in Jellicoe Cove based on underwater video review and sediment grabs.

3.1.2.2 Peninsula Harbour

Most of the substrate sampling in the Peninsula Harbour AOC has concentrated on the contaminated sediments in Jellicoe Harbour, and apart from the 2010 BioSonics survey there has been limited effort elsewhere. Appendix 2 shows representative video images from various locations in Peninsula Harbour. Of the 621 ha covered by BioSonics' hydroacoustic survey, approximately 58% was classified as sand, 10% as soft sand, and 30% as cobble. Bedrock accounted for only 1.3% of the classified area, but the hydroacoustic survey could not be reliably conducted in water depths less than 1 m. Bedrock shorelines are common along the northern and northeastern portions of Peninsula Harbour, in Carden Cove (Figure 27a), and around the islands, so the proportion of bedrock is likely underestimated when shallow waters are also considered. Portions of the shoreline adjacent to the mill have been armoured with large boulder / rubble material, while bedrock occurs along the west and east heads of the Jellicoe Cove (ENVIRON 2008a, b).

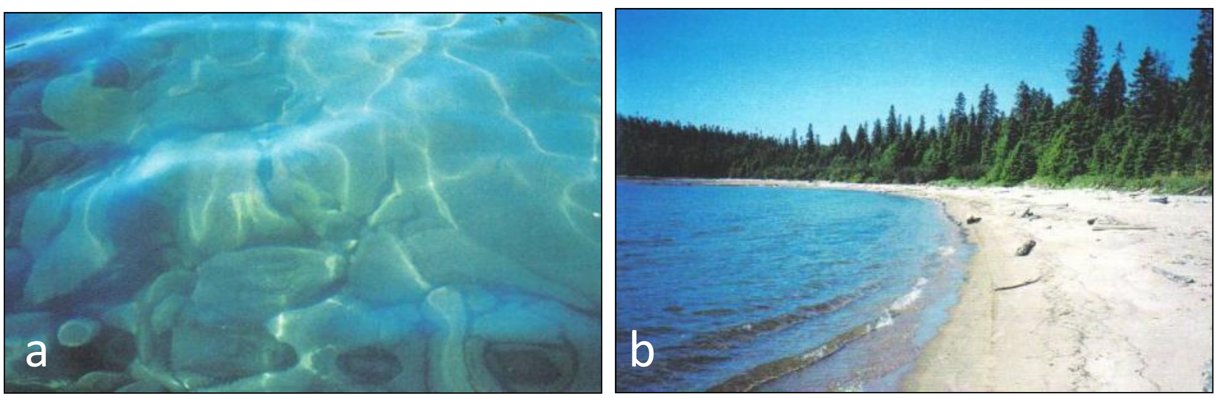


Figure 27. Bedrock and cobble in shallow water on west side of Carden Cove and sand beach at the head of the cove (Beak 2001).

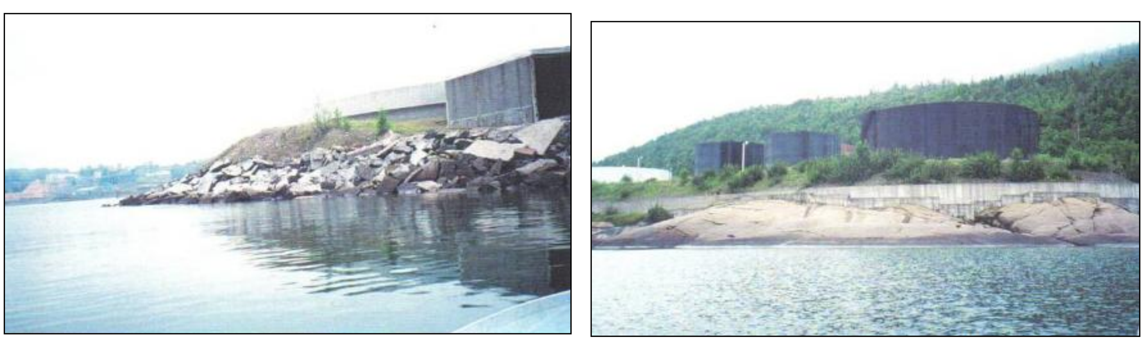


Figure 28. Heavily modified, armoured shoreline adjacent to the proposed cap area and natural bedrock shoreline further west in Jellicoe Cove Beak (2001)

Video interpretation suggests that boulder and cobble are largely restricted to shorelines and a few shoals, and that the proportion of cobble is overestimated. What limited video and ponar grab data there are, indicates that soft sediments is present in many of the deepwater areas that were classified as cobble (Figure 29, Figure 30). It may be possible that there is boulder or cobble, or hardpan clay underlying the silt that could not be identified from the video but was identified by acoustically. In most video, the metal post attached to the submersible camera in Environment Canada videos can be shown penetrating soft sediment. In some cases, it appears to stop fairly abruptly after penetrating a short distance into the sediment; it is not known if this is because the underlying substrate is firm or the camera cable became taut.

Carden Cove and Beatty Cove are the two other sheltered embayments in Peninsula Harbour that were used for log booming. Carden Cove is more protected, smaller (approximately 57 ha vs. 82 ha), and shallower, with most of the cove less than 5 m deep. More than half of Beatty Cove is deeper than 5 m, with a maximum over 20 m depending on how it is defined (Figure 2, Figure 31). Habitat mapping for Carden Cove was conducted by Beak (2001) using visual assessment in conjunction with fisheries assessment (Figure 32). Substrate in the cove was primarily fine sand with a band of clay running east-west across the middle of the bay (Beak 2000). A sandy beach if found at the head of the cove (Figure 27b). Patches of detritus are scattered in shallow water, and are presumably bark from past booming operations (see 3.3 Woody Debris). The very limited video and ponar grabs (Figure 26, Figure 40) conducted in Beatty Cove indicate that silty substrates predominate in deeper waters in the centre of the cove, with some logs present.

Figure 29. Silty sand in middle of Peninsula Harbour 280 m southeast of Blondin Island in 24 m of water classified as cobble in BioSonics (2011). Depression in sediment at arrow made from previous insertion of angle iron support.

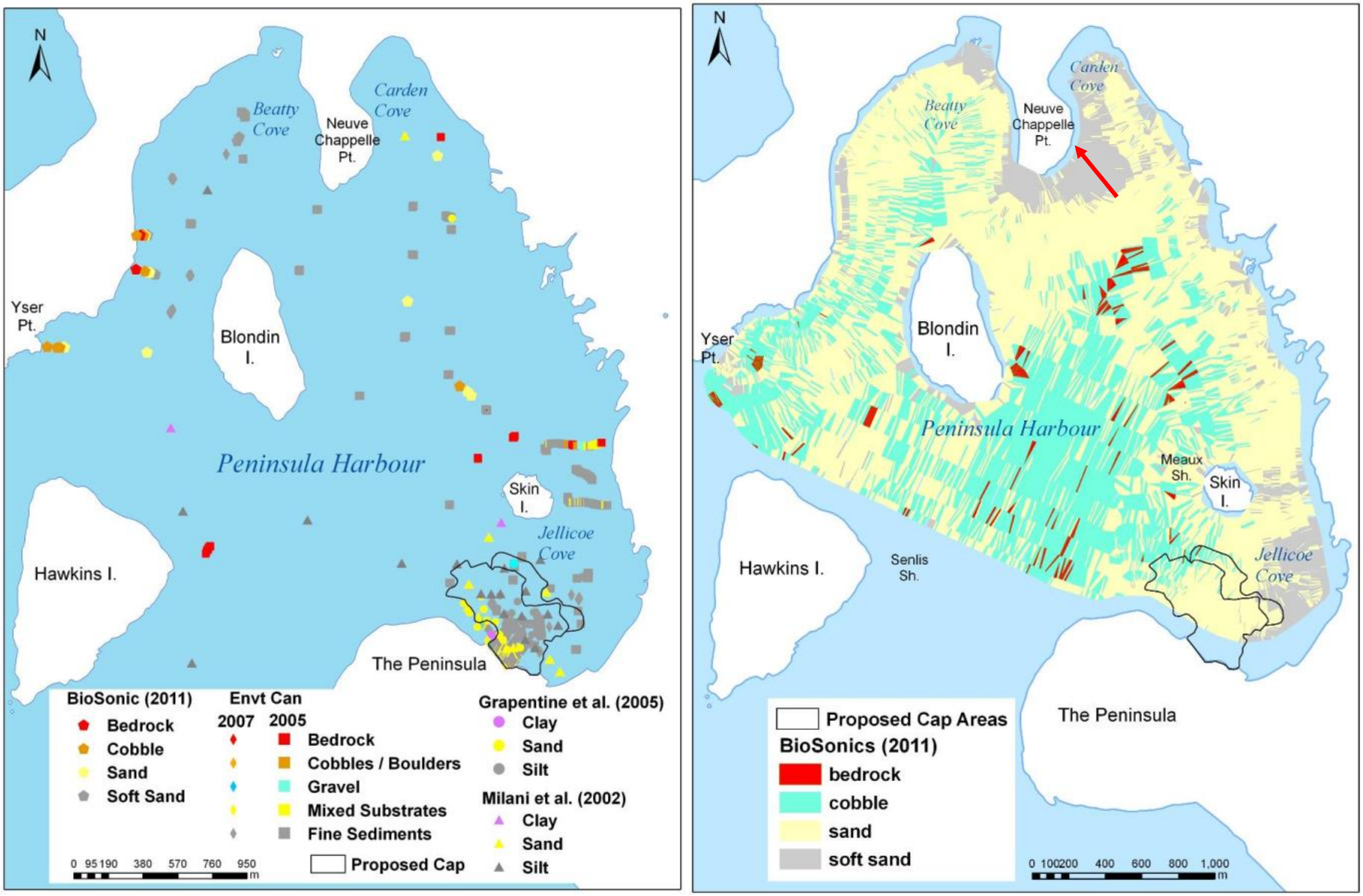


Figure 30. Substrate verification points in Peninsula Harbour based on underwater video review and sediment grabs (left) compared to substrate classification based on hydroacoustic survey (right). Arrow in Carden Cove of map on right indicates location of photo in Figure 27a.

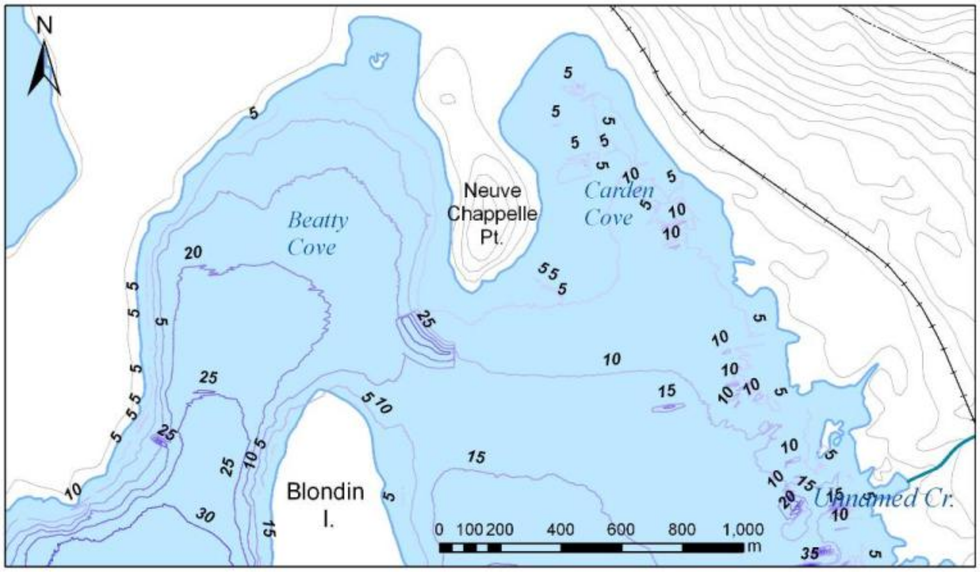


Figure 31. Bathymetry of Beatty and Carden coves based on data from BioSonics (2011) hydroacoustic survey.

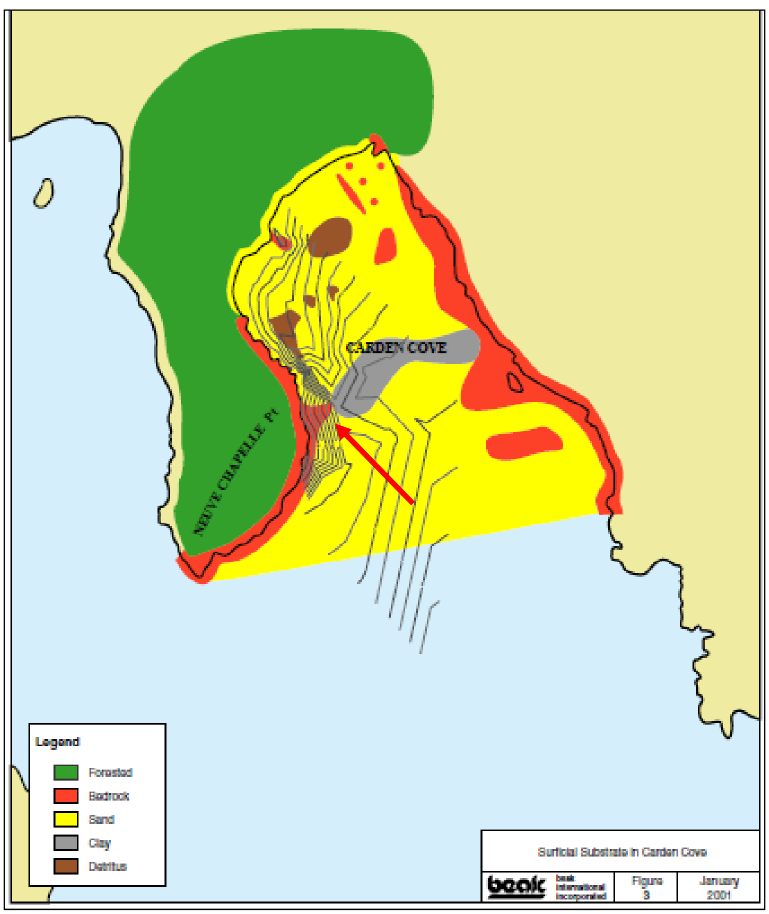


Figure 32. Substrate mapping of Carden Cove based on visual assessment (Beak 2001). Arrow indicates location of photo in Figure 27a.

3.2 Aquatic Vegetation

According to Beak (2001), aquatic macrophytes were fairly common in 2000; observed varieties included pondweed, waterweed (*Elodea* sp.) and stonewort (*Chara* spp.) Approximately 5 ha of aquatic macrophytes were mapped by Beak along the southeast shore of Jellicoe Cove in 2000 (Figure 13) of which approximately only 0.5 ha overlapped the proposed cap area. Underwater video transects in 2005 and 2007 showed a much more extensive distribution of aquatic macrophytes in Jellico Cove, including approximately 10 ha of the southern portion of the proposed cap (Figure 37). The areas where submerged macrophytes were found ranged from shallow water to approximately 12 m, with the greatest density in 4-10 m of water. Density ranged from sparse to very dense beds up to 30-50 cm in height (Figure 33). Wave action may limit submergent growth in shallow water and light penetration ultimately limits macrophyte growth in deep water (it is dependent on water clarity).

Figure 33. Dense stonewort along southern edge of cap zone.

Stonewort or muskgrass (*Chara* spp.), actually a jointed, filamentous macroalgae that resembles vascular plants, was the most abundant species based on video interpretation. The *Chara globularis* Thuill. / *vulgaris* L. complex is one of the predominant macroalgae in Georgian

Bay and the North Channel, and another similar-looking charophyte, *Nitella flexilis* is found there as well (Sheath et al. 1988). *Nitella* is more common in soft waters associated with granitic bedrock and *Chara* are typically associated with harder waters (Wehr and Sheath 2003). It can be difficult to distinguish these species in the field and on the video, but both have similar value for benthic invertebrates and fish. Although less abundant, Canada smartweed (*Elodea canadensis*) and several species of pondweeds (*Potamogeton* spp.) could be also distinguished in the Environment Canada videos (Figure 34; Figure 35).

Aquatic macrophytes are not restricted to Jellicoe Cove, but their extent in Peninsula Harbour is poorly known due to limited sampling. According to Beak (2001), aquatic macrophytes are sparse in Carden Cove, although a few small patches of pondweed (*Potamogeton* spp.) occur near the middle of the bay (Beak 2001).

Figure 34. Sparse stonewort (left) and Canada waterweed (right).

Figure 35. Pondweeds (*Potamogeton* spp.) at mouth of Beatty Cove (left) and Jellicoe Cove (right).

Figure 36. Pondweed (*Potamogeton* spp.) in proposed cap area.

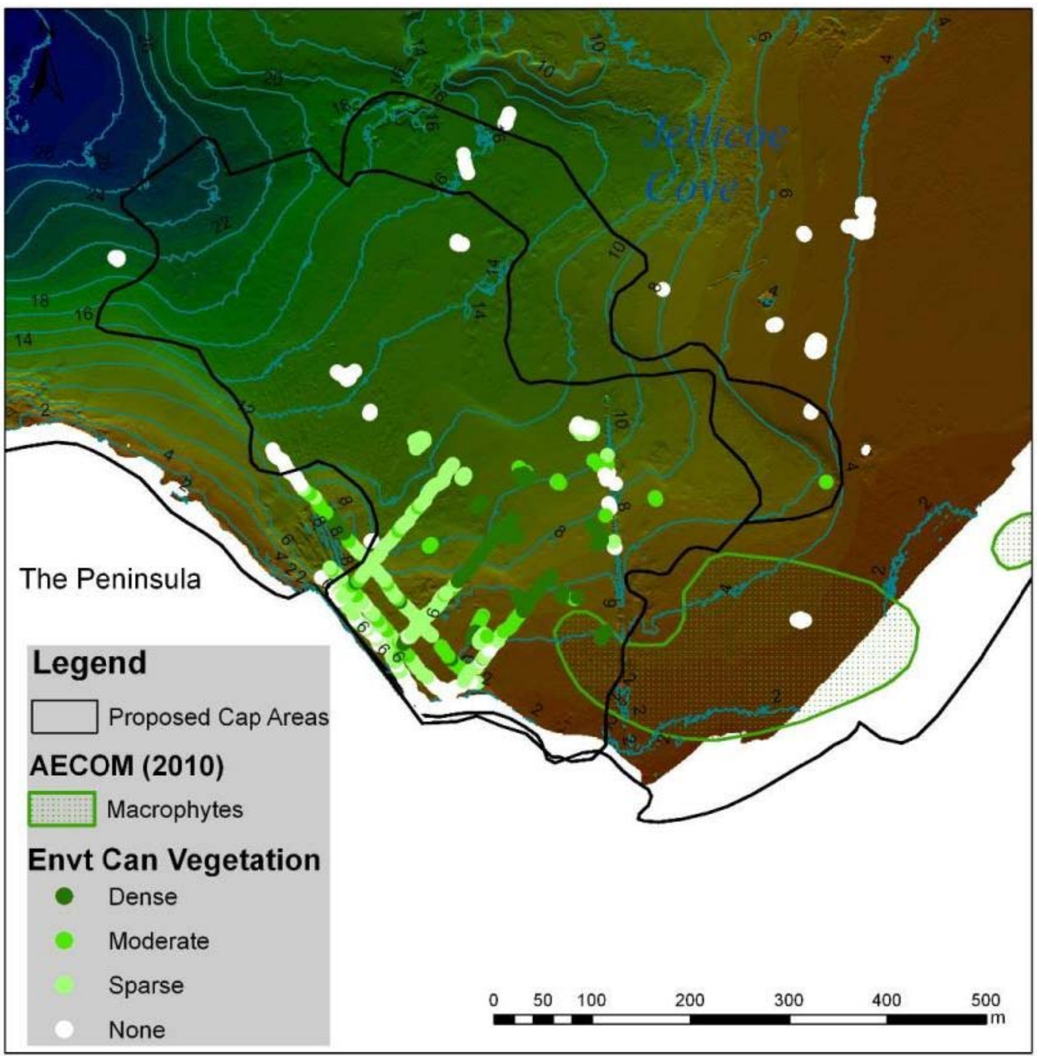


Figure 37. Distribution of submerged aquatic vegetation (macrophytes) in proposed cap area based on interpreted Environment Canada video (2005 & 2007) in relation to polygon in AECOM (2010; reproduced from Beak 2001) and bathymetry (AECOM 2009a contours; BioSonics 2010 hillshade).

3.3 Woody debris

Peninsula Harbour was used historically for building log rafts to be transported to Wisconsin (Boultbee 1967) and Buchanan Forest Products Ltd build rafts of sawlogs as recently as 1987 and 1988 (Jardine and Simpson 1990). Jellicoe, Carden, and Beatty coves were also used for log storage for over 40 years, leading to an accumulation of bark and fine woody debris that impairs water quality and aquatic biota (Peninsula Harbour RAP Team 1991). Logs were boomed in Peninsula Harbour until 1983 (Peninsula Harbour RAP Team 1991), and approximately 25,000 m^3 in Peninsula Harbour contain at least 20% bark (OMOE video commentary).

Based on video interpretation, bark and logs are abundant in Jellicoe Cove, including the proposed cap area (Figure 40). Densest concentrations observed on video were east of Skin Island, although video coverage is very unevenly distributed. Most of the logs observed in videos were relatively near the shoreline in water less than 15 m deep, reflecting booming areas). Some logs are found in much deeper water e.g., 28 m west of Blondin Island, which likely reflect logs lost from booms in transit. Single, isolated logs area present in some areas of Peninsula Harbour, but numerous logs were often observed in close proximity on video Figure 38).

Figure 38. Coarse woody debris in north end of Beatty Cove (left) and in proposed cap (right).

Most of the logs lacking bark (Figure 38). Dense accumulations of bark are found near many of the boom logs (Figure 39), and often accumulates in shallow water in wave-scalloped grooves between ridges in sand flats off the boat launch (OMOE video). Bark debris has been misinterpreted as gravel for the Environment Canada video shapefile due to its dark colour.

Logs can provide structure that may promote establishment of aquatic vegetation and cover for benthic invertebrates and fish. However, dense accumulations of logs were not natural habitat feature in Peninsula Harbour since it lacks large tributaries that would provide a source for woody debris swept downriver.

Organic material concentration in Jellicoe Cove ranges from 1-11% and is derived from woody debris and bark (AECOM 2009b). Wood, sawdust, and fibrous material with a strong hydrocarbon odour has also been observed in sediment grabs from the cove, often overlain by a thin layer of fine sediment (AECOM 2009b). Dense bark accumulations were identified as an impairment of fish habitat in Jellicoe Cove and Peninsula Harbour (RAP 1991) since their decomposition can lead to release of organic leachates, reduced oxygen availability due to microbial decomposition of organic material, and the production of toxic compounds by microbial decomposition of wood under anaerobic conditions. Milani and Grapentine (2005) found benthic invertebrate communities in Jellicoe Cove are “different” than reference, with a trend towards greater diversity and abundance of taxa in the cove, indicative of enrichment likely due to the high organic matter present in the sediment.

Figure 39. Bark (misidentified as gravel in Environment Canada shapefile) overlying sand east of Skin Island.

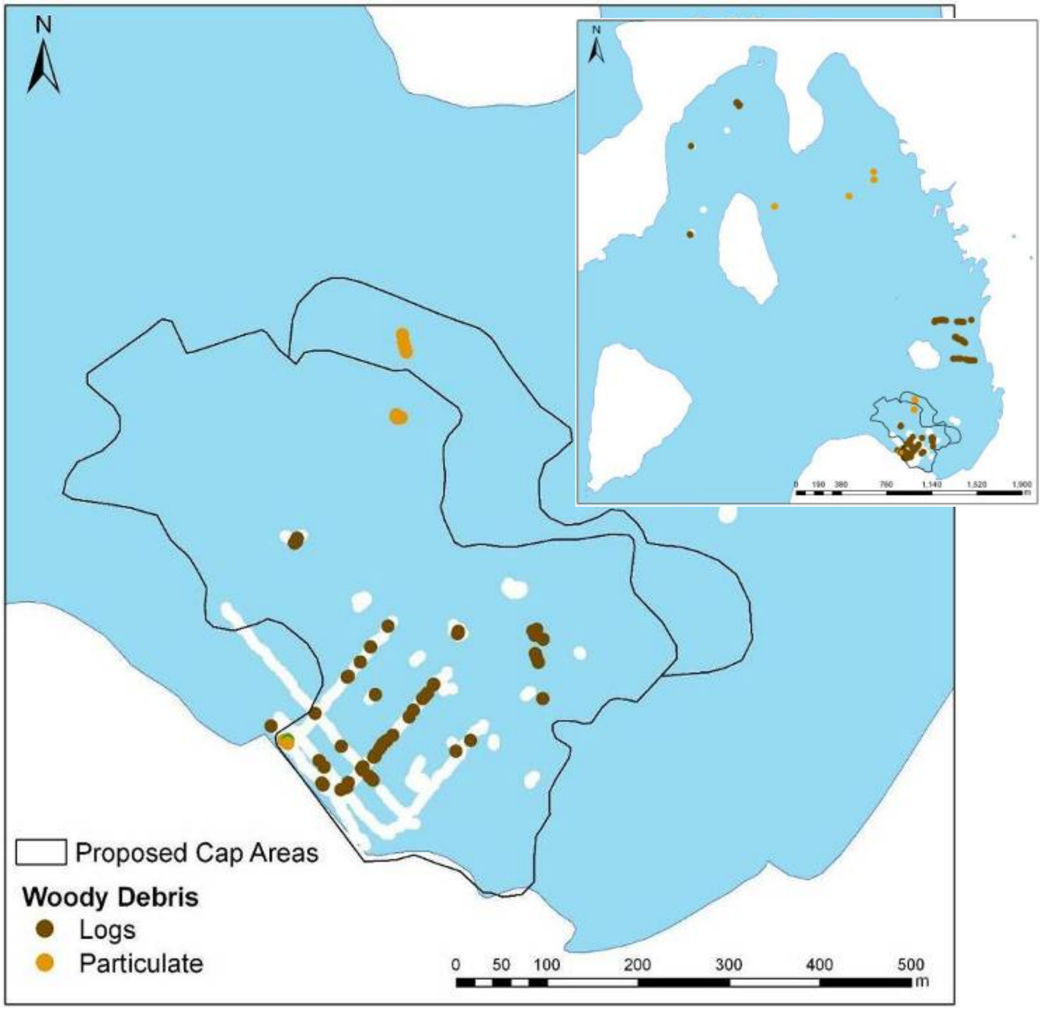


Figure 40. Woody debris identified by Environment Canada (2005, 2007) video interpretation for Jellicoe Cove and Peninsula Harbour as a whole (inset). White dots represent surveyed areas with no woody debris.

3.4 Other Environmental Parameters

3.4.1 Water Depth / Slope

Water depth in the proposed cap area increases fairly gradually from towards the northwest, reaching a maximum depth of approximately 25 m at the northwest limit of the proposed cap (Figure 41). Maximum depth in the cap area of 25 m was found in the BioSonics (2011) hydroacoustic survey as well. According to AECOM (2009b p. 26) however, the water depth in the area of the proposed cap ranges from 3-18 m; the reason for this discrepancy is unknown. Approximately 40% of the 25 ha proposed cap is in 10-16 m of water (

Table 2). Median depth in Jellicoe Cove is 12.5 m (Environmental Hydraulics Group 1993) and maximum observed depth is 28 m (Beak 2001). A summary of water depths by substrate type and vegetation is presented in Table 3. The approximate areas should be considered estimates only due to the incomplete nature of the vegetation and substrate data for the proposed cap area, and interpolation of depth classes, particular in shallow water less than 2 m.

There is a steep slope along the shore on the northern side of The Peninsula, particularly adjacent to the wharf, but much more gradual at the head of Jellico Cove. Water depths in the area of Peninsula Harbour that was surveyed by BioSonics (2010) averaged 14.3 m with a maximum of 49 m. Water depths in the protected coves were typically less than 10 m (BioSonics 2010).

The northern and eastern shorelines are very irregular with outcrops protruding into the harbour. There are three named shoals in the harbour: Meaux Shoal west of Skin Island, Senlis Shoal east of Hawkins Island and Manitoba Shoal on the outer edge of Peninsula Harbour exposed to the main Lake south of Ypres Point. All three shoals are relatively small in areal extent, approximately 1-2 ha. The total length of the Jellicoe Cove shoreline, including Skin Island, is approximately 3.3 km.

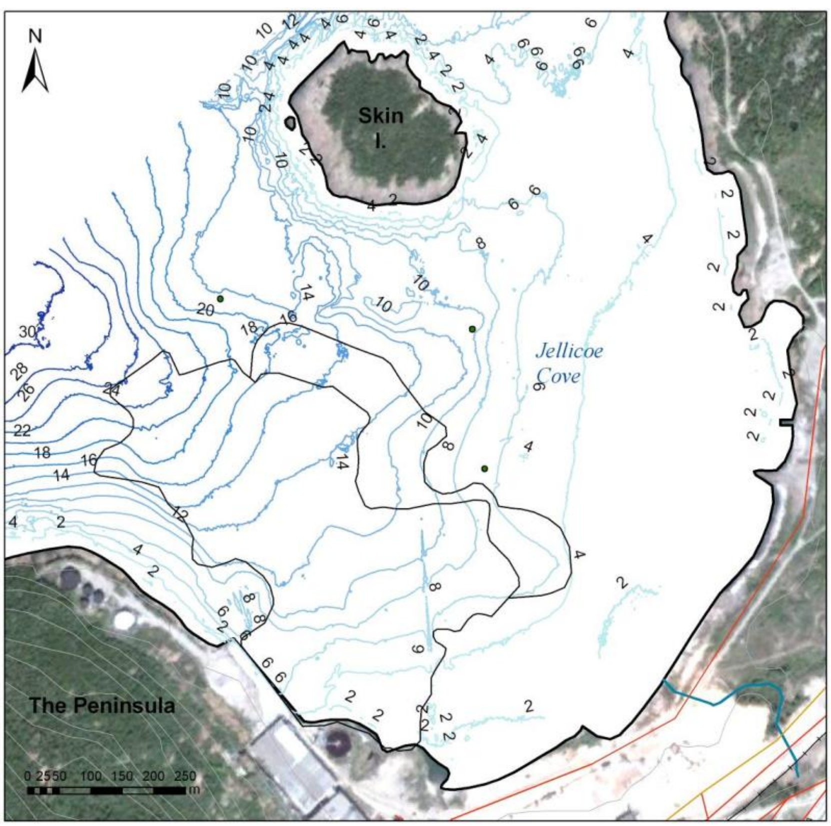


Figure 41. Proposed cap areas (black outline) overlain with bathymetry (m) (AECOM 2009a).

Table 2. Area of proposed cap within 2 m depth classes based on bathymetry (AECOM 2009a)

Depth (m)	Area (m^2)			% of Total Cap
	Main Cap	Additional Cap	Total Cap	
0-2	3,643	0	3,643	1.4
2-4	13,820	0	13,820	5.4
4-6	18,280	6,400	24,679	9.7
6-8	26,946	8,207	35,153	13.8
8-10	16,736	1,672	18,408	7.2
10-12	22,193	7,690	29,882	11.7
12-14	29,007	9,633	38,640	15.1
14-16	26,110	8,726	34,836	13.6
16-18	15,104	8,170	23,274	9.1
18-20	11,796	1,920	13,716	5.4
20-22	8,619	0	8,619	3.4
22-24	5,692	0	5,692	2.2
24-26	4,912	0	4,912	1.9
26-28		38	38	0.0
Total	**202,858**	**52,455**	**255,314**	**100.0**

Table 3. Approximate area (m^2) in various depth classes by main substrate type and submergent vegetation presence within the proposed cap area in Jellico Cove.

Depth (m)	Substrate	Vegetation	Area (m^2)
0-1	cobble	vegetated	41
0-1	gravel	vegetated	29
0-1	sand	vegetated	1,112
1-2	gravel	vegetated	37
1-2	sand	vegetated	2,424
2-5	gravel	vegetated	338
2-5	sand	vegetated	17,942
2-5	silt	bare	2,987
2-5	silt	vegetated	4,989
5-10	gravel	vegetated	1,454
5-10	sand	bare	7
5-10	sand	vegetated	12,282
5-10	silt	bare	14,703
5-10	silt	vegetated	37,358
10+	sand	bare	24,687
10+	sand	vegetated	2,324
10+	silt	bare	114,826
10+	silt	vegetated	18,646

3.4.2 Exposure / Fetch / Currents / Clarity

Peninsula Harbour is protected from the open waters of Lake Superior by The Peninsula, Hawkins Island and Ypres Point. Winds and waves from the southwest can pass unimpeded into Peninsula Harbour, but waves predominantly roll from the west and less frequently from the southwest, averaging 1.0-1.7 m during the open water season (Beak 2000). Jellicoe Cove is protected from the southeast by The Peninsula, so the predominant wave direction is from the west-northwest. There is only about 2 km of fetch from Yser Point to Jellicoe Cove, so wave height is lower, averaging 0.4 to 0.7 m (Beak 2000). Freeze-up in Peninsula Harbour generally occurs early in December, with ice break-up typically occurring in mid- to late-April, while Jellicoe Cove is reportedly ice-free during the winter (AECOM 2009). This well-protected location allows finer sediments to settle out in the deeper waters of Jellicoe Cove. Currents in the proposed capping areas average only 0.04 m/s in a west-northwest to east-southeast (Skafel 2006, 2007), which is about two orders of magnitude too low to suspend sediments in Jellico Cove (AECOM 2009; Biberhofer and Dunnet 2003).

3.4.3 Water Clarity and Quality

Secchi depth was at bottom in Carden Cove during 2000 fieldwork conducted by Beak, and over 6 m in Jellicoe Cove, indicating good water clarity and light penetration (Beak 2001). This permits aquatic macrophytes at greater water depth than is typical for more stained or turbid inland waterbodies.

A comprehensive review of water quality data for Jellicoe Cove and Peninsula Harbour was outside the scope of this study. Peninsula Harbour is oligotrophic, with dissolved oxygen ranging from approximately 10-14 mg/L, pH from 7.2 to 8.35, and conductivity 93-134 µS/cm (AECOM 2009). Water quality is Peninsula Harbour is considered relatively good, with infrequent impairment due to sediment re-suspension from storm events and propeller wash (Beak 2000). There some minor variability within the harbour associated with water depth and circulation patterns, but water quality does appear to be a limiting factor with respect to fish habitat. There are no major thermal inputs to Peninsula Harbour, and water temperatures are suitable for supporting a coldwater fish community.

3.5 Tributaries

Limited data are available for regarding habitat in the Lake Superior tributaries that flow into Peninsula Harbour. Although they would not be directly affected by the proposed capping, Shack Creek provides spawning and nursery habitat for a number of fish species that use Jellicoe Cove. Larval fish such as longnose sucker and rainbow trout disperse from Shack Creek into Peninsula Harbour, including Jellicoe Cove. Shack Creek is a permanent stream over 5 km in length with a watershed of approximately 1000 ha that includes Shack Lake (14 ha) and several other smaller waterbodies. It has a bedrock dominated mouth with some cobble and sand (Figure 42). The unnamed creek approximately 600 m north along the eastern shore of Peninsula Harbour is approximately 1 km in length and has a much smaller watershed (approximately 1000 m). Although it did not have sufficient flow to electrofish in 2000, in some years it may provide fish habitat, at least during higher spring flows.

Figure 42. Mouth of Shack Creek looking southeast towards Jellicoe Cove.

4 Fish Habitat

The 1991 RAP report (Peninsula Harbour RAP Team 1991) states that the dynamics of fish populations in the AOC are impaired because "fish habitat has been reduced due mostly to the organic (wood debris) contamination of Jellicoe and Beatty Coves, which were lake trout spawning grounds prior to 1955 (Goodier)."

The very sparse and imprecise information available for historical fish habitat prior to industrial development in Peninsula Harbour limits our ability to compare current fish habitat in Peninsula Harbour to historical use. In addition, the suite of fish species using Peninsula Harbour is different than in the past, due to changes in the Lake Superior fish community from reduced abundance of native species as a result of overharvest, habitat loss, and the introduction of non-native fish such as sea lamprey, rainbow trout, rainbow smelt, threespine stickleback, alewife, and salmon species. Lake trout is given particular emphasis because there were historical spawning records for the area, it is a top predator and the focus of a binational restoration plan (Hansen 1996), and has significant socio-economic value.

4.1 Lake Trout

4.1.1 Beatty Cove Spawning Habitat

Historical (pre-1955) lake trout spawning habitat along the north shore of Peninsula Harbour west of Beatty Cove (Figure 4) that were mapped as "significant" by Goodier(1981) appears to be relatively unimpacted. The limited video available for that area indicates that clean cobble exists out to a depth of at least 14 m along portions of this shoreline (Appendix 2, photos 56, 60), which is consistent with preferred spawning habitat for lake trout (Table 4). The exposed aspect and deeper waters adjacent suggests there is more wave energy here compared to Jellicoe Cove, which would help keep the cobble freer of silt and fine sediments that would reduce suitability as spawning substrate for lake trout and other fish. Whether there are lake trout actually using this habitat is unknown as there has been no assessment in this area. In deeper waters of Beatty Cove, the limited video data available and single ponar grab indicates that silty sediments predominate in deeper water, and at least some woody debris is present (Figure 38, Figure 40). Therefore, although there may some impairment of fish habitat in the deeper waters or farther back in Beatty Cove from logs or bark of past booming activities, impacts to potential lake trout spawning habitat along the shoreline may be minor. Habitat surveys along the western shoreline of Beatty Cove are lacking however.

Table 4. Habitat requirements for fish species confirmed from Peninsula Harbour (taxonomic order).[1]

Common Name	General / Foraging	Spawning	Nursery
Alewife	cool, open, waters (16-28 m) near thermocline to a depth of 50 m (summer) or 90 m (winter); near thermal plant outfall in winter	shallow water of nearshore areas over sand and gravel	same as nursery for summer before moving to deeper water
Emerald Shiner	pools and runs of medium to large rivers with sand or gravel substrates and cool, clear open waters of lakes; preferred water temperature range 9-23°C; often near river mouths	open water over gravel shoals or over sand in streams	0-5 m with moderate affinity for submergents and emergents on a variety of substrates but also captured in open water
Lake Chub	open waters of lakes, lake margins and gravel-bottomed pools and runs of creeks and rivers; moves to deeper, cold, pelagic waters in the summer	tributary streams over sand, gravel, or rocks	usually over gravel, sand or rocks in 0-2 m
Longnose Dace	cobble, boulder or gravel riffles of clean, cool, swiftly-flowing creeks and small to medium rivers, and occasionally along rocky shores of lakes; preferred water temperature range 13-21°C	riffles over gravel	initially pelagic then benthic in 0-2 m water over rubble to silt with low affinity for submergents
Spottail Shiner	usually in open, clear cold or cool waters of large lakes and rivers; less frequently in tributary streams with slow to moderate current and sand or gravel substrates; preferred water temperature range 13-22°C	sandy shoals or lower reaches of tributaries	in shallow to deep (>5 m) with high affinity for submergents over gravel, sand, and silt
Longnose Sucker	clear, cold, deep water (up to 55 m) of lakes and tributary streams; occasionally brackish water; preferred water temperature range 8-17°C	swift-flowing tributaries	young move downstream to lakes in early summer;
White Sucker	pools and riffles of creeks and rivers, warm shallow lakes and embayments of larger lakes usually at depths of 6-9 m; preferred water temperature range 22-26°C	swift-flowing tributaries with gravel or cobble or windswept rocky lakeshores	variety of habitats, especially 0-5 m with submergents on sand and silt, but sometimes coarse substrates
Northern Pike	clear, cool to warm, weedy bays of lakes and slow, meandering, heavily vegetated rivers; preferred water temperature range 17-21°C	shallow, heavily vegetated floodplains or shallows of lakes and rivers	warm, shallow, heavily vegetated bays or rivers with slow current
Rainbow Smelt	cool, clear, mid-waters (14-64 m) of lakes and medium to large rivers; preferred water temperature range 7-16°C	tributaries	upon hatching , larvae drift downstream to lake; often over sand beaches at night
Brook Trout	cold, clear, well-oxygenated streams, rivers, ponds and lakes with maximum water temperature less than 22°C; preferred water temperature range 13-17°C	clean gravel and cobble in tributary streams	tributary streams and nearshore areas, particularly near tributary mouths in 0-5 m with rubble, gravel or sand, and sometimes finer sediments
Chinook Salmon	mid-waters (15-60 m) in or below the thermocline; preferred water temperature range 12-16°C	clean gravel and cobble in tributary streams	tributary streams and nearshore areas, particularly near tributary mouths in 0-5 m with gravel or sand
Cisco (Lake Herring)	open, mid-waters (13-53 m) of lakes and large rivers, below the thermocline; preferred water temperature range 7-10°C	variable; gravel and rocky bottoms, sometimes vegetation, up to 64 m depth in the Great Lakes	0-2 m in spring moving to deeper water in fall, usually over sand or coarser substrates, and with low affinity for submergents.
Coho Salmon	mid-waters (16-60 m); preferred water temperature range 11-17°C	clean gravel and cobble in tributary streams	tributary streams and nearshore areas, particularly near tributary mouths in 0-2 m in spring moving to deeper water in fall; use logs jams for cover, usually on boulder or sandy substrates

Common Name	General / Foraging	Spawning	Nursery
Lake Trout	cold deeper waters (12-18m) of lakes, below the thermocline in summer; preferred water temperature range 9-13°C	clean cobble or rocky areas, often at depths of 10 m or more	cool, open and inshore waters with rocky shorelines
Lake Whitefish	cool waters (18-37 m) of lakes and large rivers, below the thermocline; preferred water temperature range 8-14°C	usually over gravel, cobble or rocks, bottom, typically in less than 8 m of water or in tributary streams or rocky shorelines	over rubble, gravel and sand in 0-2 m of water in spring/summer and moving to deeper waters in fall
Round Whitefish	shallow waters (<37 m) of deep lakes and clear streams; preferred water temperature 17.5°C	over gravel in the shallow water of lakes and streams	cool, open and inshore waters over gravel and sand; in 1-5 m in spring moving to deeper waters as they mature but also caught at surface over deep water
Pink Salmon	mid-waters (6-36 m); preferred water temperature range 13-17°C	clean gravel and cobble in tributary streams	tributary streams and nearshore areas, particularly near tributary mouths
Rainbow Trout	mid-waters of lakes; creeks and rivers with moderate flow, gravelly bottoms and riffle-pool habitat; preferred water temperature range 12-18°C	clean gravel and cobble in tributary streams	tributary streams and nearshore areas, particularly near tributary mouths
Burbot	moderate to deep waters (to 90 m) of lakes, large cool rivers and streams, often under rocks, among roots or in holes in the banks; preferred water temperature range 7-18°C	shallow bays over sand or on gravel shoals	over rubble, gravel and sand in 0-5 m water in spring moving to deeper waters in fall
Sticklebacks	shallow vegetated nearshore of lakes, ponds, pools of sluggish streams, and marine/estuarine environments; preferred water temperature range 9-16°C	nest made out of vegetation	over rubble, gravel and sand in 0-2 m water in spring moving to deeper waters in fall; moderate affinity for submergents
Threespine Stickleback	shallow vegetated areas of creeks and rivers, protected bays of lakes with mud or sand bottom, and coastal marine/estuarine environments; preferred water temperature range 9-12°C; can be pelagic	nest made out of vegetation	over gravel in 0-2 m water in spring moving to deeper waters in fall
Mottled Sculpin	cobble and gravel riffles of cool creeks, small rivers and rocky shores of lakes (<16 m deep); preferred water temperature range 13-18°C	underside of rocks or ledge	in range of water depths using rocks and logs for cover; on coarse substrates and less often on gravel or sand
Slimy Sculpin	gravelly, rocky riffles of cold streams and rocky substrates in deep (37-108 m), cooler waters of lakes; preferred water temperature range 9-14°C	underside of rocks or ledge	in range of water depths using rocks and logs for cover; on coarse substrates and less often on gravel or sand
Johnny Darter	sandy, silty, gravelly, sometimes rocky, pools of creeks and small to medium rivers, and sandy shores of lakes; preferred water temperature 22.8°C; reported to a depth of 42 m in the Great Lakes	rocky, shallow water	on gravel, sand, and silt in 1-5 m of water with a moderate affinity for submergents
Walleye	lakes (at depths up to 21 m), and pools, backwaters and runs of medium to large rivers; preferred water temperature range 19-23°C	clean gravel and cobble in tributary streams, shoals, or windswept shorelines	over gravel and sand in 0-5 m of water in spring moving to deeper water in fall, with a low affinity for submergents
Yellow Perch	lakes, ponds and pools of creeks and small to large rivers with moderate aquatic vegetation and clear water, usually at depths <9 m; preferred water temperature range 18-24°C	over vegetation or logs in lakes and streams, or sand and gravel if vegetation lacking.	over gravel, sand, and silt in 0-5 m of water in spring moving to deeper water in fall, with a moderate affinity for submergents

[1] based on Armstrong et al. (1996), Eakins (2011), Hartviksen and Momot (1987), Holm et al. (2009); Hubbs et al. (2004), Lane et al. (1996); Marsden et al. (1995); Lane et al. (1996a,b,c), Scott and Crossman (1998), Smith (2010), Stewart and Watkinson (2004), and references therein.

4.1.2 Jellicoe Cove Spawning Habitat

If historical reports are accurate, former lake trout spawning habitat in Jellicoe Cove mapped by Goodier (1981) are impaired. Unfortunately, the long history of shoreline and nearshore modification for industrial purposes obscures the historical condition of this area. The bedrock and rocky shoreline farther west in Jellicoe Cove (Figure 28) suggest that the shoreline and nearshore area adjacent to the proposed cap was originally rocky, perhaps grading to cobble, gravel, and sand substrates towards the more protected head of Jellicoe Cove where deposition would be expected to occur. Any natural spawning habitat has been eradicated where the wharf is now located, and coarse rip rap covers the remaining shoreline in the vicinity of the proposed cap and on either side of the wharf (Figure 28).

Video evidence indicates there are only small pockets of natural cobble or gravel remaining in shallow water along edge of the proposed cap, together with some rip rap (Figure 24). Consequently, there appears to be very little suitable potential cobble/gravel spawning habitat for lake trout in the nearshore cap area, apparently less than 1000-2000 m^2 , which is represents less than 1% of the proposed cap area (approximately 25 ha). Some may exist further west in Jellicoe Cove along more natural shoreline but there was no underwater video or sampling data, or fisheries assessment available further west, nor were any mapped there by Goodier (1981). A “debris/irregular area” polygon was mapped by AECOM along the shoreline west of the wharf (Figure 17) but the basis for this description is unclear.

Apart from the immediate nearshore zone mentioned above, the remainder of the proposed cap area and the adjacent areas of Jellicoe cover that were mapped as historic lake trout spawning grounds are predominantly silts, sands or a mixture. The area mapped as cobble along the southern portion of the cap by Beak/AECOM (Figure 13, Figure 14) appears to be erroneous. Based on the reviewed evidence, the proposed cap area is therefore not suitable spawning habitat for lake trout based on substrate type and the abundant submerged aquatic vegetation. Coring of subsurface sediments within the proposed cap and low sedimentation rates (1-2 mm annually) measured for Jellicoe Cove (Biberhofer and Dunnett 2003; AECOM 2009a) do not indicate that there is cobble that has been buried by fine surficial sediments or woody debris, either naturally or from anthropogenic activities. This suggests that if lake trout did spawn in Jellico Cove, they either did shoreline (potentially cobble) that is now covered by riprap or the wharf. Although less likely, they may have spawned over coarser sands and gravels in the shallower waters of the cove if there was enough wave energy to prevent deposition of silts and finer sediments that would otherwise reduce the suitability of the substrate for lake trout spawning (silty sediments can suffocate lake trout eggs).

4.1.3 Other Lake Trout Habitat

Video reviews confirm there is clean cobble in suitable water depth along Yser Point (as mapped by Goodier 1981) that is potentially suitable lake trout spawning habitat. There may be potentially suitable habitat along the rocky shoreline on windswept mainland, islands, and shoals as well, although data are lacking.

Jellicoe Cove and other areas of Peninsula Harbour provide foraging habitat for juvenile and adult lake trout. Five adult lake trout were gill-netted in the deep (>14 m), unvegetated area of the proposed cap by Beak (J1 & J4, Figure 8). The proposed cap area may provide nursery habitat for YOY lake trout, although none were caught in the limited fisheries assessments conducted to date. YOY lake trout reside in shallow water for several weeks after emergence and gradually move to deeper water as the season progresses (Bronte et al. 1995; Peck 1981). For the first few years, Lake Superior lake trout typically feed on invertebrates such as *Mysis* that are found over sandy substrates in deep water (Anderson and Smith 1971; Carpenter et al. 1974). Lake trout YOY are not typically found in heavily vegetated habitat however, so the 10 ha vegetated portion of the cap may not be very suitable nursery habitat particularly due to predation risk from large pike.

Local anglers have noted appreciable numbers of naturally-occurring lake trout in addition to stocked fish (in 1999 and 2000, lake trout were stocked in Jellicoe Cove at the mill dock), indicating successful natural recruitment outside Peninsula Harbour occurs (Peninsula Harbour RAP Team 1999). Angling success in nearshore areas suggests the presence of suitable foraging habitat for lake trout within Peninsula Harbour (Beak 2000).

4.2 Other Species

4.2.1 Spawning Habitat

The proposed cap area and Jellicoe Cove may have provided spawning habitat for some species based on known habitat preferences for fish species reported for Peninsula Harbour, and likely continues to do so. The presence of fish eggs on underwater videos from the proposed cap confirms that some spawning does occur in or near the cap. However, the significance of a few eggs on the video is unclear for a number of reasons including:

- It is unknown if the eggs were deposited in situ or were swept in from outside the proposed cap area. Typically, lake trout spawn on cobble and the eggs settle into the interstitial spaces; in contrast, yellow perch eggs are adhesive to vegetation. It is unlike the eggs were either of these two species.
- It is not known if the eggs are viable or if they hatched. They appear fairly translucent in the video and dead eggs are usually more opaque.

- The species of fish cannot be determined from the images of the egg on the video, nor from the YOY observed on the video (potentially the same species).
- Only a few (<5) eggs were apparent on the video, yet a single fish can produce thousands or hundreds of thousands of eggs depending on the species. For example, a single yellow perch egg mass contains on average 23,000 eggs (Scott and Crossman 1998).

YOY perch were found by Beak (2001) approximately 400 m east of the proposed cap in the small embayment at the boat launch on the eastern shore (Figure 8). In small lakes, yellow perch typically spawn in shallow water near rooted vegetation or coarse woody debris, but also sometimes over sand or gravel (Scott and Crossman 1998). Their semi-buoyant gelatinous egg skeins undulate with water movement and adhere to submerged vegetation or, less commonly, the bottom. The stonewort, Canada waterweed, pondweeds and other aquatic vegetation in the proposed cap may be a suitable substrate, but spawning has not been confirmed there. Less is known about yellow perch spawning behaviour in the Great Lakes, but they spawn over cobble and mixed substrates along waveswept Lake Michigan shorelines where aquatic macrophytes and woody debris are absent (Robillard and Marsden 2001).

Sticklebacks also use vegetation for spawning and the areas of bare sand within the cap could potentially serve as spawning habitat for some species such as cyprinids.

The pockets of gravel, cobble and rip rap near the shoreline may be suitable spawning habitat for species that prefer coarser substrates such as sculpins, Johnny darter, round whitefish, lake whitefish, or lake herring. Lake herring spawning grounds mapped by Goodier (1982) are too vague to determine exact location in Peninsula Harbour, and is unknown if they spawned in Jellicoe Cove and/or the proposed cap area.

Although adult northern pike have been observed in Jellicoe Cove, no suitable spawning habitat appears to be present in Peninsula Harbour due to the lack of emergent marshes or tributary streams with suitable wetlands.

4.2.2 Nursery Habitat

The proposed cap area likely provides nursery habitat for both species that have spawned in Jellicoe Cove as well as YOY that have dispersed from spawning grounds elsewhere. Species that likely spawn in Shack Creek but whose YOY or juveniles have been found in nearshore waters of the proposed cap area include at least 5 species including: rainbow trout, coho salmon, pink salmon, white sucker, and longnose sucker. The cap area also provides nursery habitat for at least round whitefish, yellow perch, burbot, cisco, lake chub, mottled sculpin, and slimy sculpin, which likely spawned in the proposed cap or elsewhere in Jellicoe Cove or Peninsula Harbour.

Most of these species were found in shallow waters (<2 m deep) which is not surprising since the YOY of most fish species in the Great Lakes occur in water depths of 2 m or less (Lane et al. 1993). Most YOY were found only along some sections of shoreline in Peninsula Harbour, but this is likely a function of sampling effort, rather than actual distribution. Larval fish likely disperse along most of the Jellicoe Cove shoreline and into deeper water of the proposed cap (>98% of the cap is greater than 2 m deep; Table 2). Deeper waters of Jellicoe Cove, and the proposed cap area, provide nursery habitat with abundant vegetation and logs to provide cover. Most sampled areas of the shoreline had little or no aquatic macrophytes.

Nursery habitat for many of these species has also been confirmed in Carden Cove or elsewhere in Peninsula Harbour. Larval fish were observed immediately to the west of the proposed cap and west of Skin Island in relatively deep water with no macrophytes. The limited data available for Peninsula Harbour, suggests that aquatic macrophytes although present outside Jellicoe Cove, may be less abundant. The deep, clear waters of Lake Superior are oligotrophic, and shallow protected bays such as Peninsula Harbour are typically more productive and support greater development of aquatic macrophytes. These macrophytes provide cover for adult and young fish, as well as their invertebrate prey that feed on macrophytes and attached algae. No YOY northern pike were found during sampling in Peninsula Harbour, which is not surprising since no suitable spawning habitat for this species appears to be present. Adult fish likely moved in from adjacent areas of Lake Superior.

4.2.3 Forage / Cover Habitat

Jellicoe Cove and the proposed cap area provide cover and habitat for adult fish whose YOY and juveniles have used Jellicoe Cove such as round whitefish. Jellicoe Cove may also provide habitat for adult fish that spawned and spent early life stages elsewhere in Peninsula Harbour or Lake Superior, such as lake trout (discussed earlier) and northern pike. Adult alewives have also been caught in Jellicoe Cove, but no younger life stages. There is no suitable spawning habitat for Threatened lake sturgeon in Peninsula harbour (they typically spawn over coarse substrates in rapids of large rivers) and no juvenile sturgeon were caught during sampling. However, they are known to spawn in the Pic River and adult sturgeon have been recorded making long distance trips in Lake Superior so it is conceivable that adults could potentially forage in Peninsula Harbour and the proposed cap area, if only sporadically.

Jellicoe Cove could potentially provide good cover for adult fish of many species due to the abundant aquatic macrophytes and logs, at least in the eastern portion of the proposed cap. The limited data available suggests that suitable foraging and cover habitat is likely widespread Peninsula Harbour however. The proposed cap would cover only 25 ha, or about ¼ of Jellicoe

Cove and only 2.5% of Peninsula Harbour. Elsewhere in Jellico Cove and Peninsula Harbour, rocky areas, logs, and at least some submergents (systematic data are lacking) provide cover for foraging and overwintering fish.

In addition, the heavily contaminated sediments of the proposed cap area are not ideal foraging habitat for fish due to mercury and PCB contamination. The benthic invertebrate community in Jellicoe Cove and Peninsula Harbour are dominated by midge larvae (Chironomidae), oligochaete worms (Tubificidae and Naididae), fingernail clams (Sphaeriidae), isopods (Asellidae), and snails (Valvatidae), with other taxa such as amphipods and oligochaetes, comprising less than 10% (Milani et al. 2002). Benthic invertebrates (midges and amphipods) from Jellicoe Cove have significantly elevated concentrations of bioavailable mercury due to exposure to contaminated sediments (Grapentine *et al.* 2005). Existing mercury concentrations have the potential to negatively impact reproductive activities of sportfish and bottom fish throughout Peninsula Harbour and there is the potential for population level effects from mercury and PCB levels on longnose suckers, the most abundant large benthivore (Sommerfreund et al. 2005).

Similar effects could potentially impact long-lived lake sturgeon if they foraged regularly in the contaminated sediments of Jellicoe Cove. As a benthivore like longnose sucker, lake sturgeon are often exposed to high contaminant loads (COSEWIC 2006b), and exposed individuals can have lower retinoids compared to sturgeon in unimpaired systems (Ndayibagira et al. 1995). Elsewhere in the Great Lakes (e.g., Lake St. Clair), tissue levels of mercury and PCBs in lake sturgeon tissue have been enough to lead to fishery closures (Baldwin et al. 1978; Hart 1987). There is no evidence however that lake sturgeon use Peninsula Harbour despite their presence in the nearby Pic River.

4.2.4 Overwintering Habitat

Depending on the species, fish could use the proposed cap area and Jellicoe Cove in egg, larval, or adult stages. Seasonal movements are known for many species such as YOY coho salmon, Chinook salmon, rainbow trout, and lake trout which use waters less than 2 m deep in the spring but move into deeper water in the fall (Lane et al. 1996b). In Lake Michigan, yellow perch move into nearshore areas <15 m deep in the spring and early summer, but move deeper in the fall, presumably following warmer water (Schaefer 1977; Wells 1968). Conversely some adult salmonids e.g., lake trout and coho salmon, will avoid warmer shallow waters less than 5 m deep during summer months but will use these areas in the winter when the water is isothermal (Lane et al. 1996a).

4.3 Assessment of Significance of Fish Habitat

Expected degree of use for the proposed cap area for spawning, nursery, and adult fish species confirmed from Peninsula Harbour is presented in Table 5. Fish habitat use is broken down by water depth, substrate type, and presence of submerged aquatic vegetation (there are no emergents) to be consistent with classes used by Fisheries and Oceans Canada (DFO) Habitat Alteration Assessment Tool (HAAT). Shallow water classes (0-1 m and 1-2 m) were pooled due to the lack of detailed bathymetric data in very shallow water. This table also provides a breakdown of area (m^2) derived from GIS for each habitat combination (e.g., vegetated silt in 5-10 m of water) present within the proposed cap area. Since there are limited field data for the proposed cap area, expected habitat use was largely derived from habitat preferences derived from the literature (e.g., Lane et al. 1996a,b,c; Table 5) while taking into consideration habitat features assessed in the current review.

The most abundant fish species in Jellicoe Cove, based on the limited sampling to date, are longnose sucker and round whitefish. The proposed cap area provides no spawning habitat for longnose suckers, since they likely spawned in Shack Creek and less than 2% (3600 m^2) of the cap is shallow water (<2 m). However, the proposed cap does provide suitable habitat for adult longnose suckers, which prefer to forage over sand and silt, often in the presence of submergents and logs in waters greater than 2 m deep. Seven adult longnose suckers were gill-netted by Beak (2001) in the proposed cap area. Data are lacking (no sampling for YOY fish was done in the proposed cap area), but YOY longnose suckers could potentially forage in the cap as well. Round whitefish prefer to spawn rubble and gravel so the cap provides little or no spawning habitat due to the lack of coarse substrate, but it provides nursery and adult foraging habitat in deeper water over bare or partially vegetated sand or silt.

Yellow perch are typically strongly associated with vegetation for spawning, nursery, and adult stages and the proposed cap may provide habitat for all life stages of yellow perch. However, actual use of the proposed cap by yellow perch has not been confirmed; no adult yellow perch were gill-netted (1.5-5” mesh) in Jellicoe Cove and only 3 YOY were seined from the small bay (JS1) to the east of the proposed cap. The proposed cap potentially provides considerable habitat for other species that use soft sediments (sand or silt) in moderate to deep water, particularly those with an affinity for submergents (e.g., emerald shiner, spottail shiner, sticklebacks), although there are also abundant bare sediments preferred by lake whitefish or cisco.

The cap provides little spawning or nursery habitat for trout or salmon that prefer shallow water areas with coarse substrates (most spawn in Shack Creek), and vegetation in deeper waters likely reduces its suitability for adults as well due to predation risk from northern pike.

Table 5. Expected degree of use (L=low; M=moderate; H=high) for spawning (S), nursery (N), and adults (A) of the proposed cap area based on water depth, submerged aquatic vegetation (SAV) presence, and substrate for fish species confirmed from Peninsula Harbour.

Depth Class (m)	**0-2**			**2-5**				**5-10**					**10+**			
SAV	**Y**			**N**	**Y**			**N**		**Y**			**N**		**Y**	
Substrate	**boulder**	**gravel**	**sand**	**silt**	**gravel**	**sand**	**silt**	**sand**	**silt**	**gravel**	**sand**	**silt**	**sand**	**silt**	**sand**	**silt**
Area (m2)	**42**	**65**	**3,536**	**2,987**	**338**	**17,942**	**4,989**	**7**	**14,703**	**1,454**	**12,282**	**37,358**	**24,687**	**114,826**	**2,324**	**18,646**
	S N A	**S N A**	**S N A**	**S N A**	**S N A**	**S N A**	**S N A**	**S N A**	**S N A**	**S N A**	**S N A**	**S N A**	**S N A**	**S N A**	**S N A**	**S N A**
Alewife	M,M,L	M,M,M	M, M,M	H,H,M	M, M,M	M,M,M	M,M,L	H	M	M	M	L	H	M	M	L
Emerald Shiner	L,M	M	M,H	M	M	M,H	H	H,M	M	M	M,H	H	H,M	M	M,H	H
Lake Chub	L L	M,M,M	M,M		M					M						
Longnose Dace	L,L,L	M,L,M	L,M,M													
Spottail Shiner	L L	M,H,M	M,H,M	M,M	M,H,M	M,H,M	M,L	M,H	L,M	H,M	H,M	M,L	M,H	L,M	H,M	M,L
Longnose Sucker			H	H	M	H	H	H	H	M	H	H	M	M	H	H
White Sucker	L	M	M,M	M,L	M	M,M	L	H	L	M	M		H	L	M	
Northern Pike			M				H									
Rainbow Smelt		M	M		M	M		H		M	M		H		M	
Pink Salmon	L															
Coho Salmon	M,P	P	L,P	P		L		M,P	P		L		M,P	P	L	
Chinook Salmon	P	M,P	M,P	P	L	L		P	P				P	P		
Rainbow Trout		M	M	H,P	M	M	M	P	P							
Brook Trout	M,M	M,M	M,M	M,L	M,L	M,L	L,L	H	M	M	M	L				
Lake Trout	L,M	L,M	L,L	L,P	L,M	L		L,M,P	L,P	M	L		L,M,P	L,P	L	
Lake Whitefish	L,L	L,M	L,M		L,M	L,M		M,H,H		M,L	M,L		M,H,H		L,M,M	
Cisco	L,L,P	L,L,P	L, P	M P	M,L	M,L	L	H,L	M P	M,L	M	L	H,L,P	M P	M	L
Round Whitefish	M	M,M	M		M	M		H,H	H	M,L	M,M	M	H,H	H	M,M	M
Burbot	M	M	L	M	M	L	L	H	H	M	M	M	H	H	M	M
3-sp. Stickleback		M,M,M	H,H, H	H	M	H	H	M	M	M	H	H	M	M	H	H
Sticklebacks		M,H	H,H,H	H	H	H	H	M	M	H	H	H	M	M	H	H
Mottled Sculpin	M	M,M,H	M,M,H	H	H	H	M									
Slimy Sculpin	M L	M,M,M	L,M,M	L M	L,L,M	L,L,M	L L	L,M,H	L M	L,L,M	M	L	L,M,H	M	L,L,M	L
Johnny Darter	L	M, H,H	M, H,H	M,H	H,H	H,H	H,H	M	M	H	H	H	M	M	H	H
Walleye		M,H	M,H	M	M,H	M,H	M	M,H	M	M,H	M,H	M				
Yellow Perch	L L	H, H,M	H, H,M	M, M,H	H, H,M	H, H,H	M, H,H	M, H,M	L, H,M	H, H,M	H, H,H	M, H,H	M, M,M	L, M,M	H, H,H	M, H,H

In summary, the proposed cap area is probably most significant for adult longnose sucker and yellow perch (in all stages) due to its submergent cover. It may also be preferred by northern pike due to the cover and prey base, but this species can also forage in a wide variety of other habitats. The proposed cap has limited value for species preferring coarse substrates, and since open sandy/silty substrates in moderate to deep water are abundant elsewhere in Peninsula Harbour, the proposed cap is not significant for those species preferring this habitat type.

4.4 Data Gaps

Despite the attention paid to the Peninsula Harbour AOC of the past few decades and numerous studies that have been conducted, there still remain significant information gaps, particularly related to the fish community and fish use of the AOC in general, and Jellicoe Cove in particular. In part, this is due to a relative lack of targeted and systematic fisheries studies in the proposed cap area. In particular, the following data gaps are identified:

- There are limited data on the abundance of aquatic macrophytes elsewhere in Peninsula Harbour, which would help determine the significance of the submergents within the proposed cap area.
- The limited video available indicated that the historical lake trout spawning habitat along Ypres Point and west of Beatty Cove is in relatively good condition. Targeted surveys could confirm if the habitat is indeed suitable and if it is currently used by spawning lake trout, lake whitefish, cisco, or other species.
- The status of fish habitat in Beatty Cove, particularly with respect to woody debris and the need/potential for rehabilitation, is poorly known.
- There is little information available on the status of fish habitat in shallow (<2 m) nearshore areas adjacent to the proposed cap area, although sampling (beach seining/electrofishing) has demonstrated that areas are used as nursery habitat. Habitat and additional fish community surveys would provide information that could be used to identify appropriate habitat remediation for these potentially important areas.
- There are limited data on actual fish use in the proposed area, particularly for spawning and nursery habitat. Most of the existing information was derived from limited gill-netting of adults. Additional surveys could confirm use and help assess significance.

Additional data from other studies would be beneficial, particularly for helping guide any additional remediation efforts or potential fish habitat compensation. However, the existing habitat and fisheries information, combined with known fish habitat preferences derived from other studies, is sufficient identify potential impacts of the proposed capping, and recommend compensation if required.

5 Potential Impacts of Proposed Capping

Discussion of impacts will be restricted to potential habitat-related impacts on fish habitat rather than direct impacts on fish during the actual capping from turbidity or other construction-related impacts. Those impacts and potential impacts on benthic invertebrates are beyond the scope of this report and will be addressed separately by AECOM in the EA screening report.

5.1 Aquatic Macrophytes

The proposed capping would cover approximately 99,000 m^2 (~10 ha) of aquatic macrophytes, primarily *Chara* but also some Canada waterweed and pondweeds, with a layer of approximately 10-15 cm of sand (Table 5). Of this, only 3600 m^2 are in waters less than 2 m deep. Submerged aquatic vegetation typically does not occur below 10 m water depth, but *Chara* is known to grow to depths of 12 m and other macroalgae are found down to depths of 30 m or more (Ciborowski et al. 2009; Wehr and Sheath 2003). Canada waterweed typically grows in a wide range of water depths, typically between 4 to 8 m deep, but as deep as 12 m (Sheldon and Boylen 1977).

The cap will initially smother at least some of the submergents, although some may be tall enough not to be covered by the cap, particular in areas with coarse woody debris which might disrupt the evenness of the cap. Among submerged macrophytes, charophytes such as *Chara* are s fast colonizers and often occur in temporary or disturbed habitats (Wade 1990; Beltman and Allegrini 1997). Reproduction in *Chara* is primarily sexual using oospores, although there is also a limited amount of fragmentation, particularly near the rhizoid (root-like structure). *Chara* oospores (propagules) can accumulate in large numbers in the upper sediment, and persist for many years, possibly decades (Proctor 1967). In The Netherlands, Van den Berg et al. (2001) reported gradual colonization of approximately 1/3 of a small lake by *Chara* (mainly *C. aspera*) after improvement in water quality created suitable conditions. Within 9 years, *Chara* spread from adjacent areas of the lake and colonized (at >50% cover) approximately 30 ha of previously unoccupied lake bottom. Although not directly comparable to the Peninsula Harbour case, it suggests that recolonization of the sediments of the proposed cap would take less than a decade, and perhaps considerably sooner.

Recolonization rates for aquatic macrophytes, particularly for the oligotrophic waters of Lake Superior, are poorly understood. Canada waterweed is a perennial that vegetatively propagates readily from unspecialized stem fragments (Nichols and Shaw 1986); sexual reproduction with seed formation is rare (St. John 1965). It has been observed in the leafy condition under snow-covered ice and can overwinter as entire plants (Stuckey et al. 1978). The dormant apices of Canada waterweed grow quickly as the water warms and light intensity increases in the spring. It is unknown to what extent, if any, it might die back under the low light conditions experienced in Peninsula Harbour during winter. *Elodea* rapidly invades areas that have been disturbed by natural or anthropogenic causes, including subtle disturbances such as accelerated eutrophication (Nichols and Shaw 1986). *Elodea* can utilize nutrients from both soil and water and does not appear to be nitrogen or phosphorus limited. Haag (1976) estimated a growing season net productivity for elodea of 160-203 g/m2 for Lake Wabmun, Alberta. In Europe, Canada waterweed is an invasive exotic with very high growth rates (Barrat-Segretain et al. 2002).

Canada waterweed is found on a wide variety of sediment types but grows best on fine sediments where organic matter is 10-25% (Nichols and Shaw 1986 and reference therein). Substrates that are too coarse don't provide good anchorage and may be nutrient-poor; conversely, fine bottom sediments can be too soft and flocculent to support smartweed growth (Nichols and Shaw 1986).

Like *Chara*, Canada waterweed is tolerant of varied water chemistry but is most common in hard, nutrient-rich, alkaline waters (Nichols and Shaw 1986). Canada waterweed does well in eutrophic conditions (Lind and Cottam 1969), but is also one of the most common submergent species along the north shore of Lake Superior (pers. obs.). Oligotrophic conditions generally prevail in Lake Superior, including Peninsula Harbour. Point source nutrients are major variable in determining the distribution of benthic macroalgae in Lake Huron, and phosphorous may be a limiting factor (Sheath et al. 1988). *Chara* and *Elodea* are not common submergents along Lake Superior shorelines due to the oligotrophic conditions and typically coarse substrates. Benthic macroalgae can be an indicator localized pollution inputs (Sheath et al. 1988) such as in Thunder Bay harbour (Harris et al. 2009), and the abundance of *Chara* in Jellicoe Cove may partly reflect greater nutrient availability in the sediment resulting from past contamination and accumulation of organics.

Nutrients such as phosphorus and nitrogen are recycled primarily through death and decay of the *Elodea* and other submergents (Nicols and Shaw 1986) and fall senescence of *Elodea* has been observed to release soluble nitrogen (Peverly and Johnson 1979). Burial of *Elodea* in the proposed capping may release nutrients of the upper layers of the substrate in Jellicoe Cove and could help promote growth of remaining plants. This may help mitigate potentially reduced availability of nutrients in existing sediments if the additional depth of the cap puts nutrients in the existing sediments beyond the rooting zone of submergents. Submergents are groing on approximately 7 ha of predominately silty substrate within the proposed cap area, with the remainder mainly on sand. Although submergents are growing on sandy sediments in the proposed cap, the sand of the proposed cap may be less suitable for submergent growth since it will lack the silts and finer sediments that are mixed in with the existing silt substrate which might slow recolonization somewhat.

Submergents in the proposed cap area are expected to regenerate in the short to medium term because:

- Not all existing plants are likely to be smothered by the 15-20 cm layer of the sand in the proposed cap;
- The proposed cap substrate appears to be a suitable growing medium for submergent species present in Jellicoe Cove (although the impacts on SAV recolonization of the loss of organics in the rooting zone and capping of silt with sand are unknown);
- Dominant submergents i.e., *Chara* and Canada waterweed in Jellicoe Cove are known to rapidly colonizing bare substrates, and
- Potential nutrients input from smothered submergents may stimulate growth of regenerating individuals if they are accessible to the rooting zone of submergents.

5.2 Fish

Potential impacts on the fish community from the proposed capping are particularly difficult to predict due to paucity of existing fisheries assessment data and the number of other factors that may influence fish distribution and abundance including other environmental variables (e.g., weather, water levels), harvest, and interspecific relationships (e.g., predation, competition), as well as the uncertainty regarding the aquatic macrophytes response to the proposed capping.

The proposed cap area does not provide significant spawning, nursery, or foraging habitat for fish species that prefer cobble and other coarse substrates and, while there will be a reduction in silt substrates, the amount of potential spawning, nursery, and other habitat over sand will increase concomitantly. Furthermore, silty substrate is abundant elsewhere in Peninsula Harbour in similar water depths. The proposed capping should benefit fish species that prefer to forage on sandy substrate compared to siltier and flocculent substrates.

The reduction in submergents may have some impacts on species that spawn over vegetation, at least in the short term. However, a short-term reduction in vegetation density may not have a significant negative impact on fish populations in Jellicoe Cove, including longnose sucker and yellow perch. Yellow perch is the sportfish species most likely to be impacted in terms of spawning habitat, but yellow perch egg masses float and will adhere to logs or sand in the proposed cap (as well as on any remaining or regenerating macrophytes). On waveswept Great Lakes shorelines, yellow perch will spawn over sand and cobble where preferred submergent vegetation or woody debris is absent (Robillard and Marsden 2001).

Reduced submergent density may negatively impact nursery, foraging habitat, and overwintering habitat for some species (e.g., yellow perch, longnose sucker, northern pike) in the short to medium term. Crowder and Cooper (1979, 1982) found that medium macrophyte densities support abundant macroinvertebrates while allowing room for fish to forage. Therefore, a reduction in submergent density in portions of the proposed cap could potentially improve foraging conditions for some fish species.
Most of the fish species found in Jellicoe Cove are found in a variety of habitats and are not dependent on submergents. For example, even though juvenile yellow perch commonly use submergents, age-0 perch in Lake Michigan showed a preference for rocky habitat (Janssen and Luebke 2004) and YOY perch were seined along the shoreline in Jellicoe Cove outside the proposed cap area.

5.3 Conclusions

Recognizing the limitations of the existing data, the proposed cap area does not appear to be critical fish habitat. Less than 2% of the cap is in shallow (<2 m) water preferred by many YOY fish including salmonids and suckers, and relatively similar littoral habitat is abundant elsewhere in Peninsula Harbour along more natural shorelines. The unvegetated portion of the proposed cap in deep water over fine-textured substrate is likely used by adult longnose suckers and round whitefish in particular. The proposed capping will cover silt substrate with sand; this may benefit slightly species that prefer sand compared to silt and vice versa, but will probably not have a significant effect on fish habitat use. Furthermore, deepwater silt habitat is common in elsewhere in Peninsula Harbour.

Available evidence suggests that the most significant impact will be the potential reduction in aquatic macrophyte abundance in the proposed cap area, which could reduce the habitat suitability for foraging adult longnose suckers and northern pike. Although data are lacking, yellow perch and small fish species in various life stages could also be affected by a reduction in submergent density. The response of submergents to disturbances such as the proposed capping is poorly understood for oligotrophic systems like Peninsula Harbour. Various lines of evidence suggest however that the plant species present in Jellico Cove are will be able to recover in the short to medium term.

Finally, the long-term benefit of reducing exposure to contaminated sediments by capping it with a layer of sand probably outweighs the any potential short-term negative impacts to fish habitat.

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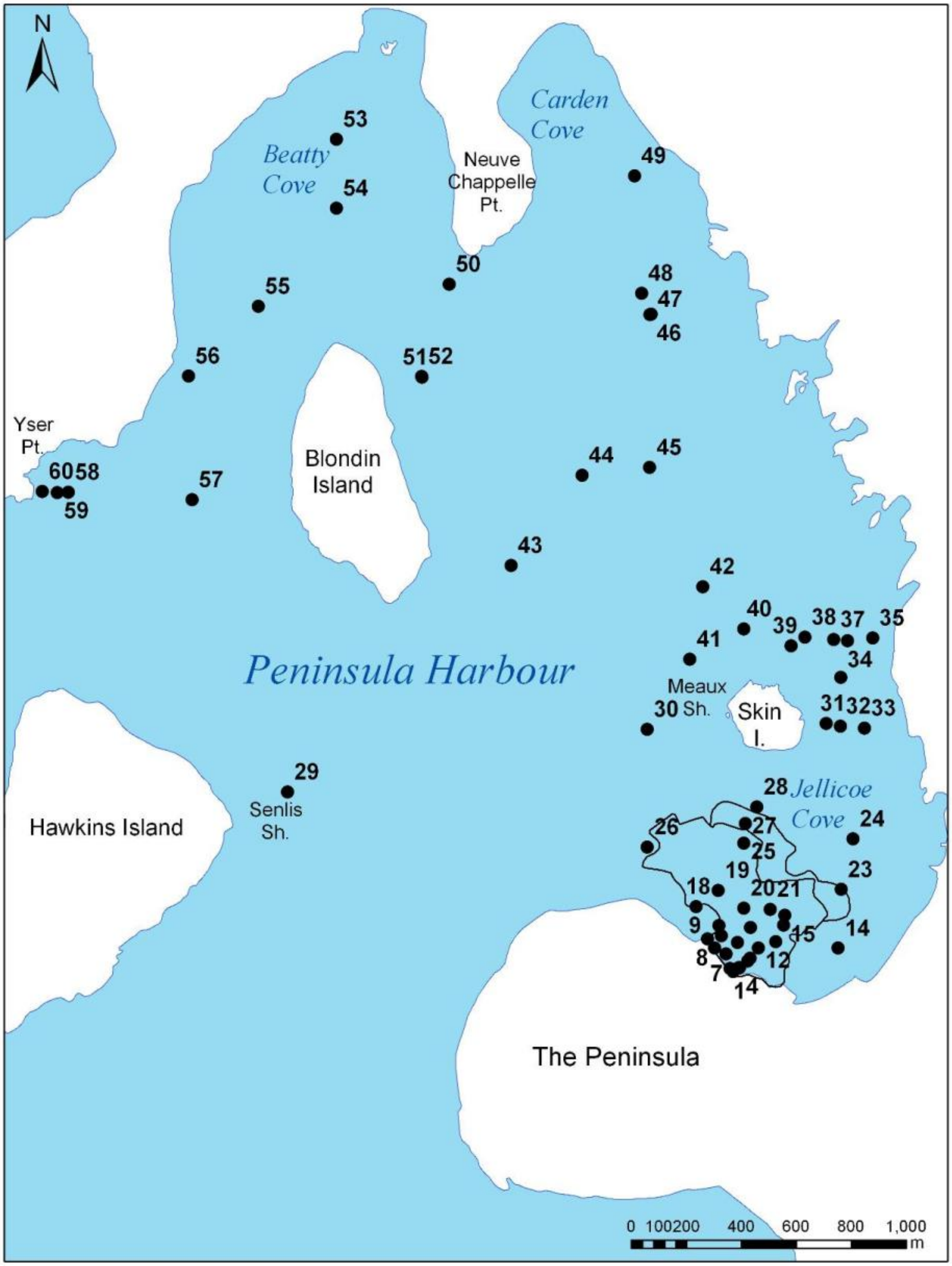
Appendix 1. Particle size* analysis from sediment grabs in Peninsula Harbour by Grapentine et al. (2005) and Milani et al. (2001). See Figure 15 and Figure 26 for locations.

Source	Site	Dominant Substrate	Sand	Silt	Clay	Gravel	Depth	Northing	Easting
Grapentine et al. (2005)	JC2A	Clay	7	19	74	0	7.5	5396712	544367
Grapentine et al. (2005)	PH20	Clay	33	14	53	0	26.2	5403155	498041
Grapentine et al. (2005)	PH17	Clay	5	46	49	0	41.0	5410755	457816
Grapentine et al. (2005)	JC3A	Clay	18	35	47	0	7.7	5396702	544382
Grapentine et al. (2005)	JC1B	Sand	84	1	0	14	9.0	5396753	544291
Grapentine et al. (2005)	JC1D	Sand	90	5	0	6	15.0	5396883	544216
Grapentine et al. (2005)	JC1C	Sand	92	4	0	4	10.0	5396832	544248
Grapentine et al. (2005)	JC7A	Sand	93	6	0	2	6.8	5396628	544454
Grapentine et al. (2005)	PH13	Sand	90	5	3	1	13.2	5402907	526305
Grapentine et al. (2005)	PH15	Sand	67	13	19	1	8.4	5399005	544152
Grapentine et al. (2005)	PH26	Sand	53	31	16	1	38.4	5398319	534292
Grapentine et al. (2005)	JC2C	Sand	44	42	14	0	15.0	5396851	544326
Grapentine et al. (2005)	JC4A	Sand	62	26	12	0	10.6	5396710	544412
Grapentine et al. (2005)	JC3B	Sand	55	31	14	0	0.0	5396780	544389
Grapentine et al. (2005)	JC5A	Sand	54	33	13	0	7.5	5396681	544432
Grapentine et al. (2005)	JC2D	Sand	46	42	12	0	16.9	5396921	544310
Grapentine et al. (2005)	JC2B	Sand	63	25	12	0	12.2	5396787	544343
Grapentine et al. (2005)	PH2	Sand	56	34	9	0	1.2	5385168	549731
Grapentine et al. (2005)	JC7B	Sand	75	17	8	0	4.8	5396640	544527
Grapentine et al. (2005)	PH18	Silt	8	53	39	0	23.3	5406082	444807
Grapentine et al. (2005)	PH16	Silt	11	52	36	0	27.4	5408595	461938
Grapentine et al. (2005)	PH22	Silt	7	67	26	0	64.8	5400026	540285
Grapentine et al. (2005)	PH14	Silt	20	58	22	0	43.6	5403841	520730
Grapentine et al. (2005)	PH21	Silt	39	45	16	0	29.4	5401241	540354
Grapentine et al. (2005)	PH11	Silt	15	70	15	0	26.9	5387649	548785
Grapentine et al. (2005)	JC7C	Silt	36	49	15	0	5.3	5396655	544603
Grapentine et al. (2005)	PH1	Silt	36	50	14	0	2.7	5385705	548946
Grapentine et al. (2005)	JC4D	Silt	12	73	14	0	13.5	5396893	544511
Grapentine et al. (2005)	JC6B	Silt	39	47	14	0	7.5	5396688	544516
Grapentine et al. (2005)	JC5D	Silt	15	71	14	0	11.8	5396833	544599
Grapentine et al. (2005)	JC5B	Silt	26	60	14	0	11.0	5396734	544485
Grapentine et al. (2005)	JC3D	Silt	28	59	14	0	14.6	5396925	544415
Grapentine et al. (2005)	JC5C	Silt	22	65	13	0	11.2	5396780	544539
Grapentine et al. (2005)	JC4C	Silt	31	56	13	0	12.6	5396830	544478
Grapentine et al. (2005)	JC6C	Silt	24	64	13	0	8.0	5396711	544590
Grapentine et al. (2005)	JC3C	Silt	35	52	12	0	13.6	5396855	544403

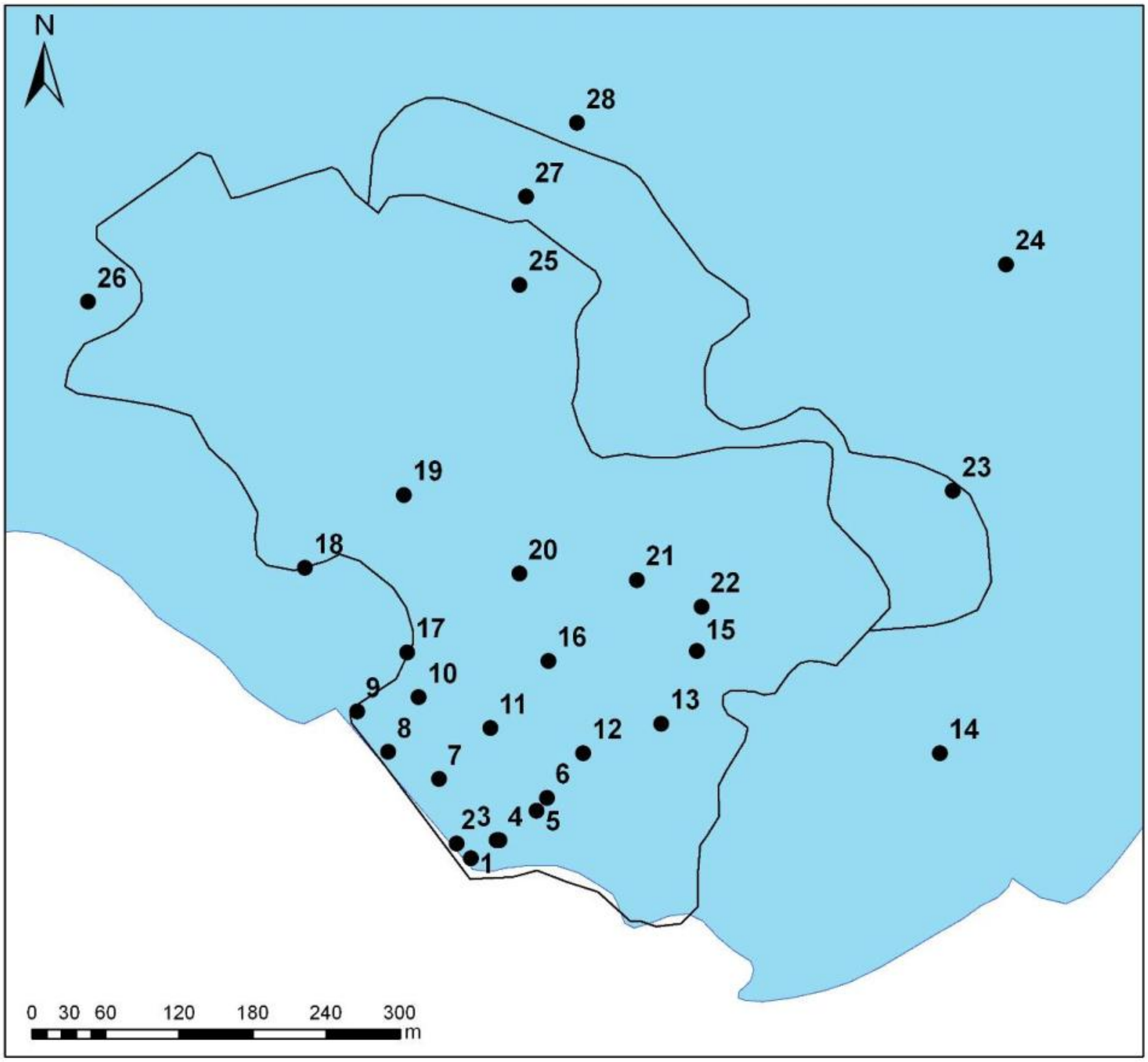
Source	Site	Dominant Substrate	Sand	Silt	Clay	Gravel	Depth	Northing	Easting
Grapentine et al. (2005)	JC4B	Silt	37	52	10	0	12.0	5396767	544445
Milani et al. (2002)	60	Clay	12	16	72	1	26.0	5397852	542605
Milani et al. (2002)	A1	Clay	2	16	82	0	12.7	5397330	544421
Milani et al. (2002)	57	Sand	83	16	0	1	1.3	5396508	544744
Milani et al. (2002)	71	Sand	82	18	0	0	4.0	5399461	543891
Milani et al. (2002)	A2	Sand	97	2	0	0	18.9	5397248	544353
Milani et al. (2002)	B5	Sand	53	40	8	0	20.3	5396990	544243
Milani et al. (2002)	C6	Sand	87	9	4	0	13.3	5396865	544240
Milani et al. (2002)	F2	Sand	53	36	11	0	8.8	5396945	544669
Milani et al. (2002)	G6	Sand	86	11	0	3	5.1	5396639	544488
Milani et al. (2002)	I5	Sand	91	9	0	0	2.3	5396576	544688
Milani et al. (2002)	58	Silt	41	48	11	0	17.0	5396937	544311
Milani et al. (2002)	59	Silt	25	63	12	0	70.5	5396138	542400
Milani et al. (2002)	61	Silt	2	76	21	0	83.6	5399337	540173
Milani et al. (2002)	62	Silt	21	67	11	0	43.1	5397343	543358
Milani et al. (2002)	64	Silt	10	78	12	0	77.2	5395566	542281
Milani et al. (2002)	65	Silt	18	66	16	0	95.2	5394937	541308
Milani et al. (2002)	66	Silt	32	56	11	0	72.7	5395830	541450
Milani et al. (2002)	67	Silt	24	67	9	0	61.6	5396555	542721
Milani et al. (2002)	68	Silt	7	76	17	0	38.6	5397392	542672
Milani et al. (2002)	70	Silt	40	51	9	0	33.0	5397105	543874
Milani et al. (2002)	289	Silt	25	61	14	0	21.5	5399162	542807
Milani et al. (2002)	A5	Silt	21	70	9	0	25.1	5397102	544179
Milani et al. (2002)	C3	Silt	23	69	8	0	15.8	5397078	544438
Milani et al. (2002)	D1	Silt	40	52	8	0	13.3	5397126	544636
Milani et al. (2002)	D4	Silt	39	54	7	0	13.9	5396937	544417
Milani et al. (2002)	D5	Silt	24	67	9	0	15.0	5396935	544366
Milani et al. (2002)	E3	Silt	38	53	9	0	12.5	5396952	544556
Milani et al. (2002)	E5	Silt	35	55	10	0	12.3	5396828	544437
Milani et al. (2002)	F4	Silt	23	68	10	0	10.0	5396814	544533
Milani et al. (2002)	G3	Silt	8	80	11	0	9.1	5396825	544678
Milani et al. (2002)	G5	Silt	42	49	10	0	6.7	5396685	544552
Milani et al. (2002)	H3	Silt	18	69	13	0	6.5	5396762	544734
Milani et al. (2002)	H5	Silt	40	49	11	0	4.5	5396639	544608

*particle size diameter classes not given, but according to Denholm and Schut (1993)
clay <.0002 mm; silt 0.002- 0.05 mm; sand 0.05-2.0 mm; gravel >2.0 mm

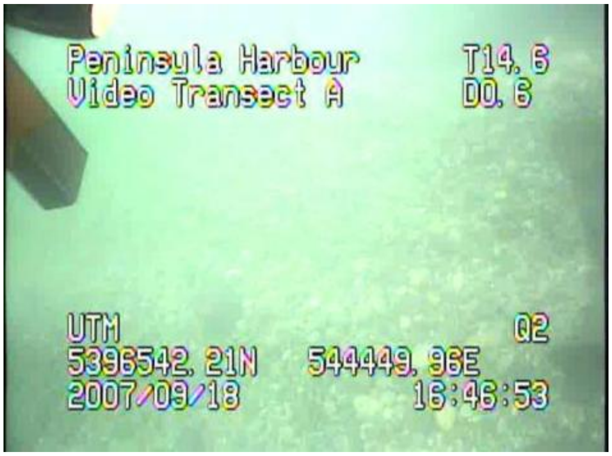
Appendix 2. Selected underwater video images for Peninsula Harbour.



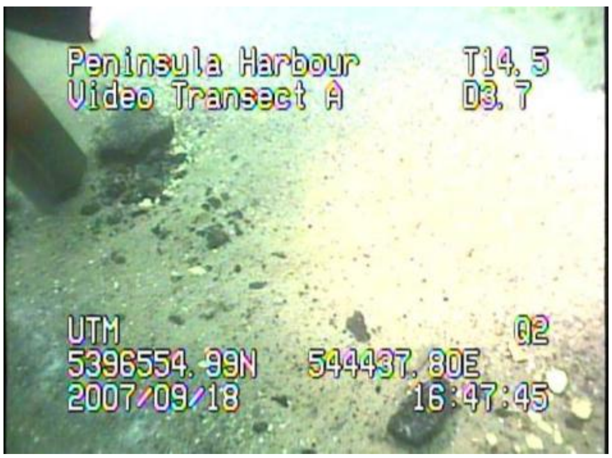
Location of Selected images from underwater video with proposed cap area (black outline).



Inset of proposed cap area with location of images from underwater video.



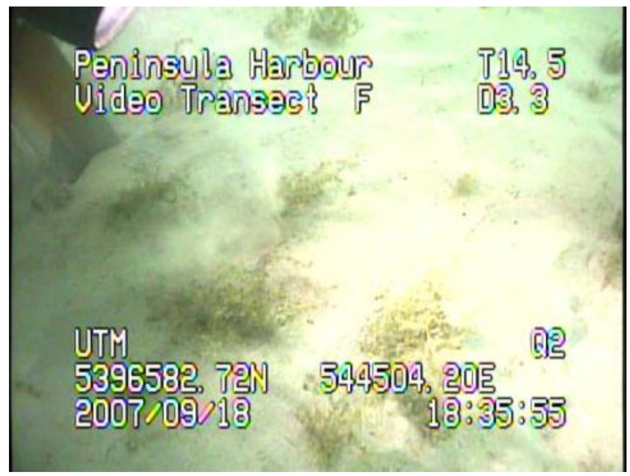
#1 Cobble and Rip rap in shallow water along shoreline of southern portion of proposed cap.



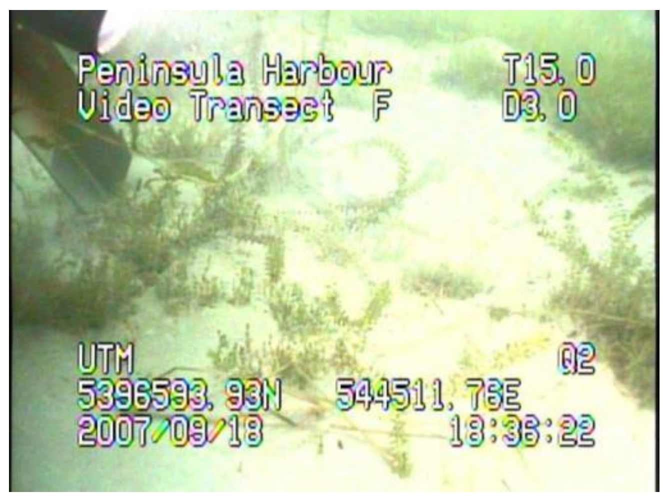
#2 Mixed substrate in shallow water along shoreline of southern portion of proposed cap.

#3 Sand adjacent in shallow water of proposed cap.

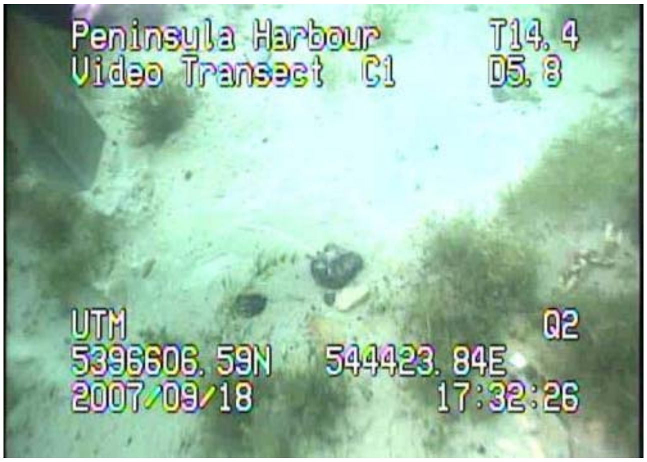
#4 Tires, rip rap, and soft sediment at southern edge of proposed cap.



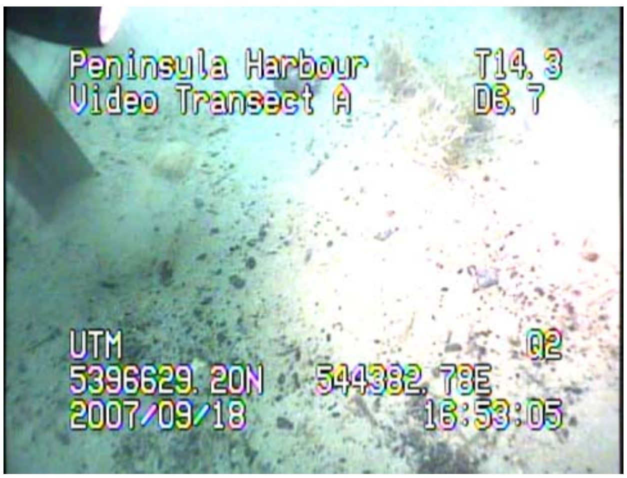
#5 Sand and sparse stonewort at southeastern edge of proposed cap.



#6 Sparse Canada smartweed in proposed cap.



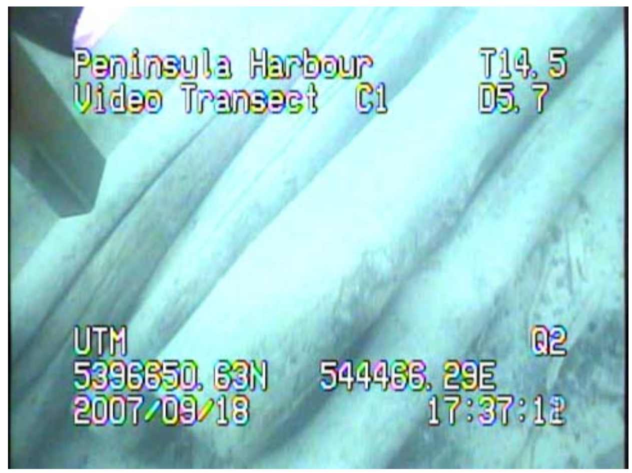
#7 "Mixed substrate" of occasional cobble and gravel over silty sand with stonewort in cap area.



#8 Mixed substrate of gravel, fragmented bark, and silty sand in shallow water of proposed cap.

#9 "Cobble" rip rap in shallow water on northwest part of proposed cap.

#10 Silty substrate with sparse stonewort in proposed cap area.



#11 Logs on silty substrate in proposed cap area.

#12 Moderate stonewort and a narrow-leavd poindweed (Potamogeton spl.)on silty substrate at the southern edge of the cap.

#13 Dense submergents at southern edge of proposed cap area.

#14 Bare sandy substrate southeast of proposed cap in shallow water mapped as submerged aquatic vegetation in AECOM.

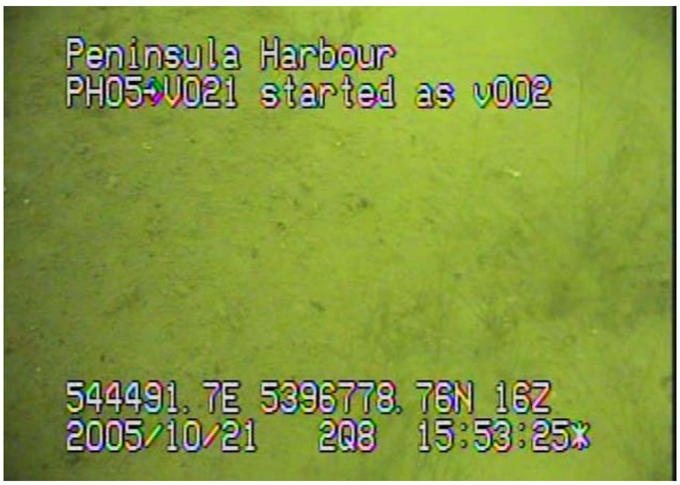
#15 Dense stonewort in middle of cobble polygon mapped as cobble by AECOM (2009) and sand by BioSonics (2011).

#16 Logs and stonewort on silty substrate in proposed cap area.

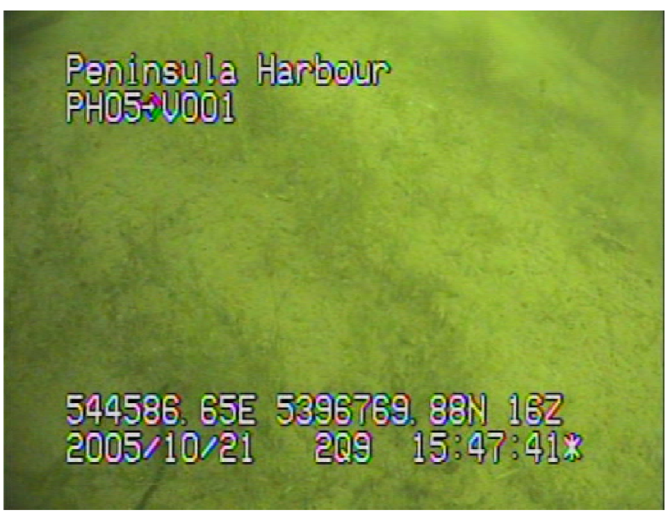
#17 Soft substrate on southest side of proposed cap in shallow water.

#18 Gravel, cobble and bark chips overlying sand at southwest margin of proposed cap.

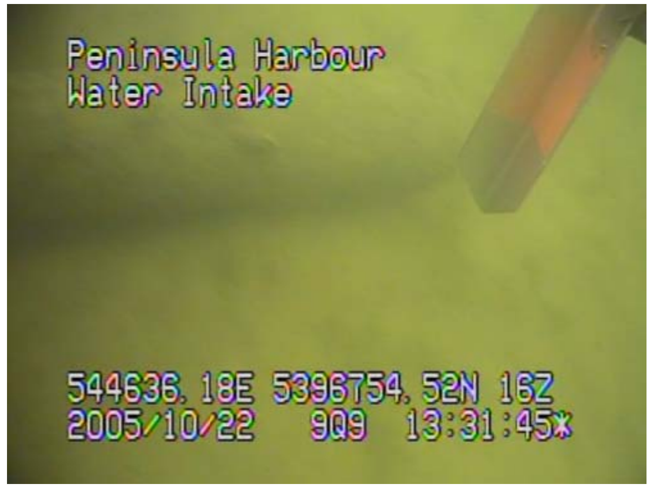
#19 Soft sediments in middle of proposed cap area.)



#20 Centre of proposed cap area with silt, some gravel and sparse macrophytes.



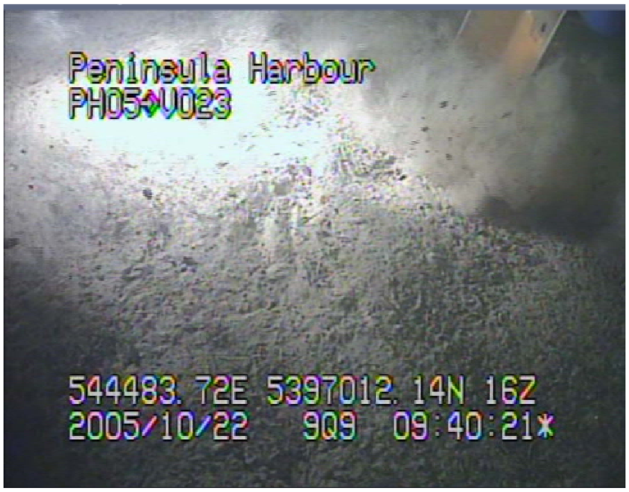
#21 Sparse macrophytes in AECOM detritus polygon.



#22 Log and silty in AECOM "cobble" polygon (Photo 13).

#23 Silty sand at northeast edge of proposed cap.

#24 Rippled sand with thin layer of silt east of proposed cap in approximately 4 m of water.



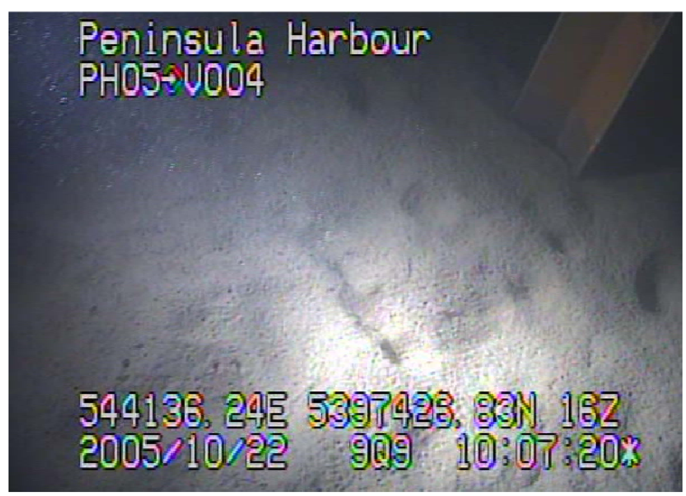
#25 Bark overlying silty substrates at north end of proposed cap.

#28 Silty bottom in new polygon mapped as silt by AECOM.

#26 Silty substrate on northwest edge of proposed cap.

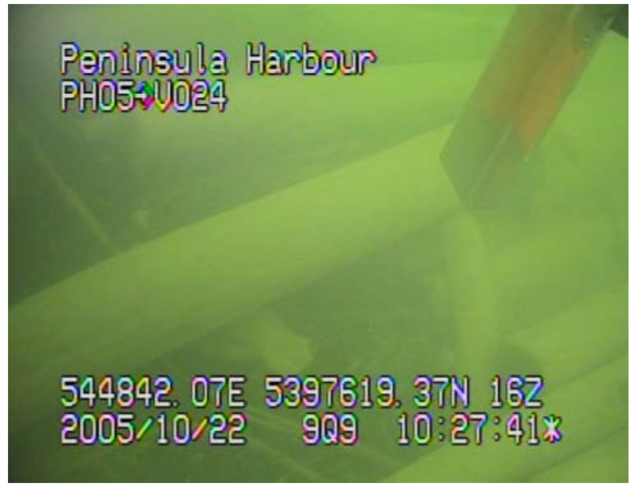
#29 Bedrock with thin layer of silt and algae off east side of Hawkins Island at Senlis Shoal.

#27 Soft bark deposits at edge of AECOM silt polygon mapped by AECOM.



#30 Soft sediment west of Skin Island.

#31 East side of Skin Island.



#34 Northeast side of Skin Island, silty? with bark deposits and pulp logs.

#32 East side of Skin Island with bark.

#35 Bark (misidentified in Envt Can shapefile) overlying sand east of Skin Island that.

#33 East side of Skin Island with logs.

#36 Bark deposits 300 m northeast of Skin Island.

#37 Bedrock shoal with thin layer of silt northeast of Skin Island in 5 m of water.

#40 Thin layer of silt over bedrock 200 m north of Skin Island in 15-16 m of water.

#38 Silty sediments northeast of Skin Island showing plume of silt from contact of camera apparatus with substrate.

#41 Bedrock on west side of Skin Island at Meaux Shoal.

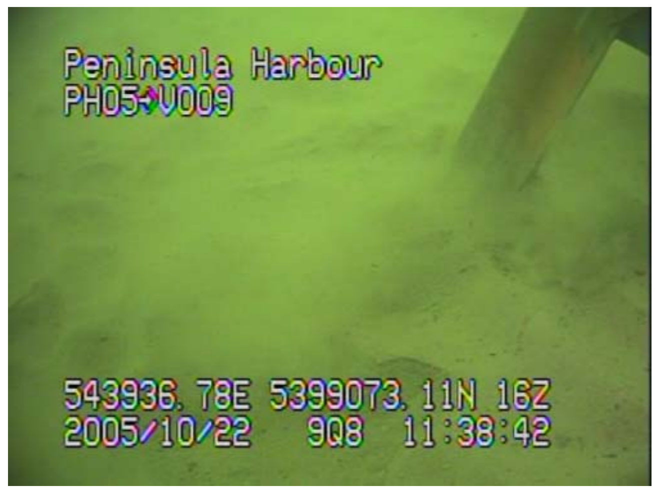
#39 Cobble northeast of Skin Island.

#42 Soft sand north of Skin Island with the occasional cobble.

#43 Silty substrate 280 m southeast of Blondin Island in 24 m of water.

#46 Gravel overlaying fairly clean sand; not much silt compared to other sites with wave ridges.

#44 Silty sand in middle of harbour east of Blondin Island.



#47 Deeper water immediately adjacent and siltier and siltier in deeper part of bay opposite Carden Cove.

#45 Silty sand at 14 m depth approximate 900 m due east of Blondin Island in middle of Peninsula Harbour.

#48 Scalloped silty sand at mouth of Carden cove in approximately 8 m of water.

#49 Smooth bedrock in Carden Cove.

#50 Silty sand off Neuve Chappelle Pt in approximately 6 m of water.

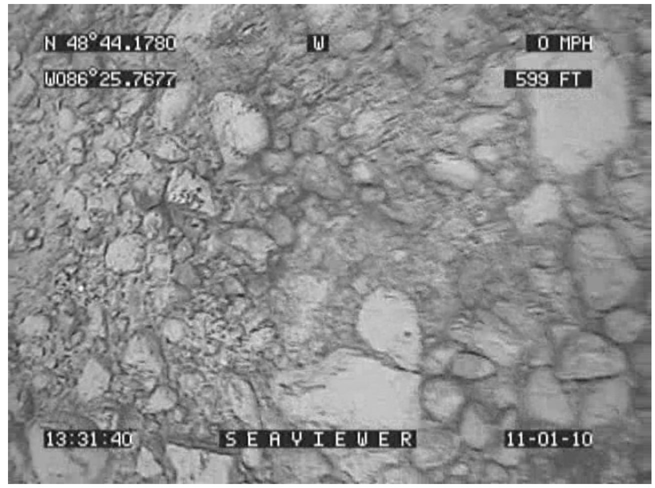
#51 Silty substrate with bark debris east of Blondin Island (Photo 24).

#52 Sparse submergent in silty substrate approximately 120 m off the northeast side of Blondin Island.

#53 Silty substrate and logs in Beatty Cove Photo 58

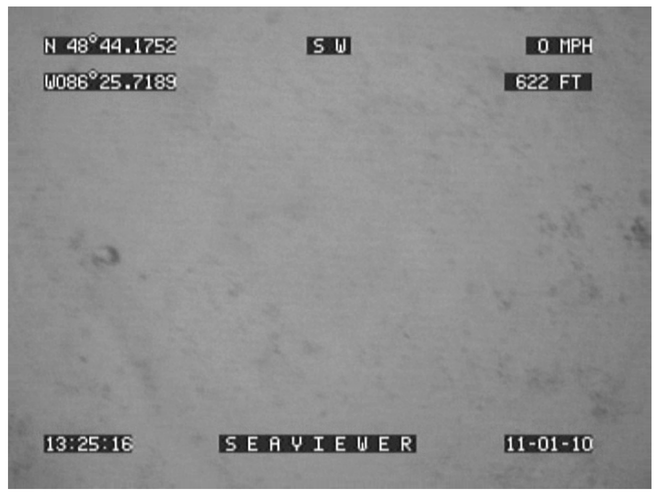
#54 Silty, flocculent substrate at mouth of Beatty Cove in approximately 18 m of water.

#55 Silty substrate in 23 m of water approximately 300 m northwest of Blondin Island.

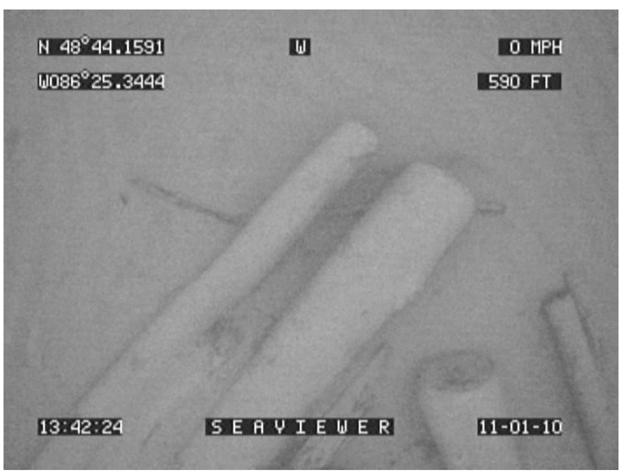


#58 Silty cobble on Yser Point.

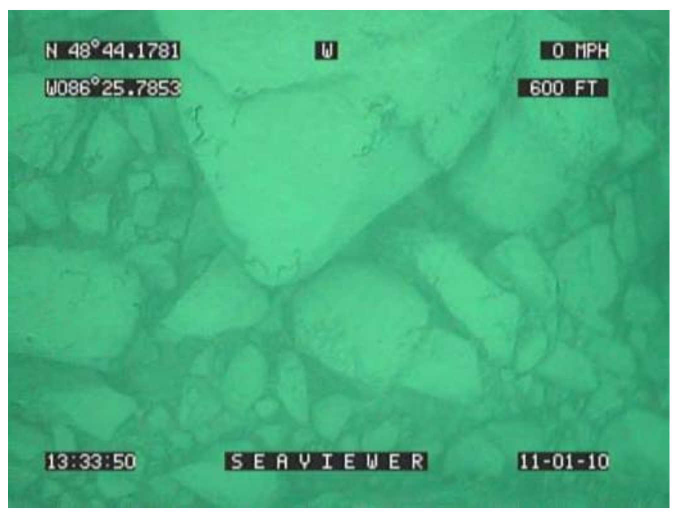
#56 Fairly clean cobble and gravel on bedrock off mainland west of Blondin Island.



#59 Silty sediments in deeper water off Yser Point.



#57 Sand and logs between Blondin Island and Yser point in 34 m of water.



#60 Rock and cobble inshallow water off Yser Point.

Appendix B

AQUATIC BENTHIC MACROINVERTEBRATE COMMUNITIES IN BEATTY COVE, LAKE SUPERIOR, 2012.

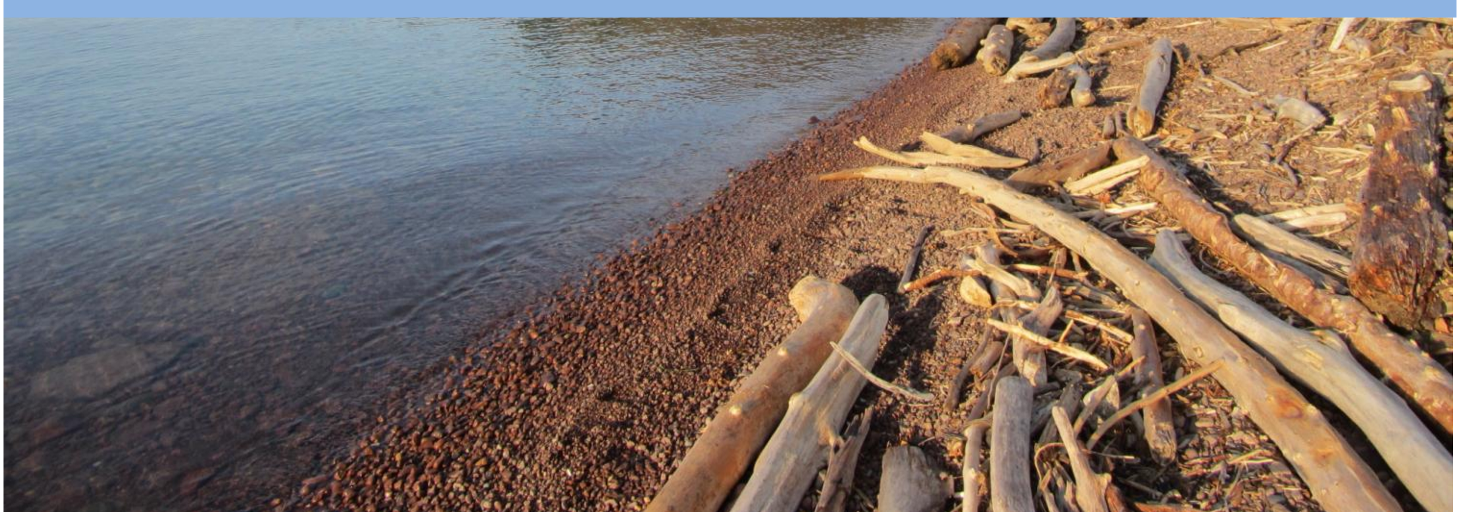
PREPARED FOR: MARILEE CHASE

COA COORDINATOR FOR GREAT LAKES

PREPARED BY: DR. KEN DEACON AND LUCIE LAVOIE

ECOSUPERIOR ENVIRONMENTAL PROGRAMS

DATE: FEBRUARY 2013



Aquatic Benthic Macroinvertebrate Communities in Beatty Cove, Lake Superior, 2012.

Dr. Ken Deacon and Lucie Lavoie
February 2013

INTRODUCTION

Beatty Cove is a small bay found within Peninsula Harbour on the northeastern shore of Lake Superior (Fig. 1a), approximately 290 km east of the City of Thunder Bay. In 1987 the International Joint Commission identified Peninsula Harbour as one of 43 degraded areas on the Great Lakes designated as individual Areas of Concern (AOC), for which a cleanup or Remedial Action Plan was required (RAP 2012). Wood fibre, bark waste and wood processing by-products were released into Peninsula Harbour by the Marathon pulp and paper mill which began operations in 1946. Initial discharges averaged 275 tonnes of waste per day (Patakfalvi 2004). Subsequently a chlor-alkali plant released mercury into the harbour from 1952 until 1977 (Environment Canada 2010). By 2004 the mill released 525 tonnes of waste per day (Patakfalvi 2004). The mill was eventually shut down in 2009 (CBC 2009). Discharges from the municipal sewage treatment plant also contributed to the contamination of Peninsula Harbour (Ontario Ministry of the Environment 2011).

One of five issues identified within the Peninsula Harbour AOC was the loss of fish and wildlife habitat caused by the degradation of fish spawning beds because of accumulations of wood fibre and bark waste (Ontario Ministry of the Environment 2011). Lake trout spawning habitat in Beatty Cove was considered impaired because of the accumulation of wood fibre from mill effluent and bark waste from log booming which ended in 1983 (Ontario Ministry of the Environment 2011). The purpose of this study is to assess habitat conditions in Beatty Cove using aquatic benthic macroinvertebrates. Aquatic benthic macroinvertebrates respond to ecosystem changes faster than other members of the aquatic community and therefore macroinvertebrates are commonly used as indicator species to assess the health of aquatic ecosystems. Relatively unimpaired sites from Lake Nipigon (Deacon 2011) and an impounded area of the Black Sturgeon River (Deacon 2013) were used for comparison with the sites from Beatty Cove.

METHODS

Three sites in Beatty Cove were sampled on 22 October 2012 according to lake methodology as outlined by Jones *et al.* (2005) (Fig. 1b). Benthic aquatic macroinvertebrate communities were

Fig. 1a Location of Beatty Cove in Peninsula Harbour Area in Recovery, Lake Superior (Ontario Ministry of the Environment 2011).

Fig. 1b Location of sampling sites within Beatty Cove in Peninsula Harbour Area in Recovery, Lake Superior, October 2012.

sampled using a travelling kick-and-sweep method with a 500-micron D-net (Jones *et al.*, 2005). Benthic organisms were collected from three transects at each of the sites by travelling from the shoreline to one metre depth, then back to the shoreline. This back and forth sampling was repeated for a maximum of ten minutes. Each transect sample was preserved in the field in 96% ethanol. The samples were sorted in the laboratory. A minimum of 100 benthic macroinvertebrates were randomly picked from each of the samples using a Nikon SMZ1500 at 10X magnification. The macroinvertebrates were identified using taxonomic keys by Clarke (1981), Peckarsky *et al.* (1990), Wiggins (1996) and Merritt *et al.* (2008). Most organisms were identified to Order or Family level to facilitate the determination of various biotic indices. Orders such as Ephemeroptera, Plecoptera, and Trichoptera are particularly sensitive to impaired water quality, and were therefore identified to the Genus level when possible.

Each aquatic benthic macroinvertebrate community was assessed according to the 27-taxa Reference Condition Approach (RCA) as outlined in the Ontario Benthos Biomonitoring Network Protocol Manual (Jones *et al.* 2005). The 27-Taxa include: Amphipoda, Anisoptera, Bivalvia, Ceratopogonidae, Chironomidae, Coelenterata, Coleoptera, Culicidae, Decapoda, Ephemeroptera, Gastropoda, Hemiptera, Hirudinea, Isopoda, Lepidoptera, Megaloptera, Miscellaneous Diptera, Nematoda, Oligochaeta, Plecoptera, Simuliidae, Tabanidae, Tipulidae, Trichoptera, Trombidiformes, Turbellaria, and Zygoptera. The biotic indices used to characterize the benthic macroinvertebrate communities include: Total Abundance, Richness, Dipteran Richness, Insect Richness, Simpson's Index, Shannon's Diversity Index, Hilsenhoff Biotic Index (HBI), % Dominants, % Ephemeroptera Odonata Trichoptera (EOT), % Ephemeroptera Plecoptera Trichoptera (EPT), % Chironomids, % Crustacea, % Dipterans, % Gastropods, % Mollusca, % Non-Dipteran Insects, % Odonates, % Pelecypods, and % Oligochaetes (Worms).

The OBBN biotic indices (Table 1) (Jones *et al.,* 2005) used to analyse the 27-taxa identified from Beatty Cove provide an insight into present and past conditions experienced by the aquatic macroinvertebrate communities. Some of the biotic indices (high % Worms, high % Chironomids) are useful for identifying sites that are heavily impacted by nutrient enrichment. In extreme cases nutrient enrichment will cause premature eutrophication resulting in low dissolved oxygen in the water, with consequent degradation of the habitat. Both worms and chironomids are tolerant of low-oxygen concentrations and become the dominant organisms in eutrophic ecosystems. Chironomids are also highly tolerant of toxic chemicals; therefore, they can survive and become dominant in conditions that kill other organisms, including worms. A high % Crustacea indicates high organic content in a habitat that never experiences lethal low oxygen concentrations. Other biotic indices (high % EPT, low Hilsenhoff Biotic Index) help to confirm high water quality at the site. Ephemeroptera, Plecoptera and Trichoptera (EPT) are intolerant of toxins and require oxygen concentrations that are close to saturation. The Hilsenhoff Biotic Index (HBI) is calculated using tolerance values assigned to the various macroinvertebrate taxa (Tables 1 & 2). EPT have low HBI values, whereas worms and chironomids have high HBI values. In lotic habitats HBI values above 6.0 are considered indicative of an impaired system (Hilsenhoff 1988), usually because of organic enrichment which can cause eutrophication. Each biotic index provides a separate insight into the quality of the habitat. The combination of several indices makes it possible to evaluate the relative, long-term health of the site and the overall suitability of the site to support a healthy fishery. Not all biotic indices are necessary to determine whether a site is impaired.

The biotic indices selected to evaluate the Beatty Cove sites were: Richness, Shannon's H' Diversity, Hilsenhoff Biotic Index, % Dominant, % EPT, % Chironomids, % Worms, and % Crustacea (Table 1). The values for these biotic indices were compared with data from five relatively unimpaired sites on the Lake Nipigon system (Deacon 2011) and one site on an impounded area of the Black Sturgeon River (Deacon 2013) to determine whether the values

Table 1. Biotic Indices: calculations and descriptions.

Subcategory	Index	How to Calculate:	Indication
Richness/Diversity	ABUNDANCE	Sum of Organisms	Possibly impaired if extremely low or high value
	RICHNESS	Count of taxa found in a sample	The greater the number of taxa the higher the quality of the habitat
	INSECT RICHNESS	Count of Chironomidae+Culicidae +Ceratopogonidae +Tipulidae +Tabanidae +Simuliidae+Odonates (Zygoptera and Anisoptera) + Coleoptera + Ephemeroptera + Hemiptera + Lepidoptera + Megaloptera + Plecoptera + Trichoptera + misc Dipterans	The greater the number of taxa the higher the quality of the habitat
	DIPTERIAN RICHNESS	Count of Chironomidae+Culicidae +Ceratopogonidae+Tipulidae+Tabanidae+ Simuliidae	The greater the number of taxa the higher the quality of the habitat
	SIMPSON'S INDEX	Proportion of species *i* relative to the total number of species (p_i), squared Squared proportions for all the species summed, and the reciprocal is taken	Probability that two individuals will belong to the same taxon
	SHANNON'S H' DIVERSITY	H'= -Sum(p_i * ln(p_i) where p_i =proportion of the count of each taxa	High values indicate increased evenness of the counts among the taxa and higher quality habitat
Composition	%AMPHIPODA	Sum of amphipoda /abundance *100	Associated with eutrophic conditions
	%CHIRONOMIDAE	Sum of Chironomidae / Abundance*100	extremely abundant in highly eutrophic situations, but present in all habitats
	%CRUSTACEANS and MOLLUSCA	(Sum of Amphipoda+Decapoda+Isopoda + Gastropoda + Pelecypoda) /Abundance*100	Associated with eutrophic conditions, but present in many habitats
	%CRUSTACEANS	(Sum of Amphipoda+Decapoda+Isopoda) /abundance*100	Associated with eutrophic conditions, but present in many habitats
	%EPHEMEROPTERA	Sum of Ephemeroptera /abundance*100	The greater the value the higher the quality of the habitat
	%GASTROPODS	Sum of Gastropoda /abundance*100	Associated with eutrophic conditions, but present in many habitats
	%HIRUDINEA	Sum of Hirudinea /abundance*100	Associated with eutrophic conditions, but present in many habitats
	%ISOPODA	Sum of Isopoda /abundance*100	Associated with eutrophic conditions
	%MOLLUSCA	(Sum of Gastropoda + Pelcypoda) /abundance*100	Associated with eutrophic conditions, but present in many habitats
	%ODONATES	(Sum of Anisoptera and Zygoptera) /abundance*100	The greater the value the higher the quality of the habitat
	%OLIGOCHAETES	Sum of Oligochaetes /abundance*100	Abundant in highly eutrophic situations, but present in many habitats
	%PELECYPODA	Sum of Pelecypoda /abundance*100	The greater the value the healthier the habitat
	%TIPULIDAE	Sum of Tipulidae /abundance*100	Possibly impaired if extremely high value, but present in many habitats
	%TABANIDAE	Sum of Tabanidae /abundance*100	Possibly impaired if extremely high value, but present in many habitats
	%SIMULIDAE	Sum of Simuliidae /abundance*100	Possibly impaired if extremely high value, but present in many habitats
	%DIPTERA	(Sum of Chironomidae+Culicidae +Ceratopogonidae +Tipulidae+Tabanidae+Simuliidae +misc Dipterans) / Total Abundance* 100	Possibly impaired if extremely low or high value
	%INSECTS	(Sum of abundance of Chironomidae+Culicidae +Ceratopogonidae +Tipulidae+Tabanidae+Simuliidae+Odonates (Zygoptera and Anisoptera) + Coleoptera + Ephemeroptera + Hemiptera + Lepidoptera + Megaloptera + Plecoptera + Trichoptera + misc Dipterans)/ Total Abundance* 100%	Possibly impaired if extremely low or high value
	%NON-DIPTERIAN INSECTS	(Sum of Zygoptera + Anisoptera + Coleoptera + Ephemeroptera + Hemiptera + Lepidoptera + Megaloptera + Plecoptera + Trichoptera)/Total Abundance* 100	A high value indicates higher water quality than a lower value
	%EPT	(Sum of Ephemeroptera + Plecoptera + Trichoptera) / Abundance * 100	A high value indicates higher water quality than a lower value
	%EOT	(Sum of Ephemeroptera + Anisoptera + Zygoptera + Trichoptera) / Total Abundance * 100	A high value indicates higher water quality than a lower value
Tolerance	%DOMINANT	Abundance of the Most Common Taxon / abundance * 100	The dominance of a pollution tolerant group indicates an impaired site
	HILSENHOFF'S BIOTIC INDEX	=SUM(x_i.t_i)/Total abundance where x_i =abundance of each taxa and t_i = tolerance value for each taxa.	A low value implies low nutrient conditions. Values above 6.0 are of concern

Table 2. Tolerance Values (Hilsenhoff 1988) used in the calculation of the Hilsenhoff Biotic Index.

Family	Tolerance	Family	Tolerance
PLECOPTERA			
Capniidae	1	Perlidae	1
Chloroperlidae	1	Perlodidae	2
Leuctridae	0	Pteronarcyidae	0
Nemouridae	2	Taeniopterygidae	2
Peltoperlidae	?		
EPHEMEROPTERA			
Baetidae	4	Metretopodidae	2
Baetiscidae	3	Oligoneuriidae	2
Capnidae	7	Polymitarcyidae	2
Ephemerellidae	1	Potomanthidae	4
Ephemeridae	4	Siphloneuridae	7
Heptageniidae	4	Trycorythidae	4
Leptophlebiidae	2		
ODONATA			
Aeshnidae	3	Gomphidae	1
Calopterygidae	5	Lestidae	9
Coenagrionidae	9	Libellulidae	9
Cordulegastridae	3	Macromiidae	3
Corduliiae	5		
TRICHOPTERA			
Brachycentridae	1	Molannidae	6
Glossosomatidae	0	Odontoceridae	0
helicopsychidae	1	Philopotamidae	3
Hydropsychidae	4	Phryganeidae	4
Hydroptilidae	4	Polycentropodidae	6
Lepidostomatidae	1	Psychomyiidae	2
Leptoceridae	4	Rhyacophiliidae	0
Limnephilidae	4	Sericostomatidae	3
MEGALOPTERA			
Corydalidae	0	Sialidae	4
LEPIDOPTERA			
Pyralidae	5		
COLEOPTERA			
Dryopidae	5	Psephenidae	4
Elmidae	4		
DIPTERA			
Athericidae	2	Psychodidae	10
Blephariceridae	0	Simuliidae	6
Ceratopogonidae	6	Muscidae	6
Blood-red Chironomidae	8	Syrphidae	10
Other (including pink) Chironomidae	6	Tabanidae	6
Dolochopodidae	4	Tipulidae	3
Empididae	6		
Ephydridae	6		
AMPHIPODA			
Gammaridae	4	Talitridae	8
ISOPODA			
Asellidae	8		

obtained for Beatty Cove were higher or lower than expected in an unimpaired site. The Hilsenhoff Biotic Index (HBI) was originally designed for analysis of stream communities; therefore, the values obtained for lentic habitats are only for comparison within this study and not necessarily indicative of impaired water quality. Aquatic macroinvertebrate communities in lentic conditions generally have a higher HBI and lower % EPT than communities in lotic conditions. General physiographic features (Table 3) combined with taxa (Tables 4-6) and biotic indices (Table 7) provided sufficient means to evaluate the quality of the Beatty Cove sites.

OBSERVATIONS

Sampling

The sampling time at some transects was reduced from ten minutes to five or six minutes to reduce sample size, as recommended by Jones *et al.* (2005) when samples contain a relatively high abundance of organisms. The percent of the sample sorted to obtain a minimum count of 100 benthic macroinvertebrates was adjusted to reflect a ten minute standard. The maximum amount of a sample that had to be sorted to obtain the minimum 100 count was 10.5% (BEA-2-3, Table 5). The remainder of the samples (Tables 4-6) required less than 10% of the material to be sorted. All samples were of an adequate size. A Quality Control re-sort of BEA-2-3 recovered 10 taxa in similar proportions to the initial sort of BEA-2-3 (Table 5). The spiny waterflea (*Bythotrephes longimanus*), an invasive species, was abundant in all the transects, particularly at BEA-3 (personal observation).

Overall, this survey of Beatty Cove provided an accurate representation of the composition of the aquatic benthic macroinvertebrate communities present during late October.

Abundance

Ephemeroptera, Plecoptera and Trichoptera (EPT) were present at all three sites (Tables 4-6). Ephemeroptera, Plecoptera and Trichoptera are indicators of a high quality aquatic habitat when abundant, which means that Beatty Cove was not particularly affected by anthropogenic inputs at the time of sampling. The EPT were most abundant (n=72) and had the greatest diversity (n=10) at BEA-1 (Table 4), followed by a decrease in abundance (n=34) and diversity (n=7) at BEA-2 (Table 5). The EPT were least abundant (n=21) and diverse (3) at BEA-3 (Table 6). Plecoptera are the most sensitive Order of the EPT to impaired water quality. Plecoptera are restricted to highly oxygenated environments, such as relatively fast flowing water or rocky shorelines exposed to strong wave action. Waves produce turbulent conditions similar to those found in streams; therefore, stream taxa are often found on storm beaches. Plecopterans are found almost exclusively in BEA-1, probably because the site has the greatest exposure to wave action.

Table 3. Habitat characteristics for Beatty Cove, Lake Superior, 2012.

SITE NAME	SITE CODE	SAMPLING DATE	LATITUDE	LONGITUDE	WATER TEMP. (°C)	D0 (mg/l)	CONDUCTIVITY (µS/cm)	pH	DOMINANT SUBSTRATE	2nd DOMINANT SUBSTRATE	WOODY DEBRIS
Beatty Cove-1	BEA-1	22-Oct-12			10.6	11.2	~45	8			
Transect #1			48°45'04.19	86°24'48.88			(wave action)		cobble	boulder	present
Transect #2			48°45'04.88	86°24'48.90					cobble	boulder	present
Transect #3			48°45'05.02	86°24'48.58					cobble	boulder	present
Beatty Cove-2	BEA-2	22-Oct-12			10.9	11.7	101	7.9			
Transect #1			48°45'06.88	86°24'47.80					cobble	clay	abundant
Transect #2			48°45'07.10	86°24'47.70					cobble	clay	abundant
Transect #3			48°45'06.02	86°24'47.36					cobble	clay	abundant
Beatty Cove-3	BEA-3	22-Oct-12			11.7	11.6	100	8			
Transect #1			48°45'06.86	86°24'43.18					cobble	clay	abundant
Transect #2			48°45'06.81	86°24'42.44					cobble	clay	abundant
Transect #3			48°45'06.85	86°24'41.47					cobble	clay	abundant

Table 3 cont'd. Habitat characteristics for Beatty Cove, Lake Superior, 2012.

SITE NAME	DETRITUS	RIPARIAN VEG (1.5-10 m)	RIPARIAN VEG (10-30 m)	RIPARIAN VEG (30-100 m)	MACROPHYTES	ALGAE
Beatty Cove-1						
Transect #1	present	none	scrubland	coniferous	absent	slimes
Transect #2	present	none	scrubland	coniferous	absent	slimes
Transect #3	present	none	scrubland	coniferous	absent	slimes
Beatty Cove-2						
Transect #1	present	none	scrubland	scrubland	submergent	slimes
Transect #2	present	none	scrubland	scrubland	submergent	slimes
Transect #3	present	none	scrubland	scrubland	submergent	slimes
Beatty Cove-3						
Transect #1	present	none	scrubland	scrubland	absent	absent
Transect #2	present	none	scrubland	scrubland	submergent	absent
Transect #3	present	none	scrubland	scrubland	submergent	absent

Table 4. Benthic macroinvertebrates from Beatty Cove-1 (BEA-1), Lake Superior, Ontario, 2012.

		Beatty Cove BEA-1-1 Transect #1 22-Oct	**Beatty Cove BEA-1-2** Transect #2 22-Oct	**Beatty Cove BEA-1-3** Transect #3 22-Oct
COELENTERATA		3	4	2
PLATYHELMINTHES		38	29	18
NEMATODA				
MOLLUSCA				
Gastropoda				
Hydrobiidae			1	
Lymnaeidae				
Physidae				
Planorbidae				1
Valvatidae				
Bivalvia				
Sphaeriidae		3	1	3
ANNELIDA				
Oligochaeta		1	1	18
Hirudinea		1		1
ARTHROPODA				
Hydracarina		1	4	1
Amphipoda				
Hyalellidae	*Hyalella*			
Gammaridae	*Gammarus*	21	34	39
Isopoda				
Asellidae	*Caecidotea*	13	14	13
Insecta				
Ephemeroptera				1
Heptageniidae	Juvenile/damaged	4	2	1
	Heptagenia	5	9	
	Leucrocuta			2
Ephemeridae	*Hexagenia*			9
Plecoptera	Juvenile/damaged			
Nemouridae	*Nemoura*	5	2	2
Perlodidae	*Isoperla*		1	
Hemiptera				
Corixidae	*Corisella*	6	3	
Trichoptera	Juvenile/damaged/ Pupa		1	
Polycentropodidae	*Polycentropus*			
Hydropsychidae	Juvenile	2	2	
	Cheumatopsyche	5	1	3
	Hydropsyche		1	
Lepidostomatidae	*Lepidostoma*	2	4	5
Limnephilidae	*Pycnopsyche*			1
Leptoceridae	Juvenile/damaged			
	Mystacides	2		2
Lepidoptera				
Crambidae				
Diptera				
Ceratopogonidae	*Probezzia*			
Chironomidae		1	1	1
Empididae	*Chelifera*			
	Chelifera/Metachela	2	1	3
	Hemerodromia	1		
Total number of individuals		116	116	126
% Sorted		4.7	3.0	2.1

Table 5. Benthic macroinvertebrates from Beatty Cove-2 (BEA-2), Lake Superior, Ontario, 2012.

		Beatty Cove BEA-2-1 Transect #1 22-Oct	**Beatty Cove BEA-2-2** Transect #2 22-Oct	**Beatty Cove BEA-2-3** Transect #3 22-Oct
COELENTERATA				
PLATYHELMINTHES			1	1
NEMATODA				2
MOLLUSCA				
Gastropoda		2	2	
Hydrobiidae				
Lymnaeidae		4	3	1
Physidae			7	
Planorbidae		10	2	7
Valvatidae			3	1
Bivalvia				
Sphaeriidae		1	1	1
ANNELIDA				
Oligochaeta		9	10	10
Hirudinea		1		
ARTHROPODA				
Hydracarina				1
Amphipoda				
Hyalellidae	*Hyalella*		2	
Gammaridae	*Gammarus*	52	56	48
Isopoda				
Asellidae	*Caecidotea*	7	16	16
Insecta				
Ephemeroptera				
Heptageniidae	Juvenile/damaged			4
	Heptagenia		4	1
	Leucrocuta	2	3	4
Ephemeridae	*Hexagenia*			
Plecoptera	Juvenile/damaged			
Nemouridae	*Nemoura*			
Perlodidae	*Isoperla*			
Hemiptera				
Corixidae	*Corisella*	4	4	5
Trichoptera	Juvenile/damaged/ Pupa		1	
Polycentropodidae	*Polycentropus*			
Hydropsychidae	Juvenile	1		
	Cheumatopsyche	1		1
	Hydropsyche		1	
Lepidostomatidae	*Lepidostoma*	1	1	1
Limnephilidae	*Pycnopsyche*			
Leptoceridae	Juvenile/damaged	1	1	
	Mystacides	1	3	3
Lepidoptera				
Crambidae			1	
Diptera				
Ceratopogonidae	*Probezzia*			1
Chironomidae		3	2	1
Empididae	*Chelifera*			
	Chelifera/Metachela	1	2	6
	Hemerodromia			
Total number of individuals		101	126	115
% Sorted		4.5	7.7	10.5

Table 6. Benthic macroinvertebrates from Beatty Cove-3 (BEA-3), Lake Superior, Ontario, 2012.

		Beatty Cove BEA-3-1 Transect #1 22-Oct	**Beatty Cove BEA-3-2** Transect #2 22-Oct	**Beatty Cove BEA-3-3** Transect #3 22-Oct	**Beatty Cove Quality Control BEA-3-3** Transect #3 22-Oct
COELENTERATA					
PLATYHELMINTHES					
NEMATODA		1	1		
MOLLUSCA					
Gastropoda			1	1	1
Hydrobiidae					
Lymnaeidae		1			
Physidae					
Planorbidae		4	1		
Valvatidae					
Bivalvia					
Sphaeriidae					
ANNELIDA					
Oligochaeta		15	22	41	60
Hirudinea		2		2	
ARTHROPODA					
Hydracarina					
Amphipoda					
Hyalellidae	*Hyalella*				
Gammaridae	*Gammarus*	40	48	36	51
Isopoda					
Asellidae	*Caecidotea*	11	10	8	8
Insecta					
Ephemeroptera					
Heptageniidae	Juvenile/damaged	4	1		1
	Heptagenia		1	2	3
	Leucrocuta	3	3	4	3
Ephemeridae	*Hexagenia*				
Plecoptera	Juvenile/damaged				
Nemouridae	*Nemoura*	1			
Perlodidae	*Isoperla*				
Hemiptera					
Corixidae	*Corisella*	17	27	6	7
Trichoptera	Juvenile/damaged/ Pupa				
Polycentropodidae	*Polycentropus*				1
Hydropsychidae	Juvenile				
	Cheumatopsyche				
	Hydropsyche				
Lepidostomatidae	*Lepidostoma*				
Limnephilidae	*Pycnopsyche*				
Leptoceridae	Juvenile/damaged				
	Mystacides	1		1	
Lepidoptera					
Crambidae		2	1	1	2
Diptera					
Ceratopogonidae	*Probezzia*				
Chironomidae			1		4
Empididae	*Chelifera*				
	Chelifera/Metachela			1	
	Hemerodromia	1		1	
Total number of individuals		103	117	104	141
% Sorted		9.2	5.5	4.6	6.2

Table 7. Mean biotic Indices, Beatty Cove, Lake Superior, Ontario, 2012.

Site	Richness	H' Diversity	Hilsenhoff Biotic Index	% Dominants	% EPT	% Chironomids	% Worms	% Crustacea
BEA-1	14.0	2.05	5.92	31.0	20.7	0.8	5.3	37.3
BEA-2	12.0	1.77	6.35	46.4	10.1	1.8	8.5	57.6
BEA-3	10.3	1.65	6.47	39.8	6.6	0.3	24.3	47.1

Chironomidae were low in abundance (n≤4) at all the sites (Tables 4-6), possibly indicating an unimpaired habitat. A high abundance of chironomids usually indicates impairment caused by anaerobic conditions associated with eutrophication/high organic content, high chemical oxygen demand and/or toxic chemicals (Environmental Protection Agency 2009a). Chironomids are often the last surviving benthic macroinvertebrates in an aquatic community because of their ability to tolerate low oxygen concentrations and toxic chemicals. The presence of EPT indicates that extremely low oxygen concentrations and high concentrations of toxic chemicals did not occur during the life cycle of these species. The low numbers of Chironomids probably reflects predation within a diverse, healthy macroinvertebrate community.

The lowest abundance of worms in the benthic communities was at site BEA-1 in transect BEA-1-1 (n=2) and transect BEA-1-2 (n=1) (Table 4). The remaining transects all contained 10 or more worms (Tables 4-6). None of the sites were dominated by worms, indicating that Beatty Cove was not particularly affected by anthropogenic inputs. BEA-2 and BEA-3 are closer to the north end of the cove, and therefore more sheltered from waves. Consequently these sites also contained an abundance of woody debris and had submergent vegetation (Table 3) which makes better habitat for worms, possibly explaining the increase in the number of worms at BEA-2 and BEA-3. Worms are intolerant of toxic substances, and are usually indicative of a nutrient/organically enriched habitat that may periodically experience low dissolved oxygen concentrations (DO) (Environmental Protection Agency 2009b). The DO in Beatty Cove was at saturation when tested (11.2-11.7 mg/l) (Table 3). DO is unlikely to fall below the cold water level for “early life stages” (9.5mg/l) or “other life stages” (6.5mg/l) (Canadian Council of Ministers of the Environment 1999) because of wave action and water currents in the cove. Also, species with a high oxygen demand such as EPT were well represented in the macroinvertebrate communities at all three sites as mentioned above, indicating that DO remains high throughout the entire year. Woody debris was abundant; however, decay of the debris was not depleting DO in Beatty cove.

Crustacea

Crustacea, which include Amphipoda and Isopoda, were abundant in the aquatic benthic macroinvertebrate communities at all sites with no fewer than 34 individuals in any transect (BEA-1-1 Table 4) in Beatty Cove (Tables 4-6). Crustacea are moderately pollution tolerant scavengers that thrive in areas with organic enrichment that experience only minor oxygen stress. The presence of woody debris and detritus at all the sites in combination with high DO (Table 3) provided ideal habitat for Crustacea. The abundance of Crustacea indicates that Beatty Cove is organically enriched, but the low number of Chironomids and Worms, plus the presence of EPT indicates that Beatty Cove is only mildly impaired.

Mean Biotic Indices

A range of values for biotic indices indicative of reference conditions was obtained from analysis of sites on Lake Nipigon and the Black Sturgeon River. Biotic index values from the reference condition sites were rated qualitatively from extremely high, to very high, high, moderately high, moderate, moderately low, low, very low to extremely low. For example a value of 60 is considered extremely high for % Chironomids, while a value of 15 is considered extremely low, whereas a value of 30 is considered extremely high for % Worms, while a value of 0.5 is considered extremely low. These reference values were used to grade the mean biotic indices obtained from Beatty Cove.

Beatty Cove-1

Beatty Cove-1 (BEA-1) (Fig. 2a, 2b) is located at the mouth of the cove and has a cobble/boulder bottom that is exposed to wave action (Table 3). Beatty Cove-1 had extremely high values for Richness (14.0) and Shannon's H' Diversity (2.06) (Table 7). The Hilsenhoff Biotic Index (5.92) was considered moderate for a lentic habitat. The % Dominants (31.0) was very low and the % Chironomids (0.8) was extremely low. The % Worms (5.3) was extremely low and the % EPT (20.7) was low. The % Crustacea (37.3) was high. Crustacea are scavengers that thrive in areas with organic enrichment that experience only minor oxygen stress. The high Richness and Shannon's H' Diversity, the moderate Hilsenhoff Biotic Index, the low % Chironomids and % Worms, plus the presence of EPT indicate that BEA-1 is relatively unimpaired. The high % Crustacea indicates that organic enrichment, probably in the form of woody debris, occurs in Beatty Cove.

Beatty Cove-2

Beatty Cove-2 (BEA-2) (Fig. 3a, 3b) is a site with a cobble/clay bottom that is somewhat exposed to wave action (Table 3). Beatty Cove-2 had a very high value for Richness (12.0) (Table 7). Shannon's H' Diversity (1.77) and the Hilsenhoff Biotic Index (6.35) were high. The % Dominants (46.4) was moderate. The % Chironomids (1.8) was extremely low while the % Worms (8.5) and the % EPT (10.1) were very low. The % Crustacea (57.6) was extremely high. Beatty Cove-2 is relatively unimpaired; however, the high Hilsenhoff Biotic Index and the extremely high % Crustacea indicate that BEA-2 probably has an even higher woody debris component than BEA-1.

Fig.2a View of Beatty Cove-1 (BEA-1), looking back towards shore.

Fig.2b View of Beatty Cove-1 (BEA-1), looking south along western shoreline of Beatty Cove.

Fig.3a View of Beatty Cove-2 (BEA-2), looking back towards shore.

Fig.3b View of Beatty Cove-2 (BEA-2), looking south from transect towards Peninsula Harbour.

Beatty Cove-3

Beatty Cove-3 (BEA-3) (Fig. 4a, 4b) is a site with a cobble/clay bottom that is less exposed to wave action than Beatty Cove-2 (Table 3). Beatty Cove-3 had moderately high values for Richness (10.3) and Shannon's H' Diversity (1.65) (Table 7). The Hilsenhoff Biotic Index was high (6.47) and % Dominants (39.8) was moderately low. The % Chironomids (0.3) was extremely low. The % Worms (24.3) was moderate. The % EPT (6.6) was extremely low. The % Crustacea (47.1) was very high. The high Hilsenhoff Biotic Index, the moderate % Worms and the high % Crustacea indicate that BEA-3 probably has a higher woody debris content than BEA-2, although overall the site is still relatively unimpaired.

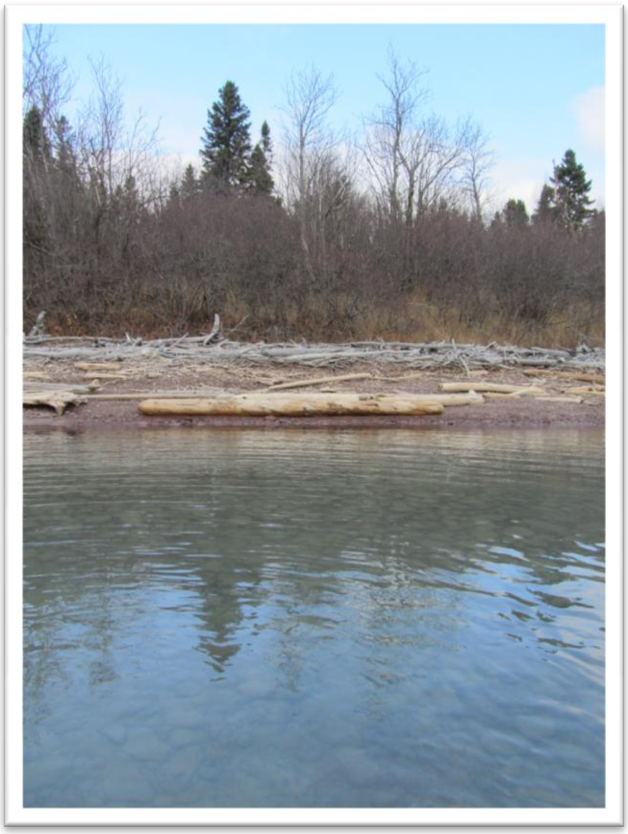


Fig.4a View of Beatty Cove-3 (BEA-3), looking back towards shore.

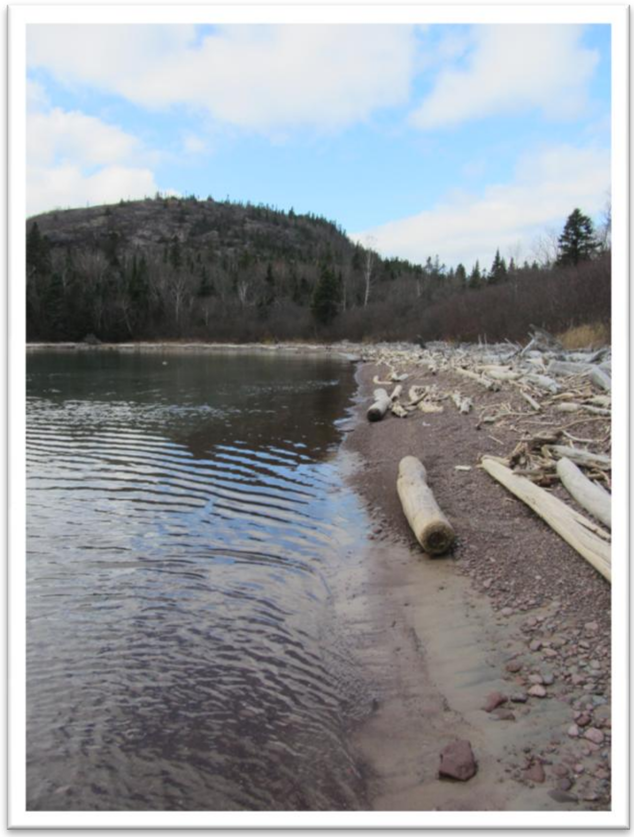


Fig.3a View of Beatty Cove 3 (BEA-3), looking west along shoreline.

CONCLUSION

Analysis of the composition of macroinvertebrate communities in Beatty Cove indicates that Beatty Cove is relatively unimpaired except for minor organic enrichment from woody debris. Crustacea comprise a large component of the macroinvertebrate communities probably because of the favourable habitat provided by the woody debris and the high DO in the cove. Overall, the relatively high density of aquatic benthic macroinvertebrates in Beatty Cove should provide abundant forage for fish. Woody debris should continue to dissipate from year-to-year; therefore, conditions within the cove should continue to improve.

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Contaminants in Peninsula Harbour Fish

A report from an analysis of long-term monitoring data

Prepared for: Environment Canada and Climate Change

Prepared by: Prof. Ken Drouillard, University of Windsor

March 30, 2019

Executive summary

Peninsula Harbour was listed as an Area of Concern in 1987 due to impairment of many beneficial uses (BUI). Elevated levels of mercury and PCB in fish from the harbour were responsible for the fish component of the Restrictions on Fish and Wildlife Consumption BUI at the AOC. The pulp and paper mill at the town of Marathon was identified as the major source of contaminants. Various improvement taken at the mill over the decades, the 1995 federal and provincial Municipal Industrial Strategy for Abatement, and a sediment remediation project conducted at the harbour in 2012 should have improved the fish contaminant body burden. The goal of this project was to examine short- and long-term trends in the fish contaminant levels to aid in the assessment of the Fish Consumption BUI.

Two fish species, Lake Trout and Lake Whitefish that have been monitored multiple times between 2012 and 2017, were studied in detail. An analysis of the recent measurements highlighted that mercury, PCB and dioxin-like PCBs are local contaminants of concern. Toxaphene is more of a lake-wide issue for Lake Superior.

There have been substantial decreases of 26%-50% in mercury and about 85% in total PCBs (PCBt) in fish from Peninsula Harbour between 2012 and 2017. There was no appreciable change in the levels of dioxins/furans and dioxin-like PCBs in Lake Trout sampled between 2013 and 2017. Simulated fish consumption advisories using only the recent (2017) measurements highlight that PCB (primary) and mercury (secondary) are still above the fish consumption advisory benchmarks.

The long-term trend analysis showed substantial declines in the levels of both mercury (69%-90%) and PCBt (85%-98%) between the1970s and 2010s. Such a trend analysis was not conducted for TEQ due to insufficient data; however, long-term trends in TEQ would mirror the trends presented for PCB. Toxaphene levels have declined between the late 1980s and 2017. Based on the findings, Toxaphene is not considered a contamination issue for the harbour.

Further decreases in the fish concentrations are expected, especially in response to the sediment remediation conducted at the harbour in 2012. However, the elevated PCB and mercury levels in the recent years still pose a potential health risk to human consumers of harbour fish. Despite an evident decreasing trend in contaminant levels, the outcome of the analysis conducted in this report based on a Tier 1 analysis of the assessment framework does not currently support a redesignation of the Fish Consumption BUI to not impaired. Recommendations are presented for a consideration as the next steps in the assessment of Fish Consumption BUI at Peninsula Harbour.

Background

Peninsula Harbour, at the Town of Marathon on the northeastern shore of Lake Superior, was identified as an Area of Concern (AOC) in 1987 because of degraded water quality caused by discharges of wastewater from the municipal sewage treatment plant and a former pulp mill with an associated chemical plant and log booming (Peninsula Harbour RAP Team, 1991). The beneficial use of Fish Consumption was identified as "impaired" due to consumption advisories in effect at the time. The BUI designation was based on mercury concentrations in larger sizes of Lake Trout, White Sucker, Longnose Sucker and Redhorse Sucker, and polychlorinated binpheynl (PCB) concentrations in some White Sucker exceeding health guidelines at the time (Peninsula Harbour RAP Team, 1991).

The pulp mill started in Marathon in 1946 (ENVIRON, 2008). A chlor-alkali plant, which used mercury as a mobile electrode, was added adjacent to the mill in 1952 to generate chlorine for the bleaching of pulp (ENVIRON, 2008). The mill discharged its effluents directly to Jellicoe Cove until 1983 (ENVIRON, 2008). A primary clarifier was added in 1972 for all effluent streams except the bleach process. In 1977, the chlor-alkali plant was closed (ENVIRON, 2008) possibly due to concerns related to the mercury pollution in the harbour. Between 1977 and 1984, the chlor-alkali plant effluent was treated to remove trace mercury (ENVIRON, 2008). The treatment stopped after 1984 as the mercury contaminated equipment were sealed and properly disposed (ENVIRON, 2008).

It has been recognized for decades that effluents from paper mills contained elevated levels of PCBs (Carr, 1977). Based on the patterns of PCB congeners in the effluents, it was concluded that the use of PCB in carbonless copy paper as an ink carrier or solvent would likely be the major source of PCB in the effluents (Carr, 1977). Environmental concerns over PCB contamination from pulp and paper mills spurred installations of waste treatment processes during the 1970s at such mills (Carr, 1977).

In 1991, the Stage 1 Remedial Action Plan (RAP) report was developed to identify environmental problems for Peninsula Harbour and determine sources of pollution in the AOC (Peninsula Harbour RAP Team, 1991). The Marathon pulp mill was identified as the major point source of contaminant discharges to the AOC. Various changes were made in the early 1990s at the mill to further improve the effluent quality. This included switching to an elemental chlorine free bleaching process in 1991, installation of a diesel backup effluent pump in 1995, and addition of a secondary treatment in 1995. From 1995 until closure of the mill in 2009, treated effluent from the mill was discharged through a submerged diffuser into Lake Superior southeast of the town (Peninsula Harbour RAP Team, 2012).

In 2012, the Government of Canada, Government of Ontario, and industry contributed to a $7 million sediment remediation project that placed 15-20 cm of clean sand and gravel on top of the most contaminated sediment in the AOC at Jellicoe Cove. This thin-layer cap is expected to create clean fish habitat, stop the spread of contaminated sediment, and reduce risk to fish, fish eating birds, mammals and people. The thin-layer cap was also the last remedial action required to restore water quality and ecosystem health in this AOC.

In order to delist the AOC, the remaining beneficial use impairments, including Restrictions on Fish Consumption, need to be assessed to build a case for changing the official designation to "not impaired".

Project goal and objectives

The goal of this project was to examine fish contaminant monitoring data collected for Peninsula Harbour to aid in the assessment of the Restrictions on Fish Consumption beneficial use impairment.

The specific objectives of the project were to:

1. Compile existing fish contaminant monitoring data for the AOC,
2. Examine recent contaminant levels in fish from the AOC, and
3. Perform statistical analysis on the long-term trends in the fish contaminant levels.

The project aims at conducting Tier 1 level analysis of the three tier Fish Consumption BUI Assessment Framework recently presented by Bhavsar et al. (2018) and shown in Appendix Figure A1.

Data compilation

Fish contaminant monitoring data collected by Ontario Ministry of the Environment, Conservation and Parks' Fish Contaminant Monitoring Program were acquired and compiled into spreadsheets. In total, there were 14,925 test measurements available for Peninsula Harbour collected between 1973 and 2017. Skinless, boneless fillets of 13 types of fish namely Lake Trout (*Salvelinus namaycush*), Lake Whitefish (*Coregonus clupeaformis*), Longnose Sucker (*Catostomus Catostomus*), White Sucker (*Catostomus commersonii*), Ling (Burbot) (*Lota lota*), Gizzard Shad (*Dorosoma*), Rainbow Trout (*Oncorhynchus mykiss*), Rainbow Smelt (*Osmerus mordax*), Cisco (Lake Herring) (*Coregonus artedi*), Redhorse Sucker (*Moxostoma carinatum*), Northern Pike (*Esox*

Lucius), Round Whitefish (*Prosopium cylindraceum*), and Walleye (*Sander vitreus*) have been monitored at a varying frequency.

Monitoring of different contaminant classes began at different time points with mercury initiated in 1973, total PCB (PCBt) and organochlorine pesticides in 1973, Toxaphene and Octachlorostyrene were added in 1986, and dioxins/furans and dioxin-like PCBs in the 1990s.

Dioxins and furans are common names for 210 related toxic chemicals that are found in very small amounts in the environment. Exposure to dioxins and furans has been associated with a wide range of adverse health effects in laboratory animals and humans. PCBs are 209 related chemicals that impact human health, including contributing to cancer (De Roos et al., 2005). Twelve PCBs are widely known as dioxin-like PCBs (DLPCB) because they interact with organisms by the same mechanism as the most toxic dioxin compound, 2,3,7,8-tetrachlorodibenzo-p-dioxin (2,3,7,8-TCDD) (van den Berg et al., 2006). Dioxin-like PCBs are among the most toxic PCBs and can drive a risk assessment of PCBs in the environment.

Toxicity potential of dioxins/furans and DLPCBs varies over five orders of magnitude (van den Berg et al., 2006). After careful review of available scientific data, the toxic equivalency factors (TEFs), defined as the toxicity relative to that of 2,3,7,8-TCDD, have been assigned to each of the 17 most dioxins/furans and 12 DLPCBs. A toxic equivalent concentration (TEQ) can be calculated for each sample by summing the multiplication of the concentration of each compound with compound-specific TEF.

The TEQs ($TEQ_{Dioxins/Furans}$ and TEQ_{DLPCB}) in this study were calculated using mammalian TEFs published by the World Health Organization in 2005. The below detection measurements were replaced with concentrations at half of the detection limits. The TEQ_{Total} concentrations were calculated by adding $TEQ_{Dioxins/Furans}$ and TEQ_{DLPCB} for each sample.

Recent levels of contaminants in Peninsula Harbour fish

Comparison with fish advisory benchmarks

First, monitoring data collected since the installation of the thin-layer cap in 2012 were examined to understand significance of the levels observed in the recent years and identify potential contaminants of concern. The maximum concentration observed for all types of contaminants monitored were compared to the fish consumption advisory benchmarks for at least 8 meals/month advisory set by the Government of Ontario (OMOECC, 2017).

Table 1: Fish advisory benchmarks for at least 8 meals/month and range in concentrations of various contaminants observed in three types of fish monitored at Peninsula Harbour between 2012 and 2017. Contaminants that exceeded the benchmarks in at least one fish species have been highlighted in bold.

Test	Benchmark	Lake Trout	Lake Whitefish	Longnose Sucker
Aldrin	117	<1	<1	<1
DDT & Metabolites	5000	<2-340	<2-46	<2-18
Hexachlorobenzene	317	<1-17	<1-3	<1-2
Mercury	0.25*, 0.6**	0.09-**1.3**	0.07-**0.4**	0.15-**0.67**
Mirex	82	<5-6	<5	<5
Octachlorostyrene	364	<1-4	<1	<1
PCB; total	105	45-**6600**	<20-**2400**	**130-2700**
Photomirex	15	<4	<4	<4
TEQ total	2.7	1.3-**36**	0.7-1.5	
Total Technical Chlordane	59	<2-56	<2-8	<2-3
Toxaphene	235	<50-**1100**	<50-170	<50-87

* for the sensitive population (women of child-bearing age and children under 15);

** for the general population; NA – not available

As shown in Table 1, maximum concentrations of mercury and PCBt in all three types of fish monitored, namely Lake Trout, Lake Whitefish and Longnose Sucker, exceeded their respective benchmarks. The maximum TEQ_{Total} and Toxaphene in Lake Trout also exceeded their benchmarks; however, they did not exceed the benchmarks in Lake Whitefish and Longnose Sucker (TEQ was not available for Longnose Sucker). The maximum mercury levels exceeded by 1.1 to 5.2 times the benchmark, PCBt levels exceeded by 23 to 63 times, TEQ_{Total} (predominantly from dioxin-like PCBs as explained later) exceeded by 13 times, and Toxaphene exceeded by 5 times. These exceedances, especially of PCBt, do not outright support a redesignation of the Fish Consumption Beneficial Use Impairment (BUI) to "not impaired" based on the Tier 1 analysis of Fish Consumption BUI Assessment Framework (Bhavsar et al., 2018).

Contaminants of local and regional concern

The comparison with fish consumption advisory benchmarks highlighted that mercury and PCB potentially continue to be of concern. The levels of dioxins/furans and dioxin-like PCBs may also be an issue. Toxaphene is the only organochlorine pesticide that exceeded the benchmark.

Mercury and PCBt were identified as contaminants of concern for Peninsula Harbour in the Stage 1 RAP process. Dioxins/furans, which could be released from a pulp and paper mill, were possibly not known contaminants when the harbour was identified as an AOC because their monitoring did not begin until the 1990s due to lack of availability of reliable analytical methods. Dioxins/furans are produced during pulp bleaching, where they are formed from chlorinated phenols. As such, they could be a legitimate contaminant of concern even though their elevated levels were not a reason for the initial BUI impairment status. However, as discussed in detail later, the majority of the contribution to TEQ_{Total} comes from dioxin-like PCBs, not dioxins/furans. Therefore, dioxins/furans are not considered a major contaminant of local concern in the AOC.

Toxaphene was not identified as a contaminant of concern likely because its monitoring in the harbour did not start until 1986 (around the time when the AOC was identified). Toxaphene is a general term used for a group of chlorinated camphene compounds introduced as an insecticide in 1947. Toxaphene was mainly used on cotton crops in the southeastern United States and entered the Great Lakes via long-range transport and deposition combined with direct runoff. Toxaphene applied to crops within the Great Lakes basin likely contributed to the elevated levels in Lakes Michigan, Erie, and Ontario as these watersheds directly receive agricultural inputs. In contrast, Toxaphene has been a lake-wide issue for Lake Superior due to an increased atmospheric deposition under the colder weather. There was no known direct emissions of Toxaphene to Peninsula Harbour. As such, Toxaphene was not considered a contaminant of local concern in this assessment. A long-term trend analysis was, however, conducted in the next section to evaluate if Toxaphene levels are declining as a result of the ban on their use in the U.S. and Canada in the 1980s and or related to clean-up actions completed within the AOC.

Short-term contaminant trends

A short-term change analysis was conducted for the recent measurements of contaminants of concern mainly mercury and PCBt, but also TEQ_{DLPCB} and $TEQ_{Dioxins/Furans}$ (along with TEQ_{Total}). The data collected between 2012 and 2017 for the three monitored species namely Lake Trout, Lake Whitefish and Longnose Sucker were considered. However, Longnose Sucker was sampled only once; as such, it was not considered in the short-term change analysis.

Figure 1: Levels of mercury (µg/g), PCBt (ng/g) and TEQ (pg/g; D/F dioxins/furans; DL – dioxin-like PCB) measured in Peninsula Harbour fish between 2012 and 2017.

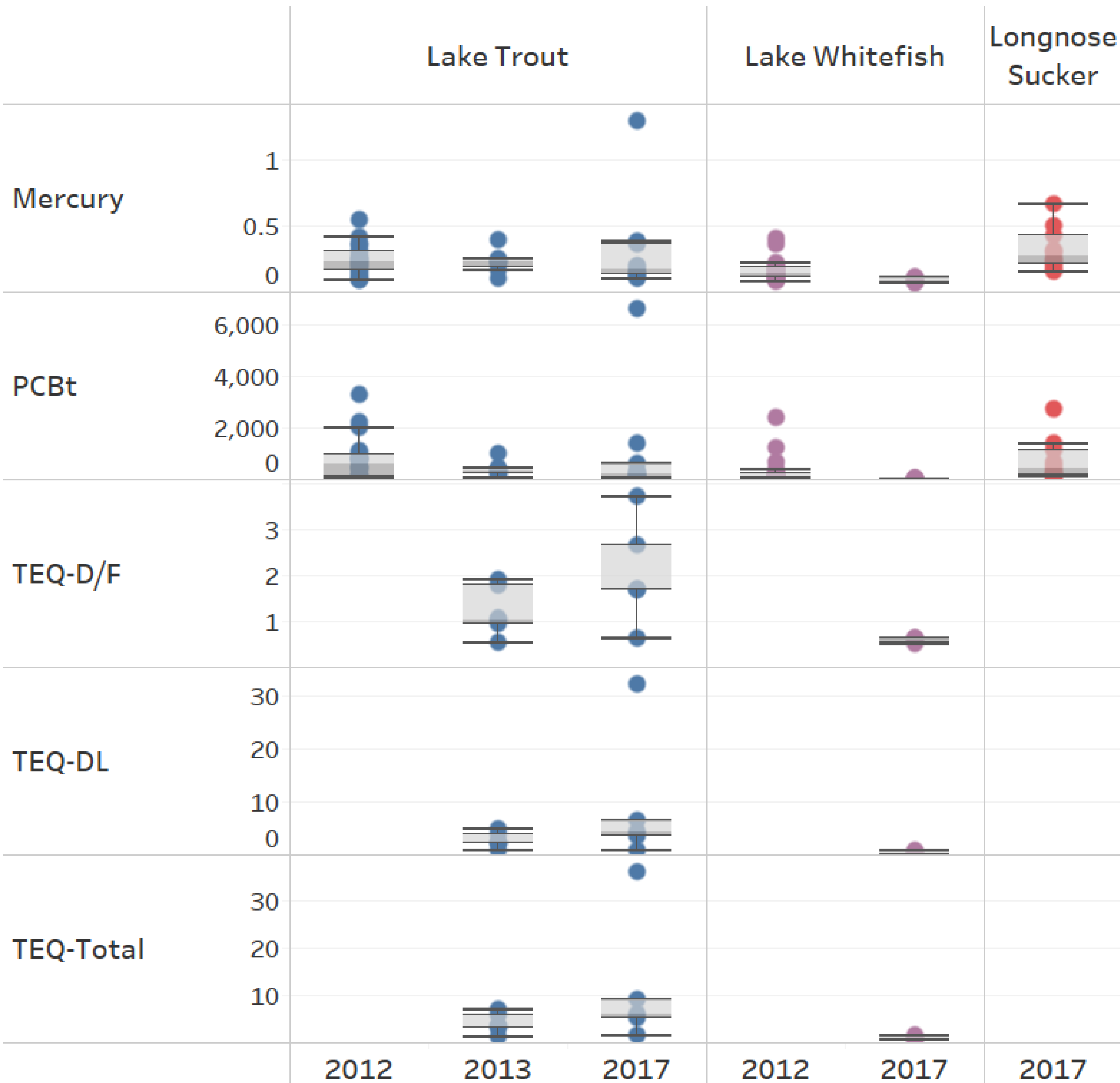


Figure 1 shows all the measurements for the select contaminants by year and fish type regardless of their sizes. The observations for Lake Trout indicate stable levels of mercury, PCBt and TEQ_{Total}, while the observations for Lake Whitefish suggest a decline in mercury and PCBt levels between 2012 and 2017. Since Lake Whitefish samples collected in 2012 were not monitored for dioxin/furan/dioxin-like PCB compounds, a short-term change for this fish could not be derived for TEQ_{Total}.

Lake Whitefish

Next, potential differences in fish sizes of the samples from the different sampling events were accounted for in the short-term change analysis. Figure 2 shows mercury and PCBt in Lake Whitefish for 2012 and 2017 against fish lengths. These graphs highlight that the Whitefish samples collected in 2017 were smaller than those sampled in 2012.

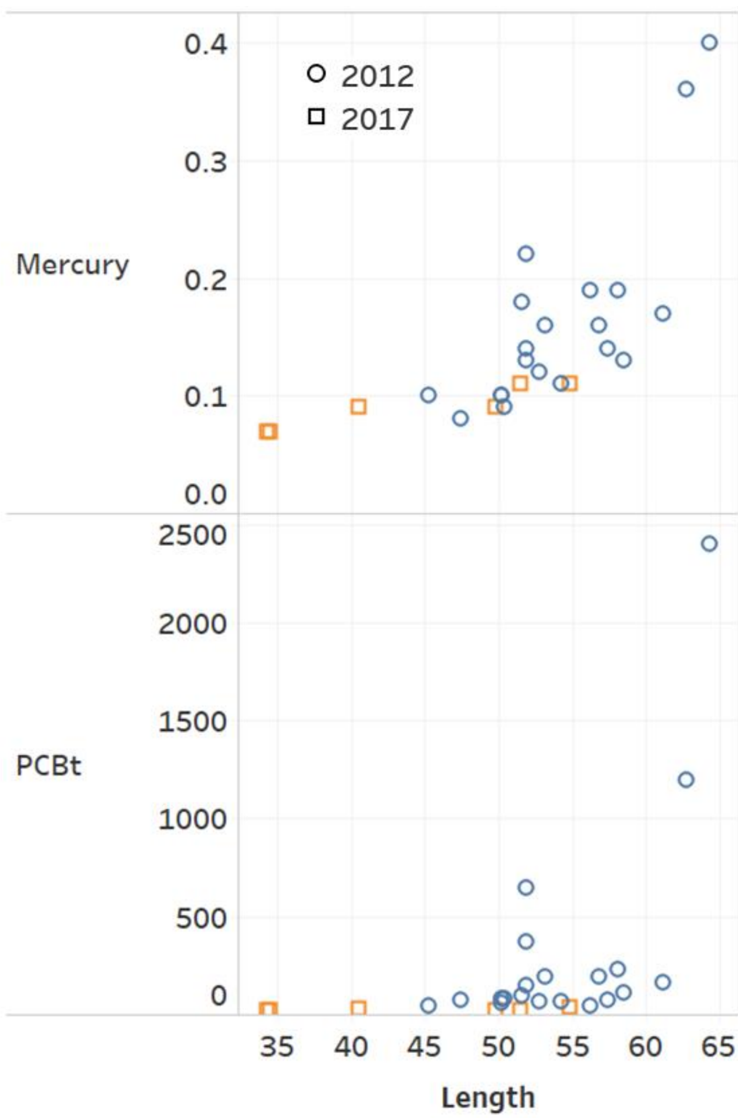


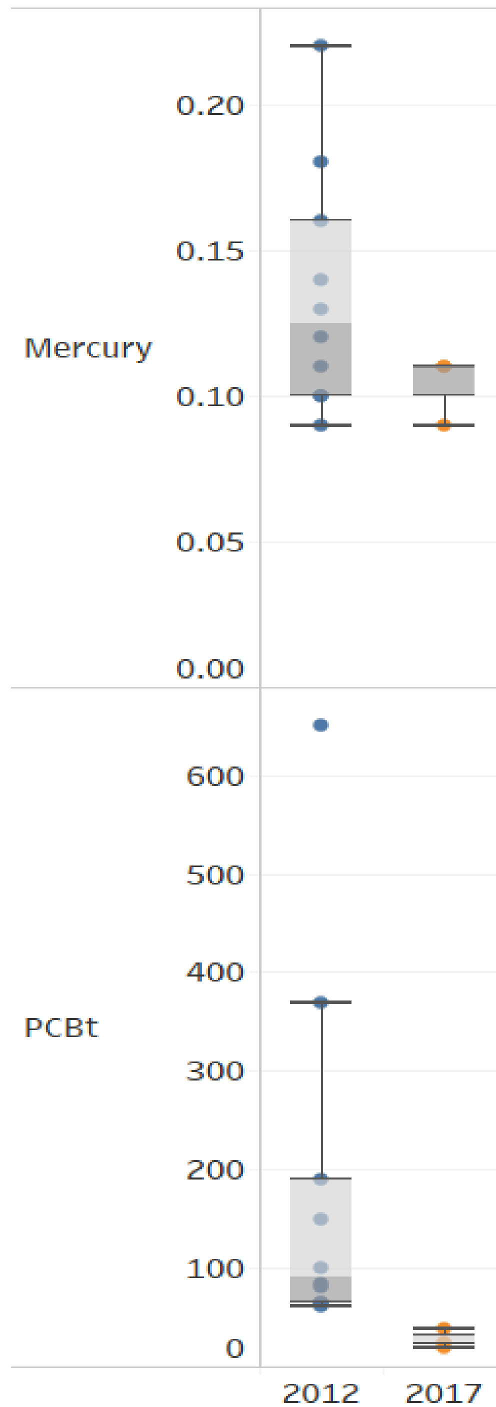
Figure 2: Concentrations of mercury (µg/g) and PCBt (ng/g) in Lake Whitefish collected from Peninsula Harbour in 2012 and 2017. Fish lengths are in cm.

A short-term temporal comparison was conducted for Lake Whitefish using a small overlapping size range of 50 to 55 cm. As shown in Figure 3, the levels of both mercury and PCBt were much lower in 2017 than in 2012 when only the similar sized fish were considered.

The mercury concentrations ranged from 0.09-0.22 µg/g (average 0.135 µg/g) in 2012 and declined to 0.09-0.11 µg/g (average 0.10 µg/g) in 2017, implying on average 26% decrease, which was statistically significant (p-value 0.05).

The PCBt concentrations ranged from 62-650 ng/g (average 182 ng/g) in 2012 and declined to <20 (detection limit) to 39 ng/g (average 28 ng/g) in 2017, implying on average 85% decrease, which was statistically significant (p-value 0.03).

Figure 3: Box plots of concentrations of mercury (µg/g) and PCBt (ng/g) in 50-55 cm Lake Whitefish collected from Peninsula Harbour in 2012 and 2017.

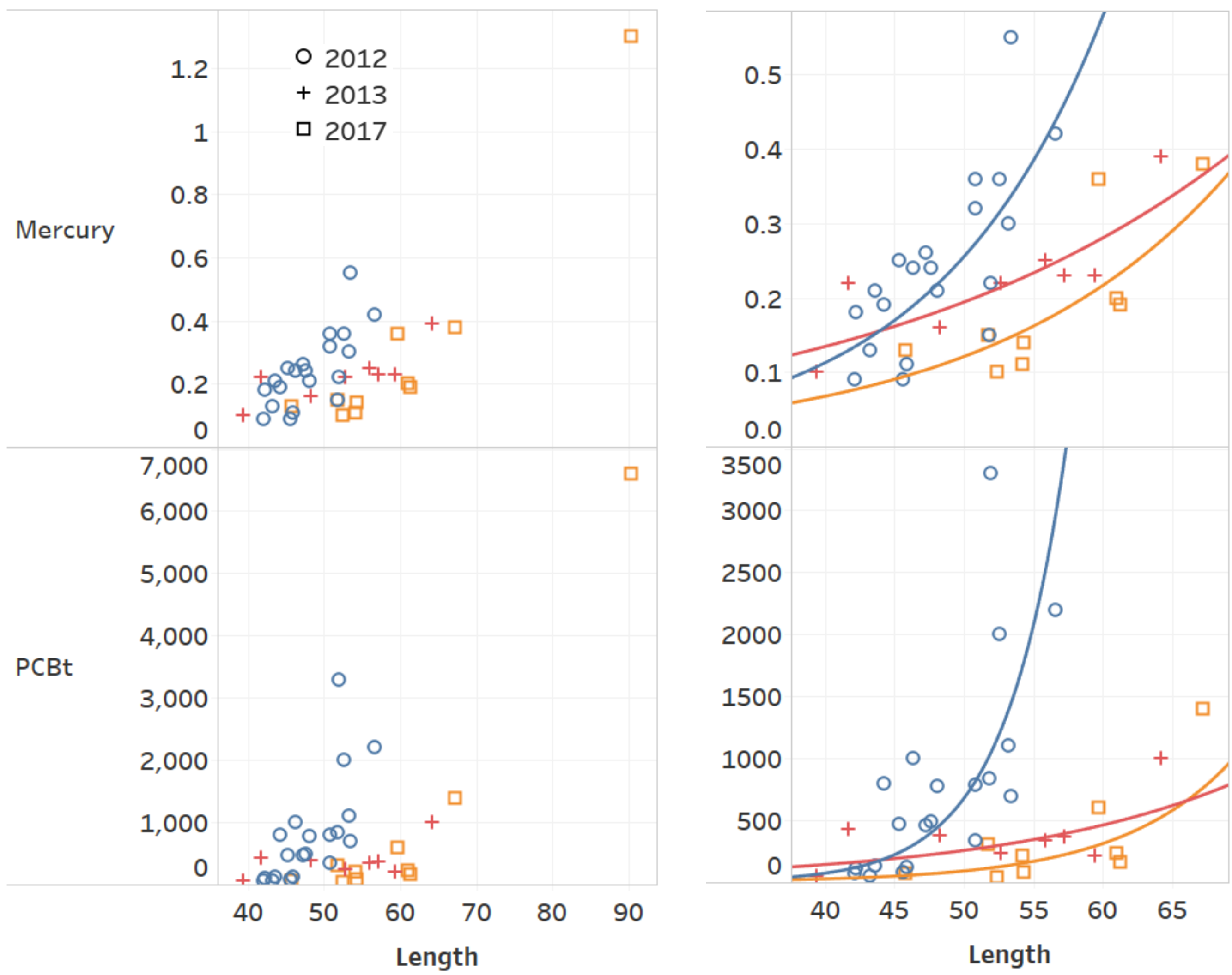


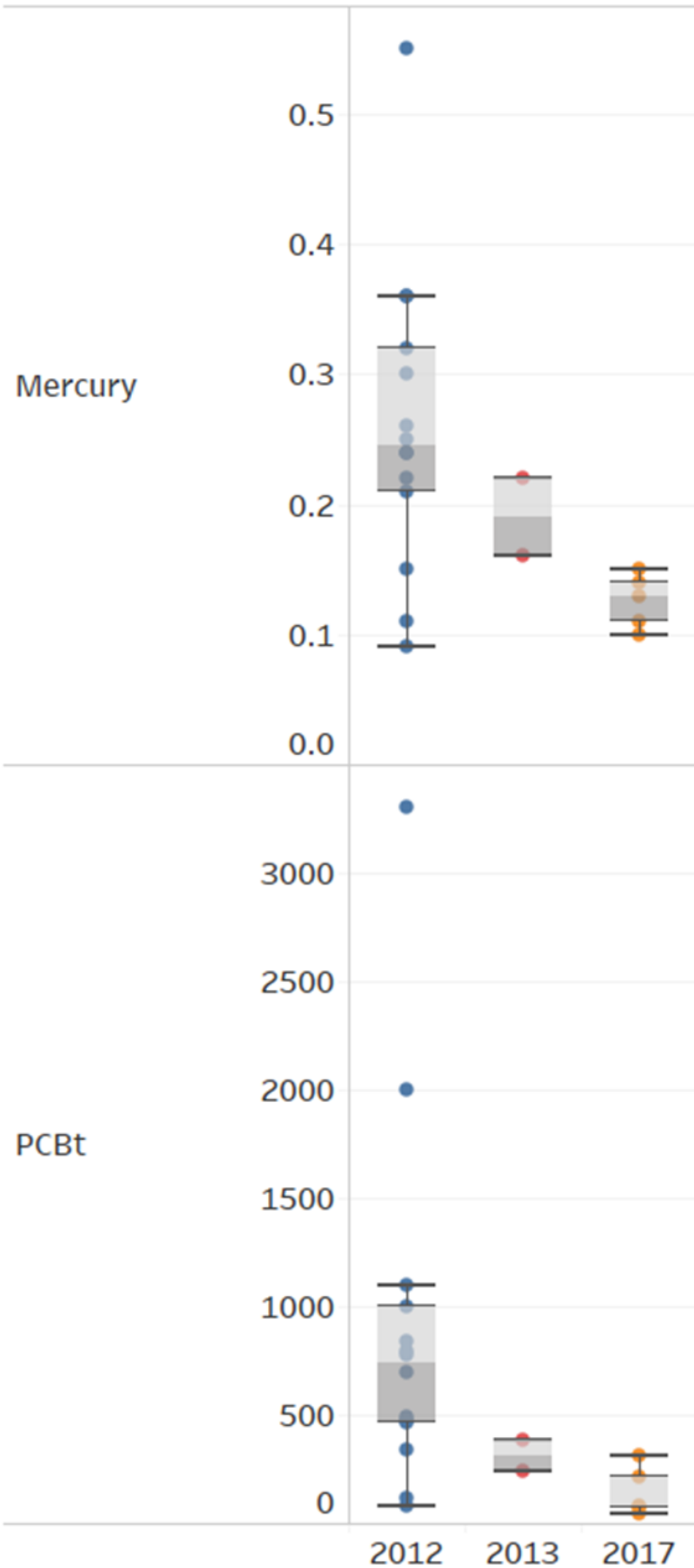
Lake Trout

Figure 4 shows fish lengths against the mercury and PCBt in Lake Trout sampled in 2012, 2013 and 2017. These graphs highlight that a single large sized (90.3 cm) Lake Trout sample collected in 2017 containing higher mercury and PCBt levels could have biased the short-term change analysis shown in Figure 1.

A comparison conducted after removing the measurements for this outlier sized fish showed generally lowered mercury and PCBt levels in 2013 and 2017 compared to 2012 (Figure 4).

Figure 4: Concentrations of mercury (µg/g) and PCBt (ng/g) in Lake Trout collected from Peninsula Harbour in 2012, 2013 and 2017. Fish lengths are in cm. Right graphics replicate left with large 2017 outlier fish removed.





Next, a short-term temporal comparison was conducted for Lake Trout using a small overlapping size range of 45 to 55 cm. As shown in Figure 5, the levels of both mercury and PCBt gradually declined from 2012 to 2013 and 2017.

The mercury concentrations ranged from 0.09-0.55 µg/g (average 0.26 µg/g) in 2012 and declined to 0.16-0.22 µg/g (average 0.19 µg/g) in 2013 and 0.1-0.15 µg/g (average 0.13 µg/g) in 2017, implying on average 50% decrease between 2012 and 2017. The decline was statistically significant at p-value of <0.001.

The PCBt concentrations ranged from 82-3300 ng/g (average 891 ng/g) in 2012 and declined to 240-380 ng/g (average 310 ng/g) in 2013, and 45-310 ng/g (average 143 ng/g) in 2017, implying on average 84% decrease. The decline was statistically significant at p-value of <0.01.

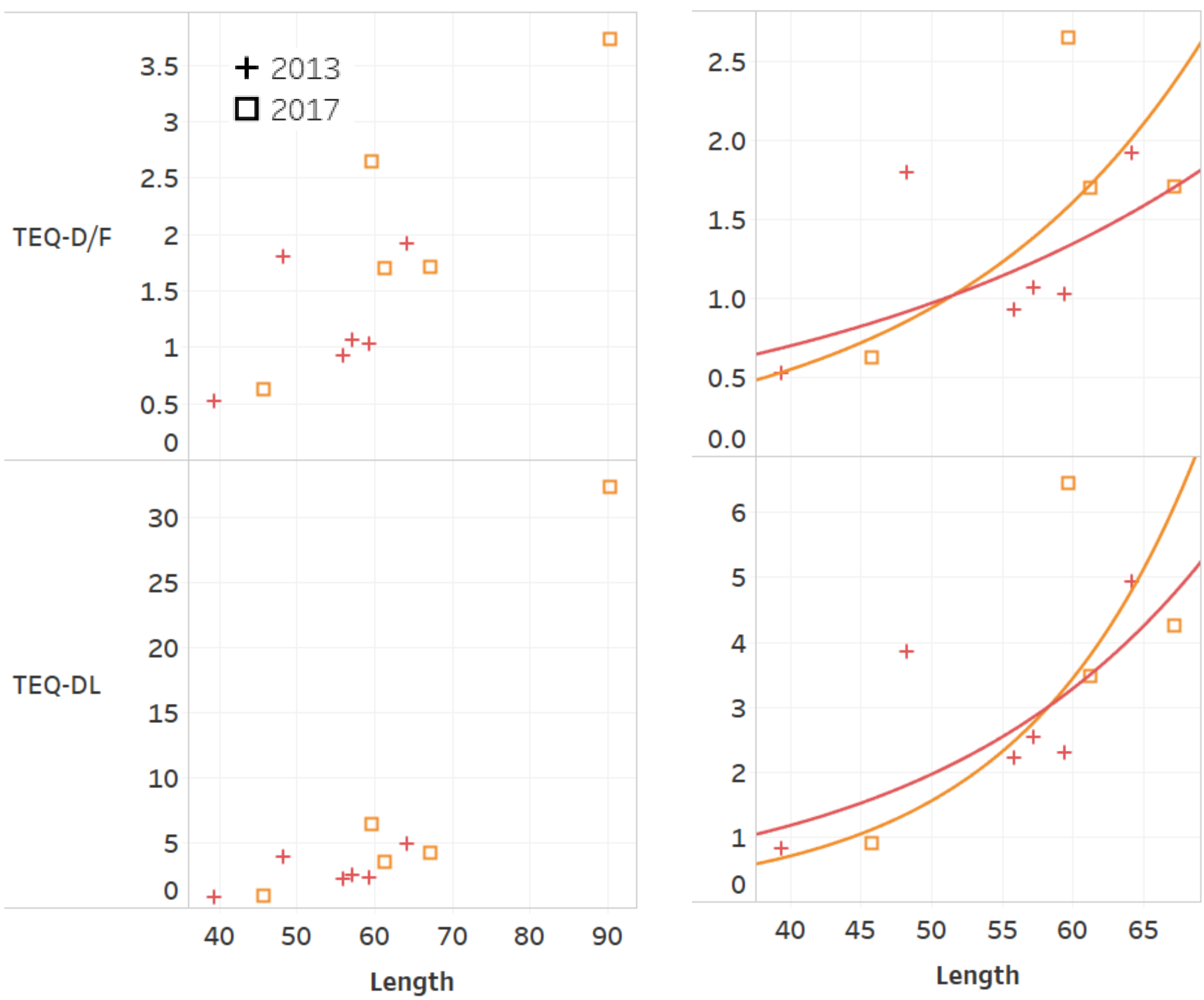
Figure 5: Box plots of concentrations of mercury (µg/g) and PCBt (ng/g) in 45-55 cm Lake Trout collected from Peninsula Harbour in 2012, 2013 and 2017.

Overall, the results show that there have been substantial decreases of 26%-50% in mercury and about 85% in PCBt in fish sampled from Peninsula Harbour between 2012 and 2017.

Dioxins-furans and dioxin-like PCBs

Dioxins-furans and dioxin-like PCBs were measured in Lake Trout collected from the harbor in 2013 and 2017. A comparison of the TEQs showed no appreciable change in the levels of dioxins/furans and dioxin-like PCBs in Lake Trout during the time periods (Figure 6).

Figure 6: Concentrations of dioxin/furan TEQ (TEQ-D/F; pg/g) and dioxin-like PCB TEQ (TEQ-DL; pg/g) in Lake Trout collected from Peninsula Harbour in 2013 and 2017. Fish lengths are in cm.



Significance of the 2017 contaminant levels

Legacy contaminants in Peninsula Harbour can present a risk to human consumers of fish from the harbour. Fish consumption advisories aimed at guiding people towards safe consumption of fish have been issued for the Great Lakes by the Government of Ontario since the 1970s. The advisory benchmarks used by Ontario are based on the tolerable daily intakes from Health Canada (OMOECC, 2017). The advisory benchmarks for mercury, PCBt, TEQ_{Total}, and Toxaphene have been presented in Table 2. The advisories issued by the government are based on the most restrictive contaminant after using all available measurements (Bhavsar et al., 2011). At present, the restrictive advisories posted for the harbour are due to elevated levels of mercury, PCBt, TEQ_{DLPCB}, and Toxaphene (www.ontario.ca/fishguide).

Next, we simulated fish consumption advisories for the harbour assuming a sole presence of mercury, PCBt, TEQ_{Total} and Toxaphene individually irrespective of the presence of other contaminants. The data collected for only 2017 were used. This simulation would help to understand the health risk to human consumers of harbour fish due to individual contaminants present in fish. The Ontario method of applying a power series regression of fish length vs contaminant concentration for each species was used. Standardized length concentrations were calculated from the regressions for every 5-cm size interval. These values were then compared with the Ontario advisory benchmarks (Table 2), and advisories (in meals/month) were calculated for each 5-cm size interval for the sampled size ranges. For understanding the significance of the simulated advisories, each individual advisory value was categorised into complete restriction (0 meal/month or do not eat), partial restriction (1, 2 and 4 meals/month), and no restriction (i.e., unrestricted = 8 or more meals/month).

Table 2: Fish consumption advisory benchmarks used by the Province of Ontario for the contaminants considered in this assessment (Gandhi et al., 2017).

	Mercury (µg/g)		PCBt	TEQ_{Total}	Toxaphene
Meals/month	**Sensitive**	**General**	**ng/g**	**(pg/g)**	**(ng/g)**
0 (do not eat)	>0.5	>1.8	>844	>21.6	>1877
1			422-844	10.8-21.6	939-1877
2		1.2-1.8	211-422	5.4-10.8	469-939
4	0.25-0.5	0.6-1.2	105-211	2.7-5.4	235-469
8	0.16-0.25	0.4-0.6	70-105	1.8-2.7	156-235
12	0.12-0.16	0.3-0.4	53-70	1.3-1.8	117-156
16	0.06-0.12	0.15-0.3	26-53	0.7-1.3	59-117
32	<0.06	<0.15	<26	<0.7	<59

Instructions on how to read simulated advisory tables (Table 3)

Step 1: Identify the type (species) of fish of interest in the left-hand column of the table.

Step 2: Identify the length of fish (in cm) of interest using the top row of the table.

Step 3: Check the advisory. The upper row of advice (no shading) is for the general population and the lower row (grey shading) is for women of child-bearing age and children under 15 (sensitive population). The number that appears in the consumption advice box for a particular species and size of fish represents the maximum number of meals of that size fish from that location that can be consumed each month, provided that fish are not consumed from any other category. One meal of fish is equivalent to 8 oz. (227 grams) of fish meat for an average 70 kg person. It is assumed that a larger/smaller person would have a proportionally larger/smaller meal.

The simulated advisories are presented in Table 3. Mercury only based advisories would be fairly lenient for Whitefish (all people) as well as Lake Trout and Longnose Sucker (general population). Restrictions advised to the sensitive populations about eating Lake Trout and Longnose Sucker would be mostly minor (4 meals/month) except for the large (>70 cm) Lake Trout that are considered very old and would not have enough time to recover from the historical contamination in response to the sediment remediation conducted at the harbour in 2012.

PCBt only based advisories would be extremely lenient (16-32 meals/month) for Whitefish; however, they would be fairly restrictive (0-2 meals/month) for most sizes of Lake Trout and Longnose Sucker for all people. These results highlight that the current PCBt levels in these fish are still a concern from the Fish Consumption BUI perspective.

TEQ_{Total} only based advisories would be extremely lenient (16 meals/month) for Whitefish; however, the advisories would be fairly restrictive (0-2 meals/month) for most sizes of Lake Trout for all people. A breakdown of TEQ_{Total} showed that 59%-90% (average 72%) of the contributions are from dioxin-like PCBs, and dioxins/furans were only a minor contributor. Since the concentrations of dioxin-like PCBs are typically correlated to PCBt (Bhavsar et al., 2007a; Bhavsar et al., 2007b), these advisories can be attributed to the PCB contamination issue. TEQ measurements for the 2017 Longnose Sucker samples are not available yet.

Toxaphene only based advisories were fairly lenient (8-32 meals/month; except very large and thereby old Lake Trout). These results highlight that the current Toxaphene levels in these fish from the harbour are not of a concern from the Fish Consumption BUI perspective.

Table 3: Fish consumption advisories (in meals/month) calculated using only the 2017 Peninsula Harbour data individually for a) mercury, b) PCBt, c) TEQ_{Total}, and d) Toxaphene in the three species sampled.

a) Advisories based on only mercury data for 2017

		15	20	25	30	35	40	45	50	55	60	65	70	75	>75cm
Lake Trout	General popn							32	16	16	12	8	8	2	
	Sensitive popn							16	8	8	4	4	0	0	
Whitefish	General popn				32	32	32	32	32						
	Sensitive popn				16	16	16	16	16						
Longnose Sucker	General popn				16	16	12	8							
	Sensitive popn				8	4	4	4							

b) Advisories based on only PCBt data for 2017

		15	20	25	30	35	40	45	50	55	60	65	70	75	>75cm
Lake Trout	General popn							8	4	2	1	0	0	0	
	Sensitive popn							8	4	0	0	0	0	0	
Whitefish	General popn					32	32	16	16						
	Sensitive popn					32	32	16	16						
Longnose Sucker	General popn					2	1	1							
	Sensitive popn					0	0	0							

c) Advisories based on only TEQ total data for 2017

		15	20	25	30	35	40	45	50	55	60	65	70	75	>75cm
Lake Trout	General popn							8	4	2	2	2	1	0	
	Sensitive popn							8	4	0	0	0	0	0	
Whitefish	General popn					16	16	16	16						
	Sensitive popn					16	16	16	16						
Longnose Sucker	General popn														
Not available	Sensitive popn														

d) Advisories based on only Toxaphene data for 2017

		15	20	25	30	35	40	45	50	55	60	65	70	75	>75cm
Lake Trout	General popn							16	16	16	12	8	8	4	
	Sensitive popn							16	16	16	12	8	8	4	
Whitefish	General popn					32	32	32	32						
	Sensitive popn					32	32	32	32						
Longnose Sucker	General popn					16	16	16							
	Sensitive popn					16	16	16							

Long-term trends in the fish contaminant levels

Selection of species

In order to conduct a robust long-term contaminant trend analysis, it is important to utilize sentinel species based on availability of historical measurements. This analysis focused on mercury and PCBt based on the larger number of historical measurements collected for mercury and PCBt and that these two chemicals were identified as the major contaminants of concern for the harbour. As shown in Table 4, Lake Trout, Lake Whitefish and Longnose Sucker were monitored relatively more frequently (at least 10 times during the 45-year period) and had a good distribution of observations throughout the time period and sample sizes for each sampling event. As such, these three species were selected for a detailed long-term contaminant trend analysis.

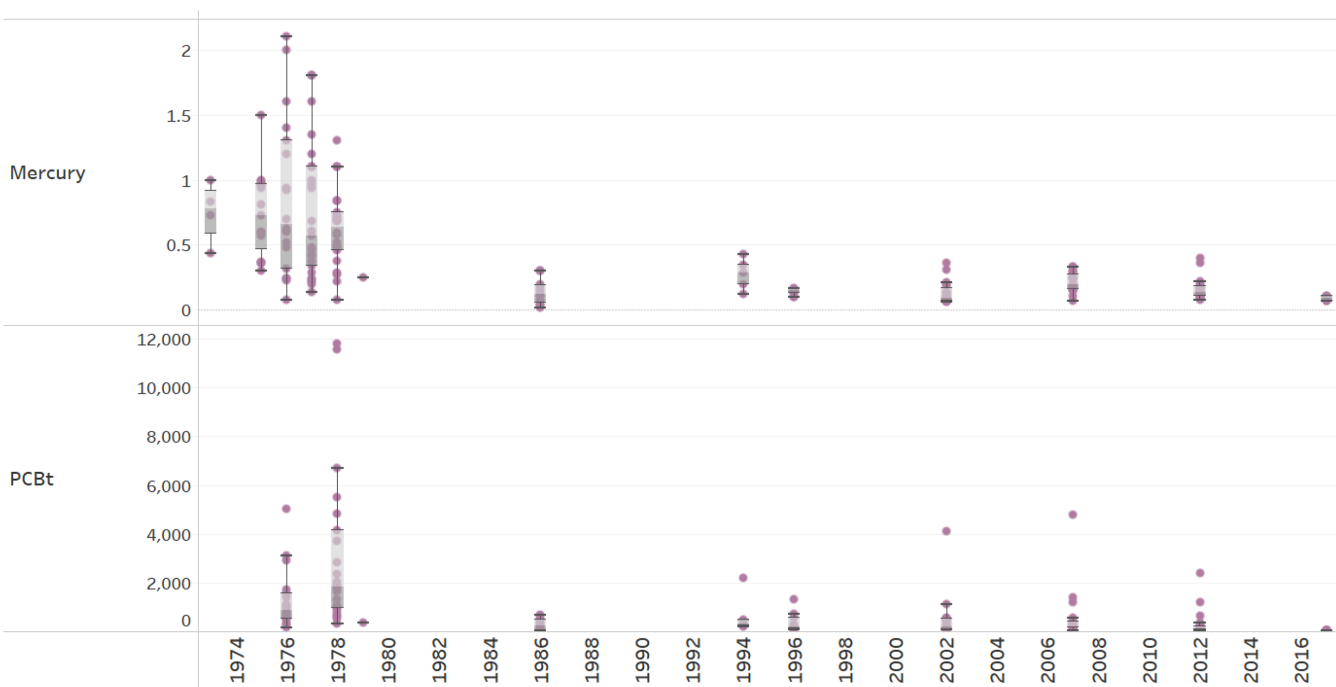
Table 4: Number of mercury and PCBt measurements conducted for various fish species sampled from Peninsula Harbour between 1973 and 2017. The fish species selected for a long-term trend analysis have been highlighted in bold.

	1973	1975	1976	1977	1978	1979	1981	1984	1985	1986	1987	1988	1989	1990	1992	1993	1994	1996	1997	1999	2002	2007	2010	2012	2013	2017
Mercury																										
Cisco				1																						
Gizzard Shad		7																								
Lake Trout	10	6	33	6	8	25	19	25	30	32	20	20	20	16	40	13	5	20	10	2	10	20		20	8	10
Lake Whitefish	4	15	18	25	22	4				11							5	10			20	20		20		6
Ling (Burbot)		2		1																		2				
Longnose Sucker		26			20					29	3			19	19	20			20		20	20				10
Northern Pike					1																					
Rainbow Smelt			1		3																					
Rainbow Trout		2		3																						
Redhorse Sucker				7																						
Round Whitefish											7					9		1					3			
Walleye																				12						
White Sucker		6	24	5	1					19	1					1										
PCBt																										
Lake Trout			31		8	21		25	30	32	20	20	20	16	40	10	5	20	10	2	10	20		20	8	10
Lake Whitefish			18		22	4				11							5	10			20	20		20		6
Ling (Burbot)																						2				
Longnose Sucker					20					29	3			19	19	9			20		20	20				10
Northern Pike					1																					
Rainbow Smelt					3																					
Round Whitefish											7					9		1					3			
Walleye																				12						
White Sucker			24		1					19	1					1										

Lake Whitefish

Figure 7 shows mercury and PCBt in individual samples of Lake Whitefish collected from the harbor between 1973 and 2017 regardless of fish lengths. These graphs highlight that Whitefish concentrations of both mercury and PCBt have dramatically declined over the years. The mercury levels ranged from 0.08-2.1 µg/g (average 0.73 µg/g) during the 1970s, and declined to 0.07-0.4 µg/g (average 0.15 µg/g) during the 2010s. The corresponding PCBt levels ranged from 150-11800 ng/g (average 2232 ng/g) during the 1970s and 20-2400 ng/g (average 250 ng/g) during the 2010s. These results show on average 80% and 89% declines in mercury and PCBt levels, respectively. However, it should be noted that these results show the spread of the observed concentrations without accounting for potential differences in fish sizes of the samples collected during the different sampling years which could influence the temporal trend.

Figure 7: Box plots of concentrations of mercury (µg/g) and PCBt (ng/g) in Lake Whitefish collected from Peninsula Harbour between 1973 and 2017.



Next, Lake Whitefish size distributions sampled over the years was compared to determine if changes to fish size have influenced the long term temporal analysis. As shown in Figure 8, Lake Whitefish collected during the 1970s typically ranged from 30-45 cm, while the samples collected post-1990 were generally larger at 45-65 cm. Larger Lake Whitefish would typically have greater mercury and PCBt concentrations compared to smaller ones from the same environment (Gewurtz et al., 2011). As such, we are confident that the decline in concentrations observed in Figure 7 are reflective of true decreases in environmental contamination and not an artifact of sampling smaller sized fish in later years.

In order to confirm the above inference, a long-term trend analysis was conducted for Lake Whitefish using a small overlapping size range of 40 to 50 cm. As shown in Figure 9, the mercury levels ranged from 0.14-2.1 µg/g (average 0.94 µg/g) during the 1970s, and declined to 0.08-0.1 µg/g (average 0.09 µg/g) during the 2010s. The corresponding PCBt levels ranged from 390-11800 ng/g (average 3207 ng/g) during the 1970s and 25-84 ng/g (average 56 ng/g) during the 2010s. The results on size standardized fish show even greater declines that average approximately 90% and 98% in mercury and PCBt levels, respectively.

Figure 8: Scatterplot of sizes (in cm) of Lake Whitefish collected from the harbour.

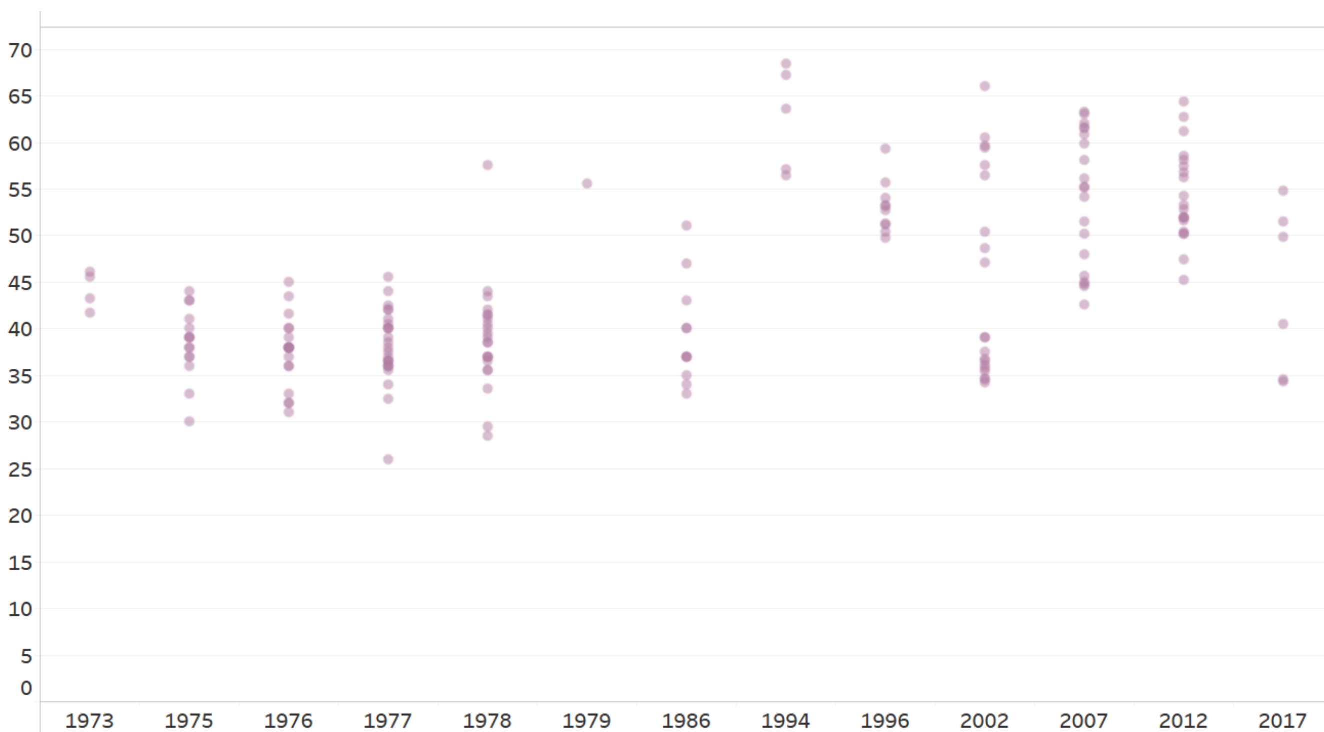
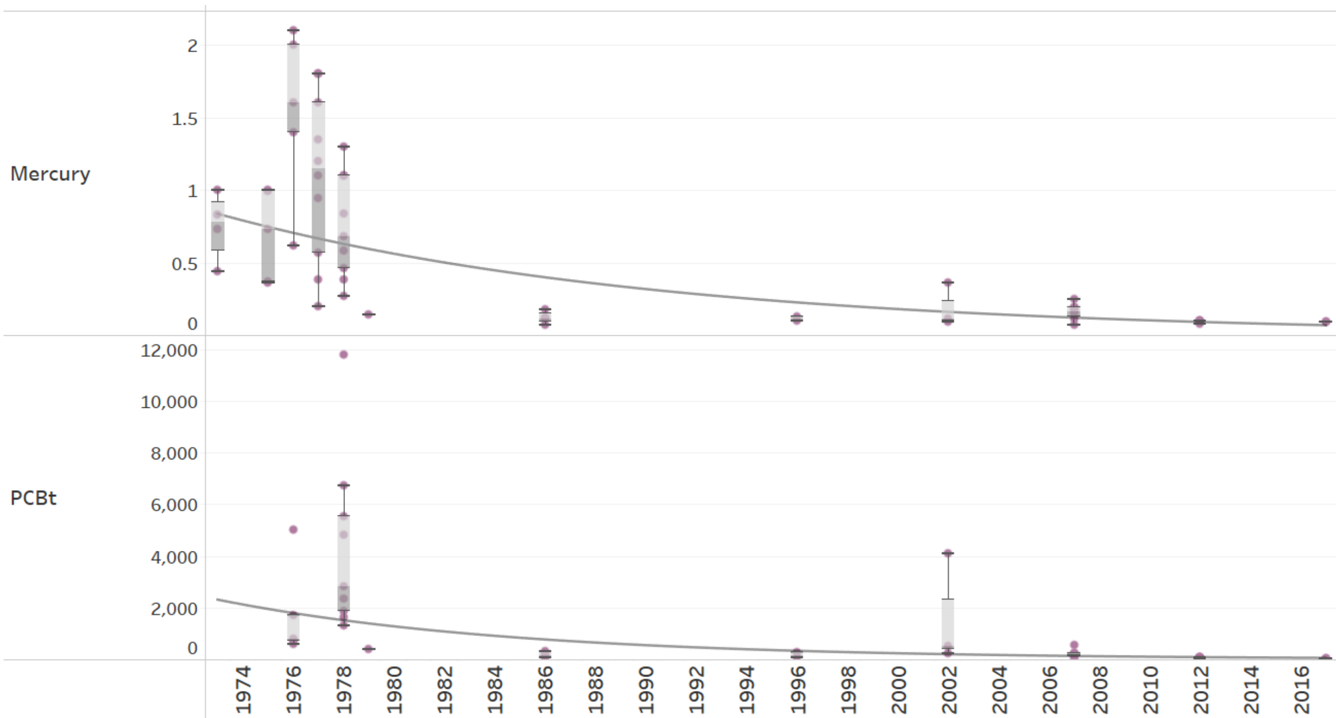


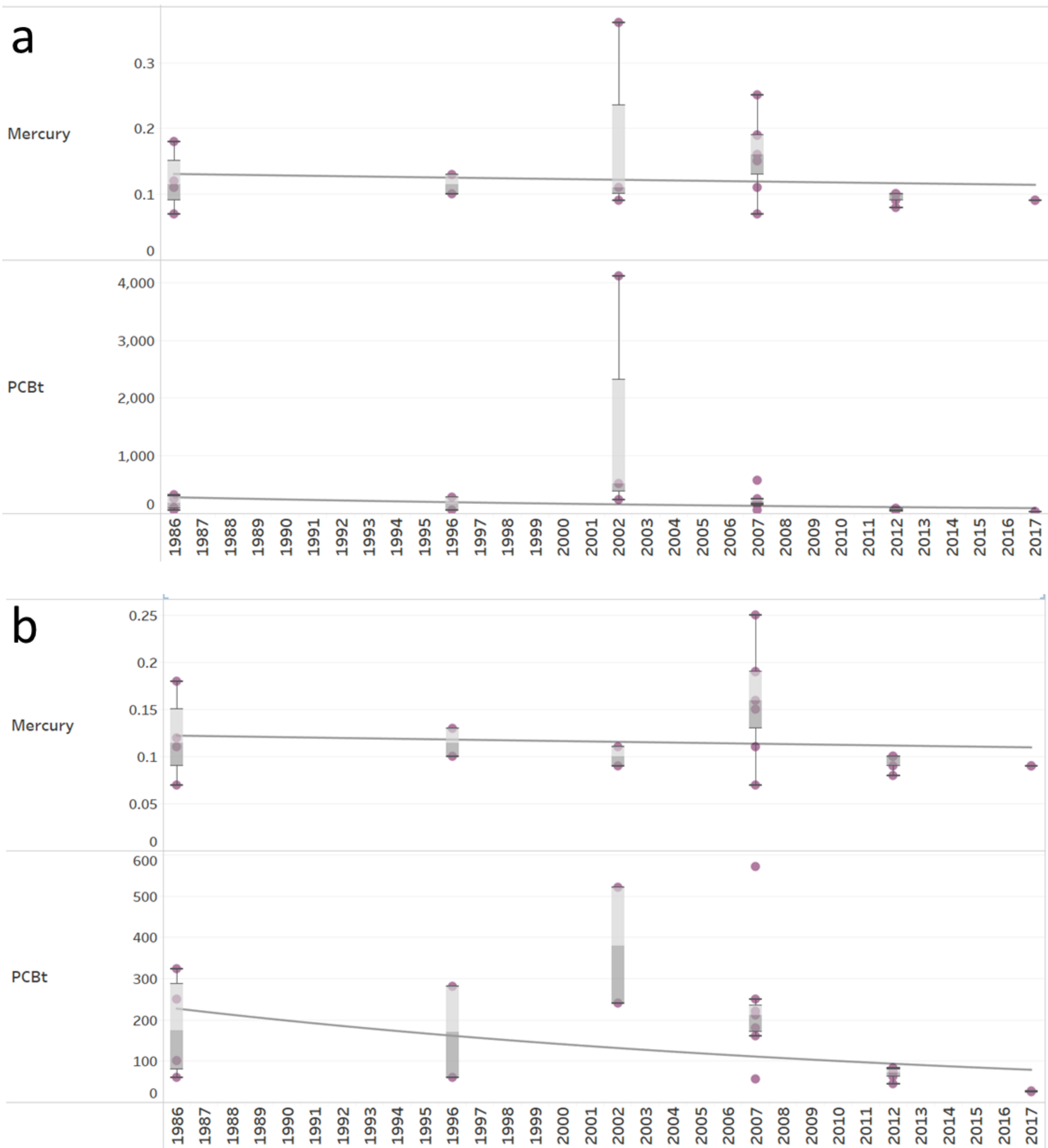
Figure 9: Box plots of concentrations of mercury (µg/g) and PCBt (ng/g) in 40-50 cm Lake Whitefish collected from Peninsula Harbour between 1973 and 2017.



The pulp and paper mill in Marathon was the major source of the contaminants of local concern in the harbour. The mill underwent major changes during the 1970s, mainly a primary clarifier added for most effluent streams in 1972 and cessation of chlor-alkali plant in 1977. As such, major improvements in the fish contaminant levels could be expected during the late 1970s and early 1980s.

Next, we examined if the declining long-term trends noted in the above analysis hold if only post-1980 data are considered. As shown in Figure 10a, the declining trends vanished for both mercury and PCBt (P values 0.63 and 0.14, respectively) under the revised post-1980 scenario. An outlier was, however, evident for the 2012 measurements. A trend analysis conducted after removing this outlier did not impact the trends much (P values: 0.65 and 0.07 for mercury and PCBt, respectively). However, the latest (2017) measurements were substantially lower than those in the 1980s (mercury 0.07-0.18 µg/g vs. 0.09 µg/g; PCBt 60-324 ng/g vs. 25 ng/g) suggesting that the declining trends have continued.

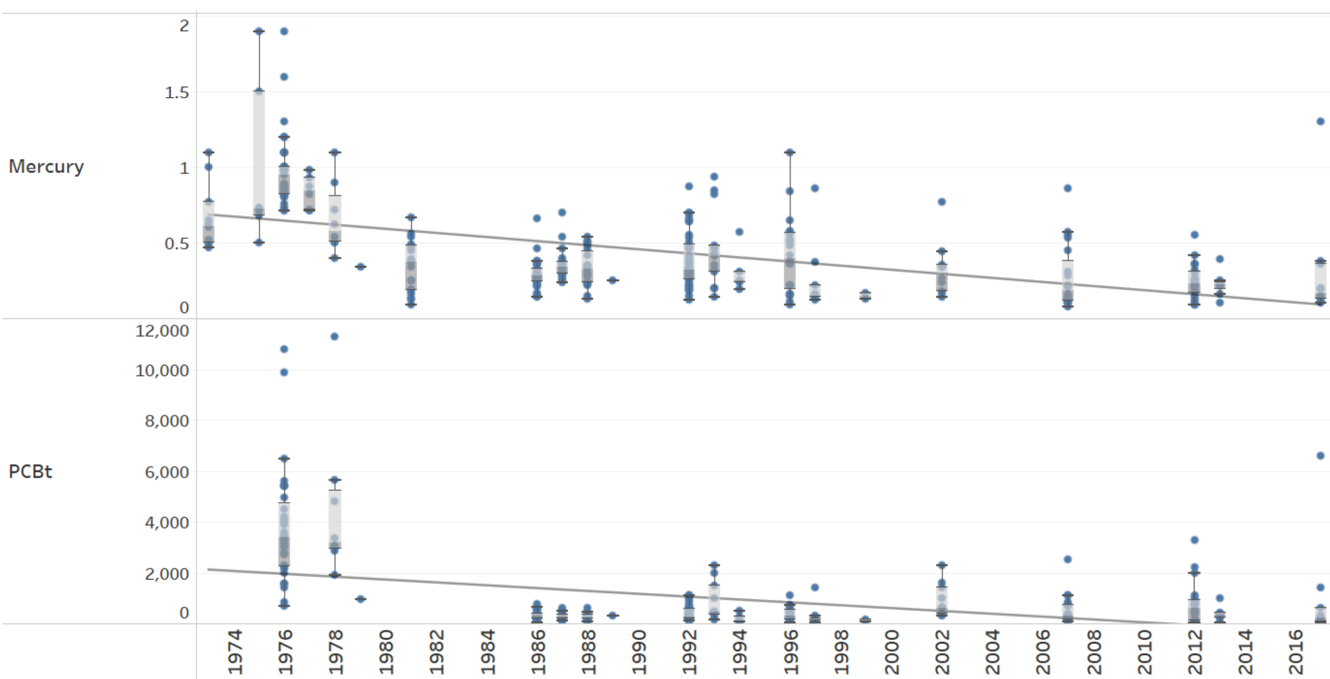
Figure 10: Box plots of concentrations of mercury (µg/g) and PCBt (ng/g) in 40-50 cm Lake Whitefish collected from Peninsula Harbour between 1986 and 2017. a) with all the values for 2002, b) after removing an outlier in the 2002 values.



Lake Trout

Figure 11 shows mercury and PCBt in individual samples of Lake Trout collected from the harbor between 1973 and 2017 regardless of fish lengths. These graphs highlight that the observed Lake Trout concentrations of both mercury and PCBt have dramatically declined over the years. The mercury levels ranged from 0.34-1.9 µg/g (average 0.87 µg/g) during the 1970s, and declined to 0.09-1.3 µg/g (average 0.26 µg/g) during the 2010s. The corresponding PCBt levels ranged from 700-11300 ng/g (average 3869 ng/g) during the 1970s, and 45-6600 ng/g (average 752 ng/g) during the 2010s. These results show on average approximately 70% and 81% declines in mercury and PCBt levels, respectively. However, it should be noted that these results show the spread of the observed concentrations without accounting for potential differences in fish sizes of the samples collected during the different sampling events which could have influenced the temporal trends.

Figure 11: Box plots of concentrations of mercury (µg/g) and PCBt (ng/g) in Lake Trout collected from Peninsula Harbour between 1973 and 2017.



Next, the distribution of fish sizes of Lake Trout sampled over the years was compared to examine variation in size as a potential confounding factor to the above temporal analysis. As shown in Figure 12, the Lake Trout samples collected from the harbor have been marginally smaller at later years (on average >60 cm during the 1970s vs. <55 cm in the 2010s). Smaller Lake Trout would typically have lower mercury and possibly PCBt concentrations compared to larger fish from the same environment (Gewurtz et al., 2011). As such, it could not be concluded that the declining mercury and PCBt concentrations observed in Figure 11 are real.

Next, the long-term trend analysis was conducted for Lake Trout measurements restricted to the overlapping size range of 55 to 65 cm fish. As shown in Figure 13, the mercury levels ranged from 0.44-1.9 µg/g (average 0.89 µg/g) during the 1970s, and declined to 0.19-0.42 µg/g (average 0.28 µg/g) during the 2010s. The corresponding PCBt levels ranged from 1400-10800 ng/g (average 4251 ng/g) during the 1970s and 160-2200 ng/g (average 639 ng/g) during the 2010s. These results on size standardized fish indicate long term declines on average of 69% and 85% in mercury and PCBt levels, respectively.

Figure 12: Scatterplot of lengths (in cm) of Lake Trout collected from the harbour.

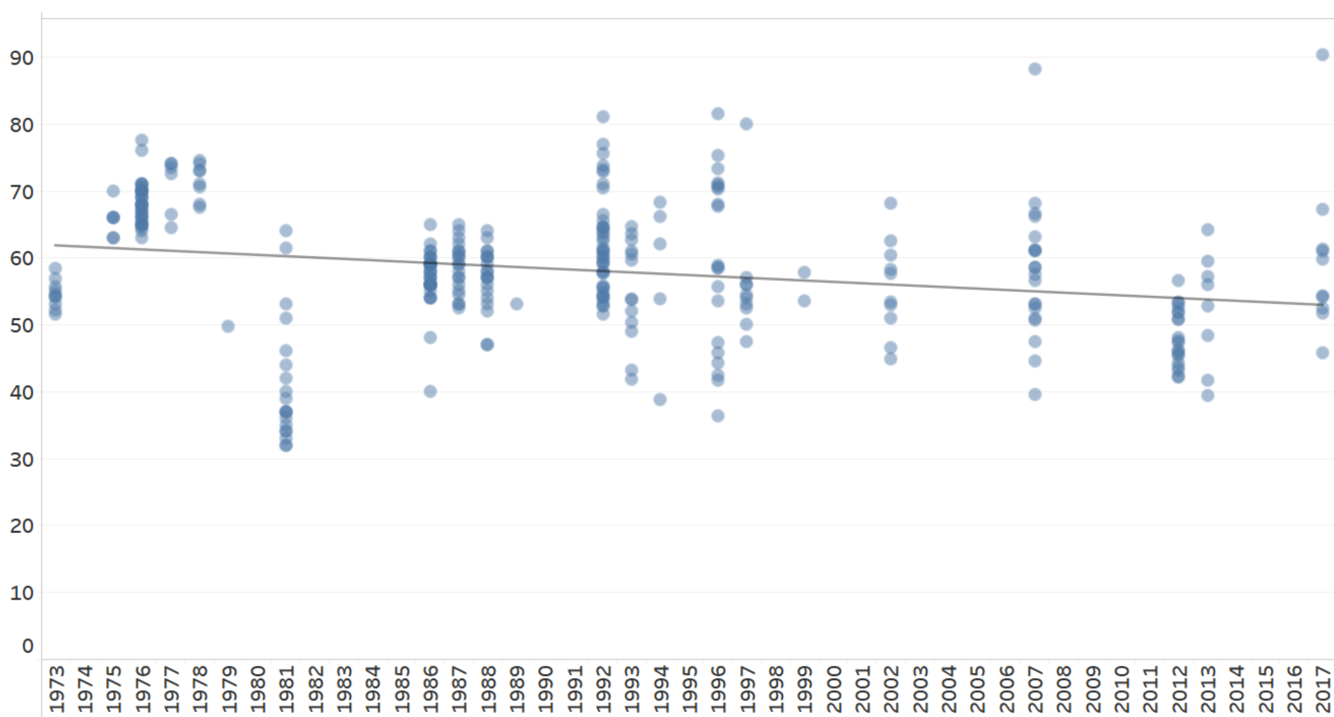
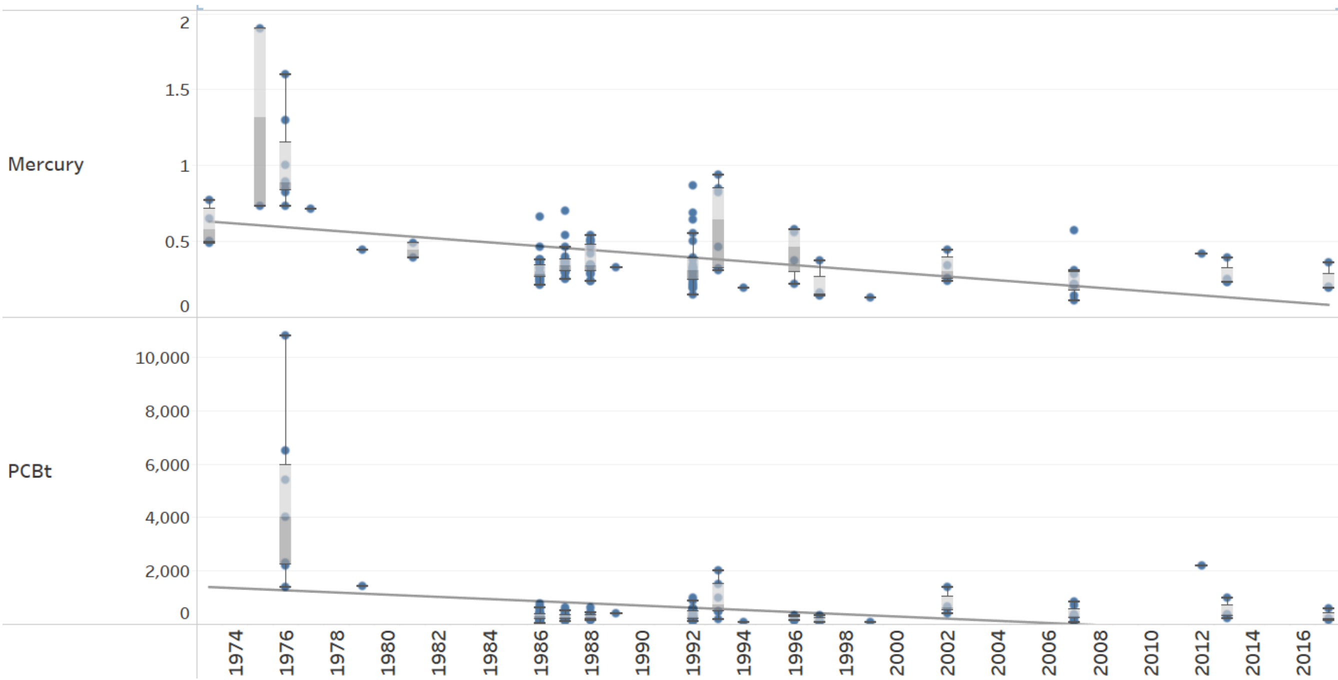
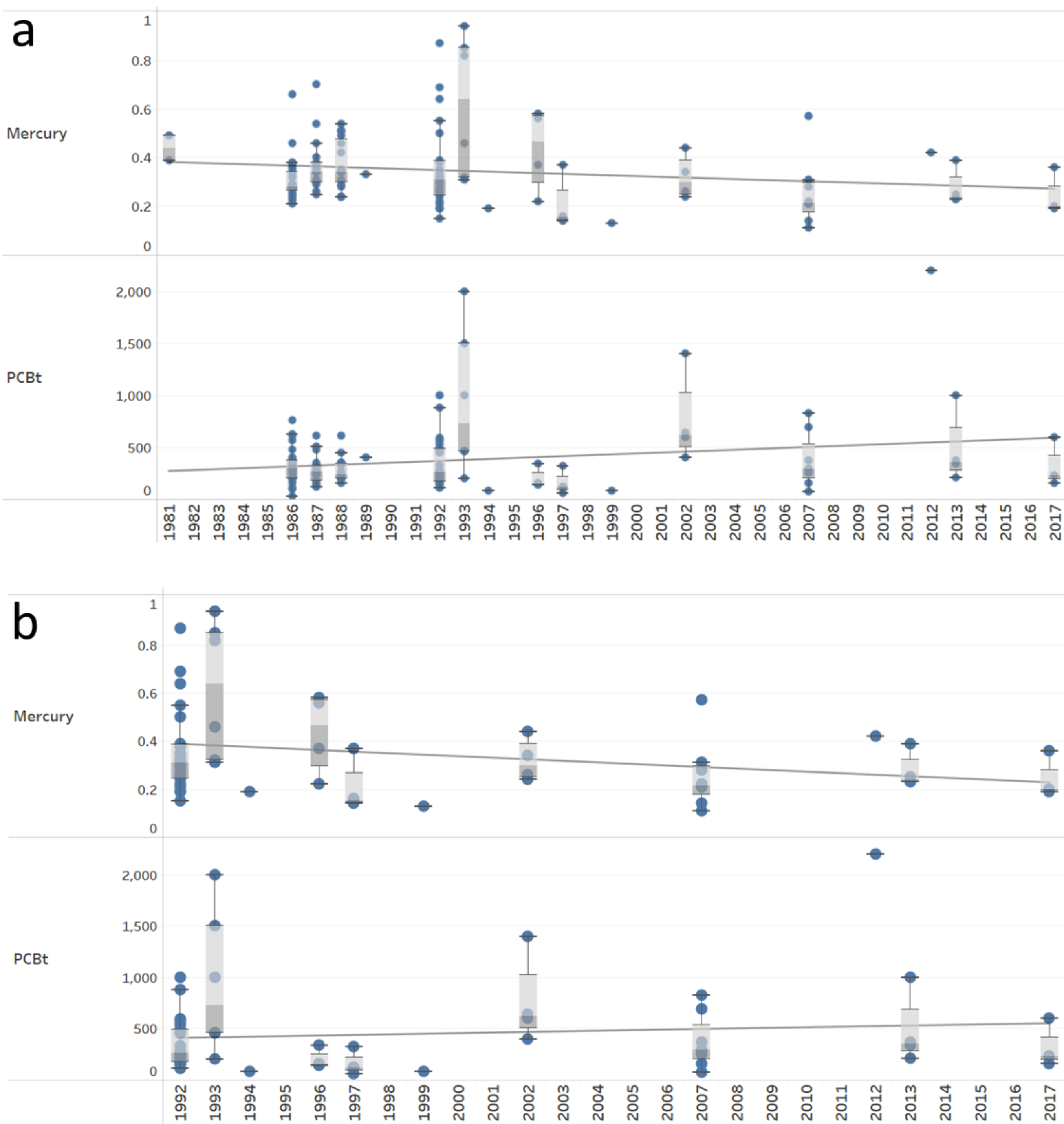


Figure 13: Box plots of concentrations of mercury (µg/g) and PCBt (ng/g) in 55-65 cm Lake Trout collected from Peninsula Harbour between 1973 and 2017.



Next, we examined if the declining long-term trends noted in the above analysis still hold when only post-1980 data collected after the major changes at the mill during the 1970s were considered. Compared to the results shown in Figure 13, the declining trend for mercury became weaker ($P = 0.07$), and switched from decreasing ($P < 0.001$) to increasing ($P = 0.02$) for PCBt (Figure 14a). Since the late 1990s, Lake Trout mercury levels are declining slowly at 0.06 µg/g per decade ($P = 0.04$) while PCB levels appear to be stable ($P = 0.43$) (Figure 14b).

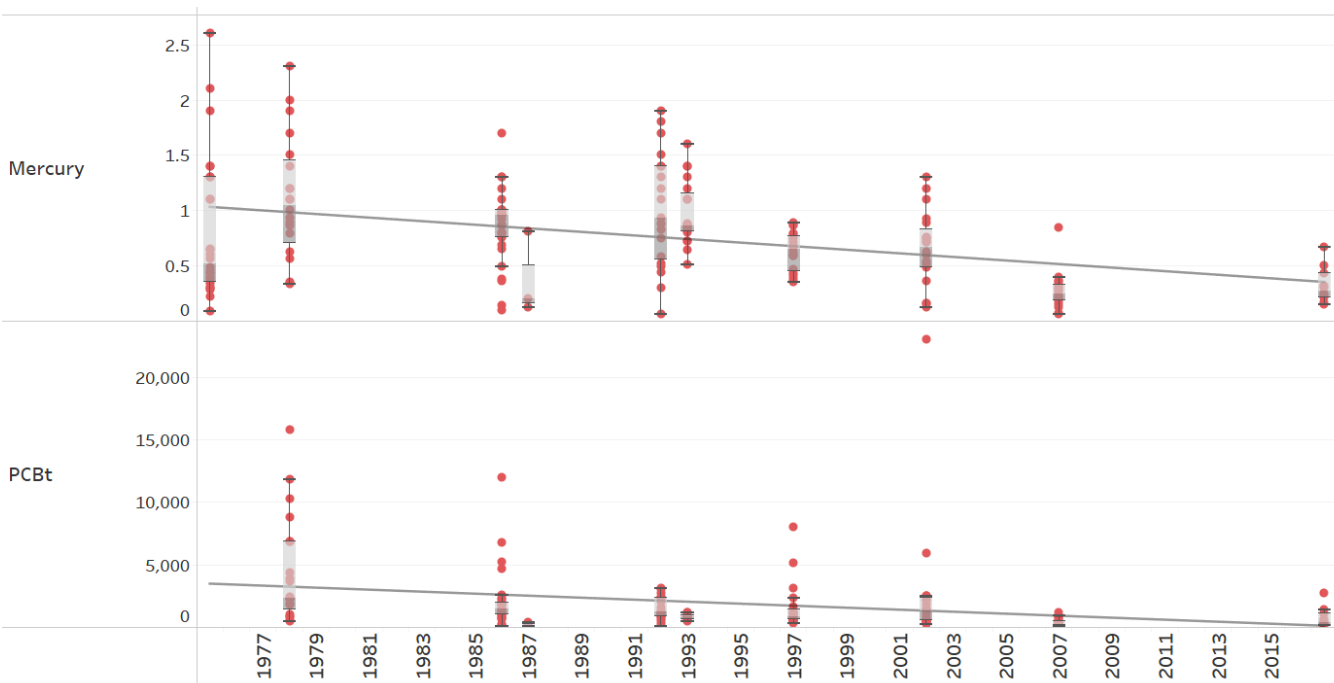
Figure 14: Box plots of concentrations of mercury (µg/g) and PCBt (ng/g) in 55-65 cm Lake Trout collected from Peninsula Harbour between a) 1981 and 2017, and b) 1992 and 2017.



Longnose Sucker

Figure 15 shows mercury and PCBt in individual samples of Longnose Sucker collected from the harbor between 1975 and 2017 regardless of fish lengths. These graphs highlight that the observed Longnose Sucker concentrations of both mercury and PCBt have dramatically declined over the years. The mercury levels ranged from 0.09-2.6 µg/g (average 0.94 µg/g) during the 1970s, and declined to 0.15-0.67 µg/g (average 0.32 µg/g) in 2017. The corresponding PCBt levels ranged from 450-15820 ng/g (average 4433 ng/g) in 1978, and 130-2700 ng/g (average 730 ng/g) in 2017. These results show on average approximately 66% and 84% declines in mercury and PCBt levels, respectively. However, it should be noted that these results show the spread of the observed concentrations without accounting for potential differences in fish sizes of the samples collected during the different sampling events which could have influenced the temporal trends.

Figure 15: Box plots of concentrations of mercury (µg/g) and PCBt (ng/g) in Longnose Sucker collected from Peninsula Harbour between 1975 and 2017.

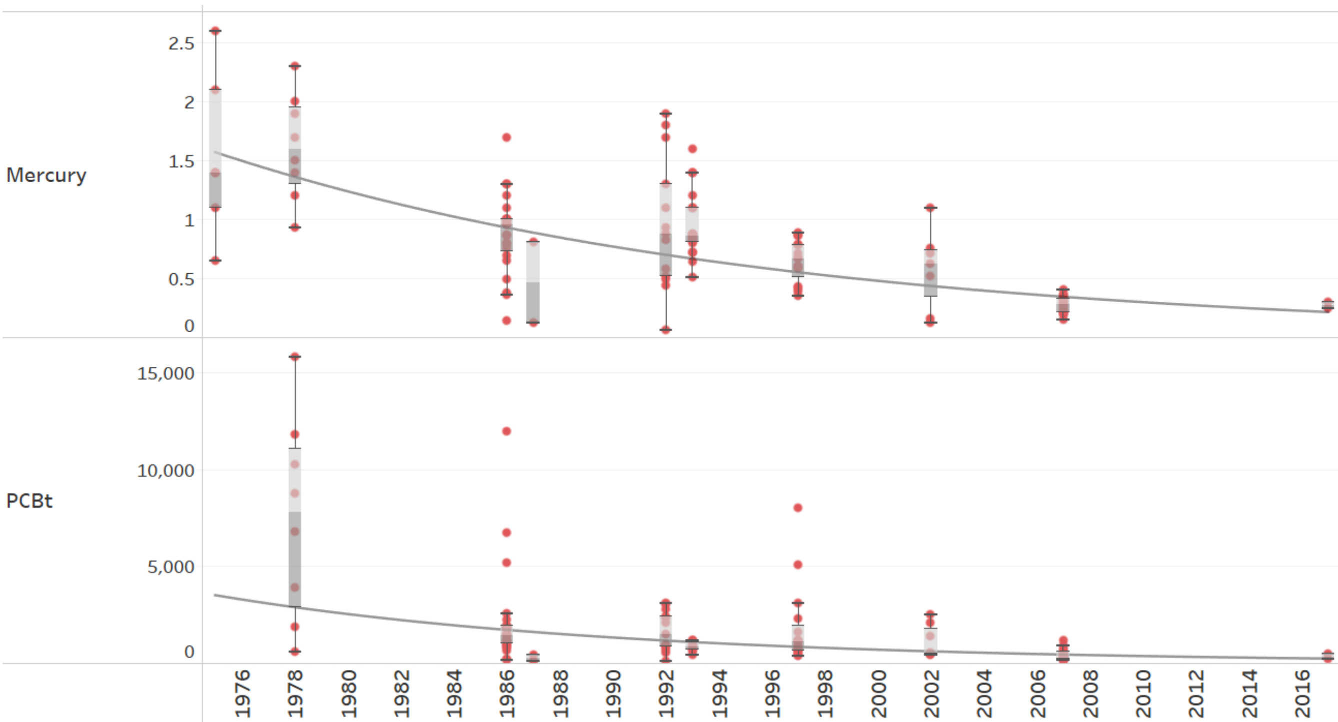


Next, the distribution of fish lengths of Longnose Sucker sampled over the years was compared to examine variation in fish size over time. As shown in Figure 16, the Longnose Sucker samples collected during the 1970s typically ranged from 22-46 cm, while the samples collected post-1990 were generally larger at 35-50 cm. Larger Longnose Sucker would typically have greater mercury and PCBt concentrations compared to the smaller ones in the same environment (Gewurtz et al., 2011). As such, we could be confident that the declined concentrations observed in Figure 15 are not an artifact related to sampling smaller fish in later years.

In order to confirm the above inference, a long-term trend analysis was conducted for Longnose Sucker using a small overlapping size range of 40 to 45 cm fish. As shown in Figure 17, the mercury levels ranged from 0.25-2.6 µg/g (average 1.58 µg/g) during the 1970s, and declined to 0.25-0.3 µg/g (average 0.28 µg/g) in 2017. The corresponding PCBt levels ranged from 575-15820 ng/g (average 7478 ng/g) in 1978, and 200-480 ng/g (average 340 ng/g) in 2017. These long term temporal trends on size standardized Longnose Sucker show even greater declines that average approximately 82% and 95% decreases in mercury and PCBt levels, respectively.

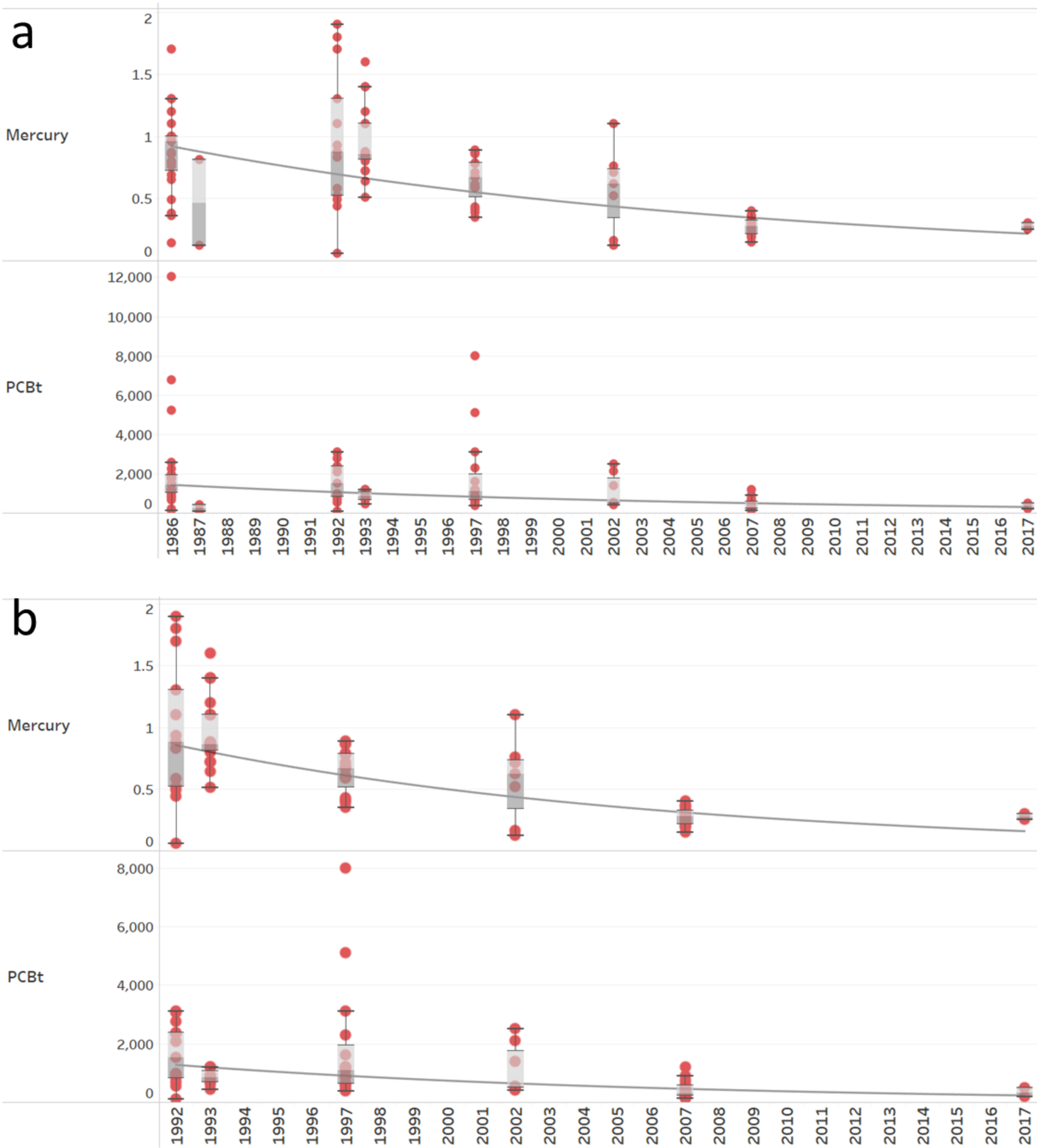
Figure 16: Scatterplot of lengths (in cm) of Longnose Sucker samples from the harbour.

Figure 17: Box plots of concentrations of mercury (µg/g) and PCBt (ng/g) in 40-45 cm Longnose Sucker collected from Peninsula Harbour between 1975 and 2017.



Next, we examined if the declining long-term trends noted in the above analysis continue to persist if only post-1980 data collected after the mill underwent major changes during the 1970s are considered. The declining trends shown in Figure 17 for mercury and PCBt were also evident when only post-1980 and post-1990 data were considered ($P < 0.001$) (Figure 18).

Figure 18: Box plots of concentrations of mercury (µg/g) and PCBt (ng/g) in 40-45 cm Longnose Sucker collected from Peninsula Harbour between a) 1986 and 2017, and b) 1992 and 2017.



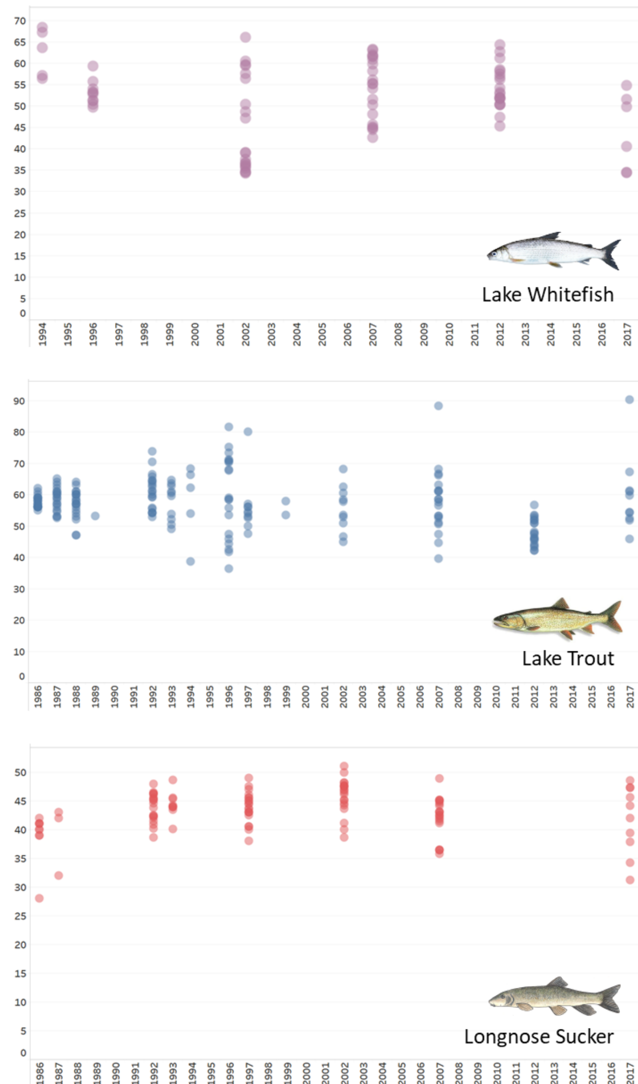
Toxaphene

As mentioned earlier, there was no known direct emission of Toxaphene to Peninsula Harbour. Toxaphene has been a lake-wide issue for Lake Superior due to its increased atmospheric deposition under the colder weather. As such, Toxaphene was not considered a contaminant of local concern in this assessment. However, a long-term trend analysis is presented here to evaluate if the Toxaphene levels are declining as a result of the ban on their use in the U.S. and Canada in the 1980s.

First, sizes of Peninsula Harbour Lake Whitefish, Lake Trout and Longnose Sucker samples monitored for Toxaphene were examined. Since the sizes varied over the years (Figure 19), narrow size ranges of 50-60 cm for Whitefish, 55-65 cm for Lake Trout, and 40-50 cm for Longnose Sucker were used in the Toxaphene trend analysis.

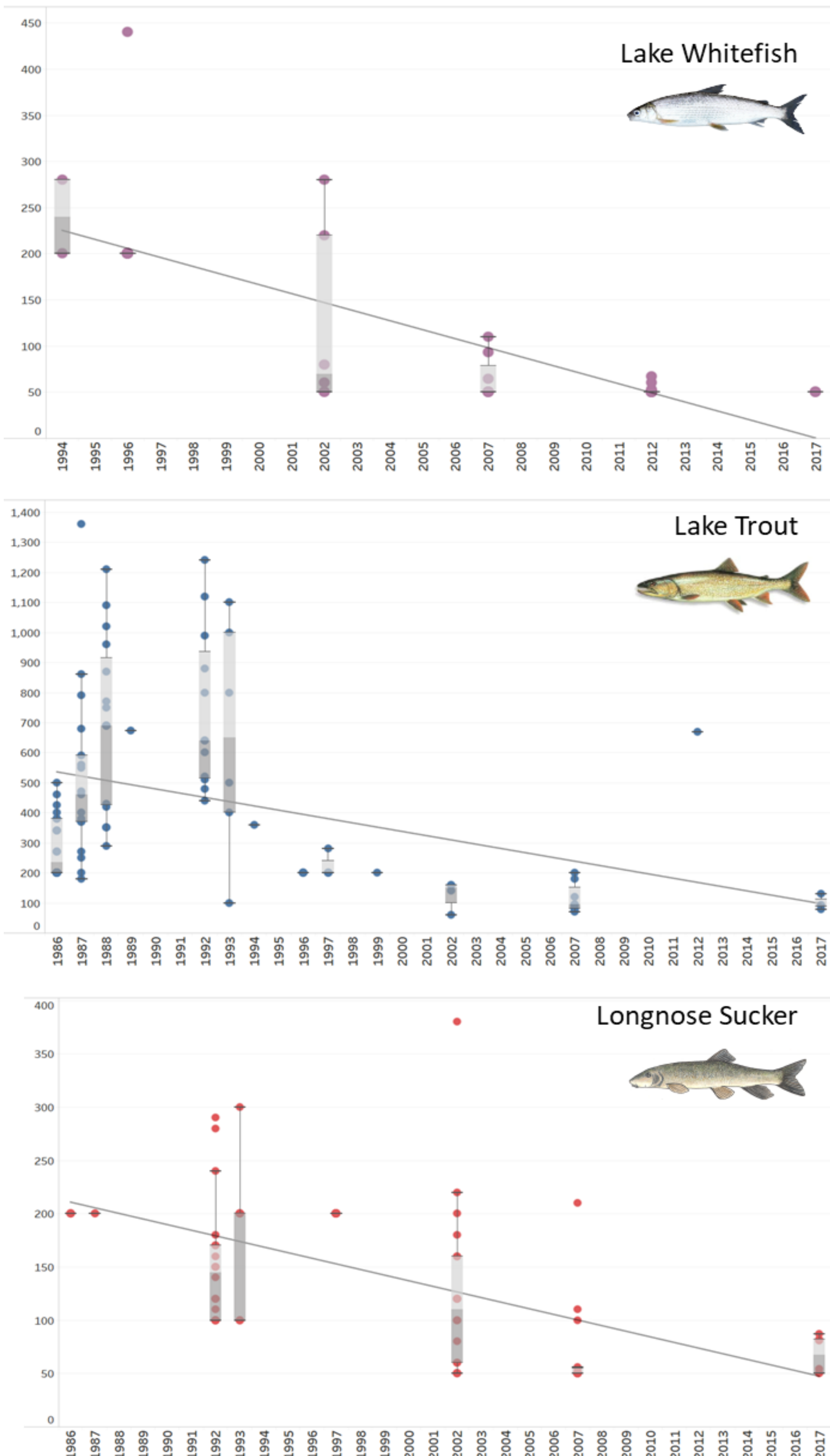
As shown in Figure 20, strong declining trends in Toxaphene levels are evident for all three species. The levels ranged from several hundreds of ng/g during the late 1980s and early 1990 to approximately 100 ng/g or lower in 2017. The latest observations for Toxaphene are close to the detection limit of 50 ng/g. These levels of Toxaphene would allow safe consumption of fish at 8 or more meals/month.

Figure 19: Scatterplot of lengths (in cm) of Lake Whitefish, Lake Trout and Longnose Sucker samples monitored for Toxaphene in Peninsula Harbour fish.



Overall, Toxaphene in Peninsula Harbour fish cannot be considered a cause for the beneficial use impairment.

Figure 20: Box plots of Toxaphene (ng/g) in 50-60 cm Whitefish, 55-65 cm Lake Trout, and 40-45 cm Longnose Sucker collected from Peninsula Harbour between 1986 and 2017.



Summary of the long-term trends

The long-term trend analysis conducted for the 1970s to 2010s after accounting for the differences in the lengths of fish samples over time showed substantial declines in the levels of both mercury (69%-90%) and PCBt (85%-98%) (mercury: 90% in 40-50 cm Lake Whitefish, 69% in 55-65 cm Lake Trout, 82% in 40-45 cm Longnose Sucker; PCBt: 98% in 40-50 cm Lake Whitefish, 85% in 55-65 cm Lake Trout, 95% in 40-45 cm Longnose Sucker). In many cases, the most recent (2017) mercury and PCBt measurements were substantially lower than those observed between the 1970s and 2000s.

However, the pulp and paper mill in Marathon, which was identified as the major source of contaminants of local concern to the harbour, had undergone several operational changes during the 1970's through early 1990's that could explain some of the long term temporal trends apart from recent sediment clean-up activities initiated in 2012. The results focussing on post 1980 temporal trends showed more variable results that were fish species dependant and either not changing or continuing to decline for both mercury and PCBt.

A long-term trend analysis for TEQ was not conducted because only Lake Trout has been monitored for dioxins/furans/dioxin-like PCBs for multiple years, i.e., only three sampling events (2007, 2013, 2017). No appreciable change in Lake Trout TEQ was observed between 2013 and 2017 in the short-term trend analysis conducted in this assessment. Further, the most recent elevated TEQ_{Total} were mainly due to the contributions from dioxin-like PCBs, which are typically correlated with PCBt (Bhavsar et al., 2007a; Bhavsar et al., 2007b). As such, long-term trends in the dioxin-like PCBs and thereby TEQ_{Total} are anticipated to mirror the trends presented for PCBt.

Toxaphene levels ranged several hundreds of ng/g during the late 1980s and early 1990s, and have declined in 2017 to approximately 100 ng/g or lower. These concentrations are close to the detection limit for these compounds and generally allow safe consumption of fish at 8 or more meals/month. As such, Toxaphene is not considered a contamination issue for the harbour.

The levels of both of major contaminants, namely mercury and PCB, have declined substantially since the 1970s.

Summary and Recommendations

Overall, PCB is a primary and mercury is a secondary contaminant of concern for eating fish caught from Peninsula Harbour. The levels of both of these contaminants have declined substantially since the 1970s; however, the elevated levels measured in the recent years still pose a potential health risk to human consumers of these fish. The declining trends observed on both long- and short-term temporal scales are encouraging and further decreases in the fish concentrations are expected, especially in response to the sediment remediation conducted at the harbour in 2012. If the Tier-1 of a suggested three-tier Fish Consumption BUI Assessment Framework (Bhavsar et al., 2018) is applied for Peninsula Harbour, **the outcome of the analysis conducted in this report does not currently support a redesignation of the BUI to not impaired**. It should be noted that the 2017 dioxin/furan/dioxin-like PCB measurements were not available for Longnose Sucker, and as such not accounted in this assessment.

The following topics can be considered as the next steps in the assessment of Fish Consumption BUI at Peninsula Harbour.

- The fish contaminant levels observed, and advisories derived from them for the harbour should be compared with other Lake Superior locations. If the levels and advisories for the harbour fish are similar or better than most other Lake Superior locations, especially those that can be considered appropriate reference locations for the harbour, it would support an assessment that lake-wide contamination is potentially impacting the quality of fish found at the harbour, and thereby a redesignation of the Fish Consumption BUI to "not impaired" could be recommended. Since the current PCBt levels in some fish are fairly elevated compared to the advisory benchmark, and the levels are still recovering likely as a result of recent sediment remediation activities, it may be appropriate to wait for another round of PCBt (and other contaminant) monitoring prior to completing this analysis).

- Spatial movement profiles and chemical fingerprints of sport fish could be collected to establish whether sport fish collected from the harbour and adjacent open lake waters show evidence of fish movements. Recent advances and interest in fish telemetry has led to a larger database of information about Great Lakes Fish movement. While it is unlikely that tagged fish from Peninsula Harbour would be available in the GLATOS database, fish movement profiles for Great Lakes Lake Trout are becoming better understood today compared to the past. Similarly, a multivariate analysis of chemical fingerprints of sport fish caught in the harbour and in adjacent fish consumption advisory zones could shed some light as to whether some indicator species, e.g. longnose sucker are more likely to spend longer residence times in the AOC compared to more mobile fish such as Lake Trout.

- A survey of consumption of fish from the harbour would be useful to better define the "beneficial use" by local people living in proximity to the AOC and surrounding areas. Information on the popularity of fish for consumption as well as eating frequency and other associated parameters (e.g., meal size, portion consumed) would help in understanding if the elevated levels of contaminants are compromising the beneficial use. Such a survey was conducted in 2008 by EcoSuperior, with the support of Environment and Climate Change Canada and Ontario Ministry of the Environment, Conservation and Parks. The purpose of the survey was to determine whether sport anglers or subsistence anglers are consuming fish from the AOC, and if so, which fish species are targeted and how much fish is consumed. The findings of the survey have been summarised by ENVIRON (ENVIRON, 2008). A review of the findings of that survey could be a good starting point in judging if additional information is needed.

- It is evident that the fish contaminant levels at the harbour are still recovering especially as a result of the sediment remediation in 2012. A continued periodic (e.g., every 3 years) monitoring of fish mercury and PCB is recommended to assess if the levels continue to decline further. The next round of fish sampling is suggested for 2020.

- If required, a food web bioaccumulation modelling study could be conducted to understand the dynamics of mercury and PCB in the harbour, and reasons for a delay or failure in improving fish contaminant levels below the fish consumption advisory benchmarks expected from the sediment remediation.

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APPENDIX

Figure A1: Fish Consumption BUI Assessment Framework presented by Bhavsar et al. (2018).

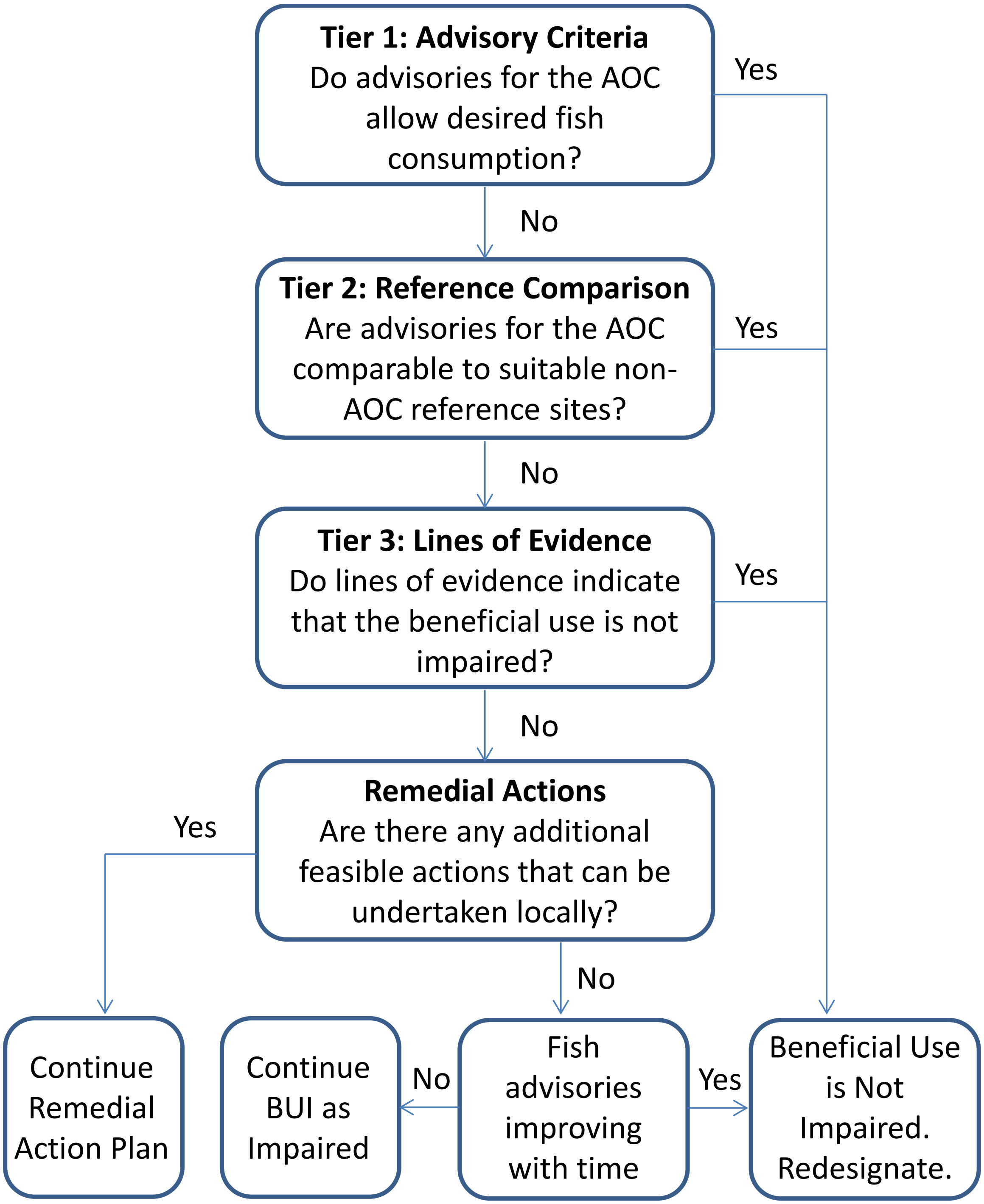

Table A1: Average concentrations of mercury (µg/g), PCBt (ng/g) and TEQ (pg/g; D/F dioxins/furans; DL – dioxin-like PCB) measured in Peninsula Harbour fish between 2012 and 2017. The data are presented in Figure 1.

	Lake Trout			Lake Whitefish		Longnose Sucker
	2012	2013	2017	2012	2017	2017
Mercury	0.24	0.23	0.31	0.16	0.09	0.32
PCBt	792	378	970	317	25	730
TEQ-D/F		1.21	2.08		0.58	
TEQ-DL		2.77	9.47		0.40	
TEQ-Total		3.98	11.55		0.98	

Table A2: Number of samples (N) and average concentrations of mercury (µg/g) and PCBt (ng/g) in 50-55 cm Lake Whitefish collected from Peninsula Harbour in 2012 and 2017. The data are presented in Figure 3.

	2012		2017	
	N	Avg. Conc.	N	Avg. Conc.
Mercury	10	0.14	3	0.10
PCBt	10	182	3	28

Table A3: Number of samples (N) and average concentrations of mercury (µg/g) and PCBt (ng/g) in 45-55 cm Lake Trout collected from Peninsula Harbour in 2012, 2013 and 2017. The data are presented in Figure 5.

	2012		2013		2017	
	N	Avg. Conc.	N	Avg. Conc.	N	Avg. Conc.
Mercury	14	0.26	2	0.19	5	0.13
PCBt	14	891	2	310	5	143

Table A4: Number of samples (N) and average concentrations of mercury (µg/g) and PCBt (ng/g) in Lake Whitefish collected from Peninsula Harbour between 1973 and 2017. The data are presented in Figure 7.

	Mercury		PCBt	
	N	Avg. Conc.	N	Avg. Conc.
1973	4	0.75		
1975	15	0.74		
1976	18	0.86	18	1287
1977	25	0.74		
1978	22	0.63	22	3091
1979	1	0.25	1	358
1986	11	0.14	11	283
1994	5	0.28	5	684
1996	10	0.14	10	352
2002	20	0.13	20	475
2007	20	0.21	20	571
2012	20	0.16	20	317
2017	6	0.09	6	25

Table A5: Number of samples (N) and average concentrations of mercury (µg/g) and PCBt (ng/g) in 40-50 cm Lake Whitefish collected from Peninsula Harbour between 1973 and 2017. The data are presented in Figure 9.

	Mercury		PCBt	
	N	Avg. Conc.	N	Avg. Conc.
1973	4	0.75		
1975	5	0.69		
1976	5	1.54	5	1764
1977	10	1.09		
1978	9	0.75	9	4322
1979	1	0.14	1	390
1986	4	0.12	4	184
1996	2	0.12	2	170
2002	3	0.19	3	1620
2007	7	0.16	7	235
2012	5	0.09	5	68
2017	2	0.09	2	26

Table A6: Number of samples (N) and average concentrations of mercury (µg/g) and PCBt (ng/g) in 40-50 cm Lake Whitefish collected from Peninsula Harbour between 1986 and 2017. a) with all the values for 2002, b) after removing an outlier in the 2002 values. The data are presented in Figure 10.

a)

	Mercury		PCBt	
	N	Avg. Conc.	N	Avg. Conc.
1986	4	0.12	4	184
1996	2	0.12	2	170
2002	3	0.19	3	1620
2007	7	0.16	7	235
2012	5	0.09	5	68
2017	2	0.09	2	26

b)

	Mercury		PCBt	
	N	Avg. Conc.	N	Avg. Conc.
1986	4	0.12	4	184
1996	2	0.12	2	170
2002	2	0.10	2	380
2007	7	0.16	7	235
2012	5	0.09	5	68
2017	2	0.09	2	26

Table A7: Number of samples (N) and average concentrations of mercury (µg/g) and PCBt (ng/g) in Lake Trout collected from Peninsula Harbour between 1973 and 2017. The data are presented in Figure 11.

	Mercury		PCBt	
	N	Avg. Conc.	N	Avg. Conc.
1973	10	0.67		
1975	6	1.01		
1976	33	0.98	31	3804
1977	6	0.84		
1978	8	0.66	8	4485
1979	1	0.34	1	951
1981	19	0.34		
1986	32	0.29	32	311
1987	20	0.36	20	287
1988	20	0.33	20	263
1989	1	0.25	1	315
1992	40	0.38	40	413
1993	13	0.45	10	880
1994	5	0.31	5	200
1996	20	0.42	20	360
1997	10	0.25	10	260
1999	2	0.15	2	110
2002	10	0.32	10	898
2007	20	0.27	20	498
2012	20	0.24	20	792
2013	8	0.23	8	378
2017	10	0.31	10	970

Table A8: Number of samples (N) and average concentrations of mercury (µg/g) and PCBt (ng/g) in 55-65 cm Lake Trout collected from Peninsula Harbour between 1973 and 2017. The data are presented in Figure 13.

	Mercury		PCBt	
	N	Avg. Conc.	N	Avg. Conc.
1973	4	0.60		
1975	2	1.32		
1976	8	1.01	7	4654
1977	1	0.71		
1979	1	0.44	1	1426
1981	2	0.44		
1986	27	0.31	27	319
1987	17	0.37	17	289
1988	15	0.38	15	289
1989	1	0.33	1	401
1992	23	0.36	23	350
1993	6	0.62	6	937
1994	1	0.19	1	80
1996	4	0.43	4	195
1997	4	0.21	4	155
1999	1	0.13	1	80
2002	4	0.32	4	760
2007	8	0.26	8	369
2012	1	0.42	1	2200
2013	4	0.28	4	480
2017	3	0.25	3	330

Table A9: Number of samples (N) and average concentrations of mercury (µg/g) and PCBt (ng/g) in Longnose Sucker collected from Peninsula Harbour between 1975 and 2017. The data are presented in Figure 15.

	Mercury		PCBt	
	N	**Avg. Conc.**	**N**	**Avg. Conc.**
1975	26	0.81		
1978	20	1.10	20	4433
1986	29	0.86	29	2125
1987	3	0.38	3	203
1992	19	1.00	19	1506
1993	20	0.97	9	820
1997	20	0.63	20	1574
2002	20	0.66	20	2565
2007	20	0.27	20	355
2017	10	0.32	10	730

Table A10: Number of samples (N) and average concentrations of mercury (µg/g) and PCBt (ng/g) in 40-45 cm Longnose Sucker collected from Peninsula Harbour between 1975 and 2017. The data are presented in Figure 17.

	Mercury		PCBt	
	N	**Avg. Conc.**	**N**	**Avg. Conc.**
1975	6	1.54		
1978	8	1.62	8	7478
1986	23	0.88	23	2195
1987	2	0.47	2	250
1992	13	0.96	13	1637
1993	19	0.95	8	853
1997	15	0.64	15	1864
2002	7	0.57	7	1137
2007	15	0.27	15	431
2017	2	0.28	2	340

Table A11: Number of samples (N) and average concentrations of Toxaphene (ng/g) in 50-60 cm Whitefish, 55-65 cm Lake Trout, and 40-45 cm Longnose Sucker collected from Peninsula Harbour between 1986 and 2017. The data are presented in Figure 20.

	Lake Trout		Lake Whitefish		Longnose Sucker	
	N	Avg. Conc.	N	Avg. Conc.	N	Avg. Conc.
1986	20	288			6	200
1987	17	514			2	200
1988	15	705				
1989	1	674				
1992	12	738			18	154
1993	6	650			9	178
1994	1	360	2	240		
1996	4	200	10	224		
1997	4	220			19	200
1999	1	200				
2002	4	130	6	123	18	126
2007	8	115	8	65	16	68
2012	1	670	15	52		
2017	3	101	3	50	6	67