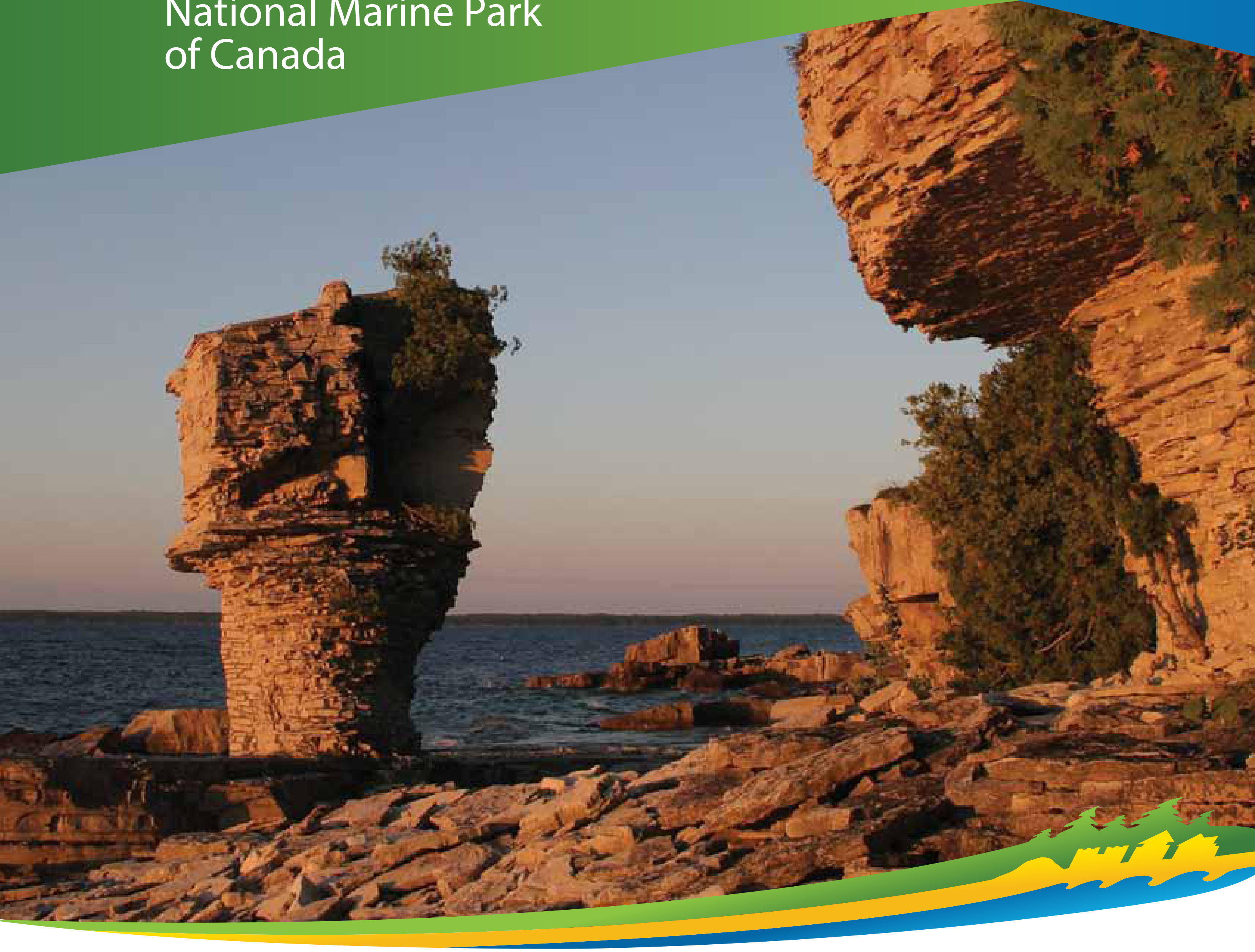
Parks Canada / Parcs Canada

Technical Compendium to the State of the Park Report 2010

Fathom Five National Marine Park of Canada



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Cover Image: Flowerpot Island at Fathom Five National Marine Park. © Scott Currie.

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1.0 INTRODUCTION

Cass Stabler

1.1 Purpose of the Technical Compendium

Parks Canada is the federal agency responsible for managing the representative system of national parks, national marine conservation areas, and national heritage sites on behalf of all Canadians. The Agency delivers its program through an integrated mandate that underscores a responsibility to protect and present these heritage places. This is held as a public accountability and requires that a State of the Park Report be produced for each park and marine conservation area every 5 years (PCA 2010). The State of the Park Report provides a snapshot of the current mandate components of the park (natural and cultural resource conservation, visitor experience, and external relations), reports achievements in reaching performance expectations, reports efforts to maintain or improve the state of the park since the last management plan, and identifies key issues for consideration in management planning (PCA 2009). This document, the Technical Compendium to the State of the Park Report, provides details and documentation of the assessment process and results that led to the evaluations of the state of natural resource conservation presented in the State of the Park Report (SoPR).

Fathom Five National Marine Park is governed in the spirit of the National Marine Conservation Areas Act (Government of Canada 2002). The Act states that Parks Canada will protect the ecosystems and biodiversity in these areas and this protection, along with the principles of ecosystem management and the precautionary principle, will be the primary considerations in the development and modification of management plans. It also states that the national marine parks will be managed and used in a sustainable manner without compromising the structure and function of the ecosystems (Government of Canada 2002). The objectives for the management of national marine conservation areas, with respect to ecosystem structure and function, are to maintain viable populations of all native species, including genetic variants, in natural patterns of abundance and distribution, to prevent non-native species from becoming established, to restore damaged or degraded ecosystems, and to maintain ecosystem functions within the range of natural variability (PCA 2010).

1.2 Structure of the Technical Compendium

In order to report on the ecological state of Fathom Five National Marine Park, a suite of indicators and measures were developed. These indicators and measures were selected in part, from both the Bruce Peninsula National Park ecological integrity monitoring program and the Fathom Five National Marine Park State of the Park Report 2003 (Parker 2007). This is only a technical compendium for the ecological indicators and measures to compliment the 2010 SoPR, it does not provide detail on the visitor experience, external relations, or cultural resources. Each indicator was selected to represent one of the main components of the park. The current state (rated as good, fair, or poor) and trend (whether the state has improved, remained stable, or declined in the five years since the previous State of the Park Report was published) of each indicator was assessed by evaluating the state and trend of several representative, quantitative measures. A brief summary of these ratings was presented in the State of the Park Report 2010. Each measure was given a symbol to represent the current state and trend (Table 1). This document provides details to explain how these ratings were determined.

Table 1. Symbols used to indicate status and trend of ecological indicators and measures.

Status		Trend	
Symbol	**Definition**	**Symbol**	**Definition**
●	The condition of the indicator/measure is considered to be good.	⬆	The indicator/measure status has improved over time.
▼	The condition of the indicator/measure is considered to be fair.	⬌	The indicator/measure status has remained stable over time.
■	The condition of the indicator/measure is considered to be poor.	⬇	The indicator/measure status has declined over time.
⬬	The condition of the indicator/measure is unknown at this time.	NR	The indicator/measure trend is unknown at this time.

This section (Section 1.0) provides information about the purpose and structure of the report. It also includes an overview of the ecological monitoring program at Fathom Five National Marine Park.

Section 2.0 is the most substantial component of the technical compendium. It is a compilation of all technical reports, one for each ecological measure, organized by ecological indicator. The technical reports follow a standard format and include the following sections, where appropriate:

i. the monitoring question, or questions (if sub-measures contributed to the overall measure), asked to understand the condition and trend of the measure including, where appropriate, threshold values and time period over which the trend was monitored,
ii. context including background information and justification for this measure as an important component of the monitoring program,
iii. a description and rationale of the threshold values including the biological significance of these values, how they were developed, and why this development approach was taken,
iv. a brief overview of the methods used to monitor and assess this measure,
v. analysis and results of the data, condition status and trend, and power,
vi. an explanation of the quality of the data and recommendations for improvement in the future,
vii. a brief discussion of the results, implications for park management, and recommendations for improving the measure
viii. a list of all individuals and organizations involved in monitoring or reporting on this measure, and
ix. a list of references for all articles and protocols referred to within the technical report.

The results from these technical reports are summarized in Appendix A including the overall status and trend of each ecological indicator. Appendix B includes an evaluation of the state of the development of each ecological measure in the ecological monitoring program. This information will guide future improvements to the ecological thresholds, power analysis, protocols, and information databases.

1.3 Overview of Ecological Monitoring and Reporting at Fathom Five National Marine Park

The ecological monitoring and reporting program at Fathom Five National Marine Park is designed to assess the state of ecological structure and function and how it is changing over time by monitoring and reporting on four ecological indicators that relate to major components of the park. Each of these indicators is assessed by evaluating representative, quantifiable measures (Table 2).

Table 2. Ecological indicators and measures in the Fathom Five National Marine Park ecological monitoring program.

Ecological Indicators	Ecological Measures
Coastal	Coastal Wetland Water Quality Lake Levels Coastal Fishes Aquatic Plant Communities Coastal Connectivity
Island	Habitat Amount and Connection Alvar Quality Colonial Waterbirds
Offshore	Water Quality Benthic Community Lake Trout Ice Coverage
Species at Risk	Not Rated

The State of the Park Report 2010 is the second state of the park report completed for Fathom Five National Marine Park. The first was completed in 2003 and some technical information was included, but no complete technical compendium was compiled. This is the first technical compendium completed for Fathom Five National Marine Park.

Difficulties with the ecological monitoring program are highlighted throughout this document; recommendations to improve these areas are also included. Many of these recommendations are based on information from the State of the Great Lakes 2009 report prepared by Environment Canada and the United States Environmental Protection Agency (EC & USEPA 2009). This report includes the most recent, science-based information about the Great Lakes system and is generally presented at the lake level. Beginning in 2011, this work will be completed on a three-year reporting cycle. Context, methods, analysis, and results, especially from the Lake Huron sections, can be directly compared to the ecological monitoring program at Fathom Five National Marine Park and should be considered when attempting to improve this program.

In order to develop a complete, consistent, and scientifically defendable monitoring program at Fathom Five National Marine Park resources comparable to those of the national parks ecological integrity monitoring program are required.

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2.0 STATUS AND TRENDS OF ECOLOGICAL MEASURES

This section is a compilation of technical reports summarizing the status and trend assessment process and results for each ecological measure in the ecological monitoring program for Fathom Five National Marine Park. Technical reports are grouped according to the ecological indicator they are used to evaluate. The results presented in this section are summarized in Appendix A as well as in the ecological indicator section of the State of the Park Report 2010 Fathom Five National Marine Park. The state of development for each of these ecological measures is presented in Appendix B.

2.1 COASTAL

Lake Huron has a complex and expansive coastline covering over 7000 km (Liskauskas et al. 2007). Extensive wetlands have formed in the protected bays, islands, and rivermouths. The complexity of the coastline, combined with the varied geology throughout Lake Huron, makes these habitats some of the most diverse in the Great Lakes (Liskauskas et al. 2007). These coastal wetlands are used by a variety of wetland dependent fish species as spawning, nursery, and feeding areas (Liskauskas et al. 2007) and are recognized as diverse, productive, and dynamic ecosystems (Young et al. 2002). Wetlands provide storm, flood, and erosion regulation, water filtration, and nesting sites, feeding grounds, and habitat for many species (Young et al. 2002). Human actions such as draining, filling, and introduction of pollutants cause many negative changes in wetland ecosystems (Young et al. 2002).

Given the biological significance and potential vulnerability to disturbance of coastal wetlands, three measures of the coastal indicator are associated directly to coastal wetlands including coastal wetland water quality, aquatic plant community, and coastal fishes, and the other two measures are lake levels and coastal connectivity. The current condition of the coastal indicator is assessed as good with a stable trend (Appendix A).

References

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2.1.1 COASTAL WETLAND WATER QUALITY

Chantal Vis

Monitoring Question

Is the water quality in coastal wetlands within Fathom Five National Marine Park in good condition (i.e., WQI > 0) and has it changed over the last five years?

Context

Many factors contribute to water-quality impairment in coastal wetlands of the Great Lakes. Among these are non-point source inputs of sediment and nutrient from agricultural and urban runoff, point-source pollution from municipal or industrial waste-treatment facilities, and carp bioturbation. Regardless of the pollution source, the resulting eutrophic and turbid conditions generally lead to a higher biomass of algae, which can reduce the species richness of submergent plants, and which can in turn affect the species richness, species composition and size structure of higher trophic levels (Chow-Fraser 2005).

Throughout the Great Lakes basin, wetlands have been lost at an alarmingly high rate following European settlement, particularly for the lower Great Lakes (Lakes Ontario and Erie; Whillans 1982). Until recent decades, most of these wetlands were lost through conversion to agricultural land and/or use for urban development. At present, however, wetlands are more at risk from non-point source pollution and in-marsh stresses such as carp bioturbation, shoreline modification, invasive species and water-level regulation than from dredging, infilling or draining (Keddy and Reznicek 1986, Maynard and Wilcox 1996, Chow-Fraser 2005). In areas such as Georgian Bay and Lake Huron, threats to wetland health are related to recreational pressures from cottage development and associated construction and use of marinas, boat launches, and from nutrient enrichment related to leaky septic fields and improper disposal of domestic sewage. Increased recreational demand and development in the next several decades could potentially degrade critical spawning and nursery habitat along the shorelines of the Bruce Peninsula and Georgian Bay. Environmental agencies responsible for protecting such critical habitat must identify these and implement monitoring programs to track their changes in quality and quantity.

To assess water quality in coastal wetlands in Fathom Five National Marine Park, a Water Quality Index (WQI) developed for the Great Lakes, and that relates changes in water-quality conditions to land-use changes, was used (Chow-Fraser 2007). This WQI is based on a comprehensive geographic coverage of the shorelines of the Great Lakes, and included highly degraded sites in Lakes Erie and Ontario (that are undergoing costly remedial action plans) as well as remote, undisturbed sites in Georgian Bay (Chow-Fraser 2007).

Thresholds

The WQI scores range from –3 to +3 and can be interpreted as indicated in Table 1 (Chow-Fraser 2005). Thresholds used for assessing the status of the measure in the park were based on these scores.

Table 1. Categories of wetland quality associated with WQI scores (after Chow-Fraser 2005).

WQI Score	Wetland Quality	EI Condition
2 to 3	Excellent	Good
1 to 2	Very good	Good
0 to 1	Good	Good
-1 to 0	Moderately degraded	Fair
-2 to -1	Very degraded	Poor
-3 to -2	Highly degraded	Poor

Methods

Water quality is monitored in Fathom Five National Marine Park following the protocols developed by Chow-Fraser et al. 2005. Water quality is monitored yearly (in summer) at 8 wetland sites on Cove Island**,** Russel Island and the mainland coast (Figure 1). Water temperature, conductivity, pH and dissolved oxygen concentration are measured *in situ* at a depth of 50 cm using a calibrated YSI multisonde water quality probe. Turbidity is also measured *in situ* using a Hach portable turbidity meter. A one litre water sample is collected from a depth of 50 cm, and sent to a certified laboratory for analysis of total phosphorus, total nitrogen, major ions, metal and chlorophyll concentrations following standard methods.

Chow-Fraser (2006) developed a series of multivariate equations to calculate WQI scores from water-quality parameters. Fathom Five National Marine Park based its assessment on the seven-parameter version equation, which includes the following variables: turbidity (TURB), conductivity (COND), temperature (TEMP), pH, total phosphorus (TP), total nitrogen (TN) and chlorophyll a (CHL), where:

$$WQI = 10.753047 - 0.946098*\log TURB - 0.837294*\log COND - 1.319621*\log TEMP - 4.604864*\log pH - 0.387189*\log TP - 0.353713*\log TN - 0.337888*\log CHL$$

Analysis and Results

Data Analysis

For Fathom Five National Marine Park, the seven-parameter versions of the WQI were calculated for each year 2005 to 2009. Data from 2006 was omitted because no chlorophyll a values were available.

Figure 1. Location of coastal weltands in Fathom Five National Marine Park. Cove Island North (CN), Cove Island Boat Passage (BG), Russel Island West (RUW), Russel Island East (RUE), Big Tub (ML4), Hay Bay East (ML1), Hay Bay South (ML2), and Hay Bay West (ML5).

Condition

Water quality was assessed as good, because all WQI values were > 0, in all years (Figure 2), with an overall average WQI of 2.57 ± 0.61, and a range of 1.61 to 3.89.

Individual water quality variables differed between the mainland and islands, with the islands sites having lower chlorophyll a (or algal biomass) and despite similar average nutrient and turbidity levels, mainland sites had higher maximum ranges of nutrients compared to island sites (Table 2). Total phosphorus exceeded Lake Huron targets (5 µg/L, EC & USEPA 2009) at all sites most of the time (84% of observations), and sites would be rated as mesotrophic (10-30 µg/L of total phosphorus) and eutrophic (>30 µg/L TP) based on phosphorus (CCME 2007).

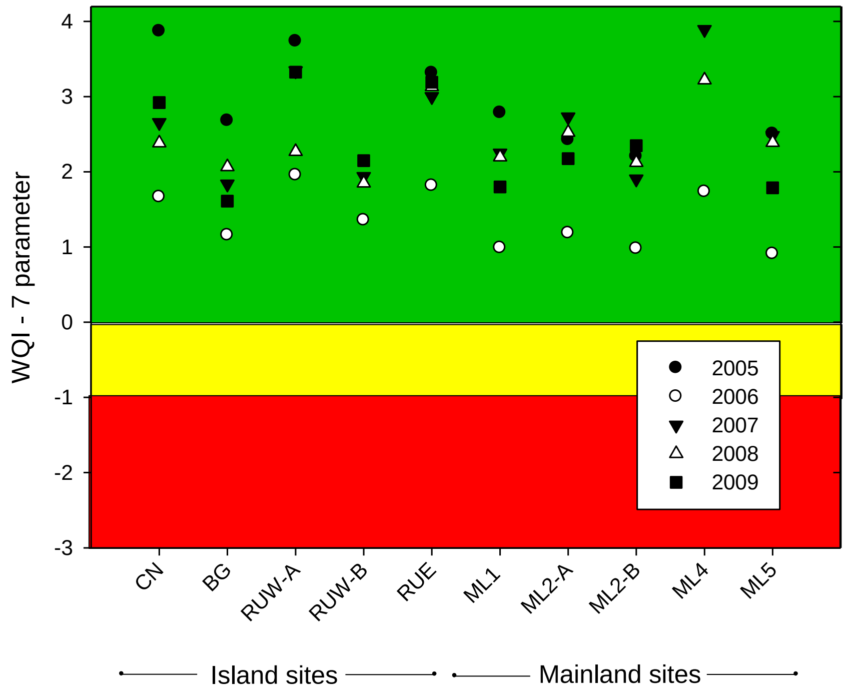

Figure 2. Water quality index (WQI) values for 2005-2009 by site in Fathom Five. See Figure 1 for sites and codes. Red, yellow, and green boxes represent poor, fair and good WQI thresholds, respectively. See Table 1 for threshold definitions.

Trend

Trend was assessed as stable, since all sites had a WQI > 0 in all years. However, linear regression of WQI values versus year did show a significant downward trend (F-value = 4.92, p = 0.033, r^2 =0.12, n=37, Figure 3). Trends in WQI should be followed over the next few years, to establish if this is a decrease in water quality is the result of inter annual variability. Individual parameters varied widely between years, and chlorophyll a or algal biomass was highest in 2009 (Figure 4). At mainland sites, there was a strong relationship between phosphorus and chlorophyll a (r^2 = 0.59, p=0.0002), which was not the case for island sites (r^2=0.03, p=0.49) (Figure 5). This would indicate that phosphorus at mainland sites is readily used by phytoplankton, and increases in phosphorus at these locations are linked to increasing planktonic algae biomass (and potential decreases of wetland habitat quality).

Power

The protocol included a power analysis and states that to achieve power of 80% to detect an effect size of 1.0 WQI unit using a paired t-test (alpha=0.05), 10 replicate samples for each of the five major wetlands identified are recommended (Chow-Fraser et al. 2005).

Table 2. Comparison of selected water quality parameters between islands and mainland sites at Fathom Five (2005-2009). Values presented are mean ± standard deviation, number of observations and the minimum and maximum values in brackets.

Parameter	Island sites	Mainland sites
Total phosphorus (µg/L)	14.1 ± 9.1 n = 24 (2.7 – 36.1)	16.9 ± 12.6 N = 24 (3.2 – 54.9)
Total nitrogen (µg/L)	454 ± 252 n= 23 (10 – 1030)	486 ± 272 n = 24 (10 – 1310)
Turbidity (NTU)	1.6 ± 1.4 n = 24 (0.3 – 5.9)	1.6 ± 1.0 N = 24 (0.1 – 4)
Chlorophyll a (mg/L)	0.9 ± 1.1 N = 19 (0.1 - 4.1)	2.3 ± 3.1 N = 18 (0.1 – 12.9)

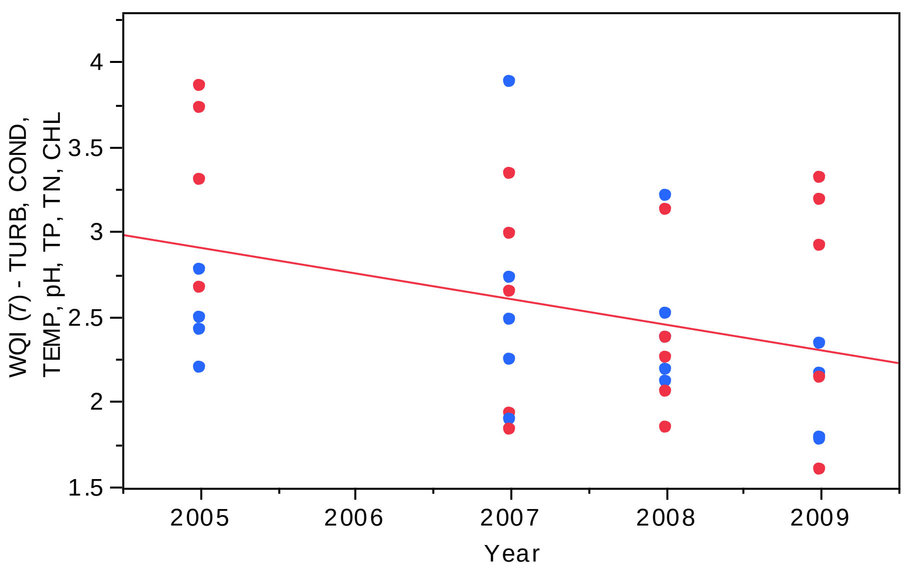

Figure 3. Linear regression of water quality index (WQI) versus year from 2005-2009 in Fathom Five National Marine Park. Red circles are island sites and blue circles represent mainland sites

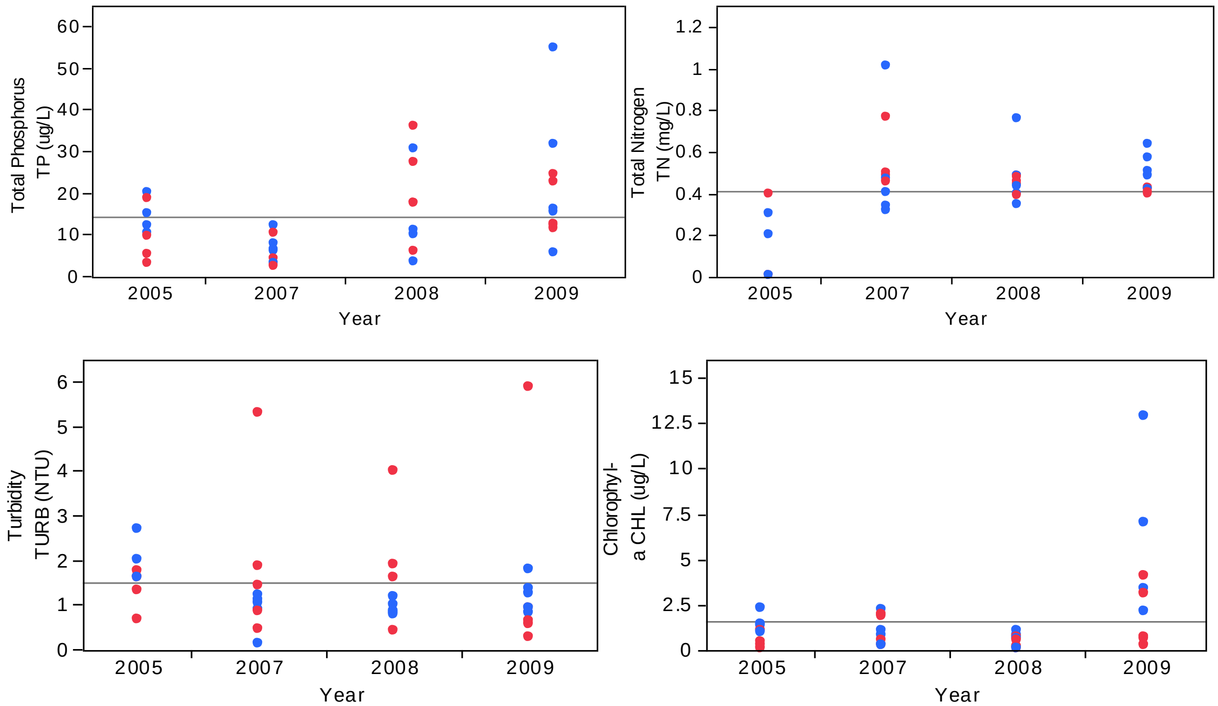

Figure 4. Total phosphorus, total nitrogen, turbidity and chlorophyll a concentrations at the wetland sites of Fathom Five National Marine Park by year. Line represents the mean of all years and sites combined. Red circles are island sites and blue circles represent mainland sites.

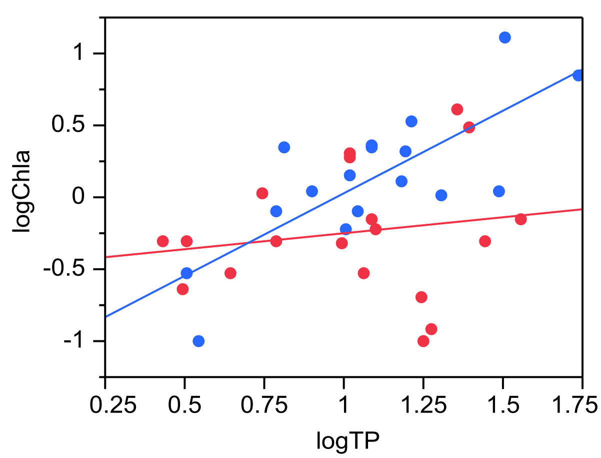

Figure 5. Linear regression of chlorophyll a (logChla) and total phosphorus (logTP in µg/L). Red circles are island sites, and the red line represents the linear regression trend for islands and blue circles represent mainland sites, with the blue line representing the linear regression trend for mainland sites.

Recommendations

The WQI is a useful indicator to compare water quality at Fathom Five National Marine Park with other Great Lakes wetland sites, however, it is mainly driven by turbidity and not as sensitive to changes in nutrients or in the bioavailability of nutrients. Fathom Five National Marine Park should examine recent increases in planktonic biomass (Chla) in the mainland wetland sites for links to shoreline development, which may require active management to protect coastal wetlands from eutrophication.

Partners

Patricia Chow-Fraser, McMaster University, Hamilton, Ontario

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2.1.2 LAKE LEVELS

Cass Stabler & Cavan Harpur

Monitoring Question

Are the majority (>50%) of daily average water levels (metres above sea level) from the five year period of 2005-2009 within the 80% confidence interval based on historical daily average water levels from 1963-2003?

Context

Hydrology is a major driver of ecological function and structure in coastal environments and naturally-fluctuating water levels are essential for maintaining healthy shoreline ecosystems in the Great Lakes. Coastal wetlands are particularly sensitive to water level fluctuations which strongly influence physical elements such as water storage, flood amelioration, ground-water recharge and erosion protection and biology, including patterns in biotic succession, biodiversity, condition of fish and wildlife and productivity (e.g., Keough et al. 1999, Mitsch and Gosselink 2007). An understanding of water level fluctuations can also provide critical information to manage nearshore development and wetland conservation efforts (e.g. Mitsch and Gosselink 2007). Alteration of natural lake level fluctuations has been equally recognized as a stressor affecting other ecosystem elements (among them shoreline movement, stabilization of sand dunes, fish access to spawning habitat, and availability of waterfowl habitat and nesting areas) as well as recreation, water consumption and other human activities in the Great Lakes (EC and USEPA 2009).

Water level monitoring is key to determining ecological condition of coastal environments. Water level changes in the Lake Huron, including fluctuations that vary on timescales ranging from hours to millennia, are the result of changes in water supplies and storage in Lake Huron related to natural factors, in combination with anthropogenic influences. Within broad scales, water inflow and outflow are dictated by climatically-induced changes that affect the components of the hydrologic cycle, most importantly: over-lake precipitation; the two main components of stream flow, which are surface water runoff and groundwater discharge to streams entering the lake; and evapotranspiration.

Thresholds

Thresholds used to assess the Lake Levels measure were developed based on a 40-year record of mean daily water level data from the Tobermory station (station no. 11690, 45.25°N, 81.67°W), located adjacent to Fathom Five National Marine Park (within 10 m of boundary). The 1963-2003 period was used to determine a baseline for daily water levels fluctuations. To assess condition, a range of variability approach was used to determine the 95% and 80% confidence intervals for each day of the year, which in combination with % observations, were the criteria for determining thresholds between poor, fair and good condition (Figure 1, Table 1). This approach provides a statistical basis for determining if the water levels over the past 5-years are within the natural range of variation, based on the 40-year historical range (Stephen McCanny pers. comm.).

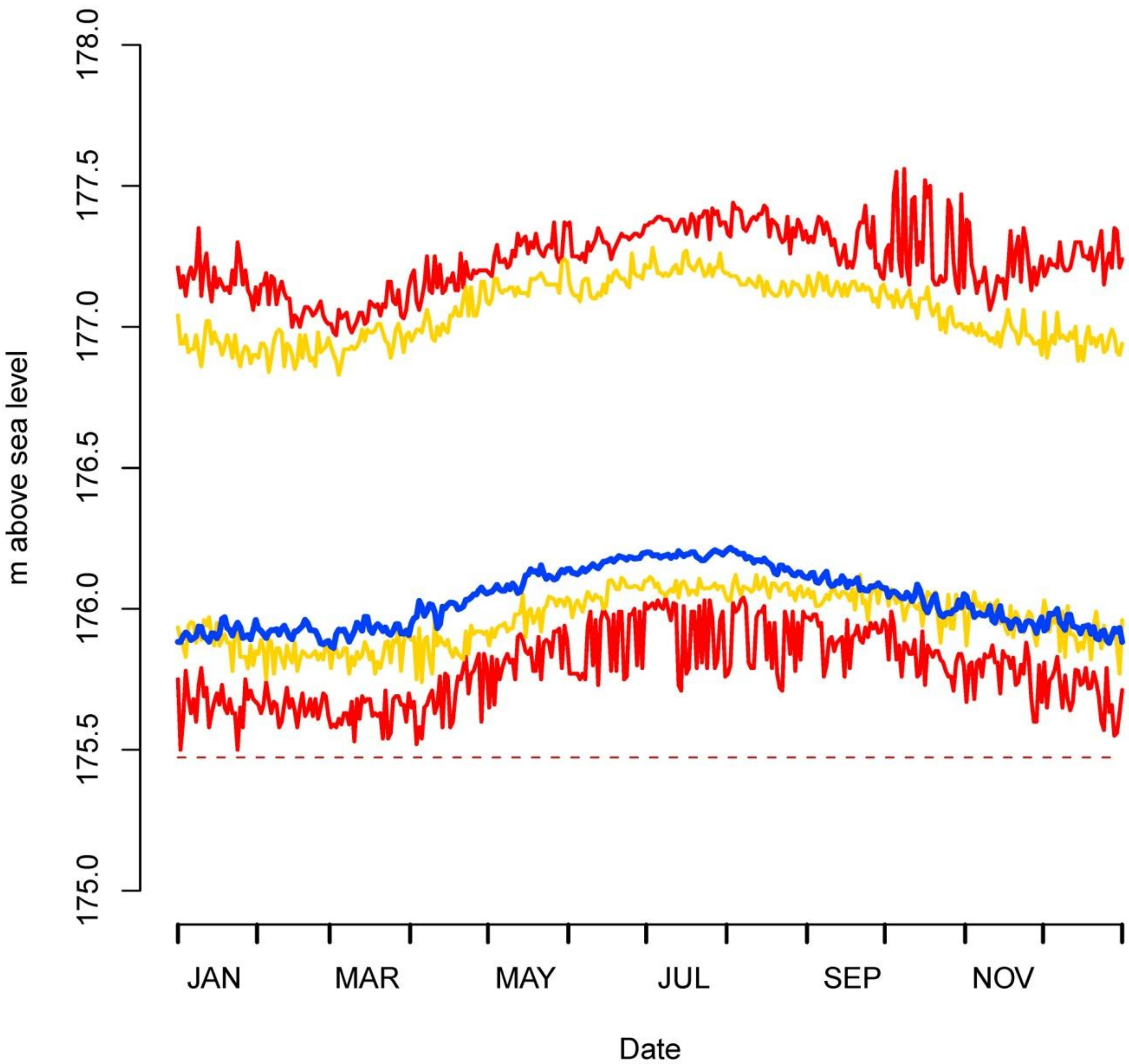

Figure 1. Average daily water levels from 2005-2009 compared to historical (1963-2003) water level range of variability. The blue line represents the 2005-2009 mean daily average water level, the yellow line is the 80% confidence interval (based on 1963-2003 data), the red line is the 95% confidence interval (based on the 1963-2003 data), and the hatched red line in the lowest water level (1963 to present).

Table 1. Thresholds to assess condition of the lake level measure in Fathom Five National Marine Park. Confidence interval (CI), upper confidence interval (UI), lower confidence interval (LI).

	Thresholds		
Status	Good	Fair	Poor
Daily mean water level	>50% of observations within 80% CI	>50% of observations within 80% to 95% CI	>50% of observations <95% LI or >95% UI

Methods

The Draft Lake Huron Water Level Monitoring Protocol for Fathom Five National Marine Park provides details about the on-going collection and management of Lake Huron water level information, which are based on data collected at the Tobermory station (LaRivière et al. 2008). Water level gauges are maintained by the Canadian Hydrographic Service (CHS) and the Tobermory gauging station (station no. 11690) is a permanent station that has been active since 1918. The data used in this analysis represent the daily mean water levels (mean of the hourly water levels), for the period between January 1, 1963 and December 31, 2009, and are presented as elevations or levels in meters above sea level, with reference to IGLD85 Datum. For the 40-year dataset, there were 119 missing observations, which represents <1% of the dataset. Missing data was estimated as the average daily mean water level for all years with data for that day in the 40-year record. There were no missing data in the 2005-2009 period dataset.

Analysis and Results

Data Analysis

An average daily mean water level for each day of the year of the 40-year period was calculated. The bootstrap method was then used to create a distribution for each day by sampling the 40 daily mean water levels for each day of the year 10,000 times (Cavan Harpur pers. comm.). From this, the 80% and 95% confidence intervals for daily mean water levels were determined for each day, and these confidence intervals were plotted for a one year period (Figure 1) and represent thresholds between poor, fair and good condition.

To evaluate the condition of the Lake Levels measure, daily mean water levels were first calculated for each day for the 2005 to 2009 period and then a five-year daily average was determined. Each 5-year daily average was then compared to the respective 80% and 95% confidence intervals of the 1963-2003 data (Figure 1). The number of times the 2005-2009 daily average fell within the 80% confidence interval, within the 95% confidence interval, or exceeded the 95% confidence interval was counted, and used to assess condition (Table 1).

Trend of the Lake Level measure was evaluated by comparing the slope of a linear regression model fitted to annual means for the period from 1963-2003 to one fitted to the annual means for the 2005-2009 period (Figure 2 and Table 2)

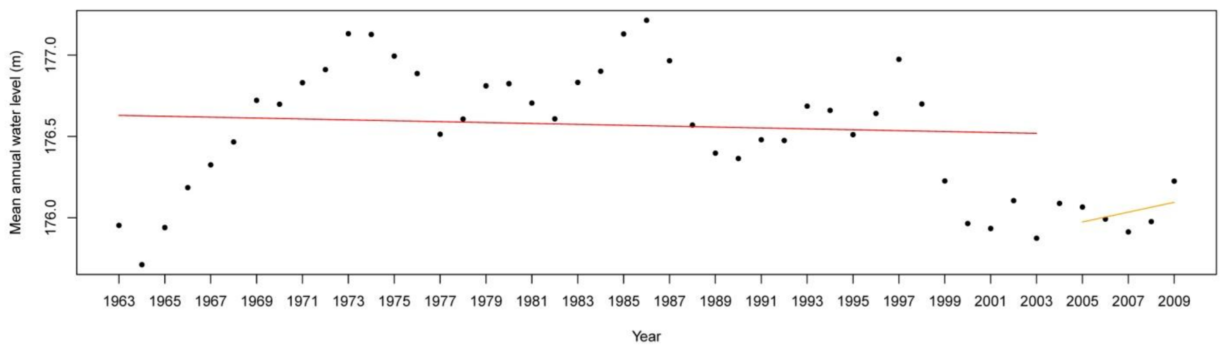

Figure 2. Mean annual water levels from 1963-2009. Red line represents the linear model fit the mean annual water levels from 1963-2003 and the orange line represent the linear model fit to the mean annual water levels from 2005-2009. The was no significant difference in the slope of these models at either the $\alpha = 0.05$ or 0.2 levels.

Table 2. Percent of daily mean water level observations in each condition category used to assess status.

Year	Good	Fair	Poor
2005	80.3 %	99.5 %	0.5 %
2006	65.5 %	99.5 %	0.5 %
2007	36.7 %	78.4 %	21.6 %
2008	59.5 %	94.8 %	5.2 %
2009	99.7 %	100 %	0 %
Average for 2005-2009	84.1 %	100 %	0 %

Condition

The condition is rated as good, because the majority (84.1%) of averaged daily water levels for 2005-2009 were within the 80% confidence interval (Figure 1, Table 2). Daily averages for 2007 were significantly lower than historic years and would have a fair ranking, but for all other years, daily averages would be ranked good.

Trend

There was no significant difference between the 1963-2003 and 2005-2009 trend lines at either the 80% or 95% confidence level (Figure 2 and Table 3).

Table 3. 80% and 95% confidence intervals (CI) for the slope of the linear models fitted to the 1963-2003 and 2005-2009 data.

CI For Slope	1963-2003	2005-2009
80%	-0.009 to 0.004	-0.035 to 0.095
90%	-0.013 to 0.008	-0.097 to 0.158

Linear models:

1963-2003: Water level = (-0.002763) * Year + 176.632241

2005-2009: Water level = 0.03027 * Year + 175.94353

Power

Power analysis was not completed for this measure.

Data Quality

Water level gauges are maintained by the Canadian Hydrographic Service (CHS) and the Tobermory gauging station (station no. 11690), is a permanent station that has been active since 1918, and the quality of the data is excellent. Data collection has changed since 1918 because the frequency of collection has increased. Prior to 1962, water levels were recorded daily, since May 18, 1962 water levels have been digitally recorded on an hourly interval, and since December 18, 2002 water levels have been recorded at three minute intervals.

Recommendations

The protocol for this measure should be completed and reviewed, including a re-evaluation of the metric and thresholds used for the assessment of this measure. The overall status of water levels for Lake Huron is mixed, an undetermined trend for 2009 (EC and USEPA 2009). It is widely accepted that the extent of the recorded water level history is insufficient to capture a comprehensive insight into lake level variability, unless examined in correlation with reconstructed water level history such as hydrographs produced by Baedke and Thompson (2000), as cited in EC and USEPA 2009. Currently, there is an on-going International Upper Great Lakes Study (http://www.iugls.org) that is expected to provide an improved understanding of the effects of regulation on the hydrology of the upper Great Lakes system, including indirect influence from regulation on unregulated lakes and physical changes in St. Clair River, and help establish lakewide objectives for this measure, which can then be adapted for Fathom Five's reporting.

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2.1.3 COASTAL FISHES

Scott Parker & Cavan Harpur

Monitoring Question

NR

Is the average annual Wetland Fish Index (WFI) value based on abundance data greater than 3.25 in the coastal wetlands of Fathom Five National Marine Park?

Context

Coastal wetlands, or wetlands with substantial hydrologic influence from Great Lakes waters, in this case Lake Huron, are biologically rich areas providing spawning and nursery habitat for many fish species (Jude and Pappas 1992). These wetlands are inherently dynamic and adapted to seasonal and yearly variations in lake levels (e.g., approx. 30 cm/seasonally and >1.5 m/32 year (Wilcox et al. 2007)). Ecosystem function and structure in these systems are altered by anthropogenic nutrient input and invasive species (Chow-Fraser 1998, Simon and Stewart 2007). Currently, coastal wetlands in Fathom Five National Marine Park are characterized by clear water with a rich assemblage of turbidity intolerant fish species (e.g., *Chrosomus sp.*, Brook Stickleback, Blackchin Shiner (Trebitz et al. 2007)). Increased nutrient runoff from residential waste water systems and fertilizers, siltation from land alteration and drainage, and non-native carp feeding, all potentially contribute to an increase in turbidity, which in turn influences vegetation and fish habitat. This may lead to a shift towards turbidity tolerant fishes (e.g., Common Carp, Brown Bullhead, Spottail Shiner (Trebitz et al. 2007)) and high algal biomass (Chow-Fraser 1998).

Fishes in the coastal wetlands of Fathom Five National Marine Park are assessed using the Wetland Fish Index (WFI) (Seilheimer and Chow-Fraser 2006). The index is based on the analysis of over 150 Great Lakes coastal wetland fish communities. The index is derived from a partial canonical correspondence analysis which ordinated fish species along a multidimensional environmental axis. The first axis (i.e., anthropogenic disturbance) was used to provide a stress gradient for each taxon, ranging from 1 (highly disturbed) to 5 (pristine). The WFI correlates well with other indices developed for coastal wetlands including water quality and macrophyte presence (e.g., Chow-Fraser 2007, Croft and Chow-Fraser 2007, DeCatanzaro et al. 2009).

Thresholds

The threshold abundance WFI values for Fathom Five are based on expert opinion (pers. comm. P. Chow-Fraser, Table 1).

Table 1. Threshold criteria for the coastal fishes measure in Fathom Five National Marine Park.

	Thresholds		
Status	Good	Fair	Poor
Wetland Fish Index	> 3.25	3.25 to 2.5	<2.5

Methods

Fish community composition is monitored in the coastal wetlands of Fathom Five National Marine Park following the protocols outlined in Chow-Fraser et al. (2005) (Figure 1). Three paired fyke nets: two large pairs (13 mm and 4 mm mesh, 4.25 m in length, 1 m X 1.25 m front opening) and one small pair (4 mm mesh, 2.1 m length and 0.5 m X 1.0 m front opening) are set parallel to the shoreline or emergent zone in water approximately 0.5 m deep for 24 hour sets in 8 coastal wetlands (islands and mainland) in early July (Figure 1). All species are collected, identified, and recorded along with the maximum and minimum total lengths for each species. Although annual regional sampling has been completed at each site since 2005, the recommended intensive monitoring (i.e., sample size of 6) on a rotational basis of one of the major wetland areas was not completed due to operational and resource limitations.

Figure 1. Coastal wetland survey locations in Fathom Five National Marine Park (ca. 2005).

Analysis and Results

Data Analysis

Fish data from each survey is entered in a MS Access database (developed by C. Harpur). The database automatically calculates the WFI values (Formula 1) for each site based on established niche breadth (T) and tolerance to degradation (U) values (Seilheimer and Chow-Fraser 2006).

Formula 1. Wetland Fish Index (WFI) formula (Seilheimer and Chow-Fraser 2006)

$$WFI = \left(\frac{\sum_{i=1}^{n} YiTiUi}{\sum_{i=1}^{n} YiTi}\right) - \sqrt{\frac{Ex}{To}}$$

Where: Y_i = $\log_{10}$ abundance of species i
T_i = value form 1-3, indicating niche breadth
U_i = value form 1-5, indicating tolerance of degradation
Ex= number or abundance of exotic species
To = total abundance

For the State of the Park 2010 report, data from 2005-2009 was analyzed. The average WFI score for all the wetlands was calculated for comparison to the thresholds. An average WFI was also calculated for each wetlands area (i.e, Cove Island (consisting Cove North and Boat Passage), Russel Island (consisting Russel Island East and West), Hay Bay (consisting of Hay Bay East, West, and Southwest) and Big Tub) to examine trends at a finer scale.

Condition

The average WFI (2.53-4.01) for all years was greater than 3.25 and based on the thresholds, this indicates that the current condition is good (Figure 2).

Trend

Not determined. The current approach is to assess against a WFI threshold value of 3.25. More intensive monitoring (i.e., increase sample size to 6 at major wetlands) is required to develop a linear regression model to permit inter-annual comparisons.

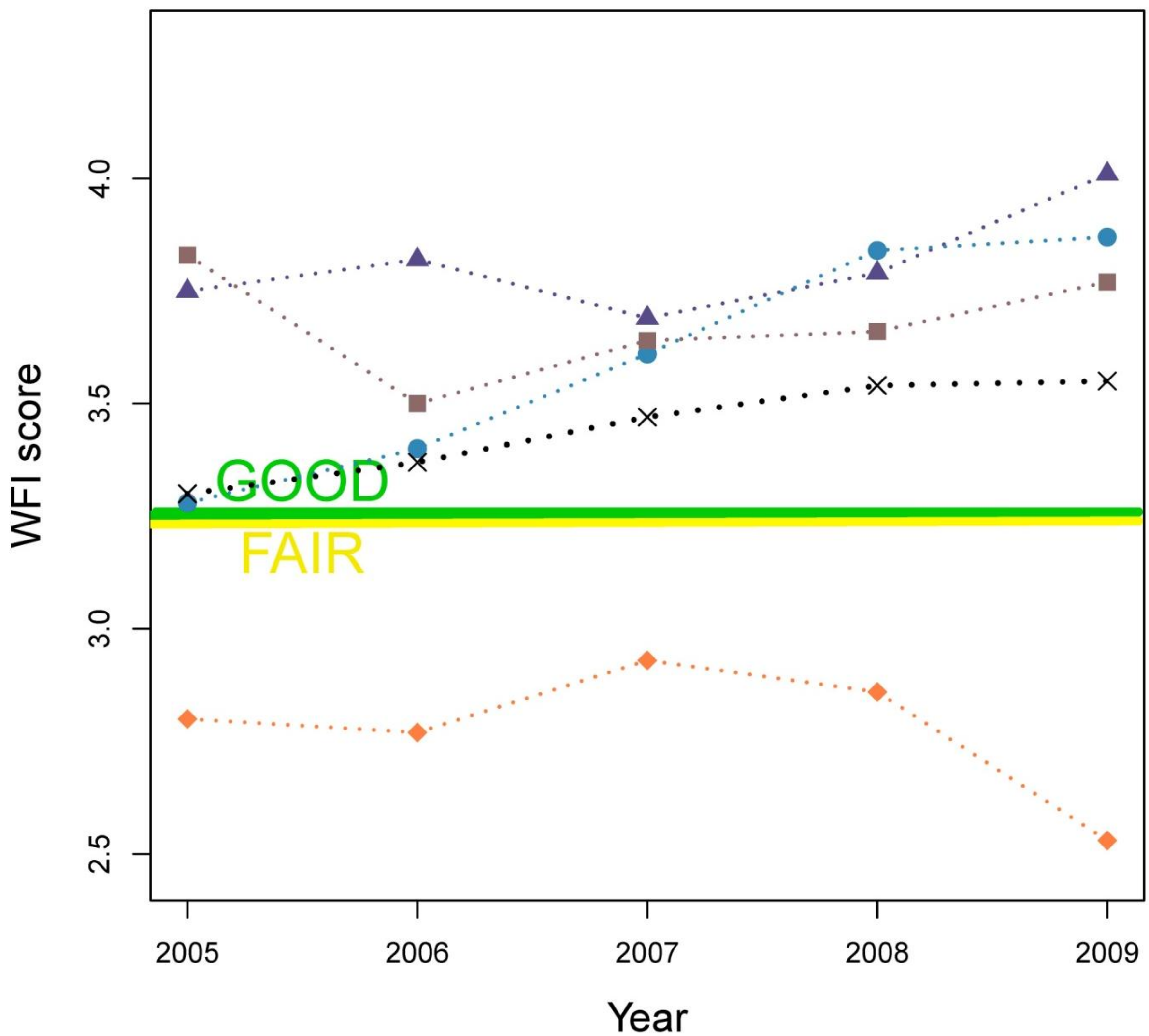

Figure 2. Wetland Fish Index based on abundance data. Average of all sites within each major wetland area in Fathom Five National Marine Park from 2005-2009. Cove Island wetlands are presented as purple triangles, Hay Bay wetlands are blue circles, Russel Island wetlands are brown squares, and Big Tub are orange triangles. The overall average for all wetlands is symbolized by a black X.

Power

The power analysis completed by Chow-Fraser et al. (2005) demonstrated that a sample size of six is required to detect a 0.25 deviation in the WFI with power of 0.80 using a one-sample t-test ($\alpha = 0.05$). Based on this, the recommendation was to intensively sample all the major wetland areas on a rotational basis (i.e., Hay Bay, Russel Island, Cove Island). Each year one major wetland would be sampled six times. The intensively sampled wetland approach would achieve 80% power using a one-sample t-test ($\alpha = 0.05$) for inter-annual comparisons, and the data from all other areas sampled once would indicate the direction of change from year to year (Table 2).

Table 2. Power analysis of the Wetland Fishes Index (Chow-Fraser et al. 2005). Effect size is 0.25 WFI units.

Sample Size	Standard Error	Power (%)
2	0.14	9
4	0.10	53
6	**0.08**	**83**
8	0.07	95
10	0.06	99

Discussion

The benefit of using the WFI to assess coastal fishes in Fathom Five National Marine Park is that it provides some indication of change and correlates well with anthropogenic disturbance (Seilheimer and Chow-Fraser 2006, Seilheimer and Chow-Fraser 2007). In addition, other partners in Georgian Bay/Lake Huron are using the methodology (e.g., OMNR). The challenge of course, and this holds for most monitoring efforts in Fathom Five National Marine Park, is the limitation in available resources. For example, more intensive monitoring would permit inter-annual comparisons but would require resources which have been limited in the past (e.g., an additional week of sampling and associated costs).

Data Quality

The data is generally considered to be good because staff at Fathom Five National Marine Park have the technical skills required to identify fish. The ability to complete intensive monitoring on a rotational basis would significantly improve the relevance of this measure and its ability to report trends.

Recommendations

When more data is available, thresholds will be evaluated by relating to known locations within each zone (i.e., pristine scores vs. impacted scores), or by comparison with levels of the other coastal measures.

Partners

Patricia Chow-Fraser, McMaster University Hamilton, Ontario.

Ontario Ministry of Natural Resources, Upper Great Lakes Management Unit, Lake Huron Office.

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2.1.4 AQUATIC PLANT COMMUNITY

Cass Stabler & Chantal Vis

NR

Monitoring Questions

i. Is the average macrophyte cover (emergent, submerged, floating plants) changing in the coastal wetlands of Fathom Five National Marine Park?

ii. Is the average macrophyte diversity index changing in wetlands in Fathom Five National Marine Park?

iii. Is the percentage of nuisance, invasive species in the aquatic plant communities of wetlands <10% (2005-2009 dataset) in Fathom Five National Marine Park and has it changed through time?

Context

Aquatic plants provide essential functions in aquatic ecosystems such as fish and plankton habitat, nutrient retention, and oxygen production and are the main primary producers in wetlands. Wetland vegetation also acts as a natural filtering system. As water enters the lake from overland flow or fast-flowing rivers, it is slowed down by the vegetation and silt is allowed to settle out (e.g., Mitsch and Gosselink 2007). The plants also absorb nutrients from the water and cycle them through the food chain (e.g., Mitsch and Gosselink 2007). Aquatic plants provide food sources for fish and wildlife species and provide oxygen through the process of photosynthesis. They are an essential structural component of habitat for reptiles, amphibians, and birds (e.g., Mitsch and Gosselink 2007). Fish habitat is largely composed of aquatic vegetation because many species require vegetation for spawning, while the juveniles seek refuge from piscivores within the plants and often forage for macroinvertebrates that are associated with submerged plants (e.g., Jude and Pappas 1992).

Aquatic plant communities have been used as indicators of human-induced degradation of wetland ecosystems throughout the Great Lakes coastline in many studies (e.g., Trebitz and Taylor 2007). Submergent vegetation, in particular, has been used to indicate wetland quality because the entire life cycle is spent within the water column and they are sensitive to changes in water turbidity and increased algal blooms, symptoms of degradation (e.g., Chow-Fraser et al. 2005). Wetland plant species diversity can also be an important indicator of ecological change, as it responds to water level changes in the Great Lakes (EC and US EPA 2009).

Thresholds

Proposed thresholds based on standard deviation approach are preliminary, as several years of data are required to develop site-specific baselines and thresholds (Table 2).

Table 1. Potential thresholds to nearshore Coastal Wetland Plant sub-measures.

Sub-measure	Good	Fair	Poor
% Nuisance species	<10%	10-30%	>30%
Macrophyte cover (average score)	<1 std from baseline	1-2 std from baseline	>2 std from baseline
Macrophyte Diversity Index (MD) (species and growth form diversity)	<1 std from baseline	1-2 std from baseline	>2 std from baseline

Note: for Macrophyte Cover and Macrophyte Diversity Index, separate thresholds for islands and mainland sites will likely be developed.

Methods

As part of the ecological integrity monitoring program, Fathom Five National Marine Park has been monitoring coastal wetlands plants within its boundaries, following the Nearshore Community Monitoring Protocol (Chow-Fraser et al. 2005, see Figure 1 page 9). The Wetland Macrophyte Index (WMI) was the recommended metric in this protocol, but later found to be not applicable to the coastal wetlands of Fathom Five National Marine Park (Pat Chow-Fraser pers. comm.). As a result, work was undertaken in 2008 and 2009 to identify more appropriate plant metrics for future aquatic plant community monitoring and reporting in Fathom Five National Marine Park.

In 2008, a method based on delineating major aquatic plant community types (emergent, submerged, floating, and wet meadow) was tested. In the field, polygons of plant distribution were outlined on maps, and ground truth points (GPS location, dominant vegetation) were recorded. This information was integrated into a GIS to calculate areal extension of habitat (Vis 2010). Areal habitat measures were not well correlated with any other wetland measures, so these were not recommended as a monitoring measure.

In 2009, based on a survey of the literature of the Great Lakes Coastal Wetland indicators, the methods of Trebitz and Taylor (2007) were adopted, in addition to noting the presence and absence of all species following the Chow-Fraser et al. 2005 protocols. Based on this method, 3 shoreline segments (permanent) are scored for the cover of emergent, submerged and floating habitats. Scores range from 0 (no plants) to 4 (substantially more plants than open water). The mean score of the 3 segments, for the 3 habitats, is averaged to determine a single cover score for each wetland, each year (macrophyte cover metric). Also based on the methods of Trebitz and Taylor 2007, 4 nuisance species are scored, in each wetland, for the following exotic and/or invasive species, *Phragmites australis* (common reed), *Typha* species (which cannot be identified to species based on morphology), *Stuckenia pectinatus* (or previously *Potamogeton pectinatus*) or sago pondweed and *Lythrum salicaria* (purple loosestrife). Using the entire dataset, (2005-2009), the % nuisance species metric was calculated as the number of nuisance species/total number of species (as a %) and used for analysis in 2010, as scores were only recorded in 2009. Finally, an estimate of % cover of macrophytes for the entire wetland is estimated, and then used to calculate the Macrophyte Diversity Index (Brazner and Beals 1997), which combines species richness (obtained from Chow-Fraser et al. 2005 protocol), growth form (based on species), and cover. The index varies between 0 and 1, with 0 representing sites with no macrophytes, and 1 the score for a site with 100% cover, with the maximum number of species observed, and high growth form diversity (Brazner and Beals, 1997).

Analysis and Results

Fathom Five contains only a few, small (< 4 ha) coastal wetlands, located in the protected embayments of the mainland and islands. The island coastal wetland sites have low plant cover (Average Cover Score = 1.25 ± 0.19) and diversity of emergent and submerged plant species (MD = 0.06 ± 0.06) (Figure 1). The mainland sites are characterized by a higher cover of macrophytes (2.63 ± 0.42) and higher diversity of species (MD = 0.79 ± 0.13). To be able to utilize the data collected in 2005-2009, the % nuisance was calculated using the presence and absence data. Based on this calculation, two of 8 sites monitored have demonstrated an increase in nuisance/invasive species beginning in 2008 (Figure 2). However, in future years, the scoring of nuisance species (started in 2009), should be used to report on invasive species, as this measure combines both presence and cover. Common reed (*Phragmites australis*) has been detected in Hay Bay and Boat Passage, and should be managed before it gets established.

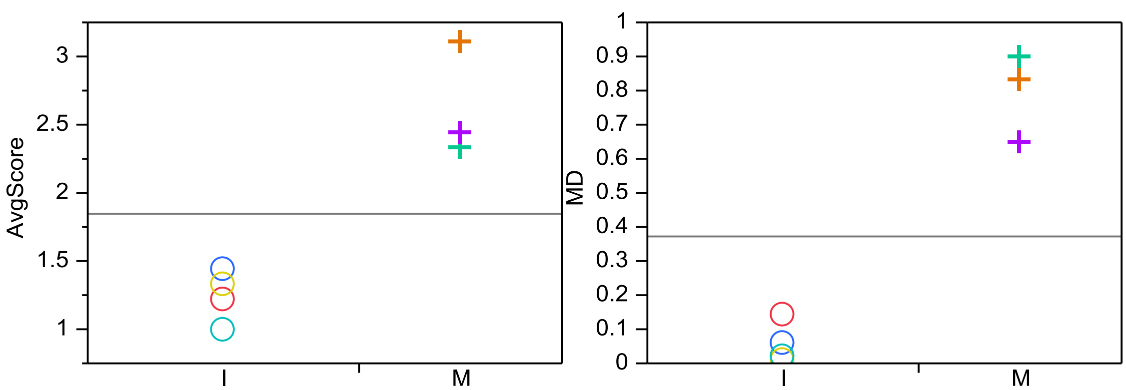

Figure 1. Differences in aquatic plant cover (AvgScore) and species/growth form diversity (MD) indices between island (I) and mainland (M) sites for the summer of 2009.

Status and trend were not assessed for the aquatic plant community measure as it is in the early stages of development.

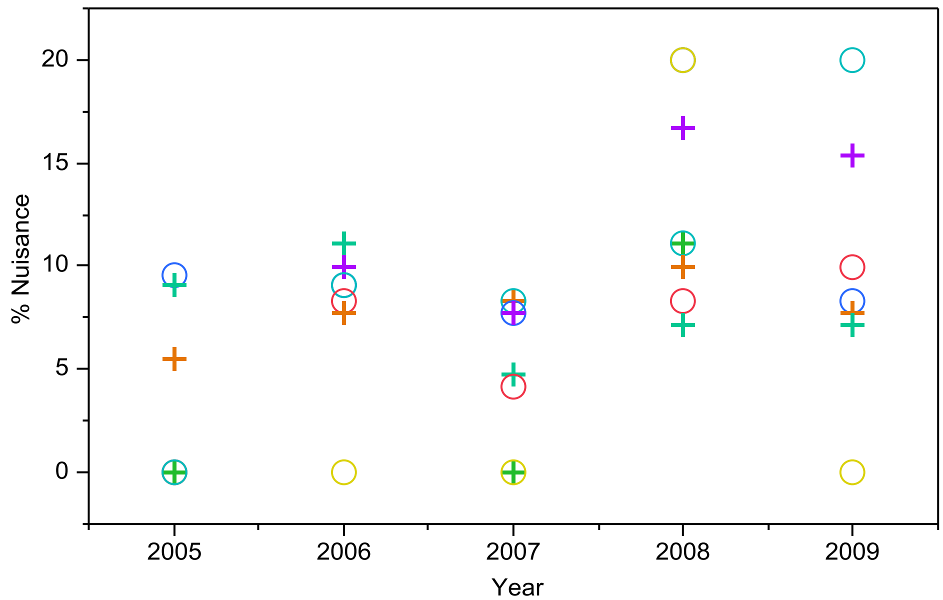

Figure 1. Percent nuisance species (invasives) in coastal wetlands of Fathom Five between 2005 and 2009. Open circles represent island sites, and crosses represent mainland sites.

Recommendations

Coastal Wetland Plant Communities is an indicator in the State of the Great Lakes 2009 report (EC & USEPA 2009). For Lake Huron, the status is rated as fair with an undetermined trend. This indicator is designed to assess the level of native vegetative diversity and cover for use as a surrogate measure of quality of coastal wetlands which are impacted by coastal manipulation or input of sediments. The three sub-measures being considered for the ecological monitoring program at Fathom Five National Marine Park could be used to assess wetland condition. Monitoring protocols for this indicator have been developed by the Great Lakes Coastal Wetlands Consortium, and are based on the invasive species plant cover and frequency, and the Floristic Quality Assessment (Albert 2008). Integration with this program should be considered for Fathom Five National Marine Park.

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2.1.5 COASTAL CONNECTIVITY

Scott Parker & Jeff Truscott

Monitoring Question

NR

Is the amount of coastal development, as measured by docks/ha in good condition within Fathom Five National Marine Park, and has it increased over a 40-year period?

Context

There is growing concern related to development impacts along the coastline of Lake Huron (e.g., Liskauskas et al. 2007, EPA and EC 2008, EPA and EC 2010). The need to protect the coastline is identified within the Fathom Five National Marine Park Management Plan (Parks Canada 1998). Fragmentation (e.g., direct loss or alteration of habitat, area and edge effects) of coastal ecosystems (e.g., Gyekis 2006, Uzarski et al. 2009) and the loss of coastal wetlands (EC and OMNR 2003) are of particular concern in the Bruce Peninsula area.

The mainland boundary of Fathom Five National Marine Park extends landward to the ordinary high water mark and is adjacent to 368 private residential lots. Parks Canada approves all in-park development along this coastline, including docks, break-walls, waterlines, and shoreline alterations. Although the environmental assessment and approval process minimize impacts, there is no explicit method or criteria to address cumulative and on-going use impacts (Parker 1993).

It is recognized that the coastline, in particular the protected bays and coastal wetlands, plays an important role in maintaining regional ecosystem structure and function (EPA and EC 2010). The coastline also represents significant social values. If, for instance, the coast of Fathom Five National Marine Park were to be completely altered with rip/rap, sheet piling, seamless docks, etc., the very character and sense of natural value and aesthetic in one of Canada's protected areas would be compromised.

Thresholds

The metric used to evaluate coastal development is docks/hectare. The current threshold values for this metric (Table 1) are based on the opinion of Parks Canada staff and are considered to be tentative. Personal observation of existing high (e.g., east arm of Hay Bay) and low (e.g., west arm of Hay Bay) density areas within Fathom Five National Marine Park guided an appreciation of the character and potential impact of shoreline development. Although no specific regional thresholds were found, other jurisdictional restrictions (e.g., Township of Lake of Bays 1999) and criteria (e.g., Swedish Environmental Protection Agency 2000) were considered (and may need to be reviewed again in finalizing thresholds).

Table 1. Threshold criteria for coastal connectivity measure in Fathom Five National Marine Park.

	Thresholds		
Status	Good	Fair	Poor
Coastal Connectivity	< 1 dock/ha	1 to 2 docks/ha	>2 docks/ha

Methods

The 244 ha study area is defined by a 100 m buffer below the ordinary high water mark within Fathom Five National Marine Park. A 100 m distance was defined to envelope all recognizable in-water developments within the park boundary recognizable in digital orthophotography at a 30 cm resolution. Developments along the mainland coast, represented as private docks, break-walls and shoreline alterations, were digitized using a GIS at a scale of 1:1000 from 30 cm orthorectified air photos taken in 1967 and 2006. The quantities and areas of in-water developments were tallied for each photo-year using the GIS (Tables 2 and Table 3). Centroids for each development feature for each photo-year were calculated in the GIS using the X-Tools 6.2 'Shapes to Centroids' command.

Table 2. Comparison of docks (in-water development) for 244 ha coastal buffer in Fathom Five National Marine Park between 1967 and 2006.

	1967	2006
# of Docks	43	170
Average # of Docks/ha	0.18	0.70
Area of Docks (ha)	0.32	0.79
Average Area of Docks/ha	0.0013	0.0032

Table 3. Results of airphoto digitization of coastal development in Fathom Five National Marine Park.

Development Type	Total Area 1967 (m^2)	Total Area 2006 (m^2)	% Increase 1967 to 2006	Annual % Increase
Buildings	15413	60632	293	7.3
Laneways	31079	112511	262	6.5
Manicured Landscapes	107015	145868	36	0.9
In-Water Development	3432	8059	135	3.4

The spatial concentration of in-water development features, per hectare of shoreline, was quantified for each photo-year using the ArcGIS Spatial Analyst 'Density' function (ESRI 2011) (Figures 1 & 2). The in-water development centroids were used as the input data. The 'kernel' (Silverman 1986) point density model was employed using a 100 m search radius and area units equalling one hectare (Figure 3). The average number of docks per hectare was calculated from the density models using the GIS.

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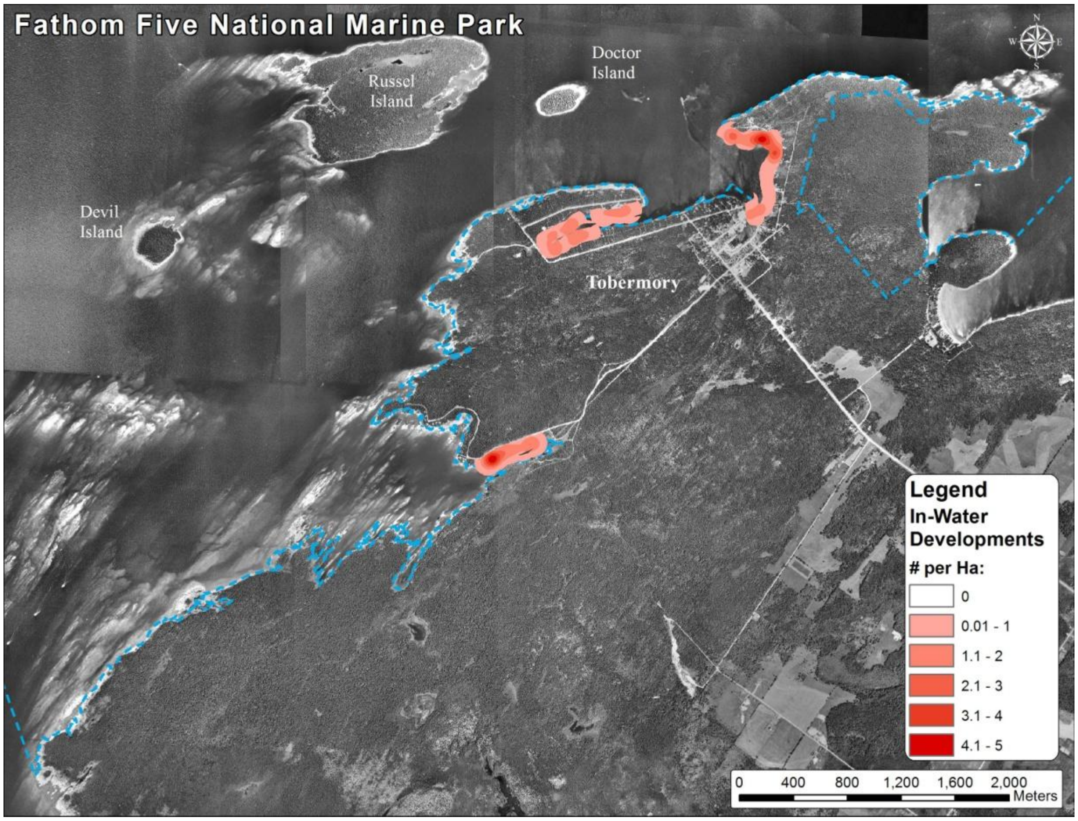

Figure 1. In-water coastal development in Fathom Five National Marine Park 1967.

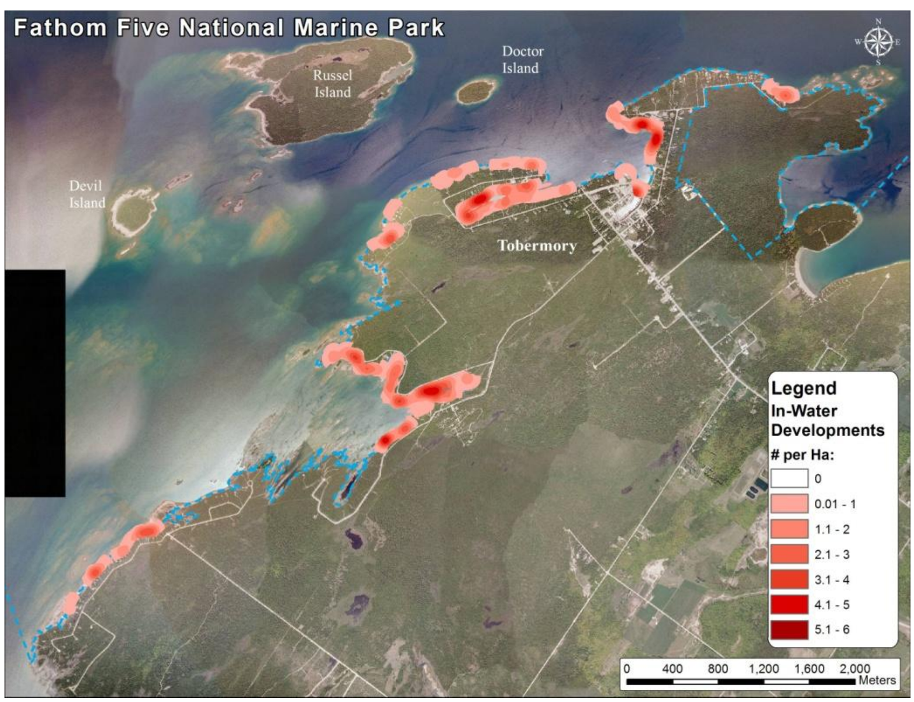

Figure 2. In-water coastal development in Fathom Five National Marine Park 2006.

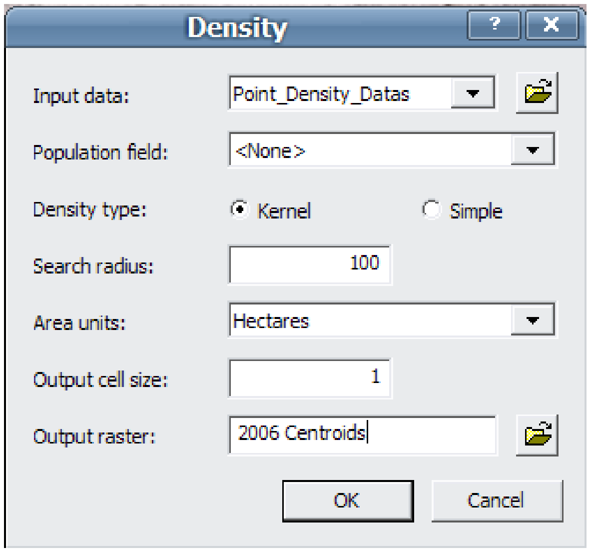

Figure 3: Example input panel for the 'kernel' density function.

Analysis and Results

Data Analysis

For the assessment of this measure, only data derived from the 1967 and 2006 series of images were used (Table 2, Figures 1 and 2). An average for the whole coast was determined.

Condition

The current condition, represented by the 2006 data of the docks/ha metric was assessed as good, with an average density of 0.70 docks/ha for the Fathom Five National Marine Park mainland coast.

Trend

Trend was not rated at this time. Only two periods (i.e., 1967 and 2006) were sampled, and the dates indicate a clear increase in the number of docks/ha between the two time periods, and in all other types of coastal development (Table 3). Based on the differences between 1967 and 2006, the rate of increase is 0.013 docks/ha/year, and if this current rate continues, the condition is expected to be rated as fair in 23 years, and poor in 100 years.

Power

Not applicable.

Discussion

Intuition alone suggests that the social values and ecological integrity of the protected area could be eroded through cumulative coastal development. Assessing the number of docks/ha is viewed as a preliminary attempt to understand and consider potential impacts. This measure and threshold warrants further study, perhaps within an adaptive management framework.

Data Quality

The air photos and digitization process is considered to be good and of sufficient resolution for this purpose. Other series (i.e., 1938, 1945, 1954, 1978, and 2010) are in the process of being orthorectified and development may be digitized as well.

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2.2 ISLAND

NR

The Fathom Five National Marine Park archipelago consists of fourteen islands and several islets, comprising a total area of 13.5 km^2 or 12% of the marine park (PCA 2010). Only Flowerpot Island has public infrastructure and receives 40,000 visitors a year (PCA 2010).

A long-term ecological objective for islands in the Great Lakes has been developed by the Collaborative for the Conservation of Great Lakes Islands (contributors to the State of the Great Lakes 2009 report). Their objective is to ensure the conservation, protection, and preservation of the islands of the Great Lakes, including their unique landforms, plants, animals, cultural history, and globally important biological diversity (EC & USEPA 2009, Henson et al. 2010).

Islands are vulnerable and sensitive to change due to their 360-degree exposure to coastal processes. Because of their isolation, many islands support unique species and communities. In Lake Huron, islands include a high number of globally rare species and vegetation communities (EC & USEPA 2009).

The status and trend of the island indicator is determined by considering the habitat amount and connection, alvar quality, and colonial waterbirds. The current condition of the island indicator is assessed as fair with no trend established to date (Appendix A).

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2.2.1 HABITAT AMOUNT AND CONNECTION

Stephen McCanny

NR

Monitoring Questions

i. What is the pattern of effective patch amount for focal species groups in the greater park ecosystem relative to the rest of the ecozone?

ii. What is the pattern of effective connectivity for focal species groups in the greater park ecosystem relative to the rest of the ecozone?

Context

Habitat loss and fragmentation is recognized as one of the key factors in the ecological integrity of small southern parks. Widespread and mobile populations are heavily influenced by the amount and spatial arrangement of habitat patches. Here, we undertake the measurement of this aspect of conservation for the island species in Fathom Five National Marine Park.

Fragcube is a tool to assess landscape-scale habitat change for a suite of focal species (Zorn and Quirouette 2009). This approach uses a classified remote sensing image and models the species-specific response to this change in two measures: (i) effective habitat amount and (ii) effective habitat connectivity, for a particular focal species. The term 'effective' is used to refer to the species-specific relationship between land cover change and habitat (Zorn and Quirouette 2009).

Effective habitat amount and connectivity are assessed for a suite of focal species groups based on ecologically scaled landscape indices, or species profiles (Vos et al. 2001). This approach is based on the principle that a landscape is occupied by multiple species with different requirements for habitat amount and connectivity that are determined by factors such as specific habitat associations (i.e., habitat generalist versus habitat specialist), species movement abilities and behaviour and dispersal scales (Zorn and Quirouette 2009). Therefore, the assessment is based on both the structure and specific function of the landscape for a selected group of species.

Species profiles are developed to coarsely define the habitat requirements for each focal species or group based on three main elements: (i) habitat type, which defines where each species lives, including forest type or land cover class, patch size and shape requirements needed to support breeding individuals and any known restrictions to habitat use (e.g., edge effects, landscape features that are avoided); (ii) cost surface, which describes how changes in landscape connectivity increase the cost of dispersal and assigns different weights to landscape features that influence dispersal (e.g., roads, non-forested areas); (iii) active dispersal range, which defines the spatial scale that individuals of a species or group access the landscape (e.g., home range, mean dispersal distance; Zorn and Quirouette 2009).

Four focal species groups are used to assess effective habitat amount and landscape connectivity at Fathom Five National Marine Park: forest amphibians, forest small mammals, coastal herptiles and marsh birds.

Thresholds

The assessment of landscape characteristics in Fathom Five National Marine Park involves development of two measures: (i) effective habitat amount and (ii) effective habitat connectivity. Each of these measures is reported as an index that summarizes the status and trend of the measure in relation to the established thresholds for each of the focal species groups.

Thresholds are based on conducting the same sets of analyses at the scale of the Great Lake islands and coastlines within the Mixedwood Plains and a section of the Boreal Ecozones (Ecoregion 5E). The selected ecozones are compared to the trends for Fathom Five National Marine Park. Thresholds were then applied to identify species landscapes that are estimated to contain sufficient habitat (i.e., a certain proportion of a moving window must contain effective habitat to be suitable; the average cost weighted distance between habitat patches must be less than the width of the moving window to be connected). Statistics on the total amount and connectivity of effective habitat (scaled to species home range) for Fathom Five National Marine Park were then extracted. This analysis is based on ArcGIS - Spatial Analyst's - zonal statistics function applied to a grid with cells of identical size and consistent with the size of Fathom Five National Marine Park. The values for thresholds were based on the 33% and 66% percentile values from zonal statistics across the ecozone. The bottom third of values were classified as poor, middle third as fair and upper third as good (Table 1).

Table 1. Thresholds used to determine status of the habitat amount and connection measure in Fathom Five National Marine Park based on statistical analysis.

	Thresholds		
Status	Good	Fair	Poor
	<33%	33% - 66%	>66%

Methods

The Parks Canada Fragcube Monitoring Protocol provides detailed information on the methodology and data analysis requirements for this project (Zorn and Quirouette 2009).

This monitoring protocol estimates changes in effective habitat amount and connectivity for selected species using classified Landsat Thematic Mapper (TM) imagery. The classified imagery, Ontario Land Cover Database, was obtained from Land Information Ontario. The Ontario Land Cover Database provides a classification of 27 land cover types, including vegetation types and non-vegetated surfaces. Modelling of Fathom Five was based on a 255 km² moving window, that covered the spatial extent of the park.

Species profiles were developed to define the habitat requirements for each focal species group. Several decisions must be taken to calculate the amount and connectivity of a species' habitat:

i. Which land cover categories are considered habitat (patch type)?
ii. What distance from developed land cover must the species maintain (buffer size)?
iii. What weight should be given to road density (or other disturbance) in determining the effective distance between patches?
iv. At what scale does the species sample the landscape (home range size)?

The answers to these questions are included in Table 2 for two focal species groups: forest amphibians and small mammals.

Table 2. Summary of focal species profiles for forest amphibians and small mammals in Fathom Five National Marine Park.

Focal Species Group	Patch Type	Buffer Size	Weight	Scale
Forest Amphibians	All Forests	30 m from non-forest, trails and roads	10K	100 m x 100 m
Small Mammals	All Forests	None	5X	1 km x 1 km

Estimation of habitat change for each focal species group was then accomplished through two main steps. First, land cover types were translated into habitat needs for selected species. This was done through considering the land cover type (e.g., conifer forest, mixed forest) and its spatial context (e.g., 30 m edge effect for forest patches adjacent to non-forest land cover types). The specific combination of land cover type and spatial context is unique to each species group. These sets of rules were applied using ArcGIS 9.3 - Spatial Analyst to create an effective habitat patch map for each species. Second, a moving window analysis was applied to each habitat patch map where the size of the moving window estimated the home range or dispersal area of the species. Within the window, the total amount and connectivity of effective habitat was calculated to determine the suitability of species landscapes throughout the study area. Amount is measured as the total area of effective habitat patches summed per window. Connectivity is measured as the mean cost-weighted distance between patches where cost is determined by a species-specific cost surface (e.g., road density, non-forest gap crossings) developed in GIS. The results are gradient maps that show areas of high and low effective habitat amount and connectivity throughout the park and greater park ecosystem for each species.

Analysis and Results

Data Analysis

Effective habitat amount and connectivity were mapped for Fathom Five National Marine Park and the Great Lakes coastal component of the Mixedwood Plains and Boreal (Ecoregion 5E) Ecozones. The effective habitat amount and effective habitat connectivity index determines if Fathom Five National Marine Park is relatively fragmented (poor), moderately fragmented (fair), or unfragmented (good) compared to areas of the same size throughout the ecozone.

Condition

The condition for habitat amount and connection for forest ecosystems in Fathom Five National Marine park was rated as fair (Table 3). The condition for habitat amount and connection for coastal ecosystems in Fathom Five National Marine park was rated as good (Table 4). Overall, the habitat amount and connection measure was rated as fair.

Table 3. Amount and connectivity of landscape characteristics analyzed for the forest ecosystem at the scale of Fathom Five National Marine Park ecosystem.

Measure	Unit	Value	Percentile	Rating
Amphibian habitat amount	m^2	3.75	30%	Poor
Amphibian habitat connection	m	9.43	84%	Good
Sm. mammal habitat amount	m^2	254	48%	Fair
Sm. mammal habitat connection	m	3.83	82%	Good
Forest ecosystem overall rating				Fair

Table 4. Amount and connectivity of landscape characteristics analyzed for the coastal ecosystem at the scale of Fathom Five National Marine Park ecosystem.

Measure	Unit	Value	Percentile	Rating
Herptile habitat amount	m^2	0.08	8%	Poor
Herptile habitat connection	m	502	93%	Good
Marsh bird habitat amount	m^2	483	68%	Good
Marsh bird habitat connection	m	4578	94%	Good
Coastal ecosystem overall rating				Good

Power Analysis

Further work needs to be done on power analysis for this approach but both confidence and power are proportional to the number of equivalent sized shorelines in the Great Lakes for a given focal species profile (60 – 400).

Discussion and Recommendations

The application of the FragCube methodology to islands will be re-evaluated in the coming years.

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2.2.2 ALVAR QUALITY

Cass Stabler

Monitoring Question

NR

Are the alvars on Bears Rump Island and Cove Island at Fathom Five National Marine Park in good quality and has quality improved or remained the same over the past five years?

Context

The alvars of Fathom Five National Marine Park are important components of the island landscape. Alvars are natural communities found in open areas of glaciated limestone bedrock with a thin soil layer. They are composed of a highly diverse and characteristic suite of flora and fauna (Brownell & Riley 2000) (Figure 1). Alvars provide essential ecological functions to a number of alvar-restricted species (Jalava 2008) (Figure 1). They have distinctive natural histories; alvars on the Bruce Peninsula are maintained by flooding and drought cycles (Brownell & Riley 2000). In the context of education and research, alvars are areas where natural heritage recreation and public education can be very successful and they are particularly valuable areas for ecological research and monitoring of climate change (Brownell & Riley 2000). Also, alvars are recognized as globally rare ecosystems (Brownell & Riley 2000, Jalava 2008, Reschke et al. 1999).

Figure 1. From right to left: Hill's thistle (*Cirsium hillii*), a rare alvar species found on Bears Rump Island ©Parks Canada. Dwarf lake iris (*Iris lacustris*), a rare species occurring of alvar species found on Bears Rump Island ©W. Waterton. The extensive bedrock shoreline of the west coast of Cove Island provides ideal alvar habitat (Jalava 2008).

Two alvar sites are located in Fathom Five National Marine Park (Figure 2). One site is located on the west end of Bears Rump Island (NAD83 UTM 17T 455000 5018220). The other site is located on Cove Island (NAD83 UTM 17T 441800 5016600).

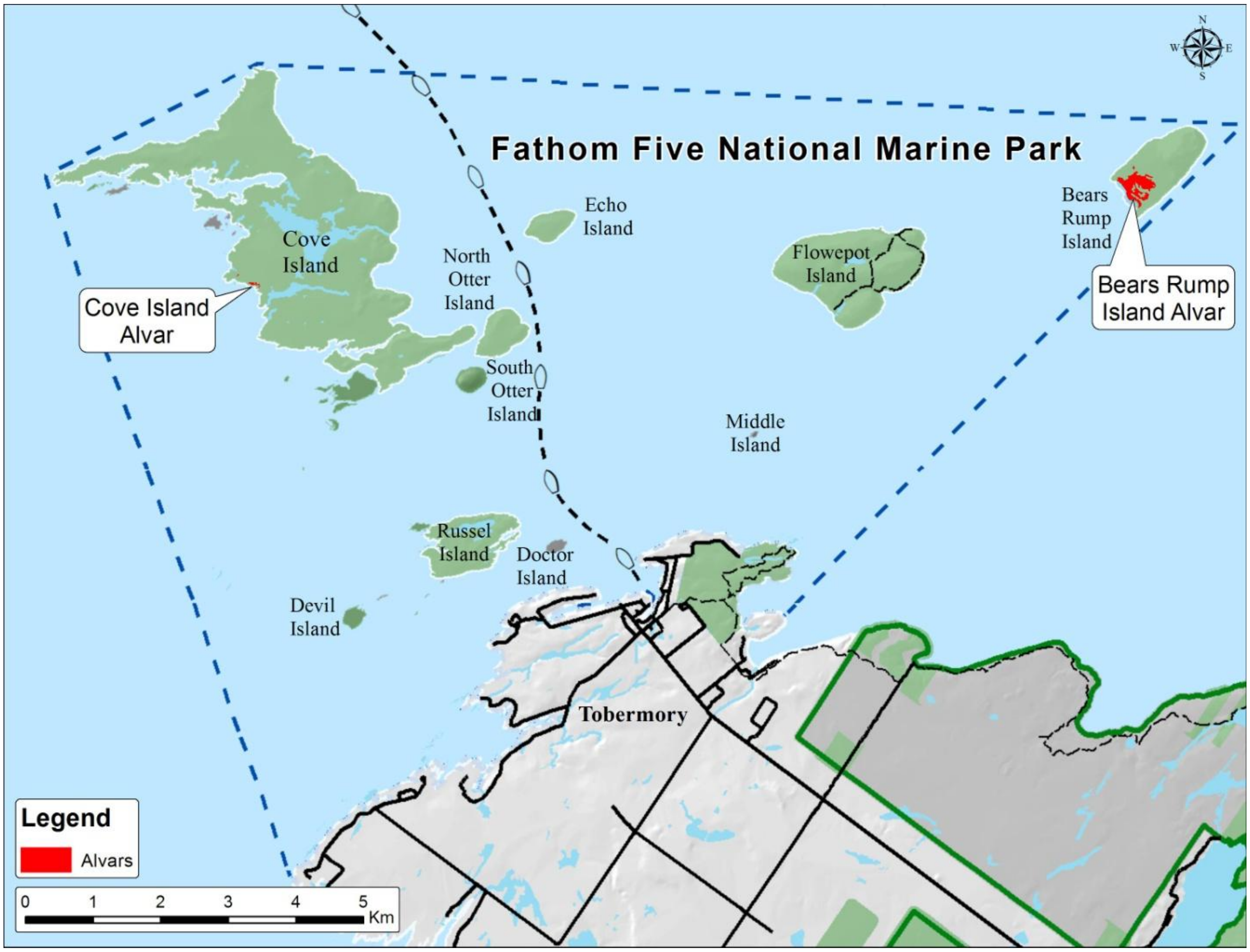

Figure 2. Locations of alvar sites in Fathom Five National Marine Park. The boundary of Fathom Five National Marine Park is delineated by the dashed line. Alvars are indicated by the red areas. Cove Island alvar is located on the west coastline of Cove Island and Bears Rump alvar is located on the west coastline of Bears Rump Island.

Thresholds

Thresholds for the alvar quality measure are adapted from one component of the standard evaluation criteria for alvar quality developed by the Federation of Ontario Naturalists and the International Alvar Conservation Initiative (IACI) (Brownell & Riley 2000, Reschke et al. 1999). The standard evaluation criteria for alvars takes into account information about regional representation, community and species diversity, special features of conservation concern, site condition, and ecological function. One component of the community evaluation criteria is spatial extent of the alvar. The thresholds developed for the State of the Park 2010 were based on this component; the combined spatial extent of all alvar sites within the park (Table 1). These area sizes were selected because they represent a significant portion of the total spatial extent of the islands that support alvar ecosystems in Fathom Five National Marine Park (Stephen McCanny pers. comm.).

Table 1. Thresholds used to determine status of the alvar quality measure in Fathom Five National Marine Park based on total spatial extent of all alvar occurrences in the park measured in hectares. These are preliminary thresholds for extent used in the 2010 State of the Park report, however, the measure and thresholds will be re-evaluated for future monitoring and reporting.

	Thresholds		
Status	Good	Fair	Poor
Spatial Extent	>10 ha	5 to 10 ha	<5 ha

Methods

Data used to rank this measure was collected from The Alvars of the Bruce Peninsula: A Consolidated Summary of Ecological Surveys (Jalava 2008). The Jalava (2008) report provides a site summary for each alvar of the Bruce Peninsula. Each site summary contains all available information about the particular alvar such as location, ownership, protection level, survey dates and surveyors, total extent of the alvar, alvar quality rank, inventory information, general site description, alvar representation, condition, diversity, ecological functions, special features, conclusions and recommendations, and references. All of this information is available for both Bears Rump Island alvar and Cove Island alvar. For this measure, the total extent of the alvar (in hectares) was recorded. The individual total extent of the alvar measures were added together. This gives a value for total spatial extent of alvars in Fathom Five National Marine Park. In order to assess the condition of the Alvar Quality measure this total value was compared to the threshold values.

Analysis and Results

Data Analysis

The total extent of the Cove Island alvar is 0.3 ha. The total extent of the Bears Rump alvar is 12.7 ha. Combined, the total spatial extent of alvars in Fathom Five National Marine Park is 13 ha.

Condition

The Alvar Quality measure is rated as good because the total spatial extent of alvars in Fathom Five National Marine Park (13 ha) exceeds the highest threshold level (>10 ha).

Trend

Trend was not rated for the Alvar Quality measure. The condition rating was determined based on one set of observations; the spatial extent of the alvars was measured one time, so there was no way to determine if this measure has changed over time.

Power

Power was not analyzed for the Alvar Quality measure because statistical analysis was not used to determine the condition or trend ratings.

Data Quality

This measure is based on limited data. Statistical analysis was not used to assess the condition rating for this measure; the rating is based on one observation collected at one time. As of yet, there is no protocol for data collection or analysis.

Recommendations

The following recommendations are provided to improve the ecological monitoring program for alvar quality at Fathom Five National Marine Park. These recommendations will improve data quality and will further the development of this monitoring measure.

The State of the Great Lakes 2009 report (EC & USEPA 2009) categorizes the Area, Quality and Protection of Special Lakeshore Communities – Alvars indicator with a not assessed status and an undetermined trend. The information that is included in this report comes from the International Alvar Conservation Initiative (IACI) (Reshke et al. 1999) and mentions that documentation of the extent and quality of alvars by IACI has been a major step forward in the conservation of alvar ecosystems. This report also notes that because of the large number of significant alvars at risk, this status should be closely monitored to ensure that they are not extirpated. Fathom Five National Marine Park can have a part in furthering these efforts.

Protocol

A protocol should be developed for this measure. This protocol should include methods for data collection, threshold development, data analysis, and determining a condition and trend rating representative of overall alvar quality ranks for multiple alvar sites. Many of these methods have already been developed by the IACI (Reshke et al. 1999) and The Alvars of Ontario study (Brownell & Riley 2000) and, where possible, these methods should be adopted by the ecological monitoring program at Fathom Five National Marine Park.

Data Collection

Standard field methods and standard data collection forms for monitoring alvar sites are available from The Nature Conservancy's Great Lakes Program Office (Reschke et al. 1999). These forms are based on national vegetation classification from the USA, but have been used for The Alvars of Ontario Study (Brownell & Riley 2000) and could be altered to meet the needs of Fathom Five National Marine Park, if necessary. The data collection methods and forms have been field tested and revised by the IACI to streamline the data collection process. Forms for monitoring vegetation plots, recording evidence of ecological processes and alvar microhabitat features, and for community ranking and description have been developed.

Permanent vegetation monitoring plots should be set up at each of the alvar sites. This will allow ecologists to revisit the same sampling area each year and monitor changes in alvar quality over the long-term. Permanent monitoring plots can also act as standard reference sites for future studies using remote sensing technologies to collect and analyze data. When setting up permanent monitoring plots the rationale, objectives, and experimental design of the monitoring program should be considered. This will ensure that the plots are the correct size and in the correct location to adequately collect precise and accurate data (Roberts-Pichette & Gillespie 1999). Several methods have been developed to mark permanent alvar monitoring plots in a secure and non-invasive manner.

Certain alvar plant species are difficult to identify in the field without specialized training. Specimens may be collected for identification at a herbarium. The IACI also presents solutions for simplifying data collection, such as grouping nonvascular plants based on growth form characteristics (Reshke et al. 1999). These modifications may be considered to ensure a manageable monitoring protocol is developed.

Community and structural data is used to classify the vegetation community types of each alvar. Once the community types are determined, this information may be used to identify which sets of specifications from the standard evaluation criteria will be used to rank alvar quality for each site. Much of this has already been done for both Bears Rump Island alvar and Cove Island alvar. The IACI recognizes 13 alvar types and 3 community types similar to alvars. The Alvars of Ontario study uses a comparable classification system, but has identified several more subclasses of alvar types based on the full range of field studies summarized in the report. The Alvars of the Bruce Peninsula study (Jalava 2008) follows the Southern Ontario Ecological Land Classification (ELC) (Lee et al. 1998). Each classification system should be considered when attempting to choose an appropriate one for the ecological monitoring program of Fathom Five National Marine Park.

Threshold Development

Thresholds for spatial extent of alvars, and other standard evaluation criteria, have been developed by the IACI (Reschke et al. 1999). These size thresholds vary by alvar community type. They were determined based on an analysis of community and structural type data carried out by the IACI (Reschke et al. 1999). The thresholds for each alvar community type are listed in Appendix 3: Alvar Community Technical Descriptions and Element Occurrence Ranking Specifications of the Final Technical Report of the IACI (Reschke et al. 1999). This information could be used to develop science-based thresholds for the current measure. It could also support development of thresholds for future assessments of this measure that incorporate additional components of the standard evaluation criteria.

Baseline Data

Alvars are a conservation priority for many organizations in Ontario. Baseline data is available from various sources for this measure. Both the Cove Island and Bears Rump Island alvars have been given an initial Overall Alvar Quality Rank (Jalava 2008). These ranks are based on definitions and methods presented in The Alvars of Ontario study (Brownell & Riley 2000) and the IACI Final Technical Report (Reschke et al. 1999). The Overall Alvar Quality Rank for Bears Rump Island is supported with scientific research. The alvar site on Bears Rump Island was inventoried on July 1 and July 10, 1992 and on July 4, 1996. Inventories were carried out at the detailed level, as reconnaissance inventories, and as brief site inspections. Vegetation, vascular plants, insects, and breeding birds were inventoried. Less information is available about the Cove Island alvar. The Overall Alvar Quality Rank is based on the best available data and expert opinion, but none of the surveys were done at the detailed level and some aspects of the site have not been studied. The alvar site on Cove Island was surveyed in 1981, 1982, 1983, 1985, 1986, 1987, 1992, 1993, and on August 22, 2006. These were reconnaissance inventories and brief site inspections. The alvars on Cove Island have been inventoried for vegetation, vascular plants, and breeding birds.

Data Analysis

Various data analysis methods have been developed to determine values related to the standard evaluation criteria. Details are available in Appendix 2: Detailed Community Analysis Methods of the Final Technical Report of the IACI (Reschke et al. 1999). And in the Methods section of The Alvars of Ontario Study (Brownell & Riley 2000). The Alvars of the Bruce Peninsula also discusses some methods for digital mapping and evaluation of the relative ecological significance of alvar communities on the Bruce Peninsula (Jalava 2008). The ecological monitoring program should adopt a set of standard data analysis procedures based on this previously completed work.

Combination of Multiple Alvar Quality Ranks

The best method to combine the individual alvar quality ranks for the Cove Island alvar and the Bears Rump Island alvar should be determined. There is a large size difference between the two sites and between the proportions of the respective island ecosystems they represent. The element occurrence ranking could be used to determine if these two sites represent two elements with distinct conservation value or if they can be treated as one element of the island landscape (Jalava 2008). If these two sites represent two distinct communities their impact in the landscape may not be additive. In this case, the combination of their scores should be re-evaluated to determine an overall value more representative of overall alvar quality in Fathom Five National Marine Park.

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2.2.3 COLONIAL WATERBIRDS

Cass Stabler

Monitoring Questions:

NR

i. What is the species composition of colonial waterbirds nesting in Fathom Five National Marine Park and how has this changed over time?

ii. What is the species abundance in terms of colonial waterbird species nesting in Fathom Five National Marine Park and how has this changed over time?

Context

Nesting populations of colonial waterbirds are common on the Great Lakes. By definition, these fish-eating birds breed in colonies, which vary in size, and are closely associated with water (Maehr & Rodgers 1985). Numbers of nesting colonial waterbirds are largely influenced by such factors as prey availability, predation on eggs or chicks, and nesting success (Blokpoel & Scharf 1991). Colonial waterbirds, as top-level predators, are also effective monitors of environmental contamination since they are likely to accumulate the highest levels of contaminants in the ecosystem. Reduced nesting success, for example, was attributed to high levels of contaminants found in eggs (Weseloh et al. 1983). Consequently, populations of nesting colonial waterbirds are closely linked to ecosystem processes around them (Hughes et al. 2007).

Five colonial waterbird species nest regularly on four shoals or islands in Fathom Five National Marine Park and the adjacent Snake Island (Figure 1). These species are: Double-crested Cormorant (*Phalacrocorax auritus*), Herring Gull (*Larus argentatus*), Ring-billed Gull (*Larus delawarensis*), Common Tern (*Sterna hirundo*), and Great Blue Heron (*Ardea herodias*) (Hughes et al. 2007). Although the largest nesting colonies are on Snake Island (just outside the boundaries of Fathom Five National Marine Park) birds from those colonies frequently forage in the marine park (PCA 2010).

Thresholds

Thresholds have not been developed for this measure (PCA 2010). Baseline data has been collected and an index of natural variability will be determined for future State of the Park reports (Hughes et al. 2007).

Methods

Details outlining sampling methods, timing of data collection, equipment required for data collection, colony locations and habitat descriptions, methods of analysis, personnel and funding requirements, field data forms, data storage, and associated background information is included in the protocol for this measure (Hughes et al. 2007).

Figure 1. Locations of the five colonial waterbird nesting sites in Fathom Five National Marine Park and the surrounding area.

Some of this work has been completed to date. Surveys have taken place from 2006-2010. There has been some comparison of community composition between years using a multivariate measure, the Bray-Curtis dissimilarity. The key advantage of multivariate measures is that they describe the most information-rich aspects of a community. This, unfortunately, does not go along with a simple explanation of what exactly a multivariate measure is describing. The Percent Difference (or Bray-Curtis Dissimilarity) Index provides a good combination of the values of completeness and interpretability. Take the following two samples:

	Cormorants	Herring Gull	Blue Heron
Year 1	50%	30%	20%
Year 2	45%	35%	20%
Absolute Difference	5%	5%	0%

The Percent Difference between two communities is calculated by taking the sum of the absolute differences and dividing by 2. In this case, there are 5% fewer Cormorants and 5% more Herring Gulls in

Year 2. It makes sense to divide the sum of differences by 2 because all of the samples add up to 100% and it logically follows that a loss in one species must be made up by an increase in another. These two samples are 5% different.

Analysis and Results

Data Analysis

The number of nests of colonial waterbirds was reported by species and the total number of nests in the community was summed over each year of the survey (Table 1). The percent of the total community composition was calculated for each species for each year (Table 2). This information was used to determine the Bray-Curtis dissimilarity index to compare community composition (richness and abundance) for each year in the survey (2006-2009) to the community composition of the first year of the survey (2006) (Figure 2).

Table 1. Number of nests of colonial waterbirds by species in Fathom Five National Marine Park from 2006-2009.

Colonial Waterbird	Number of Nests			
Species	2006	2007	2008	2009
Cormorant	590	580	630	560
Herring Gull	200	330	310	310
Blue Heron	20	20	20	30
Ring billed gull	30	80	90	30
Common Tern	30	5	40	10
Total	870	1015	1090	940

Table 2. Percent of community composition of each colonial waterbird species in Fathom Five National Marine Park from 2006-2009.

Colonial Waterbird	% of Community by Year			
Species	2006	2007	2008	2009
Cormorant	67.8	57.1	57.8	59.6
Herring Gull	23.0	32.5	28.4	33.0
Blue Heron	2.3	2.0	1.8	3.2
Ring billed gull	3.4	7.9	8.3	3.2
Common Tern	3.4	0.5	3.7	1.1

Condition

Condition was not rated for this measure.

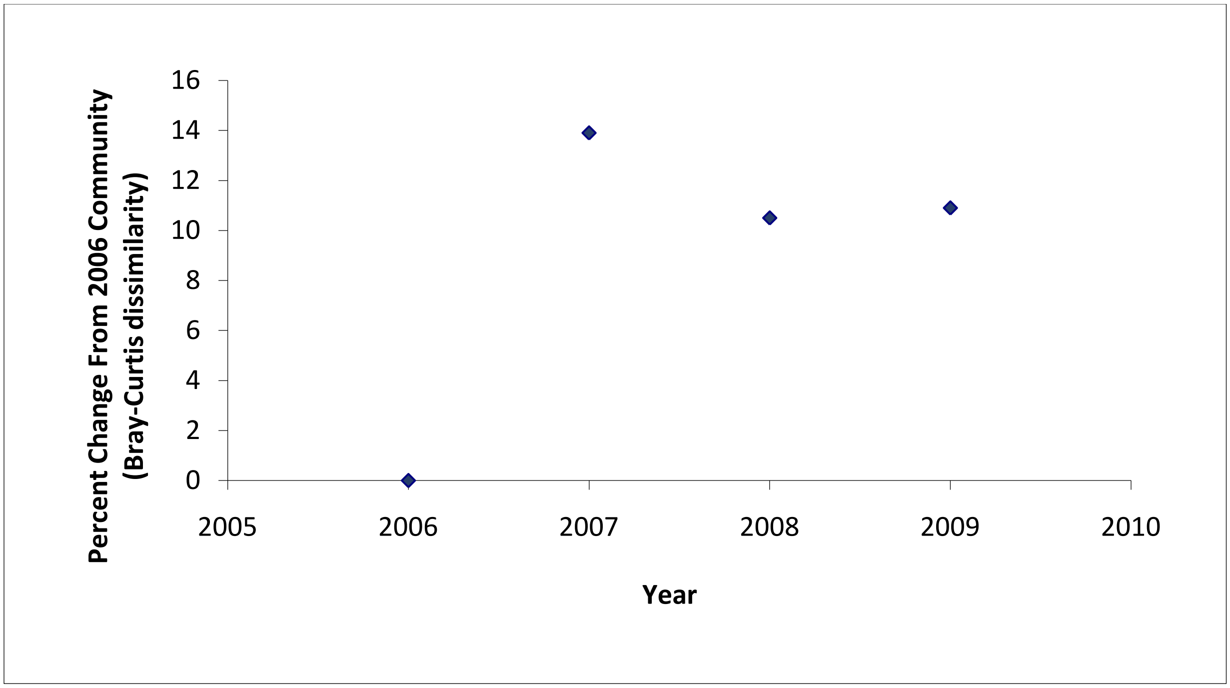

Figure 2. Percent change in community composition from 2006 to each following year from 2007-2008 in Fathom Five National Marine Park determined using the Bray-Curtis dissimilarity.

Trend

Trend was not rated for this measure.

Power

Power was not analyzed for this measure.

Recommendations

Protocol

The statistical analysis outlined in the protocol is not the same as the approach presented (Hughes et al. 2007). This section should be updated to ensure that the methods for statistical analysis are clear and repeatable for future State of the Park reports.

Long-term Monitoring Programs

For the State of the Great Lakes Report 2009, Contaminants in Colonial Nesting Waterbirds (Indicator #115) is an indicator, but colonial waterbird diversity and abundance is not. Rather, they evaluate the status of wetland bird communities only (EC & USEPA 2009).

Data Quality

Waterbird colonies in Fathom Five National Marine Park have been surveyed with varying intensity between the years of 2005 and 2010. A few historical records exist for some of the colony sites. Of 178 total counts between 2005 and 2010, the observers reported their counts as highly confident 173 times, or 97% of the time, as reasonably confident 2 times, or 1% of the time, and as not confident 3 times, or 2% of the time.

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2.3 OFFSHORE

NR

The offshore ecosystem of Lake Huron is relatively shallow among the Great Lakes (only Lake Erie is shallower), with an average depth of 59 m and a maximum depth of over 200 m. Lake Huron is the second largest of the Great Lakes by surface area at 59,600 km^2 and the fifth largest freshwater lake in the world. Surface temperatures range from 0°– 4°C in January and 12°–16°C in July and the average water residence time of Lake Huron is 22 years (GLIN 2005). It is an oligotrophic lake; low in productivity and high in dissolved oxygen concentration (>95%) (e.g., Liskauskas et al. 2007). The Lake Huron ecosystem has undergone dramatic changes in the past century from impacts such as over-fishing and the establishment of invasive species (e.g., Liskauskas et al. 2007).

The surface area of Fathom Five National Marine Park has been classified into land ecosystems, coastal ecosystems, and pelagic or offshore ecosystems (Figure 1). The land ecosystem includes any exposed land surface, the coastal ecosystem represents the littoral zone and extends from the ordinary high water mark to a depth of 10 m, and the pelagic or offshore ecosystem represents anything >10 m deep. This differs somewhat from the offshore/nearshore classification of the Great Lakes, which considers offshore in Lake Huron to be areas > 30 m depth contour (EC & USEPA 1996).

The offshore indicator is measured by water quality, benthic community, lake trout, and ice coverage (PCA 2010). The current condition of the offshore indicator is fair and no trend has been determined to date (Appendix A).

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Figure 1. A map of Fathom Five National Marine park by ecosystem type.

2.3.1 OFFSHORE WATER QUALITY

Chantal Vis

Monitoring Question

Are the offshore waters of Fathom Five in an oligotrophic state based on water quality (i.e., Total phosphorus concentration ~ 5 µg/L) and has this changed over the last seven years (2000-2007)?

Context

Water chemistry monitoring is important as it provides information on the quality of water for drinking, for recreational uses (i.e., swimming), and for the protection of aquatic life. A degradation in water quality can lead to public health issues, such as beach closures and nuisance algal mats in the nearshore, and have ecological consequences, such as shifts in algae species composition or fish kills caused by anoxia. Stressors on water quality include both regional effects, such as shoreline development, sewage inputs and land use changes which result in more runoff of nutrients and sediment to the water, and large scale stressors including climate change and changes in trophic structure resulting from invasive species. Environment Canada monitors water quality in the Great Lakes, and part of this data is used to assess the state of water quality in Fathom Five National Marine Park.

Ideally, Fathom Five National Marine Park would base this assessment on the Water Quality Index (WQI) endorsed by the Canadian Council of Ministers of the Environment (CCME 2001). Given that aquatic life can be influenced by the presence of hundreds of natural and anthropogenic substances in water, the WQI provides a useful tool that allows experts to translate large amounts of water quality monitoring information into a simple overall rating. The Great Lakes are treated separately in the freshwater quality indicator because of their disproportionate size and the unique nature of their surface water quality monitoring program (Statistics Canada 2006). For the Great Lakes, the WQI is calculated using data collected through Environment Canada's Great Lakes Surveillance Program. Each lake is sampled at multiple sites once every two or three years. The measurements taken on the rotation are then aggregated for each basin. Fifteen parameters are used in the calculation of the WQI for the Great Lakes, and they include concentrations of nutrients (phosphorus and nitrate) and metals (aluminum, arsenic, cadmium, chromium, copper, iron, lead, mercury, molybdenum, nickel, selenium, silver and zinc) (Statistics Canada 2006). However, for the Lake Huron and Georgian Bay stations within the vicinity of Fathom Five National Marine Park, not all parameters used in the WQI for the Great Lakes are measured (metals concentration data are not collected at these stations).

For this reason, the assessment of water quality is based only on total phosphorus, similar to the overall State of the Great Lakes reporting program (EC & USEPA 2009). Phosphorus is an essential element for all organisms and is often the limiting factor for aquatic plant growth in the Great Lakes. Although phosphorus occurs naturally, the historical problems caused by elevated levels have originated from anthropogenic sources. Detergents, sewage treatment plant effluent, agricultural runoff, and industrial sources have historically introduced large amounts of phosphorus into the Great Lakes. Strong efforts that began in the 1970s to reduce phosphorus loadings have been successful in maintaining or reducing nutrient concentrations in the Great Lakes, although high concentrations still occur locally in some embayments, harbours, and nearshore areas (EC & USEPA 2009).

Thresholds

The basin wide goal for phosphorus control In Lake Huron is to maintain an oligotrophic state, or its baseline condition (total phosphorus (TP) = 5 µg/L). The tentative thresholds for Fathom Five National Marine Park are presented in Table 1, and represent a combination of the lake wide objective and inter-annual variation in total phosphorus observed in Fathom Five National Marine Park waters over the last 14 years (average TP = 3.7 ± 1.4 µg/L, 1993-2007). In most aquatic ecosystems, water quality varies seasonally and annually due to fluctuations in weather (e.g. the timing and amount of precipitation, which affects the hydrological cycle), so a few years of monitoring data should be combined to assess total phosphorus levels in order to dampen natural variability (EC & USEPA 2009). As a result, a ± 2 µg/L around the TP objective of 5 µg/l was used to established preliminary thresholds between good and fair, and a further increase or decrease of 1 µg/L was used to establish the thresholds between fair and poor. These thresholds are preliminary, and more data or consultation with Great Lakes scientists is required to determine if these thresholds would result in altered lake productivity, with consequences on higher trophic levels, compared to baseline or its oligotrophic state.

Table 1. Thresholds values for total phosphorus (TP) in Fathom Five.

	Thresholds		
Offshore Water Quality	Good	Fair	Poor
TP (µg/L)	3-7	2-3 or 7-8	<2 or >8

Methods

Offshore water quality is based on data collected by Environment Canada, from 8 sites within the vicinity of Fathom Five National Marine Park, and represents waters from both Lake Huron and Georgian Bay (Figure 1). Environment Canada conducts biannual open lake cruises on all of the Great Lakes as part of Great Lakes Surveillance Program, and visits each of the Great Lakes on a two or three-year rotation. Data on nutrients, major ions, and organic contaminants, as well as physical and biological parameters are collected at 94 stations in Lake Huron and 50 stations in Georgian Bay. There are thirteen permanent sample stations within the greater park ecosystem of Fathom Five National Marine Park (Figure 1).

Each monitoring program follows standardized methods for sample collection in the field to ensure reliability of measurements. Chemical analyses are undertaken in Canadian laboratories accredited by the Canadian Association for Environmental Analytical Laboratories, ensuring that analytical methods are up to standard and proper quality assurance/quality control procedures are in place.

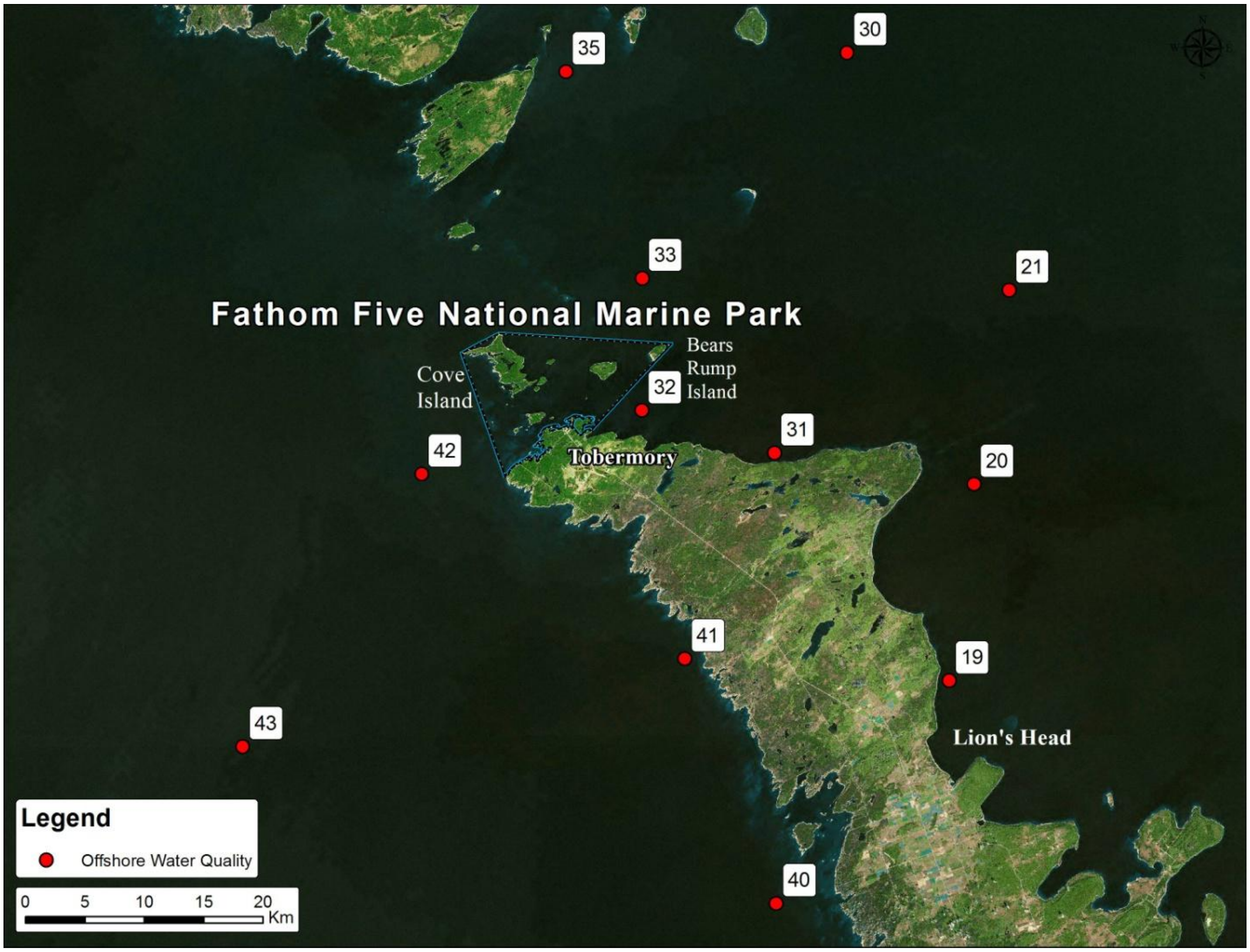

Figure 1. Stations and area of interest within Lake Huron and Georgian Bay.

In temperate lakes, the water column can become thermally stratified or layered by temperature during the summer and winter. Mixed conditions are typical during early spring and late fall. Chemical contaminants can also stratify in lakes, with their concentrations being determined in part by water density, which is in turn determined by water temperature. As part of the Great Lakes surveillance, lakes were sampled at least twice annually, once in the spring and once in the fall. If these spring and fall samples were not available, several samples were taken at various depths during another season. The results of these samples were weighted by the volume of water at the sampled depths and then averaged. Weighting by volume, however, was not always possible. As a final option, samples were taken at the surface of the lake (1m depth) (EC Great Lakes Surveillance Program).

Analysis and Results

Data Analysis

The water quality data available for the vicinity of Fathom Five National Marine Park could not be used to calculate the CCME WQI as the parameters available for these stations differ from those recommended and used for reporting by Environment Canada, and because of limited metals data in Fathom Five. Metals are only available for station 33 & 43, in 2004 and 2007 only (at 3 m depth). For the assessment of total phosphorus and total nitrogen data from 8 stations was used (19, 21, 31, 33 in Georgian Bay and 40, 41, 42, 43 in Lake Huron) to balance for inherent differences in basic water chemistry parameters between these two large water bodies (Table 2 and Table 3). For the current assessment, thermocline data was not available to be able to use the weighting method to calculate depth-integrated concentrations, so only surface water samples (1 m depth) were used in the assessment and a mean annual value for each available variable was calculated. This approach is similar to the analysis of data from Lake Ontario (Dove 2009).

Table 2. Summary of the years for which water quality data was collected (nutrients and major ions), for various stations around Fathom Five National Marine Park. GB indicates stations in Georgian Bay and LH indicates stations in Lake Huron.

						Year			
Station	**Site**	**Depth(m)**	**1993**	**1994**	**1999**	**2000**	**2002**	**2004**	**2007**
19	GB	54	X	X	X	X	X	X	X
20	GB	138		X					
21	GB	86	X	X	X	X	X	X	X
30	GB	61		X					
31	GB	66	X	X	X	X	X	X	X
32	GB	107		X					
33	GB	54	X	X	X	X	X	X	X
34	GB	49		X					
35	GB	35	X	X	X	X	X	X	
40	LH	19	X	X	X	X	X	X	X
41	LH	23	X	X	X	X	X	X	X
42	LH	44	X	X	X	X	X	X	X
43	LH	176	X	X	X	X	X	X	X
Total			9	13	9	9	9	9	8

All available data was compared to the CCME guidelines for the protection of aquatic life, and there were no exceedances in the entire dataset (1993-2007) for metals or organic contaminants. Nutrient data (total phosphorus, total nitrogen, total Kjedahl nitrogen, nitrate-nitrate), major ions (calcium, magnesium, potassium, sulphate, sodium, chloride and silicon) and other water quality variables (specific conductivity, pH, dissolved oxygen, alkalinity) were averaged for each year, for each station to determine condition and trends in nutrient. Trend analyses (linear regression) were performed on normalized ($\log_{10}$-transformed) data.

Condition

The status of water quality was based on nutrient concentrations alone, in particular total phosphorus (TP). This is also an indicator of water quality for the Great Lakes as a whole (EC & USEPA 2009). The offshore average annual total phosphorus concentration was 3.8 ± 1.8 µg/L (n=32) for the period 2000-2007, and was assessed as good. Annual total nitrogen (TN) concentration averaged 0.46 ± 0.02 µg/L (n=26), for that same time period, which was unchanged from 1984-1994 average (~0.45 µg/L, Environment Canada 1996). Nitrogen to phosphorus ratios indicate the waters are strongly phosphorus-limited (TN:TP >200) and because of stable nitrogen concentrations, changes in the ratio are driven by changes in total phosphorus in these waters.

Table 3. Differences in mean water chemistry between Lake Huron and Georgian Bay (samples from 1 m depth, average between 1993-2007). P-values of the ANOVA are presented to indicate which variables differ significantly between the 2 water bodies. ns indicates no significant difference or p > 0.05.

Water Chemistry Variables	Georgian Bay (average 1993-2007)	Lake Huron (average 1993-2007)	Probability (F-value)
Specific Conductivity (µs/cm)	194	204	0.04
pH	8.05	8.08	ns
Alkalinity (mg$CaCO_3$/L)	73.6	80.8	<0.0001
Dissolved oxygen (mg/L)	11.6	11.4	ns
Total phosphorus (mg/L)	0.0035	0.0035	ns
Total dissolved phosphorus (mg/L)	0.00177	0.00177	ns
Total Kjedahl nitrogen (mg/L)	0.135	0.131	ns
NH3 (ammonia-filtered, mg/L)	0.0026	0.0036	0.04
Nitrate-Nitrite (mg/L)	0.329	0.349	<0.001
Total nitrogen (mg/L)	0.453	0.472	0.0028
TN:TP (MOLAR)	311	321	ns
Sulphate (mg/L)	15.09	15.66	<0.001
Chloride (mg/L)	6.01	6.27	<0.0001
Silicon (mg/L)	1.25	1.38	0.0176
Calcium (mg/L)	24.4	26.2	<0.001
Magnesium (mg/L)	6.79	7.4	<0.001
Potassium (mg/L)	0.87	0.91	0.0028
Sodium (mg/L)	3.69	3.84	0.0172

Trend

Trends in water quality were assessed individually for each variable by linear regression (Table 4), and nutrients (total phosphorus, total nitrogen, Figure 2) and other variables presenting significant trends are presented (Figure 3). Total phosphorus concentrations were often below guidelines for Lake Huron (dotted line on figure), and although they generally decreased between 1993 and 2007, this trend was not significant (p = 0.16). Total nitrogen did not change significantly through time (p = 0.16), although Total Kjeldahl nitrogen increased between 1993 and 2007 (Table 4, Figure 3). The N:P ratio, an indicator of which nutrient is limiting primary production, significantly increased through time (p = 0.008), following phosphorus trends, indicating the waters of Fathom Five remain phosphorus-limited. Among the other measured variables, the major ions, sodium (Na) and chloride (Cl), and have increased significantly since 1993 (Table 4, Figure 3). Increases in these major ions are associated with road salts in smaller aquatic systems, and it is not sure what the cause of these increases would be in such a large water body as Lake Huron. Silica and potassium also increased since 1993, and pH decreased during this time period, again, it is uncertain if this has been reported elsewhere or what the cause of this decrease would be (Table 4)

Table 4. Linear regression results and test statistics for assessing trends through time in water chemistry at Fathom Five National Marine Park.

Water Chemistry Variable	Linear regression model (concentrations in mg/L)	R^2	Probability (F-value)	n
Total phosphorus (TP)			0.159	56
Total nitrogen (TN)			0.165	50
TN: TP (molar)	Log_{10} TN:TP = -25.2 ± 9.9 + 0.014 ± 0.005*Year	0.14	0.0078	50
Total Kjeldahl nitrogen (TKN)	Log_{10} TKN = -18.4 ± 3.3 + 0.0087 ± 0.001*Year	0.33	<0.0001	56
Nitrate-nitrite			0.367	50
Specific conductivity (µS/cm)			0.752	48
Alkalinity (mg $CaCO_3$/L)			0.365	56
pH	pH = 55.6 ± 11.4 – 0.024 ± 0.006*Year	0.242	<0.0001	56
Sulphate			0.573	50
Chloride	Log_{10} Cl = -7.7 ± 0.8 + 0.004 ± 0.0004*Year	0.683	<0.0001	50
Sodium	Log_{10} Na = -6.9 ± 1.0 + 0.004 ± 0.0005*Year	0.611	<0.0001	36
Magnesium			0.171	36
Calcium			0.514	36
Potassium	Log_{10} K = -3.3 ± 1.4 + 0.002 ± 0.0007*Year	0.130	0.030	36
Silica	Log_{10} Si = -11.6 ± 4.1 + 0.006 ± 0.002*Year	0.142	0.007	50

Power

A power analysis has not yet been completed.

Discussion

The offshore water quality in Fathom Five National Marine Park is good, with no exceedances of protection of aquatic life guidelines and oligotrophic conditions maintained in the offshore. Some trends in major ions and pH require further investigation or consultation with Great Lakes scientists to interpret.

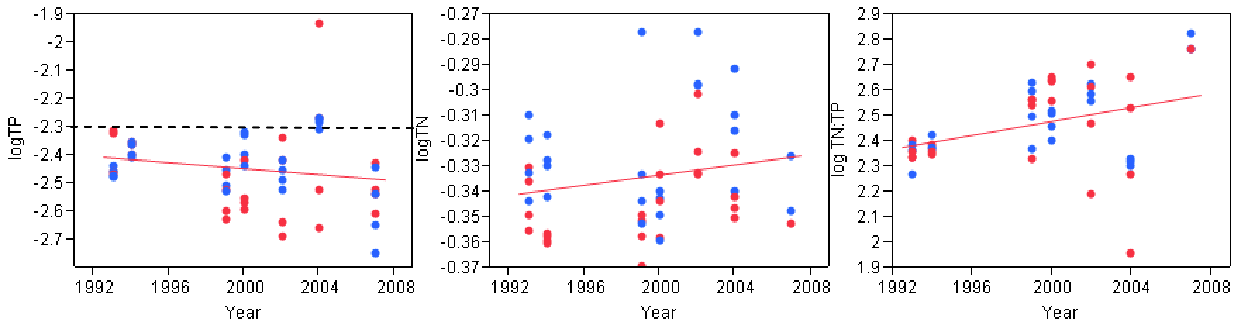

Figure 2. Trends in total phosphorus (TP in mg/L), total nitrogen (TN in mg/L) and molar TN:TP ratios (N:P) in Fathom Five National Marine Park (1993-2007). Dashed line represents TP thresholds of 5 µg/L. Stations in Lake Huron are represented by blue circles, stations in Georgian Bay by red circles.

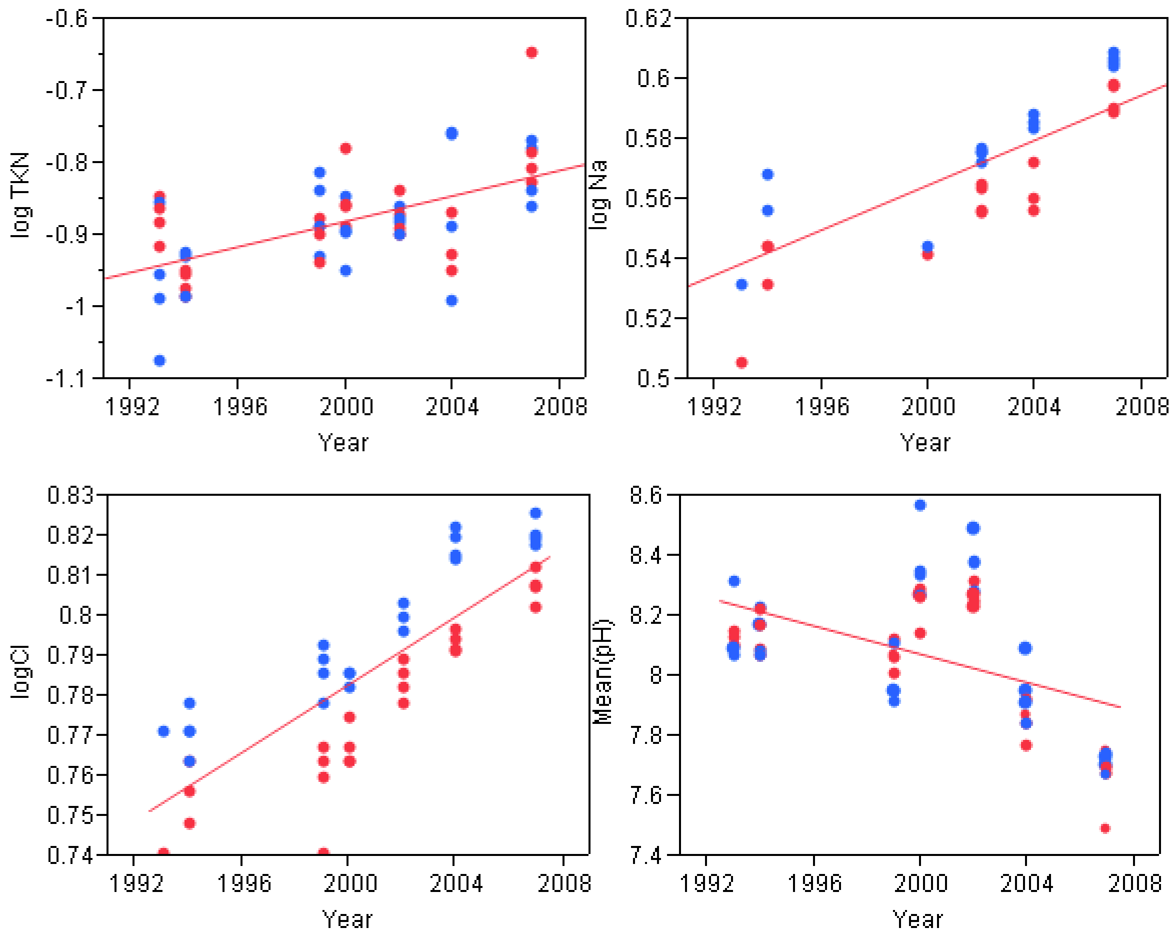

Figure 3. Trends in selected water quality variables for stations near Fathom Five National Marine Park. TKN is total Kjeldahl nitrogen in mg/L, Na-sodium in mg/L, Cl-chloride in mg/L and pH. Stations in Lake Huron are represented by blue circles, stations in Georgian Bay by red circles.

Overall, Fathom Five National Marine Park waters compare well to the overall assessment of Lake Huron offshore waters for phosphorus. This shows that efforts that began in the 1970s to reduce phosphorus loadings have been successful in maintaining or reducing nutrient concentrations in the Great Lakes (EC & USEPA 2009). However, Lake Huron has been assessed as fair, for contaminants with 13 of a possible 21 organochlorine compounds were detected in Lake Huron in 2007. Of these, 11 were commonly found, including hexachlorocyclohexane (α-HCH), lindane, dieldrin, and γ-chlordane (EC & USEPA 2009). The concentrations were generally low, reflecting historical or diffuse sources. Sampling in Fathom Five National Marine Park for organic contaminants and metals is very limited and difficult to assess based on current efforts.

Data Quality

This data does not capture the spatial and temporal water quality within Fathom Five National Marine Park, however, until the site has a funded monitoring program, this is the only data available to report on water quality.

Recommendations

A set of sites, monitored 2-3 times per year within Fathom Five National Marine Park would allow for the site to have a more accurate assessment of water quality of the site and could be used to calculate the CCME-WQI.

Partners

Environment Canada. Great Lakes Surveillance Program (http://www.on.ec.gc.ca/monitoring/water-quality/greatlakes-e.html)

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2.3.2 BENTHIC COMMUNITY

Cass Stabler

Context

NR

Understanding various aspects of the benthic community in Fathom Five National Marine Park (e.g., abundance, diversity, and the way these aspects change over time) can provide information about the state of the aquatic ecosystem, the largest component of the park. The State of the Great Lakes Report (EC & USEPA 2009) evaluates two indicators to understand the benthic community. These indicators include Benthos Diversity and Abundance (Indicator #104) and Abundances of the Benthic Amphipod *Diporeia* spp. (Indicator #123).

Intense urbanization and industrialization during the early 20th century degraded the waters and substrates of the Great Lakes (EC & USEPA 2009). By the 1980s, pollution abatement programs and natural biological processes improved the quality of habitat; aquatic species intolerant of heavily polluted environments began to replace populations of pollution-tolerant species (EC & USEPA 2009).

Monitoring the species diversity and abundance of aquatic oligochaete (i.e., aquatic worm) communities provided one of the earliest measures of habitat quality improvements in the Great Lakes. Aquatic oligochaete communities are sensitive to changes in the environment and are excellent indicators of substrate quality. When biological responses are monitored over time, subtle changes in environmental quality can be determined, possibly decades before changes are recognized in other single species indicators (EC & USEPA 2009).

The benthic macroinvertebrate, *Diporeia*, is a glacial-marine relic and was once the most abundant benthic organism in the cold, offshore regions (deeper than 30 m) of the Great Lakes (Figure 1). In the shallow, warmer, nearshore regions it was present, but less abundant. *Diporeia* feeds on algal material that settles to the bottom of the lake, and in turn, is fed on by many species of fish in the Great Lakes. As a key component in the food web, *Diporeia* was an important pathway for energy to be cycled through the ecosystem (EC & USEPA 2009). Populations of *Diporeia* reflect overall productivity of the system and are sensitive to pollution. Currently, *Diporeia* populations are in a state of dramatic decline in Lake Huron, with an overall abundance lowered by 93% compared to abundance in 2000 (EC & USEPA 2009). *Diporeia* are completely gone or rare at depths less than 60 m in Lake Huron and populations continue to decline at depths greater than 60 m.

Declines in *Diporeia* populations were initially noticed within two to three years of invasive zebra mussel (*Dreissena polymorpha*) and quagga mussel (*D. bugensis*) establishment. *Dreissena* species may be out-competing *Diporeia* for food, but evidence suggests that the reason for decline is more complex than a simple decline in food because *Diporeia* have also completely disappeared from areas where algal material is stills settling to the bottom of the lake and no local populations of mussels occur (EC & USEPA 2009). Also, there is no sign of starvation in individual *Diporeia* prior to or during population declines and *Diporeia* and *Dreissena* coexist in some lakes outside of the Great Lakes system (i.e., the Finger Lakes system in New York, USA),(EC & USEPA 2009).

Figure 1. An example of a benthic invertebrate, *Diporea* spp. © Ethan Meleg.

Thresholds

Thresholds have not been developed for this measure.

Methods

Benthics were sampled at six sites of varying depths in Fathom Five National Marine Park on September 1, 2009 (Table 1, Figure 2). Two samples were collected at Arabia, Tecumseh Cove, and Point's West. At each site, a description of the substrate (e.g., sand, silt, gravel), the sampling crew, and any comments about the sampling procedure were recorded. All samples were transported to the lab and each individual was identified to genus using a microscope.

Table 1. Benthic sampling sites in Fathom Five National Marine Park including depth at which sample was collected and UTM coordinates.

Site Name	Depth (m)	UTM Zone	Easting	Northing
Plunge pools	298	17T	451366	5013936
Tecumseh Cove	41	17T	444310	5015925
Flower Pot Island	238	17T	451938	5016086
Point's West	50	17T	442757	5015018
Arabia	105	17T	447255	5017857
South Otter and Cove Island Channel	40	17T	445108	5015183

Figure 2. Location of offshore benthics sampling sites.

Analysis and Results

Data Analysis

Collection of data was initiated in 2009, but an insufficient amount of data was collected so no analysis was performed.

Condition

Condition was not rated for this measure.

Trend

Trend was not rated for this measure.

Power Analysis

A power analysis was not completed for this measure.

Data Quality

The data collected was insufficient to complete the analysis, but could be contributed to future monitoring efforts.

Recommendations

The benthic community of Fathom Five National Marine Park is significant to the food chain and an important ecological indicator. Therefore, a protocol for monitoring a relevant aspect of this community should be developed and contributed to the ecological monitoring program at Fathom Five National Marine Park.

If possible, this protocol should be compatible with the State of the Great Lakes Report (EC & USEPA 2009). This will allow for data to be compared between studies and the work at Fathom Five National Marine Park to contribute to the understanding of the state of Lake Huron. In Lake Huron, the Abundances of the Benthic Amphipod *Diporeia* spp. Indicator (Indicator #123) is rated as poor with a deteriorating trend because the most recent lakewide survey in the main basin (in 2007) indicated that overall abundances were lower by 93% compared to abundances found in 2000. Also, in Lake Huron the Benthos Diversity indicator (Indicator #104) is rated as a mixed status with an unchanging trend.

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2.3.3 LAKE TROUT

Scott Parker

Monitoring Questions

NR

i. Is the Catch-Per-Unit-of-Effort (CPUE) metric for Lake Trout in Fathom Five in good condition (i.e., greater than 3 Lake Trout/490 m of gillnet), and has it increased or remained stable over the past five years?

NR

ii. Is the proportion of wild vs. stocked Lake Trout sampled in Fathom Five in good condition (i.e., greater than 20% of the total Lake Trout catch from natural recruitment) and has it increased or remained stable over the past five years?

NR

Context

Before the 1940s Lake Trout (*Salvelinus namaycush*) was the dominant predator in Lake Huron and was recognized for its significant social and economic value, with commercial harvest ranging from 1.8 to 2.7 million kg/yr (Baldwin et al. 2009). In the decades that followed, overfishing and invasive species (e.g., Sea Lamprey, Alewife) resulted in a lakewide collapse, and only two populations survived, one in Parry Sound and the other in Iroquois Bay (Eshenroder 1992). Following the collapse, Lake Trout recovery efforts focussed on sea lamprey control and stocking (Eshenroder et al. 1995). For decades recovery met with limited success, but by the mid-1990s the stocking of pure strain lake trout (i.e., 2 million/yr in Ontario waters) coupled with advances in sea lamprey control, contributed to some measureable recovery of Lake Trout (e.g., Reid et al. 2001, Madenjian et al. 2004, Madenjian et al. 2008, Morbey et al. 2008). However, there are emerging challenges to recovery related to new invasive species (e.g., quagga mussels, round goby) and their effects on energy and nutrient dynamics and egg predation (Paterson et al. 2009, Roseman and Riley 2009).

Fathom Five is part of the Bruce Archipelago Lake Trout Recovery Zone (LTRZ), which is located between Fitzwilliam Island and Tobermory (OMNR 2010). Commercial harvest for Lake Trout in this LTRZ between 1995 and 2006 was approximately 6,292 kg/yr. In more recent years, catch-per-unit-of-effort (CPUE) in commercial gillnets peaked in 1997 at 195.3 kg/km and has subsequently declined to approximately 40 kg/km (OMNR 2010). Fisheries assessment is partly based on commercial CPUE, but also research monitoring data using CPUE using trapnets, gillnets or trawls. Although there are advances in acoustic biomass and other techniques (e.g., Warner et al. 2009), the use of CPUE using nets is still the traditional method for assessment in this region. The effort in this report reflects a partnership with the Ontario Ministry of Natural Resources (OMNR), who employ this method for lakewide surveys.

Despite the fact that large numbers of fish are stocked (i.e., > 200,000/yr hatchery raised yearlings (OMNR 2010)) in this LTRZ, there is limited evidence of natural recruitment. Monitoring wild versus stocked fish provides insight to Lake Trout recovery. Stocked fish are fin clipped and may have coded wire tag implants.

Monitoring and managing the recovery of Lake Trout in Lake Huron is a widely held and long-standing goal (e.g., OMNR 1996, Ebener 1998, SOLEC 2009, Franks Taylor et al. 2010). Lake Trout recovery is also stated within the Fathom Five Management Plan (Sec. 8.3, Parks Canada 1998) and Parks Canada role in fisheries management is stated with the Park establishment agreement (DOE and OMNR 1987). To date, Parks Canada has completed a feasibility study in 1993 (Crawford 1994) and collaborated with the OMNR on several Lake Trout population studies. Although the species is commercially and recreationally fished in Fathom Five, Parks Canada has not realized its role in protection and managing ecological sustainable use. This is of particular concern given the fact that Lake Trout recovery remains vulnerable and no species-specific conservation measures are evident in Fathom Five. Other areas in Lake Huron that have taken enhanced conservation measures, such as the establishment of spawning refugia, have seen recovery (Madenjian et al. 2004).

Thresholds

The thresholds for this metric (Table 1) were developed in discussion with Stephen Gile, OMNR Assessment Biologist. These values reflect a local context and are based on experience from similar sampling around the Bruce Peninsula. They are considered interim and may change in time and with greater discussion.

Table 1. Two measures used assess the status of Lake Trout in Fathom Five. Lake Trout Catch-Per Unit-of-Effort and proportion of wild Lake Trout in 2009. The Catch-Per-Unit-Effort (CPUE) metric and proportion of wild Lake Trout used for this assessment is based on a spring sampling with 490 m indexed gillnet set for 24 hours at each site.

	Thresholds		
Status	Good	Fair	Poor
Catch-Per-Unit-of-Effort	>3	3 to 1	<1
Proportion of wild Lake Trout	>20%	20% to 10%	< 10%

These values are relatively low when compared to other CPUE thresholds around the Great Lakes (Madenjian et al. 2004, Madenjian et al. 2008, SOLEC 2009), where values can exceed 20 fish. Similarly, proportion of wild Lake Trout is also lower as compared to other studies (Franks Taylor et al. 2010), where >50% would be good.

Methods

The Offshore Index Assessment (OMNR 2007) consists of deploying overnight (i.e., 20-24 hours) bottom sets of monofilament gill net at 24 sites within Fathom Five. The index net is made of graded panels (i.e., 32, 38, 51, 64, 76, 89, 102, 114, 127, 140 and 153 mm), and each panel is 50 m in length, except the 32 and 38 mesh which are 15 and 25 m respectively. A net is set perpendicular to the depth contour at randomly assigned sites within a one minute grid. Current weather and forecast conditions affect actual set location. In 2009, the study was piloted with 15 sample sites (Figure 1). In 2010, 24 sites as per the

OMNR protocol (OMNR 2007) were sampled, but due to timing those results were not included in the 2010 State of the Park Report.

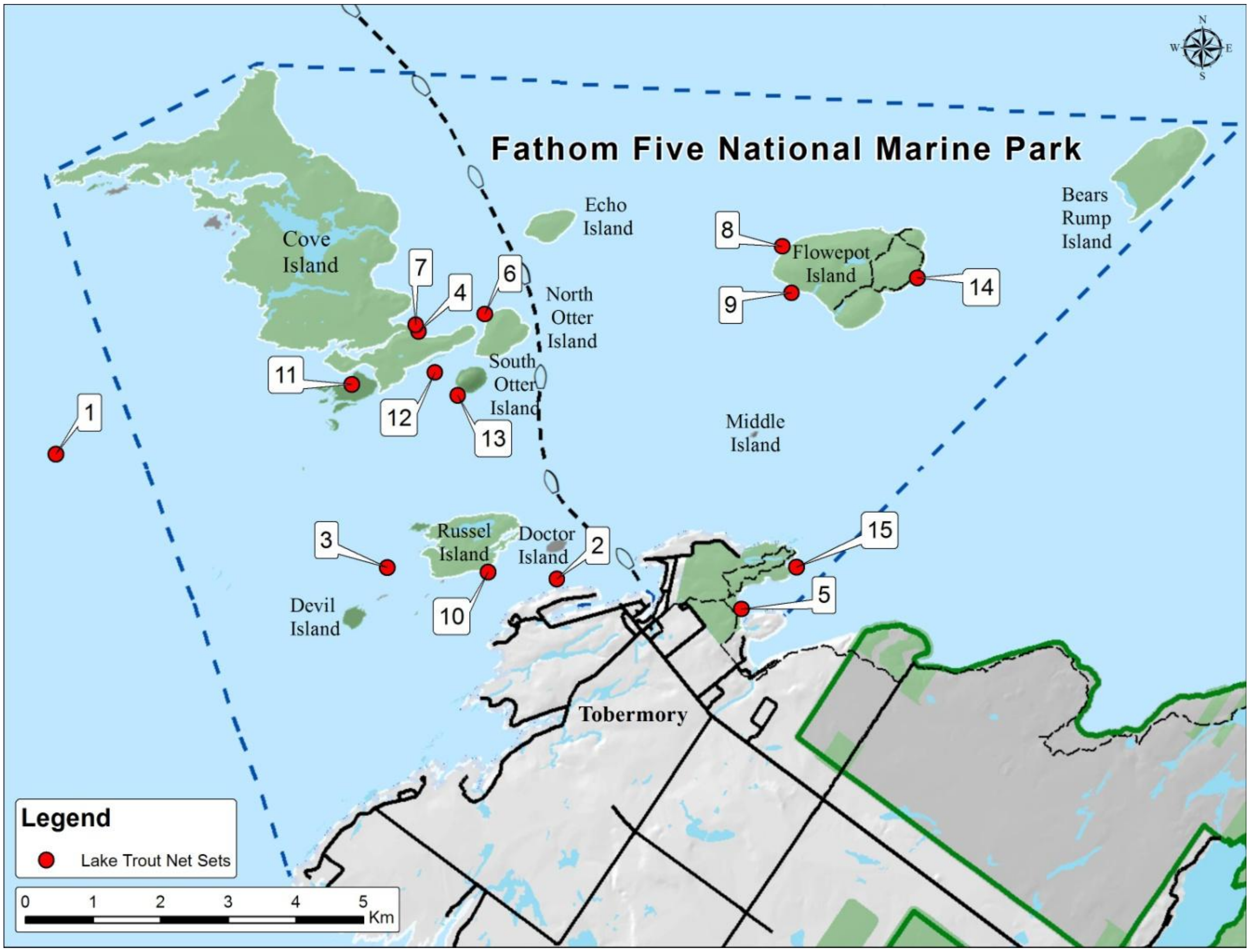

Figure 1. Net locations in Fathom Five National Marine Park in 2009.

All fish caught are systematically processed and assessed according to mesh size and species. Lake Trout are counted, and their origin (i.e., wild or stocked) is determined by examining the fish for fin clips, evidence of hatchery rearing. A suite of species specific biological samples and measures are also collected, including total length, weight, sex and maturity, stomach contents, otoliths, and lamprey marks. Whenever possible, Lake Trout are tagged and released.

The intent is to complete this survey every 4th and 5th year of the 5 year State of the Park Report cycle. The sites will be randomized and the gear and effort remain consistent.

Analysis and Results

Data Analysis

This measure reports the mean CPUE for Lake Trout in 2009, a unit of effort being a single net that was set for a 20-24 hour period, and proportion of wild Lake Trout, representing the proportion of Lake Trout caught in 2009 that had no fins clipped.

Condition

The current state was based on 2009 sample effort (Figure 1). A total of 19 Lake Trout were caught in 15 nets. Lake Trout CPUE for 2009 was 1.27 (s.d. 1.21) and proportion of Lake Trout that were wild was 15.7%.

Trend

Trend was not calculated since only one year was presented for the SOPR.

Power

Power to detect a trend was not calculated.

Discussion

These measures are tentative and will evolve in time. Integration with lakewide project is important. Based on the 2009 State of the Great Lakes report, Lake Trout in Lake Huron are assessed as having a mixed status, with an improving trend as levels of natural reproduction continue to increase, adult abundance is stable to declining, and survival of stocked fish is low and declining (EC & USEPA 2009). Fishing and sea lamprey mortality have declined since 2001 but have increased slightly during the last few years (SOLEC 2009). This is somewhat similar to the assessment for Fathom Five of Lake Trout in fair condition.

This monitoring measure is based on the OMNR's Offshore Index Assessment (OMNR 2007). Operationally, given the length of gillnet and sea conditions, a larger fish tug and crew is better suited to this task. In 2010, this Lake Trout assessment was completed again from a smaller Parks Canada vessel and sampled a total of 24 sites. In 2011, the OMNR will have a research vessel capable of this work and it is recommended that the effort continues entirely under their program. The efforts and interests of Parks Canada are better suited for smaller vessel/crew projects, focused on spawning habitat, such as the Fall Spawning Index Trapnet (FSIT) or Fall Littoral Index Gill Netting (FLIN) (OMNR 2010).

Parks Canada's relationship with others, including the Saugeen Ojibway Nations and the Ontario Ministry of Natural Resources needs to be formalized in order to better share data and influence management actions with respect to the fishery and Lake Trout recovery. For instance, CPUE for commercial harvest could be a good measure of Lake Trout recovery (OMNR 2010), however Parks Canada does not have ready access to current data due to management reasons.

Data Quality

Data quality is generally considered to be good given the identification and processing skills of those involved (i.e., OMNR and Parks Canada staff). The data and forms follow standard OMNR methods and is consistent with other efforts under the Great Lakes Fishery Commission. More years are required, to eventually build a linear regression model to improve trend analysis. In addition, as discussed, the thresholds are low and will need to be further refined in time to be in accordance with other areas of Lake Huron.

Partners

Ontario Ministry of Natural Resources, Upper Great Lakes Management Unit, Lake Huron Office

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2.3.4 ICE COVERAGE

Stephen McCanny

Monitoring Questions

i. Are the total accumulated ice coverage levels from the five year period of 2004-2005 to 2007-2009 within 3 standard errors of the historical levels from 1978-1979 to 1995-1996?

ii. Have the total accumulated ice coverage levels changed significantly over the ten year period of 1996-1997 to 2007-2008?

Context

Monitoring ice coverage patterns in the Great Lakes helps us to determine climate and water movement patterns, lake water levels, water temperature structure, and to predict spring plankton blooms (GLERL 2010). All of this information contributes to our understanding of the ecology of Fathom Five National Marine Park. The freezing and thawing of lakes is a very important aspect to many aquatic and terrestrial ecosystems. Many fish species rely on the ice to give their eggs protection against predators during the late part of the ice season. Nearshore ice has the ability to change the shoreline as it can encroach upon the land during winter freeze-up times. Even inland systems are affected by the amount of ice that forms, especially within the Great Lakes basin. Less ice on the Great Lakes allows for more water to evaporate and be spread across the basin in the form of snow. This can have an effect on the foraging animals (such as deer) that need to dig through snow during the winter in order to obtain food (EC and USEPA 2009).

Ice coverage, with little or no snow cover, allows sunlight to penetrate the surface of the lake and promotes algae growth (GLERL 2010). Changes to the amount of light allowed to penetrate will influence primary productivity as algae support all other life in the lake systems (GLERL 2010). Ice also deflects the effects of winter by protecting shores and fish habitats from wind and waves, limiting lake effect snow, reducing evaporation, and forming a stable platform to protect wetlands from erosion (GLERL 2010).

Changes in water and air temperatures will influence ice development on the Great Lakes and, in turn, affect coastal wetlands, nearshore aquatic environments, and inland environments. Globally, some inland lakes appear to be freezing up at later dates, and breaking-up earlier, than the historical average, based on a study of 150 years of data (Magnuson et al. 2000). These trends add to the evidence that the earth has been in a period of global warming for at least the last 150 years. From 1973-2009, the overall annual ice coverage on the Great Lakes has declined by about 15%. Ice density patterns have also changed over the 1973-2002 period. The occurrence of very densely packed ice has declined by more than 30% over the deepest parts of the Great Lakes and the occurrence of very densely packed ice has declined by about 20% near the lake shores. These changes are driven by both natural variability and anthropogenic causes (GLERL 2010).

The metric used in the State of Park report was total accumulated ice coverage, essentially the accumulated area of ice during the ice season (December 4th to May 14th) as a percentage of the maximum possible accumulation. An ice season with total ice cover for the entire season would have a value of 100%. This value is influenced by the peak values of ice coverage as well as the length of the ice free period. The values for the metric ranged between 9% and 46% over the 36-year period.

Thresholds

Thresholds for the ice coverage measure were developed using the Statistical Process Control method (Montgomery 2001, Dobbie et al. 2006). The historical data is examined to find a baseline period when the data is in control; where no outliers exist (Figure 1). In this case, the 19 year period from 1978-1996 contained no values more than three standard errors from the overall mean and the thresholds were developed based on this period. Thresholds for determining the departure of the measure from the baseline were developed (Table 1). They were set at two and three standard errors from the mean of the baseline period. These threshold levels allow us to understand if the total accumulated ice coverage has been within the natural range of variation. The decision rules in Table 2 were used to judge how typical the last five years were.

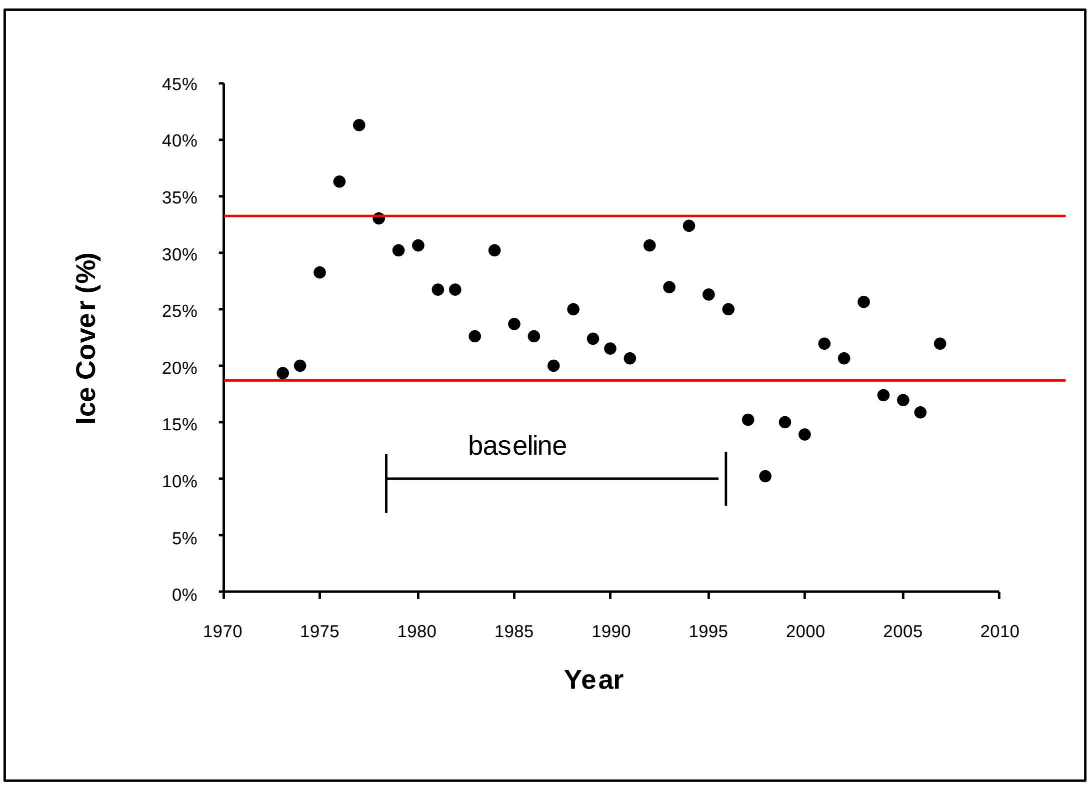

Figure 1. Historic ice cover data from IceGraph (CISA 2010). This data was used to calculate the thresholds for the ice coverage measure. The red lines indicate the poor threshold levels.

Table 1. Thresholds used to determine status of the ice coverage measure in Fathom Five National Marine Park based on average ice coverage on Lake Huron.

	Thresholds		
Status	Good	Fair	Poor
Lake Huron Ice Coverage	21% to 30%	19% to 21% or 30% to 33%	<19% or >33%

Table 2. Definitions for the status of measures with 10-30 previous observations.

Rule	Definition	Status
1	A point is 3 standard errors from the mean.	red
2	2 of 3 points are 2 standard errors from the mean.	red
3	4 of 5 points are between 1 and 2 standard errors from the mean.	red
4	14 consecutive points are less than 1 standard error from the mean.	yellow
5	14 consecutive points are alternating above and below the mean.	yellow
6	7 consecutive increasing or decreasing points.	yellow
7	7 consecutive points are above or below the mean.	yellow
8	None of the above.	green

Methods

Ice coverage data is managed and archived by the Canadian Ice Service Archive (CISA). This data is updated daily by Environment Canada and dates back to 1968. It is searchable by region and time period through the IceGraph application.

Analysis and Results

Data Analysis

The three-year running average percentage of ice coverage was calculated to give one value per ice period that takes into account that ice period plus the previous and following ice periods. The five values representing the 2003-2004 to 2007-2008 ice periods were compared to the threshold levels to determine the condition rating. A linear regression analysis was carried out to evaluate the trend over the eleven ice periods from 1997-1998 to 2007-2008.

Condition

The Ice Coverage condition is rated as poor, or red since there were three values during the last 5 years that were 3 standard errors below the mean, so we can conclude that the recent winters have been quite atypical. Decision rule 1 in Table 2 would lead us to apply a poor condition to this time sequence if even one value was 3 standard errors below the mean. This represents poor ecological integrity for this measure. Three of the last five years have fallen below the lower threshold score of 19% (PCA 2010).

Trend

The last ten years showed no significant trend (p = 0.09), so the trend is rated as stable (PCA 2010).

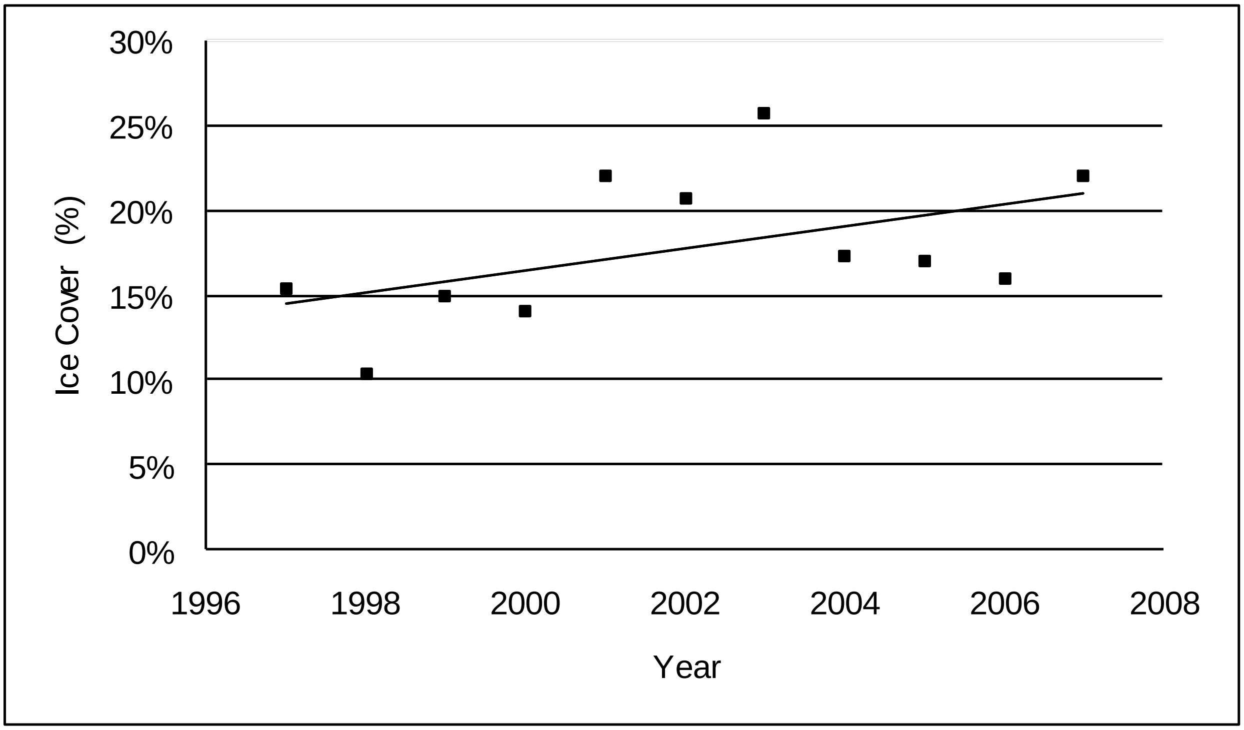

Figure 2. Ice cover data from IceGraph for the ten year period used to determine trend (CISA 2010). There was no significant trend (p = 0.09), so the trend was rated as stable.

Power

The comparison of a single season to a 19-year baseline can detect a three standard error departure from the mean with high confidence (99.9%) and power (99.9%; one sample t-test). The linear regression of the last 11 years was weak with a power of 67% for detecting a change of 1% in ice cover per year (generic power analysis with noncentrality parameter of 0.6611).

Discussion

Ice coverage has been low in recent years. The Statistical Process Control analysis would signal a departure from the baseline with only one of the last five years below 19%. It is equally notable that two of the last three years are below two standard errors (21%) from the mean. Though we found no significant trend in the last 11 years the slope on the regression is increasing, suggesting a return to former levels of ice coverage.

Data Quality

From CISA: Please note that interpolated values may be included in the output. Linear interpolation has been used to fill missing values when no ice chart was available on a specific week. This can occur within the season but it is found mostly at the beginning and end of a season.

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2.4 SPECIES AT RISK

Context

NR

Fathom Five National Marine Park provides, or is strongly suspected to provide, seasonal and year-round habitat for nine species listed on Schedule 1 of the federal Species at Risk Act (SARA) (Table 1). The submerged lands of Fathom Five are under provincial jurisdiction, therefore, species designations under the Ontario Endangered Species Act, 2007 (ESA) are also relevant to the management of species at risk in Fathom Five National Marine Park. One species that occurs in Fathom Five National Marine Park is listed on the ESA but not on the SARA (Table 1).

IMPORTANT NOTE: Due to updated methodology, the species and ranks listed in Table 1 have been updated from those reported in the Fathom Five National Marine Park State of the Park Report (SoPR 2010). The ranks in Table 1 should be used as the baseline from which to report change, not those in the SoPR.

Figure 1. Eastern Massasauga rattlesnake, a species listed on the Species at Risk Act Schedule 1 as Threatened and considered to be imperiled (MA2) based on the Managed Area Rank developed by Parks Canada. © Parks Canada.

Analysis and Results

Condition

Condition was not rated for this indicator.

Trend

More information, especially about fish species, is required before trends can be determined and reported (Stephen McCanny, pers. comm).

Table 1. Species listed on the Species at Risk Act (SARA) Schedule 1 or on the Endangered Species Act (ESA) occurring in Fathom Five National Marine Park (FFNMP). MA Rank is the Managed Area Rank developed by Parks Canada.

Common Name	SARA Designation	MA Rank[1]	MA Rank Confidence[2]	ESA Designation
Birds				
Canada Warbler	Threatened	MAUB	n/a	
Whip-poor-will	Threatened	MAUB	n/a	
Fish				
Deepwater Sculpin (Great Lakes - Western St. Lawrence populations)	Special Concern	MAU		
Shortjaw Cisco		MA1 (draft)		Threatened
Insects				
Monarch	Special Concern	MA2B, MANAM	6/11 (low)	
Snakes				
Eastern Ribbonsnake (Great Lakes population)	Special Concern	MA1	7/11 (medium)	
Massasauga	Threatened	MA2	9/11 (medium)	
Milksnake	Special Concern	MA2	6/11 (low)	
Turtles				
Blanding's Turtle (Great Lakes / St. Lawrence population)	Threatened	MAU	n/a	
Snapping Turtle	Special Concern	MAU	n/a	

[1]MA1 – critically imperiled; MA2 – imperiled; MA3- vulnerable, MA4 – apparently secure; MA5 – secure; MAU – known to occur but of unknown status. B = breeding population.

[2]MA Rank Confidence: 4 to 6 of 11 rank factors assessed = low confidence; 7 to 9 of 11 rank factors assessed = medium confidence; and 10 to 11 of 11 rank factors assessed = high confidence

Recommendations

Indicator Development

Using Detailed Assessments (DAs) in each Protected Heritage Place (PHP), Parks Canada Agency (PCA) will assess the conservation status of species, determine the magnitude of change in that status over time, and evaluate the effectiveness of management activities to conserve species. The information in DAs will be used, among other things, to report on SAR through the "State of" reporting process. PCA will only report on SARA Schedule One species that use the PHP significantly or in a consistent manner, using ranks of MA1-5 or MAU (Table 1). DAs will be updated (i.e. re-assessed) every five years, in synchrony with PHP's Management Planning Cycle, in order to measure changes in SAR conservation status over time (PCA, 2011).

A DA is the procedure that PCA applies to evaluate and document the conservation status (synonymous with *risk of extirpation*) of an individual species from a particular park. To generate the most accurate assessments, PCA has developed a procedure based on NatureServe's standardized methodology for assigning Global, National and Subnational (provincial and territorial) conservation status ranks (PCA, 2011). DAs generate Managed Area (MA) ranks by consolidating information into 13 rank factors that address various aspects of a species ecology and management at the park. Examples of rank factors include population size, species distribution in the park, threats and trends. Rank factors are evaluated through a rank calculator. Because local expertise can provide a more holistic picture of the species and its ecology, the calculator is used as a tool only. Confidence in the rank produced by the calculator is increased with the number of rank factors assessed and by the degree of confidence with which they are assessed. Information for a minimum of any four rank factors is needed to produce a calculated rank.

Monitoring to produce a minimum of information to assess at least four rank factors is recommended for each of the nine SARA Schedule 1 listed species in Table 1.

Long-term Monitoring Programs

The State of the Great Lakes 2009 report includes a Threatened Species Indicator (#8161), but the report is currently unavailable (EC & USEPA 2009). If this report becomes available during the next reporting cycle (2011) it may be a good reference when attempting to improve the Species at Risk Indicator in the ecological monitoring program of Fathom Five National Marine Park.

An additional eight SARA Schedule 1 species are thought to use, or have used, Fathom Five in a historic or irregular basis (Table 2). It is important to maintain an incidental observations database for these species in the event that they become re-established or begin to use the park in a significant manner.

Table 2. Species listed on the Species at Risk Act (SARA) Schedule 1 that are occasional visitors or historic in Fathom Five National Marine Park (FFNMP). MA Rank is the Managed Area Rank developed by Parks Canada.

Common Name	SARA Designation	MA Rank[1]	ESA Designation
Birds			
Common Nighthawk	Threatened	MANA	
Golden-winged Warbler	Threatened	MANA	
Peregrine Falcon (*anatum* subspecies)	Threatened	MAHB, MANAM	
Red-headed Woodpecker	Threatened	MANA	
Rusty Blackbird	Special Concern	MANA	
Fish			
Blackfin Cisco	SARA Schedule 2 – Threatened	MAX (draft)	
Plants			
Dwarf Lake Iris	Special Concern	MAH	
Hill's Thistle	Threatened	MAH	

[1]MANA - species is not a suitable target for conservation activities (e.g. long distance aerial and aquatic migrants that rarely use the MA, hybrids without conservation value, exotic species, accidental occurrences); MAH - Possibly Extirpated (Historical) – Known from only historical records but still some hope of rediscovery; MAX - Presumed Extirpated - Not located despite intensive searches of historical sites and other appropriate habitat, and virtually no likelihood that it will be rediscovered.

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APPENDIX A. SUMMARY OF THE STATUS AND TRENDS IN THE ECOLOGICAL INDICATORS

The status and trend of each ecological indicator was determined by integrating the status and trend ratings of the associated ecological measures. The process used to combine the measure ratings was partially based on a process developed by Parks Canada (PCA 2007). Since this is the first State of the Park Report for Fathom Five National Marine Park to use this suite of qualitative measures, ecological indicator trends are not based on changes from one State of the Park report to the next, but are determined by integrating the trend ratings for the associated ecological measures. These indicator trend ratings provide a baseline trend for future comparison between state of the park reports.

To determine status of each indicator, a score was assigned to each measure based on its status (Table A-1). The indicator score was determined by averaging the associated measure scores using the following formula (PCA 2010):

$$\text{Indicator Score} = (\sum \text{measure score}/\text{number of measures for that indicator})$$

The indicator score was compared to the status rating thresholds to determine the indicator status rating (Table A-1). All of the indicator status scores are summarized in Table A-3.

This approach is similar to the one recommended by Parks Canada (PCA 2007). Also, the information required to reevaluate this overall status based on the recommended approach is available in Table A-3. This recommended formula could be applied in order to make comparisons between indicators from this report and future state of the park reports.

Table A-1. Status rating thresholds for ecological indicator and measures scores for Fathom Five National Marine Park. Each measure is assigned a measure score based on the status rating. The measure scores for all ecological measures associated with an ecological indicator are averaged to determine the indicator score. The indicator is assigned a status rating based on the indicator score thresholds.

	Thresholds		
Status Rating	Good	Fair	Poor
Measure Score	3.5	2.5	1
Indicator Score	>3.01	1.76-3.00	<1.76

The ecological indicator trends were determined by examining the trends of the associated measures and assigning the most common measure trend as the indicator trend (Table A-2). This provides a baseline trend for future comparison within indicators. Parks Canada has recommended an approach for determining ecological indicator trends based on the trends of associated measures (PCA 2007). This approach should be used to determine indicator trends in the future.

Table A-2. Trend ratings for ecological indicators.

	Thresholds			
Trend	Increasing	Stable	Decreasing	Not Rated
Symbol	⬆	⬌	⬇	NR

The coastal indicator was given an overall score of 3.5, a good, or green, status rating. The island indicator was given an overall score of 3, a fair, or yellow, status rating. And, the offshore indicator was given an overall score of 2.4, a fair, or yellow rating (Table A-3).

The coastal indicator was also assigned a stable trend rating. No trend rating was determined for the island indicator or the offshore indicator due to insufficient information about the trends of the respective measures (Table A-3).

Table A-3. Summary of the overall ecological indicator scores, status, and trends for Fathom Five National Marine Park determined by integrating the associated ecological measure scores.

Indicator	Measure	Status and Trend	Score	Symbol
Coastal	Coastal Wetland Water Quality	↔	3.5	
	Lake Levels	↔	3.5	
	Coastal Fishes	NR	3.5	
	Aquatic Plant Community	NR	NR	
	Coastal Connectivity	NR	3.5	
		Coastal Indicator Score	***3.5***	↔
Island	Habitat Amount and Connection	NR	2.5	
	Alvar Quality	NR	3.5	
	Colonial Waterbirds	NR	NR	
		Island Indicator Score	***3***	NR
Offshore	Offshore Water Quality	↓	3.5	
	Benthic Community	NR	NR	
	Lake Trout	NR	2.5	
	Catch-per-unit Effort	NR	2.5	
	Proportion of Wild Lake Trout	NR	2.5	
	Ice Coverage	↔	1.0	
		Offshore Indicator Score	***2.4***	NR
Species at Risk		NR	NR	
		Species at Risk Indicator Score	***NR***	NR

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APPENDIX B. EVALUATION OF THE STATE OF THE DEVELOPMENT OF THE ECOLOGICAL MEASURES

The state of the development of each ecological measure is evaluated based on a set of criteria (Table B-1). This evaluation considers the completeness and quality of important aspects of the measures including:

i. the type of information used to establish thresholds,
ii. if a power analysis has been completed,
iii. if a protocol has been developed to standardize the data collection and analysis, and
iv. if the database is updated and completed for this measure.

Each of these four aspects is given a score out of 2.5. The four scores are totaled to give a total possible score out of 10 for each measure.

These four aspects have been evaluated for each of the ecological measures is this report (Table B-2). Overall, the state of the condition monitoring program in Fathom Five is poor to fair, largely due to a reliance on other agencies and researchers for data collection who work at the scale of Lake Huron. Dedicated monitoring funds for Fathom Five would improve the ability of the site to report on the ecological structure and function of the marine conservation area in a meaningful way. Good quality monitoring data provides information for both science-based management objectives and for the development of interpretation and outreach activities for Fathom Five National Marine Park.

Table B-1. Criteria for the evaluation of the state of the development of the ecological measures. This evaluation considers the level to which thresholds are established, if a power analysis has been completed, if protocol is developed for this measure, and if the database is up to date and complete.

Criteria	Evaluation statement	Score
1. Ecological Thresholds	Thresholds are well established, based on scientific literature and historical data	2.5
	Thresholds are preliminary and will be supported by a future literature review and/or an analysis of available historical data	1.5
	Thresholds are preliminary and based on a statistical approach (ex : ± 1 STD), and the appropriate range of variability will be determined by accumulating data during the next years.	1.0
	No threshold has been identified yet	0
2. Power analysis	A complete analysis has been performed	2.5
	A preliminary analysis has been performed, but requires more data to be completed.	1.5
	No analysis has been performed yet, but preliminary data are available.	1.0
	No data are available to perform an analysis	0
3. Protocol	A detailed and complete protocol has been archived in the ICE system	2.5
	A protocol is available but require some editions to be complete	1.5
	Work instructions or a draft protocol is available but have not been reviewed	1.0
	No document describing the methodology is available yet	0
4. Database	Database, including metadata, are complete, have been controlled, and archived in the ICE system	2.5
	Database are completed but uncontrolled, and/or metadata are incomplete	1.5
	Database are incomplete	1.0
	No data has been filed yet	0

Table B-2. Evaluation of the state of the development on the monitoring measures at Fathom Five National Marine Park.

Indicator	Measure	Thresholds				Power				Protocol				Data				Total
Score		0	1.0	1.5	2.5	0	1.0	1.5	2.5	0	1.0	1.5	2.5	0	1.0	1.5	2.5	
Coastal	Coastal Wetland Water Quality			x				x				x				x		6
	Lake Levels			x			x				x					x		5
	Coastal Fishes			x				x				x				x		6
	Aquatic Plant Community	x					x					x				x		4
	Coastal Connectivity		x				x			x						x		3.5
Island	Habitat Amount and Connection		x					x		x					x			3.5
	Alvar Quality		x			x				x					x			2
	Colonial Waterbirds	x					x					x				x		4
Offshore	Offshore Water Quality			x			x			x						x		4
	Benthic Community	x					x			x					x			2
	Lake Trout			x			x			x				x				2.5
	Ice Coverage			x					x	x						x		5.5