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Musquash Estuary: A Proposed Monitoring Framework for the Marine Protected Area (MPA) and Intertidal Area Administered (AIA) by Fisheries and Oceans Canada

Estuaire de la Musquash : Proposition de cadre de surveillance de la zone de protection marine (ZPM) et de la zone intertidale administrée par Pêches et Océans Canada

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ABSTRACT

This document proposes a framework for monitoring the ecosystem of the Musquash Estuary Marine Protected Area (MPA) and Administered Intertidal Area (AIA) that would pertain to managed activities and perceived threats to overall conservation objectives. The framework includes overviews of the Musquash Estuary ecosystem, previous overviews of monitoring in the estuary, and Fisheries and Oceans Canada's approach to ecosystem-based management and monitoring. The focus of this framework is to identify the state of baseline knowledge of the estuary, as well as to propose monitoring indicators, strategies, and protocols that may be used to inform management towards acheiving the conservation objectives. A governance structure and scientific approach that would facilitate next steps for a monitoring program are also proposed. Incorporation of managed activities and perceived threats is considered an essential aspect of the framework, as this provides justification for the monitoring strategies and linkages for performance assessment. The evaluation of existing and new monitoring activities is considered an interative process. A workplan to guide this process over the next 5 years is provided. The monitoring framework outlined in this document is to be considered a proposed approach for monitoring the estuary, with focus on the protected area. It is not to be considered a final monitoring plan or commitment of resources or time by any party or participant, as described within. The science advice associated with this document is outlined in a DFO Canadian Science Advisory Secretariat (CSAS) Science Advisory Report available at: www.dfo-mpo.gc.ca/csas-sccs/index-eng.htm.

RÉSUMÉ

Le présent document propose un cadre de surveillance de l'écosystème de la zone de protection marine (ZPM) de l'estuaire de la Musquash et de la zone intertidale administrée par Pêches et Océans Canada. Il vise les activités gérées au sein de ces zones et ce qui est perçu comme des menaces aux objectifs de conservation généraux. Ce cadre comprend une vue d'ensemble de l'écosystème de la Musquash, un aperçu des mesures de surveillance prises antérieurement dans l'estuaire et une description de la stratégie de Pêches et Océans Canada en matière de gestion et de surveillance axées sur l'écosystème. Le cadre proposé vise à dresser l'état des connaissances fondamentales sur l'estuaire et à proposer des indicateurs, stratégies et protocoles de surveillance pouvant aider les gestionnaires dans la poursuite des objectifs de conservation. Le document propose aussi une structure de gouvernance et une approche scientifique pour faciliter les prochaines étapes de la mise en place d'un programme de surveillance. L'intégration des activités gérées et des menaces perçues est considérée comme un aspect essentiel du cadre, puisqu'elle donne sa raison d'être aux stratégies de surveillance et permet d'établir des liens pour l'évaluation des résultats. L'évaluation des activités de surveillance nouvelles ou déjà en place est un processus répétitif, que le plan de travail fourni pourra guider au cours des 5 prochaines années. Le cadre décrit ici doit être considéré comme une proposition d'approche de surveillance de l'estuaire, axée sur la zone de protection. Il ne saurait être vu comme un plan de surveillance définitif ou comme une promesse d'engagement de ressources ou de temps de quelque partie que ce soit. Les recommandations scientifiques associées à ce document sont décrites dans un Avis scientifique du Secrétariat canadien de consultation scientifique, disponible sur le site www.dfo-mpo.gc.ca/csas-sccs/index-fra.htm.

1. INTRODUCTION

The Musquash Estuary is located in southwest New Brunswick (Figure 1). It supports rich and productive habitat for many species of invertebrates, fish, and wildlife, as well as several different marine plants (Singh et al., 2000). The estuary is one of only a few that remains in the region that has not been significantly altered by human development (Harvey et al., 1998; Platt, 1998). In addition, it supports a sensitive salt marsh ecosystem that occupies its upper reaches. Conservation and protection of the Musquash Estuary began with conservation and protection of the land that surrounded it, including the sensitive salt marsh ecosystem.

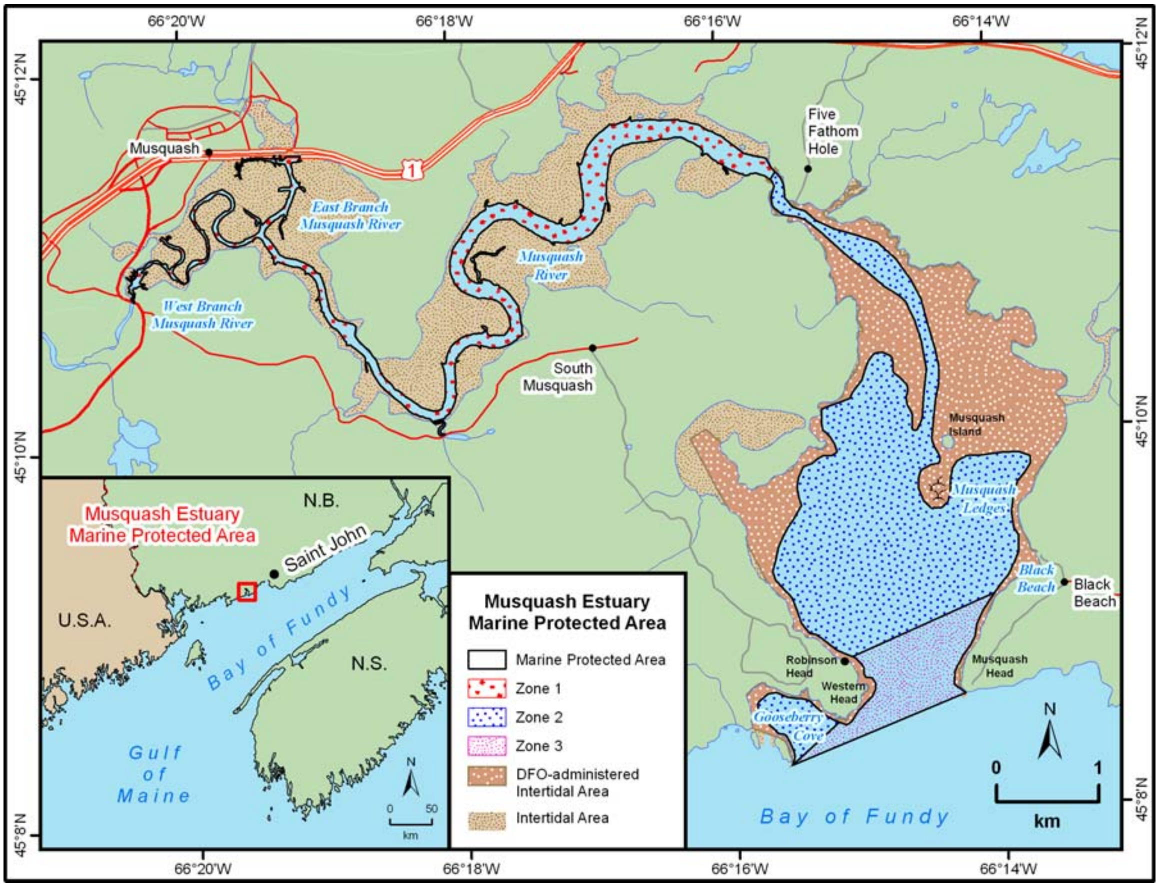

Figure 1. Musquash Estuary Marine Protected Area (MPA) and Administered Intertidal Area (AIA) that are managed by Fisheries and Oceans Canada.

To conserve and protect the waters and intertidal area of the Musquash Estuary, it was proposed as a candidate federal Marine Protected Area (MPA). To establish a federal MPA, the Province of New Brunswick transferred the administration and control of certain lands and waters in the estuary to the Government of Canada. Fisheries and Oceans Canada (DFO) manages the transferred lands and waters on behalf of the Government of Canada. The lands and waters that were transferred include all lands and waters in the Musquash Estuary up to mean low water, including the seabed to a depth of 2 metres (Figure 1). Certain other lands and waters between mean low water and mean high water, known as the intertidal area, were also transferred and are managed by DFO as the Administered Intertidal Area (AIA) (Figure 1). The Province of New Brunswick did not own all intertidal lands and waters in the estuary, so only certain intertidal areas were transferred to the Government of Canada. The remainder of the intertidal area is privately held.

On December 14, 2006, the lands and waters in the Musquash Estuary up to mean low water were designated an MPA through regulations pursuant to Canada's *Oceans Act*. The *Oceans Act*, however, does not apply to the lands and waters above mean low water and, as a result, the Musquash Estuary MPA Regulations do not apply to the AIA (Figure 1). Activities in the AIA are managed pursuant to the *Fisheries Act* and *Federal Real Property and Federal Immovables Act*. To ensure conservation and protection of the Musquash Estuary, DFO has developed a plan to manage human activities in the MPA and AIA entitled 'Musquash Estuary: a Management Plan for the Marine Protected Area and Administered Intertidal Area' (DFO, 2008). Although management actions (e.g. conditions in fishery licences) are currently being undertaken to regulate human activities in the protected area, the management plan requires an understanding of the baseline state of the ecosystem in the estuary in order to determine the success of DFO's management actions. This document proposes a framework for monitoring the state of the ecosystem of the Musquash Estuary MPA and AIA as it pertains to stated conservation objectives for productivity, diversity, and habitat. The framework includes:

- overview of the Musquash Estuary ecosystem;
- background on ecosystem-based management and monitoring;
- state of baseline knowledge and monitoring of the estuary;
- proposed monitoring governance structure and scientific approach;
- conservation objectives of the MPA and AIA;
- consideration of managed activities and perceived threats; and
- proposed monitoring actions.

The scope of the framework is for monitoring the estuary as a whole, and is not limited to the protected area boundaries. The implementation of monitoring, however, may not be undertaken on the scale of the estuary, and this is to be determined at a later date dependent on factors such as partnerships and availability of resources, to name a few. This is not to be considered a final monitoring plan or commitment of resources or time by any party or participant, as described hereafter. The science advice associated with this document is outlined in a DFO Canadian Science Advisory Secretariat (CSAS) Science Advisory Report (SAR) available at: www.dfo-mpo.gc.ca/csas-sccs/index-eng.htm (DFO, 2011).

2. BACKGROUND

2.1 MUSQUASH ESTUARY ECOSYSTEM

An estuary is a partially-enclosed coastal body of water, with a free connection to the sea, in which freshwater from rivers and streams mix with oceanic saltwater. They are considered one of the Earth's most productive ecosystems and host several habitat types that support a diverse range of wildlife. Estuaries may be surrounded by low-lying coastal grasslands called salt marshes, which are frequently covered over by the rising tide. Salt marshes that fringe estuaries perform a variety of functions including filtration of sediment and pollutants, buffering of upland areas from storm surges and floods, prevention of erosion, stabilization of shorelines, and providing refuge habitat for a number of species.

In the Bay of Fundy, more than 85% of the original salt marshes have been altered or destroyed by humans over the past 300 years (Environment Canada, 1986; National Wetlands Working Group, 1988; Government of Canada, 1991). Musquash Estuary is located in the Bay of Fundy approximately 20 km southwest of Saint John, New Brunswick (Figure 1). The estuary is unique due to its size, expansive salt marshes, and relatively undisturbed natural condition. It also exhibits a diverse number of habitat types and related biological communities with little evidence of human disturbance (Singh et al., 2000). It has been described by the Conservation Council of New Brunswick as one of the last ecologically-intact estuaries in the Bay of Fundy (Harvey et al., 1998; Platt, 1998).

The Musquash Estuary is comprised of a large embayment with a relatively narrow and deep entrance between the two rocky headlands of Western Head and Musquash Head (Hunter and Associates, 1982; Singh et al., 2000). The Musquash River flows into the shallow Musquash Harbour. The estuary drains the Musquash River and adjacent salt marshes. Musquash Estuary is a shallow, tidal estuarine ecosystem. It exhibits water depths of 1-6 m and a tidal range of 6-8 m (Wildish, 1977; Gratto, 1986). Musquash Harbour is highly turbid (i.e. muddy) due to the resuspension of bottom sediment associated with strong tidal currents (Dowd et al., 1999).

Suspended sediment in the estuary is discharged into the Bay of Fundy during the ebb tide and transported further upstream during the flood tide. Freshwater discharge into the estuary passes through a small, deactivated electric dam in the Musquash River and from several small creeks, and salinity in Musquash Harbour varies depending on the balance between freshwater inputs and seawater from the Bay of Fundy. Water in the estuary was observed to be vertically well mixed between the surface and bottom in the spring (Kristmanson, 1974,) and late summer (Dowd et al., 1999) and, perhaps, throughout most of the year (Singh et. al., 2000).

The estuary's location, shape, and oceanographic characteristics support diverse habitat and high biological productivity. Eight distinct ecosystem types, or ecotypes, that range from rocky bottom substrate to sensitive salt marsh are found in the estuary (Singh et al., 2000). They are: 1) rocky intertidal subtrates; 2) tidal pools; 3) sand and gravel intertidal beaches; 4) mudflats: 5) salt marsh; 6) panes within salt marsh; 7) subtidal soft substrate; and 8) subtidal hard substrate. The diverse habitat supports an abundance of wildlife including phytoplankton and zooplankton, invertebrates, salt marsh plants, fish, and many rare bird species (Singh et al., 2000). The diversity of habitat types is an important consideration in developing indicators and monitoring strategies and protocols. Different ecological areas (i.e. above tide, intertidal, and subtidal) will likely require very different types of monitoring strategies, protocols, and expertise.

2.2 ECOSYSTEM-BASED MANAGEMENT

Over the past decade, DFO has worked towards the ecosystem-based management of marine ecosytems (Jamieson et al. 2001). Ecosystem-based management of the marine environment is:

> *a holistic approach to managing the marine environment that seeks to ensure healthy marine ecosystem components and functions, as well as supports sustainable levels of goods and services available to humans*.

In 2001, DFO sponsored a workshop in Sidney, British Columbia, to consider ecosystem-level objectives, indicators, and reference points towards implementation of ecosystem-based management (Jamieson et al., 2001). Ecosystem objectives are viewed as broad policy objectives that can be used to guide management of all marine ecosystems in Canada. The ecosystem objectives supported by DFO are: 1) maintain ecosystem productivity; 2) maintain ecosystem biodiversity; and 3) maintain ecosystem habitat.

An ecosystem framework identifies physical, chemical, and biological parameters for an assemblage of habitat and species in a defined marine ecosystem. The approach to developing an ecosystem framework is undertaken in a few steps. First, unique sub-ecosystem types, or ecotypes, are identified based on their physical, chemical, and biological properties (e.g. mudflat and rocky intertidal areas in an estuary). Second, species and their trophic level in each ecotype are identified, taking into account seasonal migration of species into and out of the area. Third, habitat requirements for species in each ecotype are evaluated. This step identifies the physical, chemical, and biological range of properties that are required for a species to succeed in its ecotype, and provides a habitat profile for each ecotype.

The profile of each ecotype, combined with the species that occupy it, define ecozones in a marine ecosystem. The last step of an ecosystem framework identifies the optimum habitat range (i.e. ecological reference points) for sensitive species and habitat (i.e. ecological indicators) in each ecozone. In theory, changes beyond the optimum range for species and habitat in each ecozone provides early warning of environmental change in that ecozone. This level of information can be difficult to obtain and the proposed approach of the monitoring framework herein will be to begin an iterative monitoring program that is scientifically valid yet grounded by the practical requirements to meet management needs.

An ecosystem framework provides the foundation for developing an ecosystem-based management plan and ecosystem-based monitoring plan for a marine ecosystem. In the ecosystem-based management plan, operational objectives specific to the marine ecosystem are developed. The operational objectives are specific conservation targets based on the understanding of how components of the ecosystem function and how perceived threats would impact the functioning components. An ecosystem-based monitoring plan outlines the approach to evaluating the status of the ecosystem, and links the conservation objectives of the management plan to the ecological indicators and ecological reference points outlined in the ecosystem framework. Work towards development of an ecosystem framework for Musquash Estuary was undertaken by Singh et al. (2000) and Singh and Buzeta (2005; 2007).

2.3 ECOSYSTEM-BASED MONITORING

Monitoring is central to informing management actions that are designed to minimize the effects of human activities on an ecosystem (GESAMP, 1991). Monitoring is defined as the systematic collection of data or information over time to determine the extent of compliance with a pre-determined standard or position (Hellawell, 1991). An ecosystem-based monitoring plan establishes monitoring actions that can be used to monitor ecological indicators. Ecological indicators are used to assess the condition of the ecosystem and evaluate the success of achieving a conservation objective. Ecological indicators should be screened based on the following criteria: concreteness, theoretical basis, public awareness, cost, measurement, historic data, sensitivity, responsiveness, and specificity (Rice and Rochet, 2005).

While few indicators will meet all of these criteria, more robust ecological indicators should describe the spatial and temporal scales of interest while being measurable, interpretable, and change in response to external or internal forcing. A monitoring action is a parameter or test (such as measures of concentration, abundance, and relative change over time) used to assess the state of an ecological indicator; these are articulated by monitoring strategies and protocols. Last, ecological reference points define the outer limits of the optimum range, beyond which a particular ecosystem-component may experience a diminished capacity for growth, survival, or service. Steps in developing an ecosystem-based monitoring framework include (USEPA, 2008):

1. Identify ecological indicators for the system that allow you to assess the condition of the system or determine the success in achieving a conservation objective.

2. List all monitoring strategies and protocols that are currently being undertaken in the ecosystem, including where, when, and how often that they are monitored. If possible, link them to existing ecological reference points (e.g. Canadian Council of Ministers of the Environment guideline levels).

3. Determine if the list of monitoring strategies and protocols, and their spatial and temporal extent of sampling, provides enough information to determine the state of the ecological indicator. This will identify which indicators may require additional monitoring strategies and protocols to be evaluated and which indicators may not be good measures of the ecosystem and/or the conservation objectives. Good ecological indicators are supported by long-term baseline data, which permits evaluation of the state of the indicator.

4. Develop monitoring strategies and protocols that are consistent with other monitoring programs to permit comparison on a regional scale.

5. Undertake monitoring and use monitoring strategies and protocols to evaluate the state of the ecological indicators. Use the state of the ecological indicators to evaluate the condition of the system or success in achieving the conservation objectives.

6. Prior to subsequent monitoring, evaluate the monitoring strategies, protocols, and ecological indicators, and modify if necessary.

Components of a good monitoring framework include: identification of perceived threats to the ecosystem; conservation objectives; governance structure; monitoring indicators, strategies, and protocols, data management plan, and guidance on management actions (e.g. area closure to an activity) in the event negative monitoring results are observed. The following section outlines a proposed framework for the implementation of monitoring in the Musquash Estuary MPA and AIA.

3. PROPOSED MONITORING FRAMEWORK

3.1 CURRENT STATE OF MONITORING

The monitoring framework proposes to implement monitoring of current activities, taking into account perceived threats, in the Musquash Estuary MPA and AIA but also implement an ecosystem-level of monitoring to identify changes in the ecological characteristics of the estuary. An ecological overview of the Musquash Estuary (Singh et al., 2000) identified commercial and non-commercial fisheries, unique habitat, and areas of high biological diversity and productivity in the estuary. It is these valued ecosystem components that have given the Musquash Estuary special status as one of Canada’s MPAs, and it is considered that these should be well incorporated into the MPA’s management and monitoring plans.

A proposal for biological monitoring of the estuary was prepared for the Conservation Council of New Brunswick by Rangeley and Singh (2000). It provided an overview of proposed conservation goals and the need for a pilot study and a baseline inventory of the estuary to identify species, habitats, and the main environmental variables in the proposed MPA (Rangeley and Singh, 2000). An ecosystem framework for the Musquash Estuary (Singh and Buzeta, 2007) proposed indicators and monitoring strategies that would contribute to the achievement of DFO's ecosystem objectives, as outlined in DFO's framework for establishing ecosystem objectives and indicators (Jameison et al., 2001). The proposed ecological indicators and monitoring strategies were subsequently examined by a group of experts to rank them and discuss appropriate methodologies (Davies et al., 2008).

The wealth of proposed ecological indicators and monitoring strategies for Musquash Estuary emphasizes the interests expressed by the general public and scientific community in this area. Yet, despite the extensive discussions that have taken place, only some preliminary baseline information regarding the estuary has been gathered and analyzed. Further, development of an effective monitoring plan has been hampered by a lack of coordinated activity to gather and assess existing and new baseline information. A rigorous assessment of baseline data from Musquash Estuary is required to answer questions like:

> *Are the indicators, strategies, and protocols identified in the draft framework appropriate and feasible to monitor the conservation objectives of the Musquash Estuary MPA and AIA?*
>
> *What are outstanding sources of uncertainty that might influence the selection or implementation of indicators, strategies, and protocols?*
>
> *What other considerations should be taken into account in the development of a monitoring framework for the Musquash Estuary MPA and AIA?*

Baseline data offers a real world appraisal of availability of current data, feasibility to collect new data, a determination of spatial and temporal variability, minimum sample size, and correlation with other environmental variables including managed activities and perceived threats. This has yet to be accomplished, as it is an undertaking that requires significant coordination of multiple expertise and information sources, investment into gathering new information, and gathering sufficient time series to rigorously evaluate variability. This remains an outstanding yet essential knowledge gap and a priority for the implementation of a monitoring plan for the Musquash Estuary MPA and AIA: establishing a roadmap to resolve this gap is a goal of this framework.

Considering the knowledge gaps associated with the lack of baseline assessment for the Musquash Estuary, the proposed monitoring framework outlined in this document has adopted and refined the conclusions drawn from previous discussions on monitoring of the estuary (e.g. Rangeley and Singh, 2000; Singh et al., 2000; Singh and Buzeta, 2005; Singh and Buzeta, 2007; Davies et al., 2008). The framework also proposes a governance structure and general scientific approach for monitoring as the means to implementing a research and monitoring program in the Musquash Estuary MPA and AIA. As identified in the proposed management plan for performance assessment (DFO 2008), the framework should include linkages between monitoring of ecosystem components that are associated with managed activities and perceived threats.

3.2 GOVERNANCE STRUCTURE

Environment Canada has overseen monitoring of pulp and paper effluent in Canada since 1992. A strength of the program is its governance structure, which supports coordinated monitoring across the program and ensures that monitoring is undertaken in a timely and efficient manner. Curran et al. (2006) described the governance structure undertaken by Environment Canada; a similar governance structure may be adopted for governance of the Musquash Estuary MPA and AIA monitoring program (Figure 2).

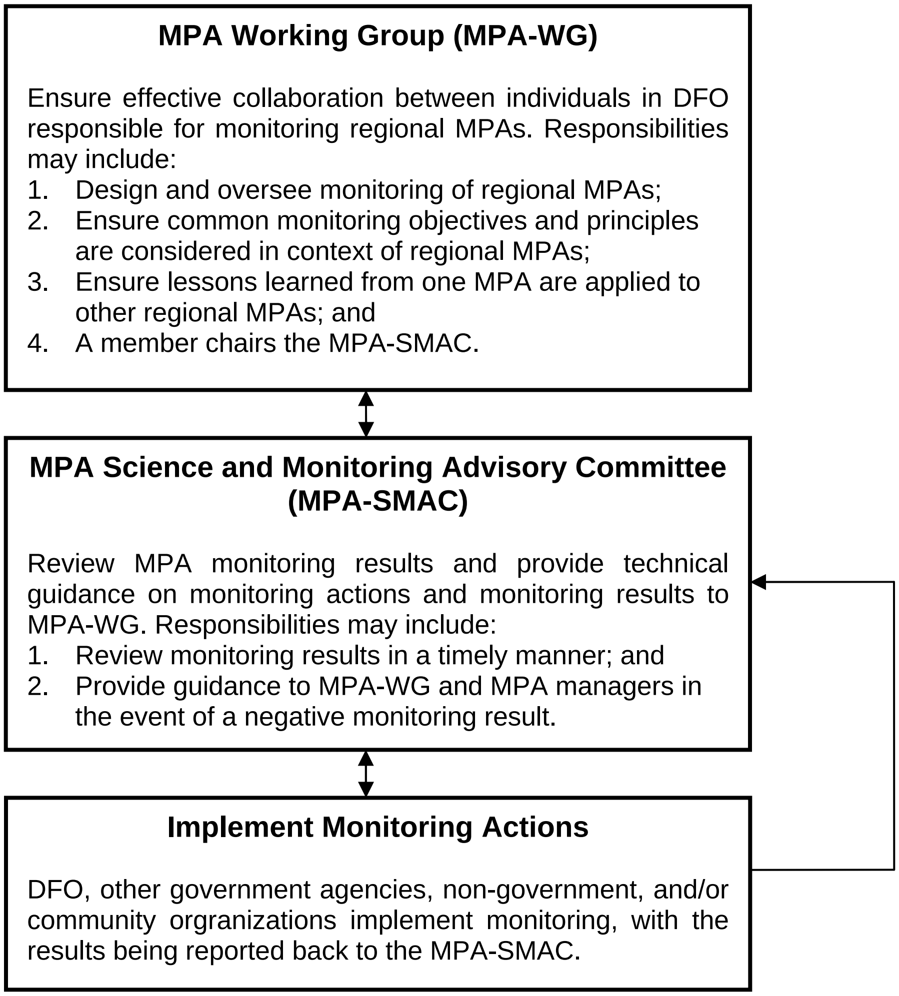

Figure 2. A proposed governance structure for monitoring the Musquash Estuary MPA and AIA.

In DFO Maritimes Region, a Marine Protected Areas Working Group (MPA-WG) may be established that consists of MPA managers from the Oceans and Science sector, including representative scientists that undertake some form of science and/or monitoring in regional MPAs. The aim of the MPA-WG would be to ensure effective collaboration between individuals in DFO that may, in part, contribute to the management and/or monitoring of MPAs (i.e. MPA-WG in Figure 2). A focus of the working group would be to ensure that science advice and support is consistent with MPA management requirements. A responsibility of the MPA-WG would be to design and oversee a monitoring program for each of the regional MPAs. An advantage of an MPA-WG would be that monitoring objectives and principles are considered in context of all regional MPAs, and lessons learned from one MPA can be applied to other MPAs where appropriate. Another advantage of an MPA-WG would be timely advice via regular reporting to MPA managers in the event that a negative monitoring result was observed in any one regional MPA.

Under the MPA-WG, an advisory committee, specific to each MPA in the region (i.e. MPA-SMAC in Figure 2), could be established to provide science and monitoring advice and support to the working group. The expert advisory committee may consist of science and monitoring experts from DFO, other governments, non-government organizations, and community stakeholders. The primary role for MPA-SMAC would be to advise the MPA-WG on monitoring plans specific to each MPA, as well as offer technical guidance on monitoring actions and monitoring results (Figure 2). To ensure coordination between the MPA-WG and MPA-SMAC, a member of the MPA-WG could act as chair of the advisory committee and be the point of contact for submission of monitoring results to the MPA-WG.

Based on the advice from MPA-SMAC and approval of the MPA-WG and/or MPA managers, DFO and other government organizations, non-government organizations, and community members may be called upon to implement the monitoring plan and submit results to the MPA-SMAC upon completion of a monitoring cycle. Upon completion of a monitoring cycle, results should be presented in written reports and presented at a meeting that follows a monitoring cycle. The frequency of a monitoring cycle would be determined by the suite of indicators and the frequency upon which informative data is being collected. The subsequent iteration of monitoring could also be scoped at this time. The proposed governance structure for monitoring MPAs should be linked to the MPA stakeholder advisory committees that have been established by DFO in the Maritimes Region.

3.3 SCIENTIFIC APPROACH

A scientific approach to monitoring the Musquash Estuary MPA and AIA may be adopted from Environment Canada’s scientific approach to monitoring pulp and paper effluent (refer to: Environment Canada, 1997; Hodson et al., 2002; Curran et al., 2006). As part of its pulp and paper effluent monitoring program, Environment Canada implements iterative monitoring cycles in which results from previous cycles are used to determine achievement of the conservation objectives (Figure 3). In regard to monitoring the Musquash Estuary MPA and AIA, four stages of investigation may take place.

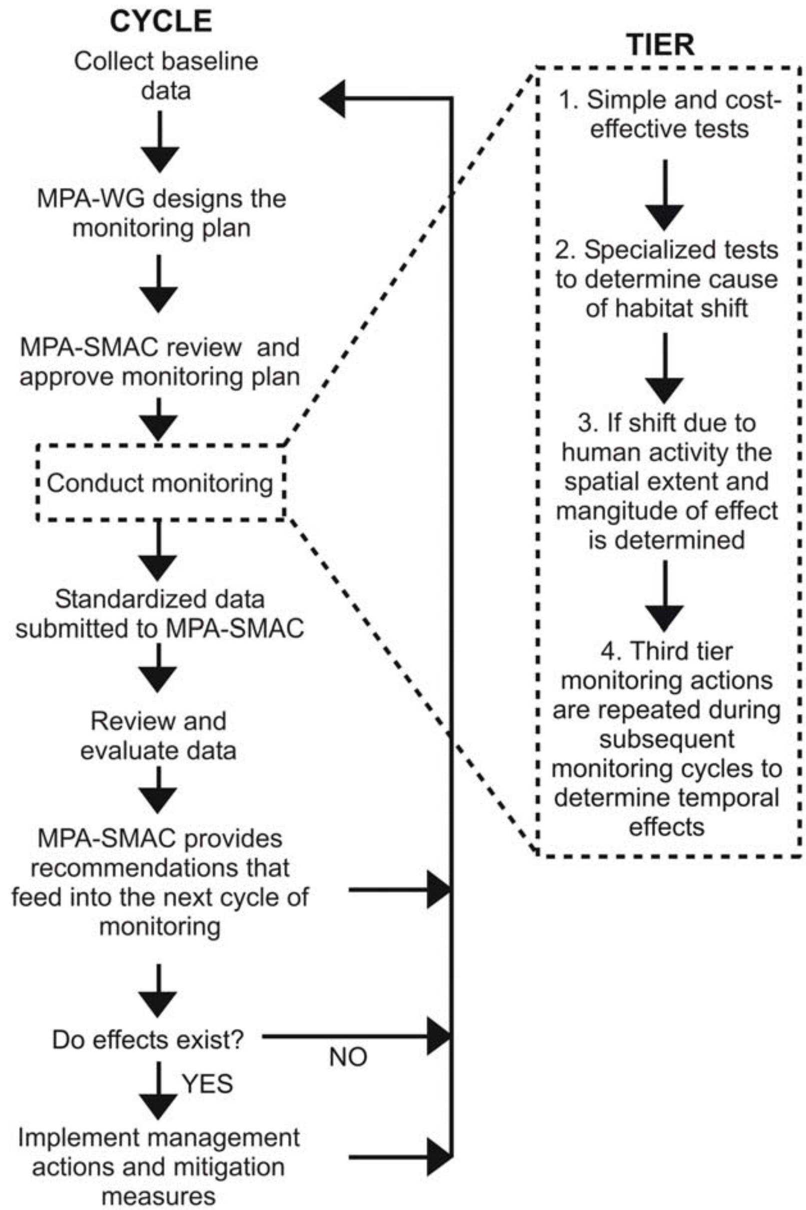

Figure 3. Scientific approach to the Musquash Estuary monitoring program. The figure is presented in Curran et al. (2006), as adapted from Environment Canada (1997) and Hodson et al. (2002).

The first stage of a monitoring cycle is the pre-design stage. At this stage, baseline information for the marine ecosystem in the Musquash Estuary is collected. In addition, information regarding managed activities and perceived threats from human activities are identified and collected. The baseline information should occur at a resolution that permits the assessment of potential impacts in the estuary, in context of the conservation objectives. At this stage, the MPA-SMAC develops operational objectives and screens indicators based on critieria of concreteness, theoretical basis, public awareness, cost, measurement, historic data, sensistivity, responsiveness, and specificity (Rice and Rochet, 2005).

The second stage, or design stage, links monitoring actions and monitoring frequency to the indicators. The monitoring design, proposed by MPA-SMAC, should provide data that can be used to determine if the operational objectives are being achieved and whether management actions are successful.

The third stage is the review and approval of the monitoring program by the MPA-WG. Although the monitoring program for the Musquash Estuary MPA and AIA should be reviewed prior to its full implementation, review during stage three should incorporate expert opinion into the design of the monitoring program through subsequent science review. This should be a scientifically-rigorous process that is based on a significant accumulation of baseline information and some understanding of how the estuary functions as an ecosystem.

Last, the fourth stage is the collection of monitoring data. It adopts a four tier-testing approach, as proposed by Hodson et al. (2002) (Figure 3):

1) Develop simple and cost-effective monitoring actions that evaluate each ecological indicator. If indicators are observed to be in the reference limits, the monitoring results are assimilated for submission and review to the appropriate governance and management structure;

2) If an ecological indicator is not in its reference limits, a second tier of specialized monitoring actions may be undertaken to determine the cause of the change. If the change is associated with natural variation (established from baseline data or literatrure review) monitoring proceeds to the data assimilation stage;

3) If the change is associated with a human activity, a third tier of monitoring action is undertaken to determine the spatial extent and magnitude of the effects. Management actions may also be implemented; and

4) The last tier, or trends of effects, repeats the third tier monitoring actions during subsequent monitoring cycles to determine temporal persistence. It is noted that this should be considered a long-term action since trends can not be established until sufficient temporal data are collected.

Upon completion of monitoring actions, the results are submitted to the established governance and management structure as proposed above. Although an annual reporting scheme would seem appropriate, the schedule for reporting would ultimately be determined based on the type and frequency of information being collected and assessed. If a shift in an ecological indicator beyond its optimum range is associated with a human activity, a management action may be implemented. Prior to implementation of a subsequent monitoring cycle the monitoring program should be proposed and reviewed within the governance structure, in order to determine if the ecological indicators and monitoring tests provide sufficient information to determine achievement of the conservation objectives. This linkage provides a feedback loop that ensures lessons learned from the previous cycle of monitoring are used to improve subsequent cycles. It will likely take several years of baseline data gathering (under Stages 1 and 2) before empirically-grounded reference levels can be established to support a full implementation of this scientific approach.

3.4 CONSERVATION OBJECTIVES

Conservation objectives for the Musquash Estuary MPA and AIA are to ensure that there is no unacceptable reduction or anthropogenic modification in:

Productivity so that each component (primary, community, population) can play its role in the functioning of the ecosystem by maintaining abundance and health of harvested species;

Biodiversity by maintaining the diversity of individual species, communities, and populations within the different ecotypes; and

Habitat in order to safeguard the physical and chemical properties of the ecosystem by maintaining water and sediment quality.

3.5 MANAGED ACTIVITIES AND PERCEIVED THREATS

A fundamental component to designing, implementing, and reviewing a monitoring plan is to establish a clear justification for acquiring the information (McDonald-Madden et al., 2010). This justification is built around both the conservation objectives as well as identifying the threats and management options. For every managed activity the perceived threat to the conservation objectives should be identified. Monitoring of the perceived threat and the management action should occur together in order to evaluate the performance of management actions. This is part of the second stage (design stage) and fourth stage, Tier # 2 and Tier # 3 of the proposed scientific approach (Figure 3).

Information on managed activities in the MPA and AIA are proposed to be acquired through the existing regulatory mechanisms and administrative bodies. If these activities are not monitored, ecosystem-level monitoring would not have the appropriate information upon which to evaluate anthropogenic induced change versus natural variability. Listed below are managed activities in the MPA and AIA. General prohibitions to human activities in the MPA (DFO, 2008) make it illegal for any person to:

disturb, damage or destroy, or remove from the Area, any living marine organism or any part of its habitat; or

carry out any activity — including depositing, discharging or dumping any substance, or causing any substance to be deposited, discharged or dumped — that is likely to result in the disturbance, damage, destruction or removal of a living marine organism or any part of its habitat.

Certain activities in the MPA however may still be allowed to occur and are exempted from these general prohibitions, but should be incorporated in the monitoring plan. Some examples of how these activities could be monitored are offered under each managed activity:

Aboriginal fishing may be carried out in accordance with the Aboriginal Communal Fishing Licences Regulations is allowed in all management zones.

Periodic survey of aboriginal community on their perceived value and effectiveness of the MPA and AIA and how it facilitates fishing in accordance with the Aboriginal Fishing Licenses Regulations.

Commercial fishing may be carried out in accordance with the Atlantic Fishery Regulations 1985, or the Maritime Provinces Fishery Regulations, for elvers or eels by means of a hand-deployed fyke net or dip net is allowed in Zone 1. Fishing for lobster by means of individual traps and for herring by means of a weir, beach seine, bar seine, or drag net is allowed in Zones 2A, 2B, and the AIA. Fishing for scallops is allowed in Zone 3, and manually fishing for clams is allowed in all management zones.

The existing reporting mechanisms for commercial fishing should incorporate a method to report commercial activities (i.e. effort, landings) that are occurring in the MPA and AIA.

Recreational fishing may be carried out in accordance with the Atlantic Fishery Regulations 1985, or the Maritime Provinces Fishery Regulations is allowed in all management zones. This includes fishing for scallops and clams by manual means, and recreational fishing for any other species by means of angling or a dip net.

Records of some recreational fishing activities are already required for license holders and should be incorporated in the MPA and AIA data management structure on an annual basis. Should consider change in policy to require a license for all recreational fishing in the MPA and AIA.

Recreational and commercial dulse harvesting by manual means is allowed in all management areas except Zone 1.

Records of dulse harvest in the MPA and AIA (commercial and recreational) need to be incorporated in the data management structure.

Operation of a marine vessel (any large vessel including ships, sail boats, and motorized personal watercraft) is allowed in Zones 2A and 2B at a maximum speed of 5 knots, and in Zone 3 at a maximum speed of 8 knots. Operation of a marine vessel is prohibited in Zone 1 except for the purpose of public safety, national defence, national security, law enforcement, or environmental emergency response and clean up. Special consideration may be given to allow a marine vessel in Zone 1 in support of scientific research activities or habitat restoration projects.

Vessel traffic (i.e. number, speed, and location) could be monitored via remote video cameras, or other vessel activity surveillance methods such as mandatory VHF hail-in.

Boat launches, wharfs, or navigational channels may be constructed, repaired, removed, or maintained in Zone 2A, if an approval or authorization is not required under the *Navigable Waters Protection Act* or *Fisheries Act*, or when the work or activity is carried out in accordance with an approval or authorization pursuant to these Acts. This type of activity is only allowed in the AIA if it supports such an activity in Zone 2A.

These activities could be monitored through the DFO Habitat Management Program, which screens these types of activities for the need of an approval or authorization pursuant to the Fisheries Act, and should be incorporated in the MPA and AIA data management structure.

Other exceptions to prohibitions in all management zones include activities carried out for the purpose of public safety, national defence, national security, law enforcement, or environmental. **Certain other human activities** are also exempted from the general prohibitions but require an activity plan to be approved by DFO prior to being undertaken in the MPA and AIA. Human activities that require an activity plan to be approved are scientific monitoring and research, educational activities, archaeological studies, commercial tourism and habitat restoration projects.

Records of all such activities as licensed or approved should be incorporated in the MPA and AIA data management structure. The degree to which these activities could impact the MPA and AIA must be monitored.

In Musquash Estuary, perceived threats can arise from proposed activities not only in the MPA and AIA, but also for activities that have zones of influence that might overlap with the MPA and AIA, including neighbouring lands, the greater Musquash watershed, and the adjacent coastal areas of the Bay of Fundy. As such, proposed activities in the greater watershed area and adjacent coastal areas should also be evaluated for their zones of influence and perceived threats during the application for approval. Appropriate monitoring and assessment methods should be identified and adopted in the management plan prior to commencement of the activity. The collection, consolidation, and reporting of this type of data is not trivial and would require a coordinated effort among DFO sectors and other government bodies.

New or emerging threats to the conservation objectives of the MPA and AIA must be regularly identified and given consideration for need of additional monitoring and assessment. Development of monitoring indicators, strategies, and protocols to address new or emerging threats may be required. In addition, the Musquash Estuary is small and, as a result, outside events that happen quickly may cause large changes to the MPA and AIA ecosystem over a short time period (e.g. increased freshwater runoff may decrease salinity in the MPA). This too may require indicators, strategies, and protocols that support event-based monitoring. Previous discussions of the potential threats to Musquash Estuary have occurred, which included a discussion of threats to the estuary beyond those identified above, (refer to Table 2 in Singh and Buzeta, 2007). The following recommendations are proposed, to ensure that current and potential threats to the Musquash Estuary ecosystem are identified in a systematic and timely manner:

- plan for a regular review of managed activities, zones of influence, and perceived threats to the estuarine ecosystem;
- link the identified threats to the ecosystem to proposed indicators;
- indicators in the proposed monitoring framework should be considered and prioritized in terms of greatest threats, management needs, and/or science needs (e.g. resolving existing data gaps) in the development of a monitoring plan;
- acquire data on managed activities (e.g. fishery landings, commercial recreational harvest, vessel traffic, and scientific activity requests) on time scales and periodicity that are compatible with environmental data;
- develop and implement a data management structure that facilitates use of information from multiple disciplines including management; and
- analyze and assess managed activities as part of a periodic assessment cycle.

3.6 MONITORING INDICATORS, STRATEGIES, AND PROTOCOLS

Priority ecological indicators for each ecosystem component were suggested by Davies et al. (2008):

- essential nutrient concentrations, water turbidity, phytoplankton concentration, and number of juvenile fish and bird hatchlings (Productivity);

- estimates of species and abundance in each trophic level, where appropriate, including the abundance of keystone/dominant species (Biodiversity); and

- historical and present physical features influencing the hydrodynamics of the estuary (Habitat).

Although the suggested indicators above offer guidance in the types of information that can be incorporated into a monitoring program, such indicators need to be aligned with specific operational objectives. Care should be taken to ensure that operational objectives are not too broad. For example, within the objectives for productivity, specific operational objectives and indicators could be:

> **Operational objective:** Maintain primary production at levels that do not limit productivity at higher levels.
> **Indicator:** Phytoplankton concentration in the estuary.
>
> **Operational objective:** Maintain recruitment of juvenile fish to ensure healthy populations of adults.
> **Indicator:** Abundance of juvenile fish in the estuary.

Davies et al. (2008) indicated that in order to carry out an effective monitoring program, there is a need for:

- baselines for the indicators of the valued ecosystem components;

- an understanding of potential ecosystem impacts from human activities (i.e. threats), the zone of influence, and subsequent relationships (or at least the connection) between the activity and the ecosystem indicators; and

- an understanding of the “natural” spatial and temporal variability of the indicator, which is usually determined through comprehensive, long-term monitoring.

Improving knowledge of the structure and function of the Musquash Estuary ecosystem is essential to establishing meaningful reference points. In the absence of defensible scientific data, the default reference point for all indicators should be a statistically significant deviation from baseline variability. This emphasizes the importance of establishing valid baseline information that captures natural spatial and temporal variability.

At present, a lack of baseline data exists for many aspects of the Musquash Estuary ecosystem, thus, indicators remain broad, with a range of monitoring strategies and protocols being proposed as a first step to evaluating the indicators. As baseline information improves and the proposed monitoring strategies and protocols are implemented, tested, and evaluated, some indicators may be dropped and others may be added, as appropriate. The linkage between monitoring objectives, indicators, reference points, strategies, and protocols should be tracked (Table 1) and periodically evaluated against managed and perceived threats to the ecosystem.

A research priority should be to build the knowledge of responses and interactions between ecosystem components in and around the estuary. For each indicator that is chosen the linkage with other ecosystem components and anthropogenic activities will need to be assessed in order to identify the reference direction that is desired, and to monitor which direction the indicators are going. Depending on the nature of the data this could take several years of repeated sampling and emphasizes the importance of establishing a program to collect valid baseline information at the earliest stage in order to capture "natural" spatial and temporal variability in a cost effective manner. Examples of monitoring activities (existing and proposed), along with information on protocols and intended indicator, are listed in Table 2, with a greater description of each being outlined in Appendix 1. These examples offer a perspective of how specific monitoring activities can be used to provide indicator data. A proposed implementation plan is outlined in Appendix 2.

It is anticipated that the first few cycles of monitoring may not fully conform to the scientific approach proposed above (Figure 3). One challenge to this approach is the need to address objectives that are directly linked with the perceived value of the MPA and AIA (e.g. bird nesting, nursery habitat for species in the Bay of Fundy, commercial fishery) and objectives for understanding ecosystem components that are most relevant to the functioning of the estuarine ecosystem as a whole. As a result, some operational objectives will be very specific to perceived values and public interest while others will take on a much broader scope until more is understood. It is important, however, that during these monitoring cycles any negative effects observed in the estuary are effectively addressed. In the absence of baseline data and understanding of the estuary ecosystem, the MPA and AIA managers should adhere to the precautionary principle, in which decision-making would err on the side of caution in the absence of scientific certainty (Government of Canada, 2003).

3.7 DATA MANAGEMENT

Data management is an essential component of a successful monitoring program. Further thought is required as to the best means of securing long-term data management, such that data accessibility and database design facilitate the sharing, assessment, and reporting of monitoring data relevant to the management of the MPA and AIA. For the Musquash Estuary MPA and AIA monitoring program, it is anticipated that data would be provided through a variety of sources both om and external to DFO. As such, guidelines to ensure that data are submitted in a standardized format should be developed and implemented. Data guidelines should allow for:

- comparison of data over time;
- comparison of data on a spatial scale; and
- emphasize the importance of metadata, which could include a brief description of the field methods and sampling protocols that support data collection.

In addition, efforts should be made to make information available to all stakeholders in a timely manner. This is essential to promote future interest in the conservation goals for the MPA and AIA, and to encourage participation of scientific expertise, managers, and user groups that reside outside of DFO.

Table 1. Linkages between objectives, proposed indicators, reference points, monitoring strategies, and monitoring frequencies. An alpha-numeric designation has been assigned for each indicator based on its conservation objective (P–productivity, B–biodiversity, H–habitat). The designations are used to link monitoring strategies and protocols (Table 2 and Appendix 1) with the general objectives and indicators that are listed in this table.

Conservation Objective	Operational Objective	Indicator	Reference Point	Monitoring Action	Monitoring Frequency
Productivity (P): Each component (primary, community, population) can play its role in the functioning of the ecosystem by maintaining abundance and health of harvested species.	Maintain biomass of secondary producers, primary and secondary consumers in each ecotype (1-8)	Biomass (e.g. benthic invertebrates, invertebrate predators, fish, birds, mammals) in each ecotype (1-8) **(P1)**	To be determined through baseline measurement	Survey of species in each ecotype using transect or quadrat sampling (visual surveys where applicable)	To be determined
	Maintain recruitment of juvenile fish to preserve perceived value as a nursery habitat for healthy populations of adults that inhabit the estuary and Bay of Fundy	Abundance of juvenile fish within the estuary **(P2)**	To be determined through baseline measurement	Survey of juvenile fish species in the estuary	To be determined
	Maintain primary production levels that do not limit productivity at higher levels	Concentrations of primary producers (eg. phytoplankton/ zooplankton/ microbial heterotrophs (bacteria), macroalgae (biomass)) in the estuary **(P3)**	To be determined through baseline measurement	Survey of planktonic community concentrations (e.g. cholorophyll a) in the estuary	To be determined
	Maintain abundance and state of harvested species perceived to be of value of the MPA and AIA	Commercial and recreational fishery landings per standardized unit effort in the estuary relative to statistical fishing area **(P4)**	To be determined through baseline measurement	Survey of landings by fishery and species that occur in and adjacent to the MPA	Schedule by fishery
Biodiversity (B): Maintaining the diversity of individual species, communities, and populations within the different ecotypes.	Maintain alpha diversity in each ecotype	Number of species (species richness) in each ecotype **(B1)**	To be determined through baseline measurement	Survey of species in each ecotype using transect or quadrat sampling (visual surveys where applicable)	To be determined.
	Maintain species community structure relative to long term changes in the region	Number and type of dominant species in each ecotype **(B2)**	To be determined through baseline measurement	Survey of species in each ecotype using transect or quadrat sampling (visual surveys where applicable)	To be determined
	Maintain number of rare species that inhabit the estuary based on perceived value as a refugium for rare or threatened species	Number of species at risk in each ecotype **(B3)**	To be determined through baseline measurement	Survey of species in each ecotype using transect or quadrat sampling (visual surveys where applicable)	To be determined
	Minimise fisheries induced impacts on non-target species	By-catch number, size, age, and sex per impacted species **(B4)**	To be determined through baseline measurement and review of historical fishery records (Virtual Data Centre)	Survey of by-catch size, age, and sex of captured individuals per fishery	Schedule by fishery

Table 1. *Cont'd.*

Conservation Objective	Operational Objective	Indicator	Reference Point	Monitoring Action	Monitoring Frequency
Habitat (H): Safeguard the physical and chemical properties of the ecosystem by maintaining water and sediment quality.	Maintain diversity and area of habitat ecotypes	Total area and location of each ecotype in the estuary **(H1)**	To be determined through baseline measurement	Map area distribution of each ecotype in the estuary using aerial photographs and GIS software	To be determined
	Maintain biogenic structure for habitat ecotypes	Total area and location in estuary of species that provide biogenic structure (e.g. marsh and rockweed) **(H2)**	To be determined through baseline measurement	Map area distribution that supports species that provide biogenic structure	To be determined
	Maintain hydrodynamic regime for habitat ecotypes	Changes in wave, tidal, freshwater outflow and sediment regime in the estuary (e.g. sediment infilling) **(H3)**	To be determined through baseline measurement including historical records from NB Power.	Field sampling coupled with hydrographic and sediment models that predict the deposition/erosion of sediment, as well as the hydrological regime	To be determined
	Maintain physical/chemical regime for habitat ecotypes	Temperature, salinity, turbidity in the estuary ecotypes **(H4)**	To be determined through baseline measurement	Survey of temperature and salinity in estuary	To be determined
	Maintain nutrient loading for habitat ecotypes	Nutrient concentrations in the estuary ecostypes **(H5)**	To be determined through baseline measurement, as well as CCME***** and literature-based guideline levels	Survey of nutrient concentrations in estuary (dissolved oxygen, silicon, iron, carbon, nitrogen, phosphorus, and turbidity)	To be determined
	Avoid contaminant loading for habitat ecotypes	Contaminant concentrations in the estuary ecotypes **(H6)**	To be determined through baseline measurement, as well as CCME***** and literature-based guideline levels	Survey of contaminant concentrations in bottom sediment and water column (dissolved and particulate bound sediment, trace metals, and organics)	To be determined

*CCME – Canadian Council of Ministers of the Environment

Table 2. Linkages between proposed monitoring activities, strategies and protocols, and indicators. The alpha-numeric designations are those identified in Table 1 above (P–productivity, B–biodiversity, H–habitat). Monitoring strategies and protocols that have been proposed may be refined or dropped and others added, as baseline knowledge of the estuary is developed. For each monitoring activity, descriptions of estimated costs, protocols, implementation, and potential principal investigators are summarized in Appendix 1.

Monitoring Activity	Monitoring Strategy and Protocol	Indicator (Refer to Table 1)
Nesting Bird Survey	Breeding Birds of the Maritimes Atlas, 5 year project (currently underway by Saint John Naturalists Club, year 3 of 5). Refer to: /www.mba-aom.ca/english/atlashow.html.	P1, B1, B2, and B3
Phytoplankton/Zooplankton	Water samples and net hauls (horizontal or oblique) taken at 3-4 fixed stations in the MPA and AIA. Sampling methodology should be comparable to existing plankton sampling programs.	P3, B1, and B2
Juvenile Fish Survey	Fishes sampled at possibly 3-4 permanent sites using beach seines and/or fyke nets. All fish species identified, sized, and sex recorded and then released.	P2, B1, B2, and B3
Marine Benthos Survey	Random stratified sampling design for 3 strata: channel, intertidal, subtidal, etc.	P1, B1, B2, B3, H1, and H2
Monitoring Paddle	Annual monitoring paddle - may require a training session for 4-6 volunteers, small digital cameras, and handheld GPS. Training and coordination of volunteers and supervision of the monitoring paddle event could be accomplished through an NGO (e.g. Friends of Musquash, Fundy Baykeeper).	B1, B2, B3, H2, and H4
Bird Survey	Christmas Bird Count (www3.nbnet.nb.ca/maryspt/CBC.html), Lepreau Bird Count - could request Musquash (http://saintjohnnaturalistsclub.org/plbo.htm), and Pt Lepreau Observatory (jgw@nbnet.nb.ca). Canadian Wildlife Service Winter Waterfowl Aerial survey and ground survey protocols.	B1, B2, and B3
Intertidal and Marsh Survey	Gulf of Maine Council (GOMC) or NaGISA (favoured because of local expertise) available online at: http://www.nagisa.coml.org/nagisa-protocols/protocolslides/ Representative area of the intertidal is selected. Three 30 m transects running parallel to the shore (High shore, Mid shore and Low shore).	B1, B2, B3, and H2
Hydrography	Four YSI probes (temperature, salinity, oxygen, chlorophyll, turbidity). Two placed at Five Fathom Wharf, bottom and surface. 10 Vemco probes (temperature and salinity) placed at intervals along the estuary. Nutrient samples taken each time the probes are deployed. Probes are deployed at fixed stations and will be retrieved, data downloaded, and redeployed at appropriate time intervals.	H3 and H4
Nutrient Sampling	Water samples taken at fixed times of year and analyzed for nutrients. Sampling to be done at same time as CTD stations.	H5
Environment Canada Water Quality Monitoring	Water samples for bacteriological analyses are collected in sterile 250 mL wide mouthed bottles (Nalgene, polypropylene or glass) at a depth approximately 20 cm below the water surface. All water samples collected are held in an insulated cooler on ice or ice packs. Sampling plans which determine the locations (sub sectors) and sampling sites are determined by the Senior Biologist at Environment Canada.	H5 and H8
Intertidal and Marsh Images	Establish specific spots along the Musquash Estuary where community, hikers, and paddlers would be instructed (e.g. posted sign) to take a photo and submit it to a website/blog. Photos monitored for changes to ecosystem.	H2 and H4
Mapping Human-use	Discussion with fisheries managers and fishing industry needs to be initiated to understand the potential usefulness of logbooks. Discussion should include lobster trap locations; verifying if scallop dragging is occurring in the MPA; requesting to be informed if clamming starts in the MPA. Vessel traffic could also be monitored using Live Webcam (see below). Specific protocols to be determined following discussion with users.	Monitoring of identified managed human and potential interactions with P4, B4, and H4
Webcams	Digital still image captured at regular time intervals during daylight hours. Station would be fixed to support long term comparison. Preference for images stored in DFO for access and periodic analysis.	Monitoring for vessel traffic and potential interactions with H2 and H3.
Beach Debris	Annual photo records and tallying debris by categories according to established protocols used in beach cleanups (Smith, 2002; Amato et al., 2003).	Managed recreational activities, H1, and H6
Aerial Survey	In line with protocols used in forestry aerial photography. Photos to be analyzed and compared to determine large scale aerial changes to habitat types.	Monitoring recreational activities, recreational harvesting, all-terrain vehicles, H1, H2, and H3.

4. DISCUSSION

To implement a coordinated and systematic monitoring plan for Musquash Estuary MPA and AIA, the following strategies are recommended:

- identify and maintain existing monitoring activities that address the indicators that have been discussed above;
- build baseline knowledge where needed and identify knowledge gaps;
- form partnerships to monitor the estuary, in order to reduce a duplication of effort;
- routinely review, refine, and improve linkages between threats to the estuary and the indicators that have been discussed above; and
- implement a scientific approach to monitor both threats to the ecosystem and the natural state of the ecosystem.

Monitoring of MPAs is new to DFO, and the first few years of monitoring the Musquash Estuary MPA and AIA will likely be a learning process. In most cases, baseline information of select ecosystem components does not exist. Considering this, priority monitoring activities should focus on:

1. monitoring the currently managed activities in the Musquash Estuary MPA and AIA.
2. establishing at least one baseline in each ecosystem component (productivity, biodiversity, habitat); and
3. investigating zones of influence for perceived threats in and adjacent to the MPA and AIA.

At present, baseline data collection is occurring simultaneously with design of the proposed monitoring framework (Stages 1 and 2). There is also recognition that not all of the suggested monitoring actions may be practical or cost effective.

The Musquash Estuary ecosystem framework (Singh and Buzeta, 2007) identified existing monitoring that has been undertaken in the estuary. Many of these activities were established by stakeholder groups, individual researchers, and interested government departments, and would generally fall under establishing baselines for ecosystem components. Although all sources of information must be assessed for quality, existing data holdings are considered a valued source of information and can offer a cost-effective means to implementing the first stages of a monitoring plan. The spatial and temporal extents of natural variation have yet to be evaluated for historical data and current monitoring activities. The evaluation of historical and current monitoring data is a logical next step for the monitoring plan. This exercise would not only evaluate where potential baseline data exists but where it is proposed to be collected and where there are gaps. Valid baseline data should be incorporated into a monitoring plan as they become available.

The potential for continued community involvement may improve with iterative cycles of review provided that appropriate training mechanisms are in place to ensure quality of the monitoring data. However, we can not assume that communities will be the most appropriate option to address long term monitoring that requires specialized skills, equipment, or an inherent level of risk. In all instances, current and proposed monitoring activities must be adequately described and categorized to the conservation objectives and proposed indicators and linked with managed activities or perceived threats. The Driving Forces-Pressures-State-Impacts-Responses (DPSIR) approach would be an appropriate framework to adopt during this process, in order to connect indicators with the drivers that make it change (Turner et. al., 2000).

Examples of monitoring activities and their connection to conservation objectives are listed in Appendix 1. An evaluation of real costs, protocols, and organization(s) that may implement the monitoring should be identified for each activity, in order to evaluate its contribution and efficacy to the overall monitoring framework. In many instances a monitoring activity can address (at least in part) more than one indicator. It is recommended that part of any prioritization process considers an added value for monitoring activities that address multiple indicators.

In order to support conservation and protection of the estuary over the long-term, an effective Musquash Estuary management plan would adopt management actions for those human activities that are deemed to be of risk to the conservation objectives of the MPA and AIA. Such activities and risks should be identified through an *a priori* review of current activities and as a regular part of the monitoring program (e.g. during each monitoring cycle). For managed activities and perceived threats, a zone of influence should be determined (i.e. spatially, temporally, and ecologically) and relevant monitoring prescribed to each, in order to establish baselines for comparison of activity against a relevant ecosystem indicator. For any new perceived threats or activities, baseline information should be established prior to adopting a new managed activity. Negative ecosystem effects associated to specified human activities or to broader environmental effects should be identified in Tier # 2 and Tier # 3 levels of investigation (refer to Section 3.3: Scientific Approach). If warranted by the presence of predicted and repeated human activities, decision rules should be developed in consultation with stakeholders. It would be important to consider how indicators would operate in a decision rule framework with respect to triggering a rule.

In the short-term, mitigation measures should be implemented through management actions to address the cause of negative effects. In addition, more intensive monitoring should be undertaken to evaluate the effectiveness of the management action. Observed negative effects may be grounds for enforcement and prosecution if contrary to the Musquash MPA regulations pursuant to the *Oceans Act* or the *Fisheries Act* and New Brunswick *Trespass Act* (for more information refer to: DFO, 2008). The need for enforcement should be determined on a case-by-case basis. In the absence of scientific certainty, or a specific cause and effect can not be ascertained, management actions may also be used to mitigate potential human effects on the ecological indicator and a re-evaluation of all activities would be undertaken in order to achieve conservation objectives. Over the long-term, policy changes may be implemented to prevent similar negative effects from occurring in the future. A proposed implementation plan for monitoring over the short term (1-5 years) is outlined in Appendix 2.

Improved public awareness should be a high-priority and implemented early in the process, contingent upon the availability of funds. DFO should continue to work with stakeholders, including the Province of New Brunswick and local land owners, to develop proactive management actions that can be undertaken to ensure long-term conservation and protection of the Musquash Estuary. This may include broader management of activities that occur in the Musquash Watershed and adjacent Bay of Fundy.

Last, sources of uncertainty exist when attempting to understand the functioning of a complex marine ecosystem such the Musquash Estuary, as well as understanding the potential impacts that anthropogenic activities may have on an ecosystem's natural processes and variability. In terms of monitoring the Musquash Estuary, the following sources of uncertainty currently exist:

- lack of knowledge of the functioning of the Musquash Estuary ecosystem, including its keystone and/or dominant species;
- lack of knowledge of the natural variability surrounding baseline conditions;
- lack of knowledge of appropriate spatial and temporal scales of monitoring protocols;
- lack of statistical certainty surrounding appropriate sample sizes and frequencies of monitoring protocols; and
- lack of certainty regarding the suitability of a proposed monitoring indicator, strategy, and protocol to accurately reflect the ecosystem structure or function that it is intended to represent.

5. CONCLUSIONS

The Musquash Estuary ecosystem framework of Singh and Buzeta (2007) identified existing monitoring activities that have been undertaken in the estuary. Many of the monitoring activities were established by stakeholder groups, individual researchers, and interested government departments, and would generally fall under establishing baselines for ecosystem components. These activities are considered to be a valuable source of information and expertise and, in most circumstances, offer a cost-effective means of baseline data collection. Although the spatial and temporal extent of natural variation has yet to be determined for the current and proposed monitoring indicators, the results of baseline data should be incorporated into a monitoring plan, as they become available. As is anticipated with all of the monitoring strategies and protocols discussed above, the potential for continued community involvement may improve with iterative cycles of monitoring.

The collection of baseline information, analysis of natural variability, correlations with environmental change and correlations with human activities remains a priority to implementing the first stages of a monitoring plan for the Musquash MPA and AIA. This document provides the context and framework underwhich this can occur. Until these first stages of evaluation are conducted, performance evaluations for indicators that are linked to operational objectives will be lacking. It is these evaluations that help determine if an indicator is sensitive to change and responsive to anthropogenic activity and reveals outstanding sources of uncertainty that might influence the selection or implementation of proposed monitoring indicators, strategies, and protocols.

Linking operational objectives with indicators and subsequent monitoring actions will be an iterative process. A planned “phased” approach should be adopted based on the three conservation objectives listed above, with consideration for those monitoring activities that can provide data for most of the indicators: for example, Intertidal and Marsh surveys can provide data for three biodiversity indicators, and possibly productivity P1; for habitat, the aerial survey is on-going and essential. Communication between stakeholders/community, managers, and scientists will need to continue throughout this iterative process. The governance framework should provide a voice to all of these parties in order to address how human activities can be managed to reduce impact where it is an issue and to help establish a clear understanding of what is an acceptable activity in the MPA and AIA. Last, an estimate of costs, protocols, and organization(s) that may contribute to the implementation of monitoring should be identified for each activity, in order to evaluate the effectiveness of an overall monitoring plan.

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7. WEBSITES

Breeding Birds of the Maritimes Atlas: www.mba-aom.ca/english/atlashow.html (operational 13 April 2011).

Christmas Bird Count: www3.nbnet.nb.ca/maryspt/CBC.html (operational 13 April 2011).

DFO Science - Management Policy for Scientific Data: www.dfo-mpo.gc.ca/science/data-donnees/policy-politique-eng.htm (operational 13 April 2011).

Gulf of Maine Council (GOMC) regional habitat monitoring: www.gulfofmaine.org/council/publications/HMSC-Regional-Monitoring-Framework.pdf (operational 13 April 2011).

Gulf of Maine Council salt marsh monitoring protocol: www.gulfofmaine.org/habitatmonitoring/saltmarshprotocol.php (operational 13 April 2011).

Global Program of Action Coalition of the Gulf of Maine wetland monitoring protocol: www.pwrc.usgs.gov/resshow/neckles/Gpac.pdf (operational 13 April 2011).

Lepreau Bird Count: http://saintjohnnaturalistsclub.org/plbo.htm (operational 13 April 2011).

Natural Geography In Shore Areas (NaGISA) International protocols for near-shore monitoring of biodiversity: http://www.nagisa.coml.org/nagisa-protocols/protocolslides/ (operational 13 April 2011).

APPENDIX 1

Below are examples of monitoring activities for the Musquash MPA and AIA. This list of monitoring activities is organized by the primary conservation objective (Table 1). Most monitoring activities could contribute information to more than one indicator (Table 2).

A1.1 PRODUCTIVITY

Nesting Bird Survey – The monitoring strategy for productivity of birds included surveys of foraging and nesting birds, and invertebrate biomass and distribution. Invertebrate prey is considered more useful than monitoring bird fledglings for example, as invertebrate prey help provide a picture of food sources for other species, including birds. However, sampling nesting activity was also highly valued, and could be accomplished with volunteers at a much lower cost.

> **Cost**: to be determined based on participants, training, and frequency
> **Protocols**: Breeding Birds of the Maritimes Atlas, 5 year project www.mba-aom.ca/english/atlashow.html
> **Implementation**: Underway, year 3 of 5.
> **Principal investigator(s):** Saint John Naturalists Club president@saintjohnnaturalistsclub.org.

Phytoplankton/Zooplankton – There are existing phytoplankton and zooplankton monitoring programs in the southwest New Brunswick portions of the Bay of Fundy. These provide baseline data for regions outside of the Musquash Estuary. The amount of water exchange in the MPA and AIA is presumed to be relatively high and, as a consequence, the plankton monitoring in the MPA and AIA will require comparisons with monitoring that occurs in the surrounding area of influence.

> **Cost:** Collection and sample preservation costs would be minimal. Sample identification costs range from $200-300 per sample.
> **Protocols:** Water samples and net hauls (horizontal or oblique) to be taken at 3-4 fixed stations in the MPA and AIA. Sampling methodology should be comparable to existing plankton sampling programs.
> **Implementation:** A review of the existing data holdings to assess appropriate protocols, estimate of workload, available expertise, and evaluation of natural variability is required before implemtation of this monitoring strategy.
> **Principal investigator(s):** DFO-St. Andrew Biological Station, Coastal Ocean Ecosystem Research Section

Juvenile Fish Survey – Although some exploratory work is required for design and to assess usefulness as an indicator, some baseline information already exists from previous surveys conducted by researchers at the University of New Brunswick, Saint John (UNBSJ).

> **Cost:** to be determined
> **Protocols:** Fishes sampled at permanent sites using beach seines and/or fyke nets. All fish species identifed, sized, and sex recorded and then released. Species will change seasonally and to establish baseline data it will be necessary to sample as much as possible, throughout the year. Local research expertise recommend every 2 weeks. Sampling would cease when sites are ice covered or when access to sites is not possible. The methodology should be comparative (i.e. frequency, sampling gear) with other studies conducted in the coastal waters of the Bay of Fundy on either side of the

Musquash MPA and AIA. Additional guidance on standardized protocols can be found through the Community Aquatic Monitoring Program (Weldon et. al., 2005; Weldon et. al., 2007).
Implementation: Some information exists from previous studies by graduate students at UNBSJ. Establishing baseline is dependent on availability of future funding.
Principal investigator(s): UNBSJ, Huntsman Mairne Science Centre Atlantic Reference Centre, DFO - St. Andrews Biological Station

A1.2 BIODIVERSITY

There has been considerable discussion on the best approach to monitor biodiversity, especially considering the intensity and frequency required to adequately sample every trophic level and habitat type, and to understand natural spatial and temporal variability. Thus, intensive biodiversity surveys are seen as useful only if there is an identified threat. In the MPA and AIA, monitoring these potential threats (e.g. human activities, heavy metals, contaminants, invasive species) is seen as more useful, as reflected in other sections of this monitoring plan. Surveys suggested for biodiversity are those that provide a glimpse at some of its components, and/or that provide an opportunity for community involvement.

Marine Benthos Survey - A survey for soft bottom infauna (greater than 500 μm) to establish baseline measures for biodiversity in the marine intertidal and subtidal ecotypes and potential linkages with hydrodynamic regime, rates of sedimentation, exposure to pollutants as a result of freshwater outflow and activities that may occur within and outside of the MPA (e.g. aquaculture, environmental spills of pollutants). This also provides information at the secondary producer, primary consumer trophic levels that serve as a food source for higher trophic-level organisms of interest (e.g. crustaceans, fish, birds, marine mammals).

Cost: $65,000 per year, majority of costs associated with sample identification and enumeration.
Protocols: Small Van veen grab (1500 cm^3), random stratified sampling design for 3 marine strata (i.e. channel, intertidal, subtidal), 10 stations per strata, 3 replicates per station, sampled 3 times per year (late winter, late summer, late autumn). Samples are weighed and sieved (500 μm), specie are identified to lowest possible taxa and enumerated. Benthic sediments are also collected for grain size analysis.
Implemention: Winter 2010 (3 years are proposed as a minimum to assess a baseline).
Principal Investigator(s): DFO - St. Andrews Biological Station, Coastal Ocean Ecosystem Research Section, Huntsman Marine Centre Atlantic Reference Centre.

Monitoring Paddle – The concept of a Monitoring Paddle was suggested by community members, but as a separate event from that of the Annual Musquash Paddle held in July or August. This survey would record small-scale changes in vegetation, erosion, and wildlife and bird sightings, and act as a watchdog for potential issues. Sevral aspects of habitat and species distributions could be sampled along the way, thus it also contributes towards monitoring for the Habitat objective. This survey is seen as comparable to monitoring for large-scale changes using an aerial survey, and would also ground truth the aerial information.

Cost: 3 small digital cameras ($200 each); 3 handheld GPS ($200 each) or Sony GPS Photo Log ($150 each); logbooks, training and field work sessions ($250). Total budget $1600.
Protocols: The Monitoring Paddle would require a training session for 4-6 volunteers, small digital cameras, and handheld GPS. Training and coordination of volunteers and supervision of the monitoring paddle event could be accomplished through an NGO (e.g.

Friends of Musquash, Fundy Baykeeper). This monitoring activity requires application for approval pursuant to the MPA regulations. Protocols: to be discussed (e.g. Christmas Bird count; GOM volunteer monitoring).
Implementation: The Monitoring Paddle could be seasonal or annual. Implementation of this monitoring strategy will require a review of the data quality and its application to the conservation objectives.
Principal investigator(s): New Brunswick Conservation Council, Fundy Baykeeper, Friends of Musquash

Bird Survey – There is much interest by volunteers to participate in this type of survey. In the past, the Canadian Wildlife Service had been doing an annual waterfowl aerial survey along the coastline, which included the Musquash area; it may still be going on and historical data is available.

Cost: low – volunteers, or obtain data from existing surveys (e.g. Canadian Wildlife Service)
Protocols/Resources: Christmas Bird Count
www3.nbnet.nb.ca/maryspt/CBC.html; Lepreau Bird Count (could request Musquash) http://saintjohnnaturalistsclub.org/plbo.htm; Pt Lepreau Observatory jgw@nbnet.nb.ca). Canadian Wildlife Service Winter Waterfowl Aerial survey and ground survey protocols
Implementation: Dependent on funding and availability of suitable volunteers.
Principal investigator(s): Environment Canada – Candian Willdlife Service, Saint John Naturalists Club (for volunteers) saintjohnnaturalistsclub.org

Intertidal and Marsh Survey – This would be a labour intensive monitoring effort and would require considerable resources for training, equipment, and data management. Nonetheless, this type of monitoring strategy is widely used in other management areas, and was strongly supported at the 2007 workshop. Generally, it requires initial training and collection and preservation of species vouchers for later analyses by an experienced contractor. It would be worthwhile to provide an opportunity for the community, academics, and NGOs to assess whether this is feasible and/or to test the concept in the field. Specifically, and effort should be made to engage instructors at UNBSJ, to coordinate their need for field instruction in undergraduate and graduate courses/projects, with that of the monitoring and research needs for the Musquash MPA and AIA. Musquash Estuary could then be a regular site for field work and, if standard protocols are applied, this could provide a long-term data series at a very low cost (after the initial investment).

Cost: High initial investment, long-term lower cost if it is managed well.
Protocols: GOMC or NaGISA (favoured because of local expertise) available online at: http://www.nagisa.coml.org/nagisa-protocols/protocolslides/. Representative area of the intertidal is selected. Three 30 m transects running parallel to the shore will laid out (High shore, Mid shore and Low shore). Along each of the transects, at five randomly selected spots, three separate quadrats will be deployed. One 1.0 m x 1.0 m quadrat will have all ground cover estimated, one 0.5 x 0.5 m quadrat will have all plants identified and estimated, one 25 x 25 cm quadrat will have everything removed (plants and animals) and then identified and weighed. If possible, similar transets are done in the subtidal at 1, 5, and 10 m depths. This may not be possible in Musquash Estuary because of the terrain and poor visibility, however, the 1 m depth may be possible, but this will have to be evaluated in the field. The estimate is that this process will take 2 days and between 5-10 people.
Marsh: A mudflat and a saltmarsh transect should also be included. Transects would probably only need to be checked once per year or maybe every two years, at the same

time of year. One way would be to determine upper and lower limits of the most obvious species, which would be include basic presence-absence data, or a more in-depth study would include abundances and biomass at several tidal levels per transect.
Implementation: The rocky intertidal NaGISA protocol was started by a UNBSJ graduate student in 2009, and will be completed again in 2010. Longer term implementation plans are required. Marsh and mudflat surveys will be dependent on available funding.
Principal investigator(s): UNBSJ and Huntsman Marine Centre Atlantic Reference Centre for species identification training and voucher analyses.

A1.3 HABITAT

There was a strong consensus among the 2007 workshop participants that the most important performance indicators for habitat are a record of the historical and present activities (e.g. area disturbed by scallop draggers) by monitoring and mapping; physical features (i.e. dam) influencing the hydrologic regime (i.e. temperature, salinity); water quality levels (e.g. coliform counts, turbidity); and changes to biogenic structure provided by marshes or rockweed, seen as closely connected to both habitat and biodiversity (see surveys under biodiversity component) (Davies et al., 2008). Indicators associated with this ecosystem component are considered the most practical as they are all closely connected to the other components of biodiversity and productivity, and provide a broad base of information useful in monitoring potential threats. Thus, monitoring effort is focused on this component. The annual Monitoring Paddle also contributes towards monitoring for the Habitat objective.

Hydrography – 4 YSI probes (temperature, salinity, oxygen , chlorophyll, turbidity). Two placed at Five Fathom Wharf, bottom and surface. 10 Vemco probes (temperature and salinity) placed at intervals along the estuary. Nurients samples taken each time the probes are deployed.

Cost: On-going costs associated with maintenance, retrieval and deployment.
Protocols: Probes are deployed at fixed stations and will be retrieved, data downloaded and redeployed at appropriate time intervals.
Implementation: Ongoing since 2008.
Principal investigator(s): DFO-St. Andrews Biological Station, Coastal Ocean Ecosystem Research Section

Nutrient sampling – Sampling to be done at same time as CTD stations and sent to the Bedford Institute of Oceanography for analysis.

Cost: Approximately $600 per survey
Protocols: Water samples taken at fixed times of year and analysed for nutrients.
Implementation: Depends on funding, but ideally should be at least 3-4 times a year.
Principal investigator(s): DFO-St. Andrews Biological Station, Coastal Ocean Ecosystem Research Section, DFO-Bedford Institute of Oceanography.

Environment Canada Water Quality Monitoring - Environment Canada (EC) monitors clam beds, in which Musquash Estuary is included. Environment Canada has considered dropping this site because of lack of interest by the industry. As the cost of sampling Musquash Esutary is included in the overall EC clam bed survey, it is unclear whether there would be a cost to DFO if monitoring was continued for purposes of the MPA and AIA. Information includes shellfish classification, fecal coliform counts, temperature, salinity, and sanitary observations. We have received a sample report for last year, and are still investigating these data (e.g. cost, time series, and usefulness).

Cost: None to DFO (at present).
Protocols: All water samples for bacteriological analyses are collected in sterile 250 mL wide mouthed bottles (Nalgene, polypropylene or glass) at a depth approximately 20 cm below the water surface. All water samples collected are held in an insulated cooler on ice or ice packs. Sampling plans which determine the locations (sub sectors) and sampling sites are determined by the Senior Biologist at Environment Canda. Sampling is carried out under various environmental conditions including adverse weather such as wind, fog, heavy periods of precipitation, dry conditions, and different tidal stages. Sampling stations are located through GPS or triangulation and/or using sampling stations maps and descriptions. Hydrological conditions including water temperature and tidal cycle are recorded as well as meteorological conditions. Samples are then sent to a laboratory for fecal coliform counts.
Implementation: Done only on an as needed basis.
Principal investigator(s): Environment Canada.

Intertidal and Marsh Images – Establish specific spots in the MPA and AIA where the community, hikers, paddlers, would be instructed (e.g. posted sign) to take a photo and submit it to a website/blog.

Cost: for signage, and for data handling. Website costs could be minimal if one of the popular sites is used (e.g. Facebook, blogging). Initial web set up could be contracted out to Friends of Musquash or the Conservation Council of New Brunswick and maintained as a non-government site. Costs are also assigned to cameras and GPS units used for the annual monitoring paddle.
Protocols: to be defined
Implementation: Requires exploration of concept with the community, and to test methods of delivery and storage of images. It would provide an excellent opportunity for community participation.
Principal investigator(s): Friends of Musquash or Conservation Council of New Brunswick.

A1.4 MANAGED ACTIVITIES

A list of currently managed activities is described in Section 3.4. Monitoring of these activities is essential to the second tier of investigation that would seek to determine what (if any) managed activities could result in changes to the ecosystem indicators. If activities are not regularly monitored then ecosystem-level monitoring will not have the appropriate information upon which to evaluate anthropogenic induced change versus natural variability.

Mapping Human-use – Knowledge of fisheries-related activities assists in meeting all of the Productivity (e.g. contribution of MPA to total catch), Diversity (e.g. bycatch species), and Habitat (e.g. area of MPA disturbed by dragging activity) objectives. A discussion with fisheries managers and fishers needs to be initiated, in order to develop a survey and to understand the potential usefulness of logbooks. Documentation should identify lobster trap locations; verifying if scallop dragging is occurring in the MPA; requesting to be informed if clamming starts in the MPA and AIA. Vessel traffic could also be monitored using Live Webcam (see below).

Cost: Very low, if fishers are willing to volunteer the data.
Protocols: Needs development with fisheries managers and fishers. A survey of fish harvesters to enquire about their activities in the MPA and AIA in the past, and their

understanding of the ecosystem and its components (Davis and Wagner, 2003). **Implementation:** Dependent on cooperation from fishers.
Principal investigators: DFO Fisheries and Aquaculture Management, DFO Conservation and Protection

Webcams – Remote video surveillance offers a cost effective means of monitoring human activities and ecosystem changes over extended periods of time. The application of standard observation points recorded over regulator time intervals would establish a scientifically-valid time series of activities and comparative environmental change. The proposed location of choice is the Musquash Head lighthouse, although other possible locations include Black Beach, Five Fathom Wharf, and the old bridge pillars next to the highway. The Musquash lighthouse has the most potential for the videocam because of security and power source. The Musquash Lighthouse is now owned by the Lorneville Recreation Association, and they are interested in this type of monitoring application. At the lighthouse location, a camera could monitor boat traffic entering/departing the MPA and AIA, scallop dragging and lobster fishing activities, large fauna, and any possible oil spills or plumes in proximity of or entering into the MPA and AIA. The observations assist with the Habitat objective, as vessel activity is linked to habitat disturbance by fishery activities, but also it provides an indicator of productivity in the MPA and AIA. Additional application of the live web cam would be to determine if weather conditions are appropriate for planned field work in the area and to enhance public communications and awareness of the Musquash Estuary MPA and AIA.

Cost: The estimated cost to install 2 fixed cameras at the Musquash Lighthouse location would be $14,000. Annual service and maintenance costs are estimated at $2000 per year. Long term data hosting and storage costs need to be considered with respect to DFO Informatics or through a partnership with stakeholders or another agency.
Protocols: Digital still images captured at regular time intervals during daylight hours. Station would be fixed to support long term comparison. Preference for images stored in DFO for access and periodic analysis.
Implementation: Dependent on funding.
Principal investigator(s): Oceans, Contacts: Musquash Lighthouse, Lorneville Recreation Association.

Beach Debris Survey – Dumping on Black Beach is a severe problem. The monitoring of this issue was suggested by Friends of Musquash. Methodology suggested is that of annual photo records and tallying debris by categories according to established protocols used in beach cleanups (Smith 2002; Amato et al. 2003). There is a National Beach Cleanup database that should be followed up with. This monitoring strategy would not only provide data to monitor effectiveness of the cleanup, but also provide an opportunity for involvement by the community and by their youth (e.g. scouts, schools), minimizing costs, and more importantly, pressure to those doing the dumping that should result in a decrease in debris. Local schools (Musquash, Lepreau, Dipper) and Scout troops, should be contacted to get youth involved (e.g. Adopt a Beach). Point Lepreau Generating station has offered garbage pickup in the past. The **safety** of community participants such as youths should always be considered in involving them in Musquash Estuary monitoring strategies such as this.

Cost: Dependent on how much of shoreline will be covered.
Protocols: As per national beach cleanup database.
Implementation: Started 2009 under contract for Black Beach/Gooseberry Cove beach.
Principal investigator(s): Friends of Musquash; Eastern Charlotte Waterways "Adopt a shoreline" program 506-456-6187 ecwinc@nbnet.nb.ca ; Fundy Baykeeper; scout

leaders for volunteers (contact Fire Dept where groups meet: Musquash/Dipper Harbour 506-772-2702, info@musquashfire.ca, no reply yet).

Aerial Survey – Ongoing, next one would take place in 5-10 years.

Cost: Up to $3000 per survey
Protocols: In line with protocols used in forestry aerial photography. The next survey will follow the same protocol as the last completed one. The photos will be analyzed and compared to determine large scale aerial changes to habitat types.
Implementation: First aerial photo completed in early Fall 2007.
Principal investigators (s): Not defined.

APPENDIX 2

***Proposed workplan** for baseline/monitoring data collection for the Musquash Estuary MPA and AIA (2008 - 2012+)*

Field Season	Review of monitoring plan, protocols, and data (includes CSAS review of monitoring plan)	Proposed monitoring activities	Other requirements
2008-10	• Develop monitoring framework based on (i) ecological overview, ecosystem framework, and advice from monitoring experts, (ii) ongoing and planned research activities, and (iii) unanticipated opportunistic activities in Musquash Estuary	• Identifying existing activities that will support baseline understanding of ecosystem components • Undertake priority baseline monitoring of ecosystem components as per first stage of scientific approach to evaluate, feasibility, spatial and temporal variability, and linkages with overall ecosystem function	• Musquash MPA and AIA program **biologist required** to co-ordinate and lead review of monitoring plan, oversee proposed monitoring activities, oversee other science requirements, communicate and lead collaboration with stakeholders, academics, and other government organisations identified within the monitoring plan (includes participating as member of MPA-WG and co-chair of MPA-SMAC) • Establish MPA-SMAC • Musquash MPA and AIA management plan will be the framework for which monitoring, research, assessment and advice will be directed
2010-11	• Draft monitoring framework will undergo CSAS review and receive approval from the Maritimes Region MPA Working Group and Musquash Estuary MPA Science and Monitoring Advisory Committee	**Database development and maintenance:** • Establish database of existing data, linked to guidelines • Review, coordinate, and collect data from existing monitoring programs within estuary (e.g. Environment Canada, Ducks Unlimited) **Habitat monitoring activities:** • Water quality sampling at select stations in MPA and AIA (e.g. CTD, nutrients, trace metals, organics, phytoplankton/chlorophyll-a, SPM, d-Oxygen) • Surveys of perceived threats associated with human-induced activities (e.g. clamming, scalloping, human trampling, presence of trash) • Upstream freshwater input (records from NB Power) • Suspended and bottom sediment characterization (e.g. composition, grain size, sedimentation rate) • Habitat/ecotype mapping using LIDAR and aerial photography, with ground-truthing, linked to GIS (including estimate of total area in estuary linked to biogenic structure) **Productivity and biodiversity monitoring activities:** • Commercial fishery catch/by-catch study (species biomass, age, sex, discarded) • Quadrat surveys of flora, fauna, and invertebrates, linked to GIS (including identification of species at risk, exotic species, and opportunistic species) • Identification of exotic species in region • Fish surveys using seines and fyke nets for three seasons	• Research zones of influence around mouth of Musquash Estuary, in the Bay of Fundy (underway) • Development of hydrographic and sediment models for estuary, which may include fieldwork (opportunistic and to be developed over long term)

***Proposed workplan** (cont'd).*

Field Season	Review of monitoring plan, protocols, and data(includes CSAS review of monitoring plan)	Proposed monitoring activities	Other requirements
2011-12	• Review monitoring activities and protocols, and provide input to subsequent years cycle of monitoring	**Database development and maintenance:** • Collect data from existing monitoring programs in estuary (e.g. Environment Canada, Ducks Unlimited). • Incorporate baseline data and monitoring results from previous field season into database **Habitat monitoring activities:** • Water quality sampling at select stations in MPA and AIA (e.g. CTD, nutrients, trace metals, organics, phytoplankton/chlorophyll-a, SPM, d-Oxygen) • Surveys of impacts associated with human-induced activities (e.g. clamming, scalloping, human trampling, presence of trash). • Upstream freshwater input (records from NB Power) • Suspended and bottom sediment characterization (e.g. composition, grain size, sedimentation rate) • Visual habitat/ecotype survey to determine status **Productivity and biodiversity monitoring activities:** • Commercial fishery catch/by-catch study (species biomass, age, sex, discarded) • Visual flora, fauna, and invertebrates surveys to determine status. • Identification of exotic species in region • Fish surveys using seines and fyke nets for three seasons	• Research on the affects on the MPA and AIA ecosystem from upstream, mixed waters of the Bay of Fundy/Saint John River • Development of hydrographic and sediment models for estuary, which may include fieldwork (opportunistic and to be developed over long term)
2012 - onward	• Review monitoring activities and protocols, and provide input to subsequent years cycle of monitoring	**Database development and maintenance:** • Collect data from existing monitoring programs in estuary (e.g. Environment Canada, Ducks Unlimited). • Incorporate baseline data and monitoring results from previous field season into database **Habitat monitoring activities:** • Water quality sampling at select stations in MPA and AIA (e.g. CTD, nutrients, trace metals, organics, phytoplankton/chlorophyll-a, SPM, d-Oxygen) • Surveys of perceived threats associated with human-induced activities (e.g. clamming, scalloping, human trampling, presence of trash) • Upstream freshwater input (records from NB Power) • Suspended and bottom sediment characterization (e.g. composition, grain size, sedimentation rate) • Visual habitat/ecotype survey to determine status **Productivity and biodiversity monitoring activities:** • Commercial fishery catch/by-catch study (species biomass, age, sex, discarded) • Visual flora, fauna, and invertebrates surveys to determine status. • Identification of exotic species in region • Fish surveys using seines and fyke nets for three seasons	• Development of hydrographic and sediment models for estuary, which may include fieldwork (opportunistic and to be developed over long term)