Musquash Estuary Marine Protected Area Ecosystem Framework and Monitoring Workshop Report

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By

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LIST OF ACRONYMS

CTD	Conductivity-Temperature-Depth
DFO	Department of Fisheries and Oceans
EO(s)	Ecosystem Objective(s)
GPAC	Global Programme of Action
GOMC	Gulf of Maine Council
LIDAR	Light Detection and Ranging
MAC	Musquash Advisory Committee
MPA	Marine Protected Area
NaGISA	Natural Geography In-Shore Areas Project
NB	New Brunswick
NH	New Hampshire

ABSTRACT

This report presents the proceedings of the Musquash Estuary Marine Protected Area Ecosystem Framework and Monitoring workshop, held in December of 2007 in St. Andrews New Brunswick. Workshop participants ranked proposed performance indicators associated with operational strategies under the three broad ecosystem components of biodiversity, productivity, and habitat. Participants also identified the types of surveys most appropriate for monitoring these indicators in the Musquash Estuary Marine Protected Area. The ranked indicators and preferred survey types are summarized on Tables 1 and 2 of this report. The workshop assisted in the process of outlining overall monitoring goals and general protocols to establish the first field season. Workshop participants offered valuable suggestions specific to the Musquash Estuary MPA in terms of the most effective ways to measure how the ecosystem objectives can be met.

RÉSUMÉ

Ce rapport présente un compte rendu des discussions tenues à l'atelier sur l'élaboration d'un cadre de surveillance et de gestion écosystémique pour la zone de protection marine de l'estuaire de la Musquash, qui a eu lieu en décembre 2007 à St. Andrews, au Nouveau-Brunswick. Les participants à l'atelier ont classé les indicateurs de rendement proposés associés aux stratégies opérationnelles dans trois grandes catégories écosystémiques, soit la biodiversité, la productivité et l'habitat. Les participants ont également déterminé les types de relevés les plus appropriés pour surveiller ces indicateurs dans la zone de protection marine de l'estuaire de la Musquash. Les indicateurs classés par ordre d'importance ainsi que les types de relevés privilégiés sont résumés dans les tableaux 1 et 2 du rapport. L'atelier a permis d'exposer les grandes lignes des objectifs globaux en matière de surveillance ainsi que les protocoles généraux visant la première saison de travaux sur le terrain. Les participants ont fait de très bonnes suggestions – propres à la ZPM de l'estuaire de la Musquash – en ce qui concerne les moyens les plus efficaces d'atteindre les objectifs écosystémiques.

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INTRODUCTION

This document presents the proceedings of the Musquash Estuary Marine Protected Area (MPA) Ecosystem Framework and Monitoring workshop held December 6, 2007 at the W. C. O'Neill Arena in St. Andrews, New Brunswick. The purpose of the workshop was to review the Musquash Estuary MPA ecosystem framework (Singh and Buzeta 2007) and to evaluate the proposed monitoring, a result of previous input and discussions. The review focused on the science aspects of the ecosystem framework. The Musquash Estuary MPA Ecosystem Framework will be incorporated into the MPA Management Plan and used to guide decisions regarding on-going and new activities.

Previous work on the Musquash Estuary framework and monitoring includes a workshop held in Saint John, with many of the same participants attending (Singh and Buzeta 2005). The Musquash Estuary ecosystem framework (Singh and Buzeta 2007) incorporates work by Jamieson et al. (2001) on national Ecosystem Objectives, Gavaris et al. (2005) on an ecosystem framework for the offshore (Georges Bank), and Parker and Rutherford (2005) on the steps required in developing an ecosystem framework.

Jamieson et al. (2001) reported on the outcome of a national workshop on objectives and indicators where three overarching Ecosystem Objectives (EOs) were identified in order to implement ecosystem-based management. These conceptual conservation objectives were categorized into three components: biodiversity, productivity, and habitat. Using these broad guidelines Gavaris et al. (2005) developed an ecosystem-based framework for managing the Canadian Fisheries on Georges Bank. The Musquash Estuary ecosystem framework (Singh and Buzeta 2007) was developed, with some modifications, along the same lines as the one for Georges Bank. Three broad conceptual objectives (one each for biodiversity, productivity, and habitat) were identified for Musquash Estuary. Using the three overall ecosystem objectives and considering the human activities occurring and impacting the Estuary, a series of sub-objectives and operational strategies (suitable for operational management) were developed. Once the operational strategies were developed, suggested relevant performance indicators, that could be used to determine whether the operational objectives were being met, were identified. These are presented in detail in Table 2 of Singh and Buzeta (2007).

This workshop was an opportunity to review the Musquash Estuary MPA ecosystem framework and to proceed towards identifying indicators (based on the performance indicators identified for the operational strategies) and methodologies that could be started for the first field season (short-term monitoring goals), knowing that additional monitoring should take place in the long-term. Workshop participants were provided with Singh and Buzeta's (2007) report, tables showing proposed performance indicators and survey types, and a reference list prior to the workshop. The tables showing proposed performance indicators and survey types, and the reference list, are included in this report as Appendix l. A list of workshop participants and their affiliations is attached as Appendix ll.

The workshop assisted in the process of outlining overall monitoring goals based on the operational strategies, and general protocols to work on for the first field season. The details on the protocols were to be defined after the workshop, using the workshop input as guidelines. Participants were asked to submit reference material specific to methodology or reference points. This report on the proceedings of the workshop contains:

- Summary of discussion on ecosystem framework.
- Ranked performance indicators.
- Summary of usefulness of proposed monitoring for at least three performance indicators for each ecosystem objective.
- Discussion on the merits of the GPAC-GOMC Habitat Monitoring protocols for Musquash Estuary.
- Populated “Table of suggested performance indicators and monitoring surveys” with rankings, comments and references.

While this workshop was the science review for monitoring, following the workshop there will be subsequent reviews by individual managers, stakeholders and the Musquash Advisory Committee (MAC). These reviews will provide an opportunity for input on other aspects of the monitoring plan, such as stakeholder acceptance, practicality, cost, and volunteer participation.

BACKGROUND PRESENTATIONS

The Estuary Ecosystem

Dr. Rabindra Singh of DFO, St. Andrews, NB, presented an overview of the ecosystem framework document (Singh and Buzeta 2007). This document entitled “An Ecosystem Framework for the Management of Musquash Estuary Marine Protected Area” is available at
http://www.dfo-mpo.gc.ca/Library/327758.pdf.
Points presented were

- the goals identified for the Musquash Estuary by the MPA Planning Group;
- the Musquash Estuary MPA objectives within the context of DFO’s national ecosystem objectives for ecosystem-based management;
- the ecosystem objectives for biodiversity, productivity and habitat and the proposed operational strategies;
- the proposed performance indicators for use in a monitoring program;
- an examination of the managed activities in the Musquash Estuary.

GPAC-GOMC Protocols

Dr. Al Hanson, Co-chair of the Gulf of Maine Habitat Monitoring Committee and of Environment Canada, Sackville, NB, presented an overview of the GPAC-GOMC (Global Programme of Action – Gulf of Maine Council) protocols. He stressed how GPAC-GOMC protocols provide comparable information, and forms part of a regional story using regional compilation and analytic tools. This process allows an understanding of change over time and provides an understanding of the causes of change.

A description of the GOMC (Gulf of Maine Council) regional habitat monitoring is available at:
http://www.gulfofmaine.org/council/publications/HMSC-Regional-Monitoring-Framework.pdf

The Gulf of Maine Council salt marsh monitoring protocol is described at the following web site:
http://www.gulfofmaine.org/habitatmonitoring/saltmarshprotocol.php

The GPAC-GOMC wetland monitoring protocol is described at
http://www.pwrc.usgs.gov/resshow/neckles/Gpac.pdf

NaGISA Protocols

Dr. Gerhard Pohle, NaGISA (Natural Geography In Shore Areas Project) Regional Coordinator for the Atlantic Ocean and of Huntsman Marine Science Centre in St. Andrews, NB, explained the NaGISA protocols and how this effort is part of a census of marine life. NaGISA looks at the near-shore and makes use of reference sites. He suggested that Musquash might be a useful reference site. NaGISA International protocols for near-shore monitoring of biodiversity are available on the web site: http://www.nagisa.coml.org/Protocols

National Ecosystem Indicators

Dr. Andrew Cooper, a member of DFO's National Ecosystem Indicators Working Group, and of DFO, St. Andrews, NB, spoke on the criteria for the selection of indicators. The working group is developing these criteria to support the selection of appropriate indicators for a wide range of activities such as aquaculture, oil and gas, fisheries, and marine protected areas. He stressed that no indicator can meet all of the criteria and therefore a suite of indicators is necessary. Although many examples of appropriate indicators are available for specific compliance and management objectives there remains a challenge in trying to identify appropriate indicators for general ecosystem well-being or what is being defined as ecosystem services. The criteria that are being examined for DFO's national ecosystem indicators include:

Interpretation

- Concreteness
- Public awareness

- Theoretical bias

Implementation

- Availability of Historical Data
- Cost
- Measurability

Application

- Sensitivity
- Specificity
- Responsiveness

RANKING OF PERFORMANCE INDICATORS

Prior to the workshop, participants were given a table (Appendix I) presenting proposed performance indicators relevant to the operational strategies for each of the national ecosystem components: biodiversity, productivity and habitat (Jamieson et al. 2001). The table presented five types of surveys and examples of possible protocols that could be used to obtain information for each of the proposed performance indicators. Participants were asked to rank the various proposed performance indicators for the three ecosystem components, and make further comments on the table to help focus on the most critical performance indicators and protocols.

This ranking process was summarized, and performance indicators were shaded in grey according to importance (Table 1). Performance indicators in dark shading were considered the most important in the ranking. While this table summarizes the rankings, important additional information is included in the discussion sections of this report. The corresponding operational strategies for each of the performance indicator referred to below is listed in Table 2 of Singh and Buzeta (2007).

BIODIVERSITY

Ranking

Participants generally felt that all of the proposed performance indicators for biodiversity were important, and each of the indicators received at least one vote as the participant's first choice (Table 1).

The one ranked most important was

- The number of species in each trophic level, and abundance of keystone species

The two indicators ranked next were

- number and distribution of exotic species in MPA in relation to regional data
- number of species within each ecotype.

Indicators ranked of next importance were

- number of distinct viable populations for species within the estuary
- the percent area and location of each ecotype.

Discussion

Discussion on biodiversity ecosystem objectives stressed the overall goal of maintaining biodiversity, and the need to understand what species are present. As one participant suggested, “don’t loose anything…it is all important….species don’t disappear without cause”. It was stressed that reference points are necessary and there is a need to understand natural variability. Relationships with economic species and charismatic megafauna are important and need to be understood, as is the connection of species within community structure, and cause and effect of species distributions. There is a need to identify key indicator species that are relevant to Musquash and to be able to communicate monitoring results to the public.

Participants felt that measuring disturbances is more important than measuring the opportunistic species that take advantage of such disturbances. There was considerable discussion on what was the best approach to monitor biodiversity. Comments included

- it is better to monitor comprehensively over a long timeframe than monitor every year;
- rotational monitoring is appropriate for some indicators;
- “count everything” sampled if possible or store samples for later analysis;
- maintain competency of monitoring crew (annual monitoring achieves this, while infrequent sampling requires retraining);
- it is critical to sample at the same time of year in order to obtain comparable data.

Table 1. List of ranked performance indicators for each of the three ecosystem components: biodiversity, productivity, and habitat. Indicators in dark shading were considered the most important in the ranking. While this table summarizes the rankings, important additional information is included in the discussion sections of this report. The corresponding operational strategies for each of the performance indicator referred to below is listed in Table 2 of Singh and Buzeta (2007).

Performance Indicators		
Biodiversity	**Productivity**	**Habitat**
Number and species in each trophic level, abundance of keystone species	Essential nutrient concentrations, historic water turbidity and phytoplankton concentration	Historical and present physical features influencing hydrologic regime
Number and distribution of exotic species in MPA in relation to regional data	Number of juvenile fish and bird hatchlings	Percent area of species providing biogenic structure (marsh rockweed)
Number of species within each ecotype	Total biomass for harvested species*	Percent area and frequency of habitat disturbed/or lost
Number of distinct viable populations for species within the Estuary	Trophic levels present in each ecotype, estimate of biomass and distribution	Contaminant levels in sediment; toxic levels in biota (need to model zone of influence, could include nutrient levels)
Percent area and location of each ecotype	Mortality rate from fishing activities	Historic and present water quality levels
Ratio of opportunistic species to other species	Bycatch and mortality estimates of impacted species	
Measures of bycatch, mortality rate, of impacted species*	Percent size/sex/age in catch and in areas impacted by activities	
Number of local populations of species at risk	Estimates of human use/presence based on monitoring of all activities	

* There was some discussion among participants on the importance and availability of bycatch data (see discussion below).

PRODUCTIVITY

Ranking

The ranking of productivity performance indicators showed much stronger consensus both for the top choices and for indicators that could be dropped (Table 1).

The top choice performance indicators, ranked first in importance were

- essential nutrient concentrations, historic water turbidity and phytoplankton concentration
- number of juvenile fish and bird hatchlings (reproductive success)

Ranked second in importance was

- total biomass for harvested species.

The third in importance was

- trophic levels present in each ecotype, estimates of biomass and distribution

Other performance indicators which did not score in the top three by any of the participants include

- mortality rate from fishing activities (information not available);
- bycatch and mortality estimates of impacted species;
- percent size/sex/age in catch and in areas impacted by activities;
- estimates of human use/presence based on monitoring of all activities.

Several participants suggested that discarded catch be dropped because the level of fishing activity in Musquash Estuary is low.

Discussion

Discussion of performance indicators for productivity included the need to measure ecosystem outputs such as the number of juveniles and hatchlings present in the Estuary. In the case of the third ranked performance indicator “trophic levels present in each ecotype, estimates of biomass and distribution” there was a strong consensus among participants that monitoring of the biomass and distribution of invertebrates is essential. Monitoring invertebrates was considered more important than monitoring bird fledglings. Birds have a high metabolism and are good indicators of the productivity of the estuary, but monitoring their invertebrate prey will help provide a picture of food sources for other species, including birds. Hence, it was suggested that the monitoring strategy for productivity should include some monitoring of invertebrates biomass and distribution.

Monitoring fishery based impacts such as “bycatch and mortality estimates” ranked low because of the issue of scale. The population dynamics for species targeted by the fishery generally occur in a much greater area than the MPA. As a result, the information obtained from just the MPA would likely not be correctly interpretable.

HABITAT

Ranking

There was a strong consensus among workshop participants that the most important performance indicator was

- historical and present physical features influencing hydrologic regime (i.e. dam).

The performance indicator ranked second was

- percent area of species providing biogenic structure (marsh, rockweed).

Ranked third in importance were

- percent area and frequency of habitat disturbed/or lost;
- contaminant levels in sediment; toxic levels in biota (need to model zone of influence, could include nutrient levels);
- historic and present water quality levels.

Discussion

For the habitat performance indicators, participants raised questions regarding the difficulties in determining the area disturbed by the scallop draggers. The performance indicator suggested in Singh & Buzeta (2007) is “percent area and frequency of habitat disturbed/or lost”. It was recognized that there is a connection between harvesting and habitat disturbance (especially with clams and scallops). For such activities, it will be necessary to identify the zones within the Estuary that will be monitored for disturbance. In order to monitor changes in the hydrologic regime of the Estuary, a regular geomorphic survey of the channel was suggested.

There was considerable discussion on the pros and cons of LIDAR (Light Detection and Ranging) and the need for ground-truthing. Commercial satellite imagery may be as good or better, however digital elevation mapping would require LIDAR.

From a management point of view, it is important to know changes in contaminant levels and their source (e.g. Saint John Harbour). The discussion concluded that it is necessary to have an understanding of the state of both the physical and chemical aspects of the habitat. For example, permanent water quality monitoring stations with the ability to effect immediate download of the data will be helpful to determine whether there are changes in water quality levels.

There were several general points of agreement including

- the need for regional mapping to include all areas which might influence the Musquash Estuary MPA;
- more detailed mapping of the individual zones of the MPA;
- monitoring of habitat and biodiversity are closely connected.

DISCUSSION OF USEFULNESS OF MONITORING OPTIONS

Workshop participants indicated their support for good baseline data and agreed that once established, the monitoring frequency for some performance indicators could be on a three or five-year frequency rather than annually. For some performance indicators it might take up to 10 years to establish baseline data that is more than a “snapshot in time.” There is a need to focus on the connection with human activities and on potential impacts from these activities. This link is critical to understanding what is happening, as management decisions will need to be made based on the findings.

Monitoring should assist in the understanding of natural drivers of change and natural variability in the performance indicators.

MONITORING REQUIREMENTS

Minimum Requirements

For minimum monitoring requirements, workshop participants expressed the need to know

- what species are present;
- physical and chemical mapping of the Estuary, and areas of influence to the Estuary;
- how to understand natural processes and variation;
- the impacts of clamming, scallop dragging and other human activities.

In order to know these things, it will be necessary to

- survey the species present in the Estuary;
- map chemical and physical aspects of the Estuary and areas of influence;
- map scallop dragging areas (if information is available);
- map clamming areas (if this activity occurs again within the Estuary); and

- look at performance indicators within each habitat (each habitat type will potentially be affected differently and needs to be monitored differently).

Ranking of survey types

Workshop participants reviewed five survey types and identified the most appropriate ones for the performance indicators for each of the three broad ecosystem objectives.

- Type A: Baseline surveys of resident biota, visual GIS survey of key plants, bird and wildlife, invasive species, and assessment of natural variability and succession. This may include non-destructive quadrat sampling in each ecotype. Included in Type A are

  - Community-based ecological monitoring (e.g. Shore Keepers) survey (marsh, intertidal);
  - GPAC-GOMC regional protocols;
  - NaGISA protocols for near-shore sampling of biodiversity;
  - Fixed photo stations for vegetation (marsh, intertidal).

- Type B: Monitoring of critical life cycle stages and habitat utilization, including

  - Juvenile fish (beach seine);
  - Fish in marsh pannes;
  - Bird nesting sites, fledglings;
  - Elver counts (dip nets).

- Type C: Monitoring habitat quality and productivity (CTD, chlorophyll, nutrients, Secchi disk, oxygen, contaminants, fresh water input), including

  - CTD stations in ecotypes or management zones;
  - GPAC-GOMC protocols (2-3 fixed stations);
  - Contaminant levels (sediment/tissues, bacterial);
  - Sedimentation, erosion rates.

- Type D: Monitoring habitat impacts of human activities

  - Logbooks, data collection by fishers, activity proponents.

- Type E: Baseline of habitat and ecotypes

  - LIDAR, aerial survey, multibeam ground survey.

Workshop participants identified the most useful survey types for each of the performance indicator. These are shown below in Table 2. As with Table 1, information from the discussion should be considered along with the table.

Table 2. Monitoring protocols suggested by participants as being useful for determining whether operational strategies within each of the three ecosystem components are being met.

Survey types	Biodiversity	Productivity	Habitat
Type A - Baseline of resident biota	GPAC-GOMC regional protocols NaGISA nearshore protocols	NH volunteer manual and Shore Keepers for marsh intertidal	GPAC-GOMC to link GIS data Aerial photos
Type B - Life cycles and habitat utilization	Juvenile fish (beach seine and fyke nets Fish in marsh pannes Aerial surveys for birds; ground surveys for other birds	Juvenile fish Bird nesting sites Elver counts by dip nets Invertebrate survey (Clean Annapolis River Project)	Juvenile fish in marsh pannes Bird nesting sites Elver counts
Type C - Habitat quality and productivity	GPAC-GOMC protocols with 2-3 fixed stations	GPAC-GOMC protocols	Contaminant levels in sediment Water quality surveys to determine contaminant levels* Nutrient levels should be surveyed along with contaminant levels CTD stations GPAC-GOMC protocols 2-3 fixed stations NaGISA for historical and physical/biological features Sedimentation surveys, erosion rates
Type D - Habitat impacts of human activities	Logbooks and data from fishers	DFO standard fishery monitoring Recreational fishing?	Logbooks and data from fishers and activity proponents of area used Areas dredged Infrastructure as well as activities should be monitored (roads, etc.)
Type E - Baseline of habitat and ecotypes	LIDAR, aerial photos and multibeam ground surveys Historical surveys and photos Satellite imagery		Aerial photographs and 2007 LIDAR for percent area providing biogenic structure, vegetations structure and hydrologic changes Ground-truth satellite imagery

* There was some disagreement among participants on the best way to determine contaminant levels.

Discussion
In terms of monitoring progression, in the near future there is a need for broad scope biodiversity monitoring. This leads to the selection of indicator species for each ecotype, and of indicator species for predator/prey assemblages. In order to make monitoring more manageable, there is first the need for baselines for all three ecosystem components: biodiversity, productivity, and habitat. This includes a full assessment of biodiversity. Productivity and habitat only need to be monitored in relation to keystone species, unless negative trends are observed and are unexplained. It is necessary to develop protocols, actions, and timeframes for an emergency/contingency ecosystem framework if negative trends are observed and unexplained. If biodiversity objectives are not being met and explanation from monitoring is not clear, then a keystone approach may not be appropriate as currently applied (i.e. performance indicators should explain observations).

MONITORING OPTIONS

TYPE A SURVEYS (Baseline surveys of residents biota)

Workshop participants strongly supported the need for good baseline data that were comprehensive with regard to species. There was no discussion on the New Hampshire (NH) volunteer manual or other community based surveys (http://www.mass.gov/czm/volunteermarshmonitoring.htm; http://www.des.state.nh.us/Coastal/Resources/documents/AVolunteerHandbook.pdf). However, comments on the tables handed in by the participants provided considerable scientific advice on Type A surveys for Musquash Estuary. These comments are included in the following sections.

Biodiversity
With regard to biodiversity, mention was made that GPAC-GOMC protocols are useful for species in each ecotype. NaGISA approved protocols for vegetation, birds, fish, insects and invertebrates were also considered useful. There was a suggestion that the nekton sampling techniques used in GPAC-GOMC protocols may need to be customized to the Bay of Fundy/Musquash Estuary system because of challenges that the tidal range brings to the effectiveness of the techniques suggested in the GPAC-GOMC sampling protocol. Regarding surveys of the number of species within each ecotype, it will be necessary to clearly define “opportunistic species”, “keystone species”, “exotic species”, and “population”. The participants did not discuss the degree to which this baseline work may already be available**.**

Productivity
It was suggested that the NH volunteer manual and Shore Keepers survey (marsh, intertidal) might be used to survey chlorophyll and essential nutrient concentrations. While there is an important need to record the total catch

biomass for harvested species, this was recognized as a challenging task. In order to obtain such information there will be the need to implement a series of changes in the way data and information are recorded for commercial and recreational fisheries. As it stands presently, there is a lack of relevant available information on Musquash Estuary from fishing and harvesting activities.

Habitat

It was suggested that it is possible to use GPAC-GOMC protocols to link GIS data for models. Fixed photo stations are not considered by some participants to be as useful as aerial photos. It was noted that none of the suggested Type A surveys could be used to determine the percent area and frequency of habitat disturbed. As with biodiversity, there is a question whether the GPAC-GOMC protocols will work subtidally. GPAC-GOMC protocols are useful in determining the percent area of species providing biogenic structure (marsh, rockweed). It is important to have regular geomorphological assessments, including bank stability.

TYPE B SURVEYS (Monitoring of critical life cycle stages and habitat utilization)

An understanding of critical life cycle stages and habitat utilization was seen as important, however in some instances difficult to obtain.

Biodiversity

Type B surveys of juvenile fish (e.g. using beach seines) and fish in marsh pannes to determine the number of species in each trophic level received considerable support. It was noted that it is important to determine how each species uses the habitat (e.g. lifestage(s) found, and the specific purpose that the habitat is used for). Such information is needed when considering fish habitat management Regulations that could be applied to human activities. It was suggested that only small fish might be caught in pannes. It was also suggested that the use of fyke nets and beach seines at high tide be considered for sampling fish use of the marsh and pannes. Regional level data from outside of the Musquash Estuary MPA is available for beach seines at five to seven sites on either side of the Estuary. If the number of fish in each trophic level is important in maintaining trophic levels, then gear other than beach seines will be needed because beach seines will only catch juveniles.

The number of local fish species/populations at risk may be obtained by looking at the literature. For example, most species of fishes are known to migrate distances that exceed the scale of the Musquash Estuary MPA, therefore a first step is a literature search. If some fishes are identified as maybe residing in the Estuary for their whole life, then this could be tested via simple mark-recapture studies. It is possible that the only species in this category is the mummichog (*Fundulus heteroclitus)*.

Exotic species can be identified through beach seining, fyke nets and maybe gill nets. The number and distribution of exotic species in the Estuary in relation to regional data is largely unknown for the Bay of Fundy area as there is no historic data for this area.

Surveys of bird populations also help to indicate productivity of fish and invertebrates. Several participants remarked that surveys of bird nesting sites are difficult to do, especially in an area as large of the Musquash Estuary MPA. In order to determine the number of local bird species/populations at risk, it was noted that aerial surveys are useful for waterfowl, however ground surveys are necessary for other birds.

Productivity

The performance indicator ranked highest for productivity was the “trophic levels present in each ecotype”. The remaining indicators listed in Table 1 are potential causal factors explaining why higher level productivity may be impacted or changing. As in other discussions, the importance to productivity of detached marine plants, invertebrates and larvae was noted. Reproductive success was seen as an important key to determining productivity. It was noted that the Musquash Estuary MPA is a juvenile fish nursery area; therefore, in terms of biomass an increase of juvenile fish would indicate an increase in productivity. The output to open ocean and the nursery/nutrient output of salt marshes are important indicators of productivity. It was noted that juvenile fish in the salt marsh are important from a productivity and habitat perspective.

There was considerable support for monitoring juvenile fish, bird nesting sites, and elver counts (e.g. by dip net). In terms of bird nesting sites, however, it was recommended that brood surveys are more accurate, and the important thing is determining the reproductive success of birds. The Vickery Index (Vickery et al. 1992) and the Maritime Breeding Bird Atlas (Erskine 1992) may be useful. Ducks Unlimited has completed three years of aerial surveys (2005-2007), three times each year (May-pairing survey, July brood survey and October-staging/migration), covering the entire Musquash Estuary.

A possible methodology for marine invertebrate surveys has been developed by Andy Sharpe at Clean Annapolis River Project.

Habitat

Type B surveys of juvenile fish, fish in marsh pannes, bird nesting and elver counts, were also supported by participants as being useful for the determining whether the operational strategies under the broad habitat ecosystem objective were being met. Specific suggestions for survey include plants, seaweeds, sea grasses and invertebrates. In terms of fish species, three habitats are important, and survey methods were suggested for these: intertidal (beach seines), subtidal channels (gill and fyke nets) and the marsh pannes (beach seines and fyke nets).

TYPE C SURVEYS (Monitoring habitat quality and productivity)

Generally speaking, few participants commented or indicated preferences for Type C Surveys for monitoring productivity. This may mean that these were considered of less importance, or, that participants did not have adequate time to consider them.

Biodiversity

GPAC-GOMC protocols (2-3 fixed stations) were supported for biodiversity by some workshop participants. This protocol is already being used in other areas along the Atlantic coast of the United States. Hence, the use of these protocols in other locations will provide a local/regional context and comparison so that the results would not be viewed just in isolation.

Productivity

In terms of the operational strategies under the broad ecosystem objective for productivity, there was some support for the GPAC-GOMC protocols.

Habitat

One participant supported Type C surveys to determine contaminant levels in sediment, and for historical and present water quality levels. However, another suggested that these could be included in water quality analysis. Other participants questioned the use of contaminant level surveys to determine historical and present water quality levels. Rather than focusing on contaminants, it was suggested that surveying water quality would lead to the sources of contaminant types (e.g. organics, coliforms, inorganics, etc.).

CTD stations were ranked high by a participant who suggested that data loggers be used in order to collect data throughout the year, year after year. CTD stations and surveys of sedimentation and erosion rates were favoured to help determine historical and present physical/biological features influencing the hydrologic regime. The use of CTD stations to monitor for the “percent area and frequency of habitat disturbed” performance indicator was questioned by three other participants. CTD stations for monitoring fresh water input (e.g. from the hydrodam) were considered useful for historical and present biological features. There was general support for GPAC-GOMC protocols (e.g. 2-3 fixed stations) and a suggestion that they are preferable to the surveys of sedimentation and erosion rates for monitoring percent area and frequency of habitat disturbance. It was suggested that nutrient levels be surveyed along with contaminant levels. Surveys should be conducted in both marine and fresh water areas. It was suggested that NaGISA survey protocols would also we useful along with the GPAC-GOMC protocols for determining historical and present physical/biological features.

To determine historical and present physical/biological features, Type C sedimentation surveys could use aluminum plates, installed to detect sediment changes linked to high definition GPS.

TYPE D SURVEYS (Monitoring habitat impacts of human activities)

Type D surveys monitoring habitat impacts of human activities did not receive much attention from workshop participants; however, the general discussion of the three broad ecosystem objectives focused considerable attention on determining how to understand the human drivers of ecosystem change. It is necessary to record use of the marsh for activities such as tourism, kayaking, ATV use and hiking. A possible result of habitat monitoring could be opportunities for habitat restoration and removal of barriers to fish passage.

Biodiversity

Participants discussed the usefulness of logbooks and data collection by fishers and activity proponents in order to measure impact of bycatch on non-target species within the Musquash Estuary MPA. This type of information is considered useful when collected at a sufficiently large scale to be appropriate to an entire population; however, Musquash Estuary would only account for a small proportion of the population, so it would be unlikely to provide any useful estimates of population mortality. Logbook records by fishers on any species observed while in the area around the Musquash Estuary was briefly discussed as potentially useful.

Productivity

In terms of productivity, standard DFO fishery monitoring was thought to be useful; however, Musquash Estuary would only account for a small proportion of an entire fish population. Monitoring for juvenile fish was considered more appropriate as marshes and estuaries are generally thought to contribute towards recruitment of fish populations. A participant wondered if recreational catch is important and it was agreed that this information could be collected by volunteer logging.

Habitat

Logbooks and data collection by fishers and activity proponents would be useful to determine the percent area and frequency of habitat disturbed or lost. Surveys should include areas of dredging. Monitoring of the location of human activities should be done. Especially important is the area where lobstering and scallop dragging occur. Included should be roads, homes, businesses, industry (dam), fishing and agricultural activities occurring within the Musquash Estuary watershed.

TYPE E SURVEYS (Baseline surveys of habitat and ecotypes)

LIDAR, aerial surveys, and multibeam ground surveys received considerable support. Where possible, historical surveys should be used to determine trends and change over time. Surveys should be comprehensive, but need not be frequent. Satellite imagery was added as a Type E survey technique.

Biodiversity
Historical photos, infrared and LIDAR surveys are useful to map zones and should be updated every few years. These types of surveys are useful in providing information needed for geomorphological assessments of the estuary.

Productivity
Workshop participants did not indicate support of surveys for performance indicators under the productivity operational strategies within this ecosystem component.

Habitat
Since the historical aerial photos and 2007 LIDAR provide detailed mapping of habitats, they are useful in establishing baselines for percent area and frequency of habitat disturbed. For percent area of species providing biogenic structure, LIDAR can be linked to vegetation structure. LIDAR can also be used to model hydrologic changes and high tide changes with sea level rise. One participant suggested that these Type E surveys were not useful for percent area and frequency of habitat, but were useful for historical and present physical/biological features. Ground-truthing of satellite imagery is necessary if this is used as a method to map habitat types.

CONCLUSIONS

The workshop provided an opportunity to review the Musquash Estuary MPA ecosystem framework (Singh and Buzeta 2007), and to evaluate the usefulness of the proposed monitoring. The list of performance indicators for each of the three ecosystem components was discussed and priority indicators were identified, as shown in Table 1.

Priority performance indicators were those identified the most by participants. These included: the number and species in each trophic level and abundance of keystone species (Biodiversity); essential nutrient concentrations, historic water turbidity and phytoplankton concentration, and number of juvenile fish and bird hatchlings (Productivity); and historical and present physical features influencing hydrologic regime (Habitat).

Survey types were discussed to measure these performance indicators and some of the most useful ones are listed in Table 2. The various monitoring protocols identified as useful for determining whether each of the three ecosystem objectives are being met, were those selected most often by participants. For example, GPAC-GOMC protocols were identified as useful for determining that each of the three ecosystem objectives of biodiversity, productivity and habitat were met, and as a useful protocol for two surveys, Type A (biological baseline surveys) and Type C (habitat baseline surveys). For Type C surveys specifically, the GPAC-GOMC protocols were the only survey type generally agreed upon by participants. Survey types that monitored contaminants or sedimentation/erosion were deemed narrower in scope, and useful for answering specific questions, but a more comprehensive survey would still be required. There was recognition that CTD stations are a survey type that is included in the GPAC-GOMC protocols, with CTD stations either sampled 1-2 times a month or continuously by permanently moored dataloggers. However, it was felt that the strength of the GPAC-GOMC protocols is based on the usefulness in monitoring for a suite of indicators, and on the ability to compare data collected in other estuaries along the coast of the Gulf of Maine.

Type B survey (juvenile fish) was identified as being useful for determining whether all three ecosystem objectives are being met, but in particular that of productivity. Ground surveys of nesting birds also rated highly for measuring productivity, and both survey types are considered to be easily implemented.

Types D surveys, specifically the monitoring of use of the marsh and estuary for activities such as tourism, kayaking, ATV use, and fishing, were thought to be important. However, a system of data collection would need to be developed for most of these activities. There is limited fishing activity within the Musquash Estuary, nonetheless, logbook records by fishers on any species observed while in the area around the Musquash Estuary was considered potentially useful. Aerial photos and LIDAR provide detailed mapping of habitats, and therefore considered useful in establishing baselines for percent area and frequency of habitat disturbed.

Workshop participants offered valuable suggestions specific to the Musquash Estuary MPA in terms of the most effective ways to measure how the three broad ecosystem objectives can be met.

Science advisory committee

A Musquash Estuary MPA Science Advisory Committee will be established to discuss the details of monitoring methodologies, frequency and duration of monitoring. Participation will require an annual meeting to review monitoring plan and results, although the majority of the Committee’s work could be done via electronic communication. The first task of the Committee would be to review the methodology of the monitoring planned for 2008/09. There is a need for this Advisory Committee to review the comments provided during this workshop. For example, comments regarding monitoring performance indicators for biodiversity, and settle on an acceptable monitoring strategy.

A number of workshop participants agreed to participate in this Committee. The Committee will act as Advisors that can review the detailed sampling methodology (e.g. sample size, transect length, reference points that trigger a red flag, etc), data analyses, and offer recommendations and conclusions, once the monitoring is under way.

ACKNOWLEDGEMENTS

The authors would like to thank the workshop participants for their generous contribution of time and ideas during this workshop. Their input will have a direct benefit to the implementation of a monitoring plan for the Musquash Estuary MPA. Many participants also expressed interest in being members of the Musquash Science Advisory Committee. Our thanks also go to Penny Doherty and Andrew Cooper for reviewing the draft manuscript and making suggestions to improve it.

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APPENDIX I: REFERENCE MATERIAL PROVIDED TO PARTICIPANTS

Table of suggested performance indicators and of monitoring survey types.

Prior consideration of performance indicators and monitoring survey types by the participants helped achieve the workshop goals. Participants were requested to read the material ahead of time and to make comments on the table provided during the workshop (Table I.i-ii). The table was then submitted during the workshop wrap-up.

The list of performance indicators normally listed in column 1 of the Table I.i is a lengthy list; therefore for presentation purposes within this appendix, we have listed these separately in Table I.ii.

The three points below were given to participants for their consideration, and their notes provided the basis for our conclusions and were recorded as part of the workshop proceedings:

1st. Ranking of Performance Indicators within each ecosystem component (Table I.i). The list of performance indicators for biodiversity, productivity, and habitat are provided in Table I.ii.

> Which performance indicators are most useful or appropriate as a measure of achieving the operational strategies under each broad EO?
> Participants were asked to add a numeric ranking within each cell of column 1 in Table I.i.

2nd. Suggested Survey Types (A-E) for the various Performance Indicators. Refer to Table I.i, row 1, for Survey Types A-E.

> Are these surveys appropriate in principle, to measure those Performance Indicators listed in Table I.ii?
> Participants were requested to evaluate and insert comments within each cell of the matrix.

3rd. Suggested monitoring protocols listed in Table I.i, row 2, for each survey type A-E.

> Would these protocols / general methods detect change/trends in each of those Performance Indicators?
> Participants were requested to evaluate protocols and insert any citations for specific methodologies.

In most cases, surveys suggested fulfilled the requirements for monitoring more than one Performance Indicator. During the workshop, we would only have time to review a subset of the Performance Indicators and monitoring protocols listed, and these were indicated in the table (see Table I.i) with a "[1]".

Participants were provided with three unpopulated tables for each of the three ecosystem components: (A) Biodiversity, (B) Productivity, (C) Habitat. Participants were asked to rank the performance indicators and indicate which survey type (A-E as shown on Table I.i) were appropriate protocols for each of the suggested indicators listed in Table I.ii.

Table I.i. Example of table provided to participants. [1]See text for explanation.

See list of Performance Indicators in Table I.ii.	Survey Type A - Baseline GIS survey of resident biota.				Survey Type B - Monitoring of critical life cycle stages and habitat utilization.				Survey Type C - Monitoring habitat quality & productivity. (CTD, chlorophyll, nutrients, Secchi disk, oxygen, contaminants)				Survey Type D - Habitat impacts from human activities	Survey Type E - Baseline of habitat & ecotypes
↓	NH Shore Keeper	GPAC-GOMC[1]	NaGISA	Fixed photo station[1]	Juvenile fish[1]	Fish in marsh	Bird nesting sites[1]	Elver counts[1]	CTD	GPAC-GOMC-fixed stations[1]	Contaminants	Sedimentation & erosion	Fishing, recreation, new proposals[1]	LIDAR, aerial survey, ground survey[1]

Table I.ii. List of performance indicators considered by workshop participants

Biodiversity indicators	**Productivity indicators**	**Habitat indicators**
Percent area and location of each ecotype	Essential nutrient concentrations, historic water turbidity and phytoplankton concentration	Percent area and frequency of habitat disturbed/or lost
Number of species in each trophic level. Abundance of keystone species	Trophic levels present in each ecotype, estimates of biomass and distribution	Contaminant levels in sediment; toxic levels in biota
Number and distribution of exotic species in MPA in relation to regional data	Total catch biomass for harvested species	Percent area of species providing biogenic structure (marsh, rockweed)
Number of distinct/viable populations for species within the estuary	Mortality rate from fishing activities	Historical and present water quality levels
Number of local populations of species at risk	Bycatch and mortality estimates of impacted species	Historical and present physical features influencing hydrologic regime
Number of species within each ecotype	Number of juvenile fish and bird hatchlings	
Ratio of opportunistic species to other species	Estimates of biomass changes	
Measures of bycatch, mortality rate of impacted species	Percent size/sex/age in catch and in areas impacted by activities	
	Estimates of human presence/use based on monitoring all activities	
	Discarded catch	

APPENDIX II: WORKSHOP PARTICIPANTS

Workshop participants included:

- Hank Deichmann Naturalist, Hampton, NB
- Gerhard Pohle Huntsman Marine Science Centre, St. Andrews, NB
- David Methven University of New Brunswick, Saint John, NB
- Penny Doherty DFO, Dartmouth, NS
- Mike Parker Consultant, Bridgetown, NS
- Laura Jardine Consultant, St. Andrews, NB
- Paul Macnab DFO, Dartmouth, NS
- Mary Mills DFO, St. George, NB
- Stratis Gavaris DFO, St. Andrews, NB
- Jennifer Martin DFO, St. Andrews, NB
- Barry Hill New Brunswick Dept Fisheries, St. George, NB
- Anita Hamilton DFO, Dartmouth, NS
- Deanne Meadus Ducks Unlimited, Sackville, NB
- Al Hanson Environment Canada, Sackville, NB
- Blythe Chang DFO, St. Andrews, NB
- Andrew Cooper DFO, St. Andrews, NB
- Kats Haya DFO, St. Andrews, NB
- Rabindra Singh DFO, St. Andrews, NB
- Maria-Ines Buzeta DFO, St. Andrews, NB