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Information in Support of Monitoring Protocols and Strategies for Selected Indicators in the Tarium Niryutait Marine Protected Area (TNMPA)

Renseignements en appui aux protocoles et aux stratégies de surveillance pour les indicateurs choisis dans l'aire marine protégée de Tarium Niryutait

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ABSTRACT

The Tarium Niryutait Marine Protected Area (TNMPA) includes three sub-areas located at the edge of the Mackenzie River Delta, in the Beaufort Sea Large Ocean Management Area (LOMA). Fisheries and Oceans Canada (DFO) Science sector is required to support the *Health of the Oceans Initiative* by delivering scientifically defensible indicators, protocols and strategies for monitoring the conservation objective(s) (CO) of MPAs. The CO for the TNMPA is “to conserve and protect Beluga Whales (*Delphinapterus leucas*) and other marine species (anadromous fishes, waterfowl and seabirds), their habitats and their supporting ecosystem”. The Central and Arctic regional DFO Science sector has developed a hierarchal framework of 82 indicators for the TNMPA CO. The regional DFO Oceans sector chose five of the 82 indicators and requested Science advice on protocols and strategies for each. The selected indicators relate to ecosystem structure and biodiversity (species lists and surveys), population structure and abundance of Beluga (sighting effort – distribution and abundance), and anthropogenic noise as an ecosystem stressor.

This report presents information on other monitoring programs that are relevant to the TNMPA and specific advice on the protocols and strategies for each of the five selected indicators. The level of development of the various protocols varies by indicator. For example, Beluga aerial survey techniques are well established and there is a wealth of internal DFO expertise and extensive baseline information available from past surveys, while there are little baseline data available for anthropogenic noise. Survey protocols will need additional development as indicators are evaluated and protocols are further refined based on the success of the indicator(s), management needs and stakeholder concerns (e.g., selection of focal species for surveys).

RÉSUMÉ

L'aire marine protégée de Tarium Niryutait (AMPTN) comprend trois sous-zones situées autour du delta du fleuve Mackenzie, à l'intérieur de la zone étendue de gestion des océans (ZEGO) de la mer de Beaufort. Le Secteur des sciences de Pêches et Océans Canada (MPO) doit appuyer l'*Initiative sur la Santé des océans* en fournissant des indicateurs, des protocoles et des stratégies défendables du point de vue scientifique pour la surveillance des objectifs de conservation des AMP. L'objectif de conservation pour l'AMPTN est de conserver et de protéger les bélugas (*Delphinapterus leucas*) et d'autres espèces (poissons anadromes, sauvagine et oiseaux de mer), leurs habitats, ainsi que les écosystèmes qui les soutiennent. Le Secteur des sciences de la Région du Centre et de l'Arctique du MPO a élaboré un cadre hiérarchique de 82 indicateurs pour les objectifs de conservation de l'AMPTN. Le Secteur des océans du MPO dans la région a choisi 5 des 82 indicateurs et a demandé des avis scientifiques relativement à des protocoles et des stratégies pour chacun. Les indicateurs choisis sont liés à la structure et à la biodiversité de l'écosystème (listes d'espèces et relevés), à la structure et à l'abondance de la population de bélugas (effort d'observation – distribution et abondance), et au bruit anthropique en tant que facteur de stress pour l'écosystème.

Le rapport présente des renseignements sur d'autres programmes de surveillance qui sont pertinents pour l'AMPTN ainsi que des avis scientifiques relatifs aux protocoles et aux stratégies pour chacun des cinq indicateurs choisis. Le degré d'élaboration des divers protocoles varie en fonction de l'indicateur. Par exemple, les techniques de relevé aérien pour les bélugas sont bien établies, et le MPO dispose d'une grande expertise et d'une abondance de renseignements de référence tirés des relevés précédents. Cependant, il y a peu de données de référence pour ce qui est du bruit anthropique. Les protocoles de relevé devront être élaborés davantage à mesure que les indicateurs seront évalués et que les protocoles seront affinés d'après leur réussite, les besoins en matière de gestion et les préoccupations des intervenants (p. ex., sélection des espèces prioritaires pour les relevés).

INTRODUCTION

Under the *Health of the Oceans Initiative*, Fisheries and Oceans Canada (DFO) Science sector was asked to provide advice on protocols and strategies for five selected indicators to monitor the success of the conservation objective (CO) for the Tarium Niryutait Marine Protected Area (TNMPA) in the Beaufort Sea (Figure 1). The CO for the TNMPA is “to conserve and protect Beluga Whales (*Delphinapterus leucas)* and other marine species (anadromous fish, waterfowl and seabirds), their habitats and their supporting ecosystem”.

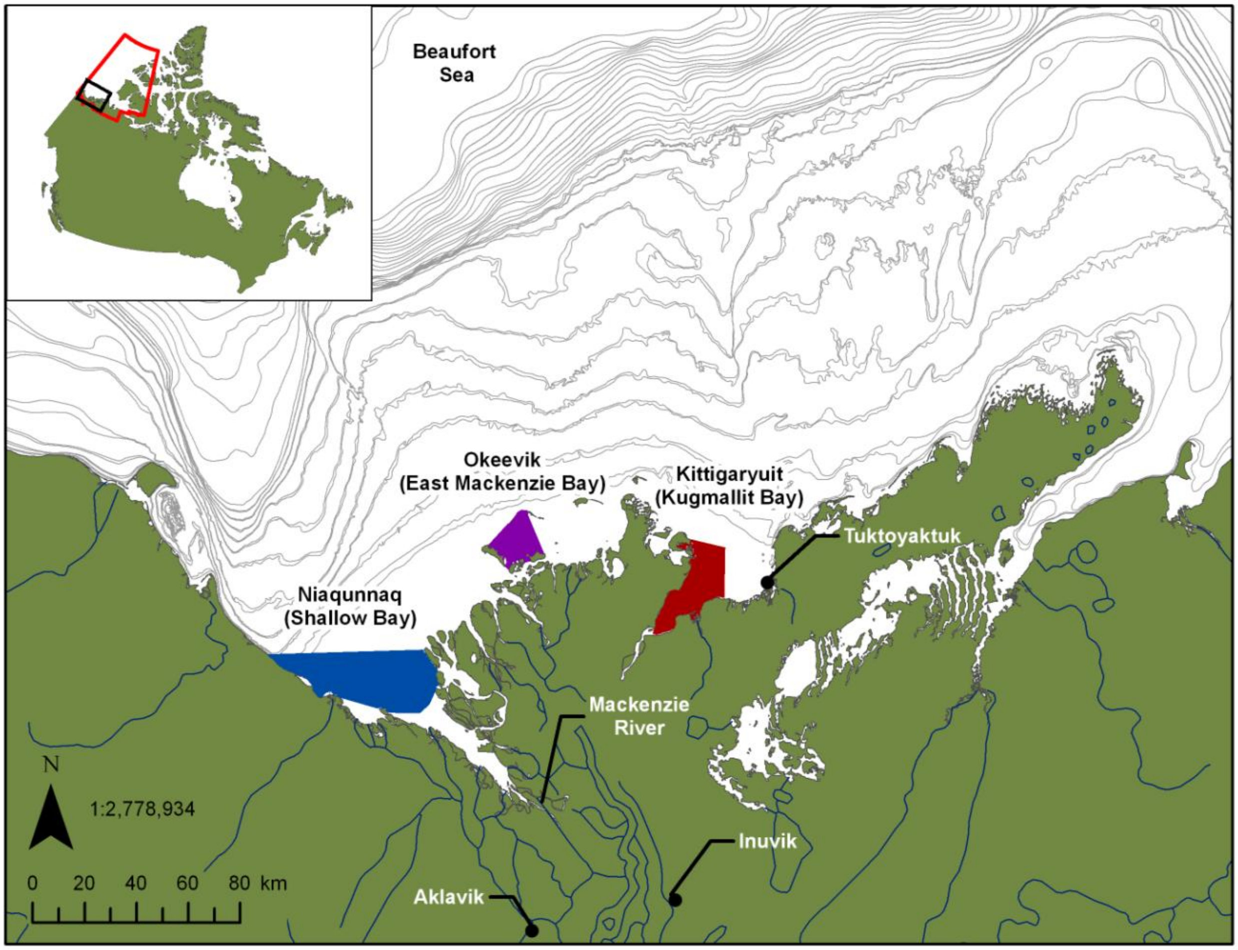

Figure 1. TNMPA sub-areas are indicated by the blue (Niaqunnaq), purple (Okeevik) and red (Kittigaryuit) shaded areas within the Inuvialuit Settlement Region and the Beaufort Sea Large Ocean Management Area (indicated by red lines within inset map).

The TNMPA is located in the Mackenzie River Estuary, within the Beaufort Sea Large Ocean Management Area (LOMA) and the Inuvialuit Settlement Region (ISR) defined in the Inuvialuit Final Agreement (Figure 1). The TNMPA includes three separate sub-areas: Niaqunnaq (Shallow Bay), Okeevik (in Beluga Bay, east Mackenzie Bay near Kendall and Pelly Islands) and Kittigaryuit (Kugmallit Bay) (Figure 1). All three areas are used by Beluga each summer, and all support subsistence harvesting. The TNMPA sub-areas correspond to the Zone 1a of the Beaufort Sea Beluga Management Plan (FJMC 2001). Further descriptions of the ecological setting within the TNMPA can be found in Cobb et al. (2008) and Loseto et al. (2010). Ecosystem monitoring is an important tool that can be used to determine whether actions undertaken to conserve valued ecosystem components are successful and to discover ecological trends within a given study area. Monitoring indicators were identified during a 2009 Regional Science Advisory Meeting (DFO 2010a,b; Loseto et al. 2010) for the TNMPA. Participants developed a new framework that identified 82 indicators based on their scientific value for monitoring and assessing the ecological health of the TNMPA. DFO Oceans programs division chose five of the 82 indicators (Table 1) and requested Science advice on protocols and strategies for each. Selected indicators relate to ecosystem structure and biodiversity (species lists and surveys), population structure and abundance of Beluga (sighting effort – distribution and abundance), and anthropogenic noise as an ecosystem stressor. The five selected indicators include some of the priority indicators identified by Loseto et al. (2010) (Table 1).

Table 1. Categories, elements and selected indicators (chosen by DFO Oceans) that form a hierarchical framework for monitoring and assessing the TNMPA CO (Loseto et al. 2010). Indicators identified as priority by Loseto et. al. (2010) are identified by an asterisk (*).

Category	**Element**	**Indicator**
1.0 Ecosystem Structure	1.1 Biodiversity	1.1.1 Species lists
		1.1.5 Surveys
3.0 Population Structure of Key Species (Beluga)	3.1 Distribution	3.1.1 Sighting effort*
	3.2 Abundance	3.2.1 Sighting effort*
6.0 Noise & Other Physical Stressors	6.1 Noise	6.1.1 Anthropogenic Noise*

Monitoring protocols explain how data are to be collected, managed, analyzed and reported and are a key component of quality assurance for any monitoring program (Oakley et al. 2003). Monitoring protocols allow for long-term standardization in study design and sampling procedures, while the protocols for sample and data analysis should be upgraded whenever opportunities arise (Kenchington 2010). Standardized protocols are necessary to detect changes over time and to allow comparisons of data among places, and years (Oakley et al. 2003), which are necessary for reporting. A strategy is a short description or discussion of current monitoring methods and programs, it is a plan of action, or a set of options ('strategic choices') designed to achieve the goals.

This report presents information on monitoring programs that are relevant to the TNMPA, and specific advice on the protocols and strategies for each of the five selected indicators listed in Table 1. For each indicator, a brief review and/or summary of data that currently exists, the protocols and strategies to measure and monitor (including areas where community-based monitoring (CBM) could be incorporated), and the challenges and/or gaps that exist with the suggested protocols and/or strategies (i.e., required baseline data collection or research projects) are presented.

Information on the ecology of the Beaufort Sea and on monitoring programs and strategies (including CBM programs) was collated from a wide variety of sources, including peer-reviewed literature, government documents, non-government organizations (NGO) and consulting reports, internet pages, and personal communications with researchers and managers. Sources were collected through numerous database searches (e.g., WAVES, Canadian Science Advisory Secretariat, Arctic Science and Technology Information System, Web of Science), general internet searches (e.g., Google, Google Scholar), and expert knowledge. A Regional Science Advisory meeting held in Winnipeg on February 9 and 10, 2012 brought together internal (i.e., DFO) and external expertise to develop science advice for the five selected indicators, and some of the results of this meeting are reflected in this document (i.e., indicator protocols and strategies). The document therefore focuses on the collection of data for monitoring the TNMPA rather than the methods of analyzing the resulting data.

PLANNING FOR ECOSYSTEM MONITORING IN THE TNMPA

A comprehensive monitoring program is required as a way to measure MPA effectiveness and improve management actions, thereby permitting an adaptive management approach (Pomeroy et al. 2004; IOC 2006). Monitoring is a long-term activity that needs to be maintained for an extended period, however programs also need the flexibility to discard uninformative indicators or adopt new ones relating to emerging threats, and to correct faulty methodology (Kenchington 2010). A monitoring program also needs to be sensitive to the effects of management actions, relevant to management objectives and stakeholder concerns, cost effective, grounded in scientific theory, and supported by the scientists who will conduct the surveys and analyses (Kabuta and Laane 2003; Pomeroy et al. 2004; Ferguson et al. 2012).

The five selected indicators for the TNMPA include a mix of those that can be directly measured (e.g., anthropogenic and ambient noise levels) and those that must be derived from measurements (e.g., Beluga relative abundance based on survey data) (c.f. Kenchington 2010). Standardized monitoring protocols should be developed for each indicator, and these should use rigorous, reproducible methods. Data collection programs should be designed to use simple, existing, and proven instruments and analytical methods. The MPA sub-areas are strongly influenced by adjacent ecosystems (e.g., riverine outflow), therefore monitoring activities for the TNMPA should be integrated with similar programs conducted in the LOMA and the Mackenzie River (Loseto et al. 2010). Highly mobile and widely distributed species, including Beluga, anadromous fishes, and marine birds, spend a limited amount of time each year in the MPA. Selecting some indicators that can be used to monitor at a larger spatial scale is recommended in this case (Loseto et al. 2010). For example, offshore aerial surveys (Loseto et al. DFO unpubl. data) and satellite telemetry studies (e.g., Loseto et al. 2006) would provide information on Beluga abundance, distribution, habitat use and migration patterns.

INTEGRATION WITH EXISTING EFFORTS

The TNMPA monitoring program should be integrated into regional, national and international monitoring programs to the greatest extent possible, but must also not compromise the fulfillment of the specific needs of the MPA (Kenchington 2010). Relevant existing programs exist at international (e.g., Circumpolar Biodiversity Monitoring Program (CBMP)), national (e.g., Northern Contaminants Program), and regional (e.g., Northwest Territories Cumulative Impact Monitoring Program (CIMP), Northwest Territories (NWT)/Nunavut (NU) Breeding Bird Atlas program) scales. A number of relevant local-scale monitoring efforts also exist and most involve DFO researchers and managers (e.g., Hendrickson Island Beluga sampling program, Arctic Coastal Ecosystem Studies (ACES) program, subsistence fishery harvest monitoring and CBM of Dolly Varden Char (*Salvelius malma*)). Two programs are described below: 1) the CBMP, a circum-Arctic monitoring program, and 2) the ACES program, a DFO-led study that is currently active in the TNMPA collecting baseline data.

The CBMP is the main program of the Arctic Council's Conservation of Arctic Flora and Fauna (CAFF) Working Group. CBMP is an international network of scientists, government agencies, indigenous organizations and conservation groups that are cooperatively working to integrate monitoring efforts for living Arctic resources. The primary functions of CBMP are to coordinate existing Arctic biodiversity monitoring programs, address knowledge gaps, and identify new programs by gathering, integrating, and analyzing data and communicating results (Petersen et al. 2004; Gill et al. 2008). The CBMP network has produced a number of documents that assist and guide practitioners in the development of monitoring plans and survey development. Some of these documents include a recent comprehensive plan for monitoring Arctic marine biodiversity (Gill et al. 2011, Vongraven et al. 2009), frameworks for cetacean, pinnipeds, polar bear (Simpkins et al. 2009; Vongraven and Peacock 2011), and seabird (Petersen et al. 2008; Irons et al. 2011) monitoring. The CBMP also recognizes the importance of CBM to Arctic biodiversity conservation. This includes incorporating both the value of Traditional Ecological Knowledge (TEK) and the ability to employ standard scientific monitoring procedures to citizen scientists in order to extend the reach and effectiveness of monitoring programs (Fleener et al. 2004; Huntington 2008; Gofman 2010). The contributions of local peoples should be maximized within the TNMPA monitoring program, which will help to ensure that the plan remains relevant and responsive to local concerns (existing programs provide an efficient starting point for monitoring plan development).

The ACES program was developed by DFO as an ecosystem-based approach to increase our understanding of the coastal Beaufort Sea and assist with monitoring the TNMPA (Walkusz et al. DFO unpubl. data; Loseto et al. DFO unpubl. data). Data collection included shore- and vessel-based sampling, using a shallow draft 30-foot catamaran (*Beaufort Explorer*) and a 19-foot Zodiac. The sampling program collected data on primary productivity, zooplankton communities, benthos, and fishes in the Niaqunnaq/Shallow Bay MPA sub-area. Transects covered gradients in water depth, transparency and suspended sediments, which are required to assess spatial variability and oceanographic/freshwater impacts (Walkusz et al. DFO unpubl. data). The methods used by the ACES program are applicable to monitoring in the TNMPA to varying degrees, depending on survey priorities. Two years of sampling have occurred in the Niaqunnaq/Shallow Bay sub-area, and the near shore work will continue in 2012 and 2013 (Lisa Loseto, pers. comm., DFO Winnipeg). The ACES program also fits in with a proposed larger-scale Beaufort Sea monitoring and research program (Lisa Loseto and Jim Reist, pers. comm., DFO Winnipeg).

TYPES OF MONITORING REQUIRED

Kenchington (2010) describes different types of monitoring (with some overlap), which are summarized in Table 2, including examples that are relevant to the TNMPA. For all indicators, monitoring activities will require a mix of baseline, trend and effectiveness monitoring, with some activity monitoring (e.g., noise levels, fish harvest), plus compliance and regulatory monitoring conducted by enforcement personnel.

All indicators require a temporal baseline against which future changes are monitored. Baseline monitoring includes steps such as characterizing the ecosystem, determining levels of natural variability, and quantifying initial values. The Commission for Environmental Cooperation's (CEC) ecological scorecard for MPAs indicates that the baseline should be the pristine or near-pristine condition, not the state when the MPA was put in place (CEC 2011). Ideally, indicators would have a pre-existing baseline (Kabuta and Laane 2003; Pomeroy et al. 2004; Kenchington 2010), but the availability of present (or past) data varies among the selected indicators. For some indicators, particularly Beluga abundance and distribution, there is a long history of research and a robust baseline dataset that extends back to the 1970s (details below). For other indicators (e.g., ocean noise), baseline data will have to be collected since a complete dataset does not currently exist (limited data are available) and in some cases proxy data may be available (e.g., information on changes in shipping intensity and industrial activity, the use of small vessels by local harvesters).

Table 2. Types of monitoring (from Kenchington 2010) and their applicability to the TNMPA.

Type of monitoring	Description	Relevance to the TNMPA
Baseline	Establishing a temporal baseline against which future changes are monitored, includes ecosystem characterization, determination of levels of natural variability, and quantification of initial values	All five selected indicators require baseline data to varying extents depending on current data availability
Trend	On-going monitoring of temporal changes in the selected indicators, extending from an established baseline	All five selected indicators require trend data as part of long-term monitoring program
Effectiveness	Monitoring focused on the attainment of management goals and objectives (i.e., the CO), usually requiring a combination of baseline and trend monitoring	Applies to all five selected indicators.
Activity	Monitoring the effects of a specific human activity (e.g., anthropogenic noise levels, harvesting, contamination near point sources)	Anthropogenic noise, harvesting activities
Compliance	Monitoring of a specific activity to ensure that is conducted in a manner permitted by the terms of regulations and permits (often a form of activity monitoring)	Exploration activities, harvesting activities
Regulatory	Usually a type of compliance monitoring capable of collecting evidence for enforcement, can also be a type of activity monitoring that is not dependent on specific permit requirements	Industrial activities, nearshore construction (fish habitat impacts)
Threat	Monitoring of a suspected threat, distinct from monitoring the effects, which could include both point-source and non-point source threats	Changes to sea ice conditions (concentration, break-up dates), contaminant levels

A decision will need to be made as to whether a suitable baseline exists for each of the selected indicators, and protocols for baseline monitoring can be developed where necessary (the same protocols can and should be used for continued trends monitoring). A comprehensive survey of available baseline data will be a primary step in the development of a monitoring program for the TNMPA. Some information is summarized here, but baseline data needs will ultimately depend on identified priorities for indicators (e.g., focal taxa for surveys) and chosen protocols (e.g., 1970s data available for Beluga aerial surveys). Baseline surveys, where necessary, should be conducted for 2-3 years, preferably 3 years (a single year will provide no information on variability and two years may produce highly divergent results).

Baseline monitoring will need to be followed by continued trends and effectiveness monitoring. Indicators will have to be monitored at an appropriate frequency to detect changes over management-relevant time scales, and to provide a signal that can be detected amidst natural variability (Kabuta and Laane 2003; Pomeroy et al. 2004; Kenchington 2010; Ferguson et al. 2012). The frequency of monitoring activities will likely vary by indicator and/or the species or species groups being monitored, which relates to the natural variability in the dynamics of the population(s) in question. For example, Gill et al. (2011) recommend that surveys of the benthic community be conducted every three years, whereas Beluga aerial surveys could be conducted on a decadal scale.

INDICES FOR MONITORING

Indices help synthesize a large set of information into a single value and provide a simple diagnostic about community or ecosystem health (Diaz et al. 2004; Dauvin 2007). There are a number of index measures that have been used in the context of protected areas management and/or biodiversity conservation. Some of these may be applicable for use in the management of the TNMPA. For example, the index of biotic integrity (Karr 1981) has been widely used in freshwater and estuarine systems (Rocklin et al. 2011). This index could be used to facilitate comparisons of ecosystem integrity in adjacent ecosystems, such as the Mackenzie River and the estuary.

There has, however, been little consensus regarding the best ecological indicators for marine fish assemblages (Claudet et al. 2006; Pelletier et al. 2005), and a number have been developed. One simple index is the Marine Trophic Index (MTI) (Bhathal 2005; Pauly and Watson 2005), developed by the Fisheries Center at the University of British Columbia as a way to track the trophic structure of fisheries harvests. The index has generally been used at larger spatial scales such as a country’s Exclusive Economic Zone (EEZ) or Large Marine Ecosystems (LMEs), but could be explored as a useful index at smaller spatial scales to track changes in fish harvests over time. Historic landings information could also be used to retroactively calculate the index. Rocklin et al. (2011) recently developed the Response Groups based on Sensitivity (ReGS) indicator as a simple yet flexible method to focus on the abundance of different response groups with differing sensitivity to a particular disturbance (e.g., harvest pressure, warming water temperature). This index requires more data than the MTI, but could also prove useful for MPA management.

Effectiveness monitoring in the TNMPA will require consideration of time series data from numerous indicators. Trend data will be collected at varying temporal and spatial scales, and with different units of measurement (e.g., population size as number of animals, noise levels measured in decibels (dB), diversity and abundance indices, water temperature in degrees Celsius). Each time series could be normalized by dividing by its standard deviation (SD), as is done with data from DFO's Atlantic Zone Monitoring Program (AZMP), to allow a more direct comparison of trends among the different indicators (Galbraith et al. 2010). The CEC has developed a standardized ecological scorecard and condition report as a tool for assessing the condition of North American MPAs (CEC 2011). The approach is based on an ecosystem framework and follows a flexible design that can be adapted to any MPA. The scorecard and condition report can also assist with the design of monitoring programs and reporting information. Managers should explore the use of the CEC scorecard and reporting system for the TNMPA.

ASSESSMENT

INDICATOR PROTOCOLS AND STRATEGIES

Species Lists (Indicator 1.1.1)

Species lists are considered a basic indicator of biodiversity and species richness, but can also provide some information about community structure (Loseto et al. 2010). A comprehensive species list can present the current known level of biodiversity in a defined area and observed temporal changes could indicate ecosystem-level shifts (if suitable data are available). Regular monitoring of this indicator could also identify the occurrence of colonizing species in response to climate change and/or anthropogenic activities. Loseto et al. (2010) note that some basic sampling is needed to update the list by taxonomic group. This sampling/survey work will be necessary to continue to populate the species lists but could also provide data and/or information that could be used to inform other monitoring indicators (e.g., stable isotopes, fatty acids). This type of indicator could be considered a value-added indicator since it provides data for more than one indicator.

A species list for the TNMPA (current to 2004) has been developed following an extensive literature review (Stewart 2012). In this review, not all of the sampling locations were identified by map coordinates in the original studies; some locations were only denoted by dots on a map. Consequently, species are listed as present in a particular area or as present in one or more of the three designated areas of the MPA if the coordinates or dot appeared to occur within the MPA boundaries. Since sampling efforts within the MPA have been limited, species that were present within the 5 m depth contour (within the Mackenzie Estuary) but not necessarily within one of the MPAs were noted separately, as the absence of these species from a particular MPA sub-area may be a sampling artifact. Species that have been identified within the region but not within the 5 m contour in the immediate area have also been noted. Their absence from the MPA may be a sampling artifact or it may be related to environmental conditions. In either case, their inclusion is expected to facilitate future additions to the list and comparison with other areas. Stewart (2012) includes four Kingdoms in the species list: Plantae, Monera (unicellular organisms with a prokaryotic cell organization, e.g., bacteria), Protozoa (single-celled eukaryotes), and Animalia.

Strategy

A list of species present in a MPA is a primary tool for biodiversity assessment, and a number of metrics can be calculated using these data (e.g., species richness, evenness, community structure) (see Indicator 1.1.2 - Biodiversity indices, Loseto et al. 2010). The calculation of these various metrics, and the caveats associated with their use, are well-established and are not described here in detail. However, if it is determined that suitable data are available (i.e., a reasonably complete list), these methods provide a cost-effective way to track changes in biodiversity in the MPA in addition to the presence/absence data. These various metrics can also be used for spatial comparisons (e.g., inside versus outside the TNMPA and comparisons among the three sub-areas) and potential temporal comparisons (i.e., charting biodiversity and community structure changes over time), depending on the availability of information (Loseto et al. 2010).

Local knowledge and TEK can make a significant contribution to the development of this indicator. Local residents have inherent skills to closely observe nature, and these skills are transferred from generation to generation (Fleener et al. 2004). This type of information and data are valuable because they are based on observations over long time periods, are inexpensive to collect, invite the participation of locals as citizen scientists and can sometimes incorporate subtle multivariate cross checks for environmental change (Moller et al. 2004). Local residents can be trained to employ standard scientific monitoring procedures, thereby extending the reach and effectiveness of programs that rely on a limited number of trained scientists to carry out monitoring (http://www.caff.is/community-based-monitoring). Additionally, this creates the potential for year-round or, at minimum, an expanded temporal scale over which the systematic or opportunistic collection of data is possible.

A variety of information sources can be used to populate the species list, and a detailed database would provide an organized format to compile the list(s) and add additional information with respect to the source and other species information. For example, the conservation status of the various taxa would be an important component of any monitoring program and may help guide research and management priorities. The species database could also include information on relative abundance, which is related to conservation status. In addition, a number of other variables could be added to the database depending on monitoring and research needs. For example, information on reproductive biology, life-history, and ecology (e.g., prey items, trophic level, predators) could be incorporated and would be of significant value for modeling and monitoring ecosystem structure and function. Life-history and ecological information is available through published literature and/or existing databases (e.g., http://www.fishbase.org/search.php; Froese and Pauly 2012). These large databases provide ready access to a volume of data on species found in the TNMPA, but are also known to contain errors. Original sources should therefore be identified and consulted as a database is being developed. Published information on trophic level and food habits could augment data collection needs for Element 1.2 (Trophic structure) identified by Loseto et al. (2010).

Protocol

A variety of research efforts and data sources can contribute to a list of species present in the TNMPA. Much of the work can be conducted as a desk- or office-based exercise (e.g., literature reviews, searches of museum catalogues, queries to active researchers), although field-based research (Indicator 1.1.5) can target taxonomic groups that have been insufficiently sampled and help to supplement regular species list updates (Loseto et al. 2010). Literature reviews, database searches, queries to researchers, and other office-based efforts represent a cost-effective way to collect information on biodiversity in the TNMPA, as salary and wages for staff are the only major expense.

Managers will need to carefully consider the value of populating a list for biodiversity monitoring, since it will likely be difficult to determine when the list is complete and the list will also likely contain variable taxon coverage. In addition, the current level of information for each taxonomic group varies, ranging from complete lists for marine mammals and a seasonal list of fishes in the Beaufort region (Coad and Reist 2004) to incomplete lists for zooplankton, phytoplankton and benthos (Loseto et al. 2010). Initial priorities include completing the lists for these three groups, and conducting a desk analysis to determine the extent of remaining work to populate the lists for other groups (e.g., pathogens, fishes) (Loseto et al. 2010). Similar work will need to be conducted for marine and coastal bird species. The current species list (Stewart 2012) includes waterbirds and shorebirds known from the region using the range maps from a field identification guide (Alsop 2002). Additional sources are available and should be consulted, such as online species lists for the NWT (e.g., Avibase (http://avibase.bsc-eoc.org) and Birdlist (http://www.birdlist.org)). Other sources of information on marine birds include the NWT Species Monitoring Infobase (continually updated by the NWT General Status Ranking Program (NWT-GSRP)), harvest and population index data compiled by the CIMP, and the NWT/NU Bird Checklist Survey. The NWT/NU survey program has been coordinated by the Canadian Wildlife Service since 1995 and contains extensive information on bird sightings provided by volunteer surveyors and extending back to the 1970s in some cases. The database includes numerous checklists for the Mackenzie delta region and will aid in the development of a comprehensive species list for the MPA (the database also includes some information on effort and could therefore be used to estimate relative abundance).

As a first step, recent DFO-led research in the Beaufort Sea (e.g., ACES, monitoring of subsistence fisheries, invasive species monitoring) and other research programs (e.g., ArcticNet) will need to be reviewed for the identification of additional species in the areas defined by Stewart (2012). This work can be conducted as a component of a general search and review of recent published literature (e.g., peer-reviewed journal articles, government documents, consulting company reports). The species list can be used to develop a set of keywords to search for information by taxon group, region and geographic coordinates. Surveys (Indicator 1.1.5) will provide additional information for the species list/database, and a schedule should be established for updates as results become available. Other sources include museum collections and online depositories such as the Global Biodiversity Information Facility (GBIF) and the Ocean Biogeographic Information System (OBIS). Loseto et al. (2010) also indicated that the species lists should be compared spatially, in- versus outside the TNMPA and among the three sub-areas and, if the necessary information is available, temporally. The species list (Stewart 2012) is organized by sub-area, allowing some comparisons, although the level of completeness for the different taxonomic groups needs to be considered.

The information on conservation status within the species database should be compiled at multiple spatial scales; for example, territorial (NWT list), national (Committee on the Status of Endangered Wildlife in Canada (COSEWIC), *Species at Risk Act* (SARA)), and global (International Union for Conservation of Nature (IUCN)). The database should include the assessment date to recognize the temporal scale and should also incorporate updates as they occur (COSEWIC re-assessments occur every 10 years and NWT assessments every 5 years). If relative abundance is also included in the species database, descriptive codes (e.g., common, rare, extra-limital) could be assigned, however they may vary by taxon group (e.g., relative abundance of birds is easier to assess than benthic invertebrates).

As discussed previously, TEK can be incorporated into the development of the species list. Some information is available through published TEK summaries (e.g., Byers and Roberts 1995; Hartwig 2009). It is suggested that additions and revisions to the species list, or variables in a database, should incorporate information from periodic TEK surveys and workshops. It is also suggested that a community reporting system be developed and communicated to local residents. This system would allow local resource users to report sightings of rare or unusual species, potentially new species and relevant ecological observations. This could also be expanded to include effort data and to collect systematic observations as part of a dedicated survey program.

Updating the species list (or database) as new information becomes available is a straightforward process, but it is essential that the appropriate human resources be assigned ownership and responsibility. Managers should develop a schedule for regular updates to the list (e.g., yearly, semiyearly, biannually). Effort may be dependent on funding availability and variation in staff workloads, but explicit scheduling will ensure timely monitoring results for adaptive management. For the species list and database to be effective as a biodiversity monitoring tool it will need to be a “living document” that receives on-going updates and refinements. Much of the necessary work is straightforward, and it could be conducted by temporary personnel (i.e., students, contractors) provided a consistent method is developed and used.

Surveys (Indicator 1.1.5)

Rigorous field surveys will be a critical component of a monitoring plan for biodiversity and ecosystem structure in the TNMPA. Surveys can be used to map species distributions, and in some cases identify habitat use. Mapping species distribution patterns (particularly key species) and monitoring for shifts in distribution could indicate change and identify a need for research and investigation (Loseto et al. 2010). To date, four key species have been identified for monitoring in the TNMPA: Beluga, Broad Whitefish (*Coregonus nasus*), Least Cisco, (*Coregonus sardinella*) and Arctic Cisco, (*Coregonus autumnalis*). Identified indicators for these key species are related to population structure (distribution, abundance, and size, sex and age structure) and health (demographic rates, nutrition and condition, inter-annual stability in diet, contaminant burdens, incidence of diseases and parasites, reproductive success, and natural mortality rates) (Loseto et al. 2010). While only two of the identified indicators (Beluga abundance and distribution) in Table 1 are focused on one of the key species, surveys should be designed to collect information for these other key species as well.

Strategy

No single survey method/design can effectively collect data on the wide variety of taxa that are required for a biodiversity monitoring program, and a variety of taxon-specific methods are required. The CBMP uses the definition of biodiversity from the Convention on Biological Diversity (CBD), as "the variability among living organisms from all sources…and the ecological complexes of which they are a part; this includes diversity within species, between species and of ecosystems". It is also not possible to monitor every species that is known or expected to occur in the TNMPA. Managers will need to select a subset of species or species groups to survey, and develop appropriate survey designs around these taxa. Taxa should be selected based on a number of factors including socio-economic importance, ecological role (trophic level, prey items, habitat type, etc.), utility as an indicator, conservation status (local, regional, national, global), monitoring cost-effectiveness and logistical considerations. Many sampling programs can be developed around ecological communities (e.g., benthic surveys, marine birds) and include a number of different species or species groups. Community involvement will be an important component in survey plan development and execution.

Potential species and communities for priority monitoring are listed in Table 3. This is not meant to be an exhaustive list (for instance, no benthic species are listed), or to suggest that surveys need to be conducted for all of these species or species groups, rather it highlights the current status of a number of species. The list includes ecologically significant species and communities (ESSC) that were previously identified for the Beaufort Sea LOMA (Cobb et al. 2008), rare and/or sensitive species (SARA, COSEWIC, NWT-GSRP), those identified as a CO for the TNMPA or listed as a priority indicator in Loseto et al. (2010) (i.e., the four key species noted above), high-priority species identified in community conservation plans for each of the three delta-area communities (Community of Aklavik et al. 2008; Community of Inuvik et al. 2008; Community of Tuktoyaktuk et al. 2008), and indicators for marine environmental quality used for the 2005 and 2010 NWT Environmental Audits (SENES Consultants Ltd. 2005, 2011). The list includes two "data deficient" species (COSEWIC), the Pigheaded Prickleback (*Acantholumpenus mackayi*) and the Bearded Seal (*Erignathus barbatus*). Pigheaded Prickleback are considered rare in the Beaufort Sea (Coad and Reist 2004), but the marine form is known from Tuktoyaktuk Harbour and Kugmallit Bay (COSEWIC 2003). Cobb et al. (2008) considered these species to be data deficient until research can be conducted to determine their status in the LOMA.

*Table 3. Species and ecological communities of increased management attention in the Beaufort Sea, including the Tarium Niryutait Marine Protected Area (TNMPA). The list includes Ecologically Significant Species and Communities (ESSC) identified for the Beaufort Sea Large Ocean Management Area (LOMA), those identified in the Conservation Objective (CO) for the TNMPA, those considered to be at risk or sensitive in national and territorial status ranking systems (*Species at Risk Act *(SARA), the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) or the Government of the Northwest Territories Species 2006–2010 General Status Ranks (NWT)), high-priority species identified in community conservation plans (CCP), and indicators used in the 2005 and 2010 NWT Environmental Audits. Note that no benthic species or communities are included in the table.*

Taxon Group	Species or Community	Scientific Name	Rationale	Conservation Status
Algae	Ice algae community		ESSC	
Invertebrate	Herbivorous zooplankton community		ESSC	
Invertebrate	Herbivorous zooplankton	*Limnocalanus macrurus*	ESSC	
Invertebrate	Ice-associated amphipods		ESSC	
Invertebrate	Mysids	Mysidae	ESSC	
Fish	Arctic Cod	*Boreogadus saida*	ESSC	
Fish	Arctic Char	*Salvelinus alpinus*	ESSC, NWT indicator	
Fish	Northern Dolly Varden	*Salvelinus malma malma*	TNMPA CO, CCP, listed species, NWT indicator	COSEWIC: Special Concern (Western Arctic population); NWT: Sensitive (Rat River and Big Fish River populations)
Fish	Least Cisco	*Coregonus sardinella*	TNMPA CO, CCP, sensitive species	NWT: Sensitive
Fish	Arctic Cisco	*Coregonus autumnalis*	ESSC, TNMPA CO, CCP, sensitive species	NWT Sensitive
Fish	Broad Whitefish	*Coregonus nasus*	TNMPA CO, CCP	

Table 3 Continued…

Taxon Group	**Species or Community**	***Scientific Name***	**Rationale**	**Conservation Status**
Fish	Pigheaded Prickleback	*Acantholumpenus mackayi*	Data deficient species	COSEWIC: Data Deficient; NWT: Undetermined
Bird	Red-throated loon	*Gavia stellata*	NWT indicator	NWT: Secure
Bird	Ivory Gull	*Pagophila eburnea*	Listed species	SARA: Special Concern; COSEWIC: Endangered; NWT: May be at Risk
Bird	Waterfowl community (ducks, geese, swans, loons)		TNMPA CO, sensitive species, NWT indicator	NWT: Sensitive (multiple species)
Bird	Thick-billed Murre	*Uria lomvia*	TNMPA CO, sensitive species	NWT: Sensitive
Bird	Shorebird community		NWT indicator	NWT: Sensitive (multiple species) (Red knot, *Calidris canutus*: *rufa* subsp. Endangered (COSEWIC), roselaari type Threatened (COSEWIC), both NWT: May be at Risk.
Marine mammal	Beluga (Eastern Beaufort Sea population)	*Delphinapterus leucas*	ESSC, TNMPA CO, CCP, NWT indicator, MPA indicator	COSEWIC: Not at Risk; NWT: Secure
Marine mammal	Bowhead (Bering-Chukchi-Beaufort population)	*Balaena mysticetus*	ESSC, CCP, listed species	COSEWIC: Special Concern; NWT: Sensitive
Marine mammal	Ringed Seal	*Pusa hispida*	ESSC, CCP, NWT indicator	COSEWIC: Not at Risk; NWT: Secure
Marine mammal	Polar Bear	*Ursus maritimus*	ESSC, listed species, CCP, NWT indicator	SARA and COSEWIC: Special Concern; NWT: Sensitive
Marine mammal	Bearded Seal	*Erignathus barbatus*	Data deficient species, CCP	COSEWIC: Data Deficient; NWT: Secure

Survey designs should be similar to previous or on-going research efforts in the Beaufort Sea to allow comparison of results and efficient merging of data sets. Survey design should also be closely aligned to those used by other Arctic biodiversity monitoring programs. Surveys need to be designed to meet local conservation objectives, but should also contribute to larger monitoring programs at circumpolar scales. The CBMP and ACES programs provide important information for the development of a TNMPA survey program.

Protocol

The CBMP marine plan (Gill et al. 2011) includes a sampling design (approach and protocols) for the taxon groups identified as priority indicators: plankton, sea-ice biota, benthos, fish, seabirds, and marine mammals. The CBMP process provides valuable information for the development of a monitoring plan, but the protocols (Gill et al. 2011) vary in their level of detail and in their applicability to the TNMPA. Co-management partners (e.g., DFO, Hunter and Trapper Committees (HTCs), Fisheries Joint Management Committee (FJMC)) will need to co-operatively identify the main priority species, or species groups, that need to be surveyed (i.e., those listed in Table 3, or additional taxa), and this will guide the development of survey plans. The CO for the TNMPA identifies anadromous fishes, waterfowl and seabirds as priorities for conservation (in addition to Beluga), and surveys for these groups will be priorities. Protecting their habitats and supporting ecosystems is also an objective, and surveys will need to address these needs as well. Considerable background work has been conducted in the area (e.g., the ACES program), and appropriate survey designs have previously been used for many taxon groups.

Depending on priorities (i.e., taxon groups), sampling methods used by the ACES team in 2010 and/or 2011 should be continued in the Niaqunnaq/Shallow Bay sub-area and expanded to the Okeevik (East MacKenzie Bay) and Kittigaryuit (Kugmallit Bay) sub-areas, with modifications as necessary based on priorities and improvements to methodology. Sampling intensity (i.e., sample sizes, number of stations) will also be dependent on logistical and funding concerns (Walkusz et al. DFO unpubl. data). The discussion below provides information on protocols that may be used, depending on the taxon groups selected for surveys. Final survey protocols (additional design details - gear types, parameters to be measured) are dependent on the species/species groups selected as indicators. In addition, a detailed literature review for pre-existing information (e.g., baseline data, research protocols) will need to be conducted for all identified taxa for surveys (Loseto et al. 2010).

Plankton

Techniques used by the ACES program to sample phytoplankton and zooplankton in the Niaqunnaq/Shallow Bay sub-area can be extended to collect baseline and trend data for MPA monitoring. In 2010, water samples were collected at mid-column depths using a Niskin bottle and a bucket from the Beaufort Explorer or using a bucket for nearshore surface water (Walkusz et al. DFO unpubl. data). Samples were assessed for stable isotopes and fatty acid analysis, biomass, diversity of bacteria, phytoplankton and other microorganisms and for constituents that influence microbial productivity (i.e., inorganic nutrients, dissolved organic carbon and nitrogen, suspended sediments). Oceanographic sampling was also conducted at each station. Hydrographical measurements were made using a hand-held probe that measured salinity, temperature, dissolved oxygen and turbidity, at discrete depths. A similar instrument was used by the on-shore sampling crew. Two oceanographic moorings were also deployed for the duration of the 2010 field study. In 2011, water parameters were measured using a CTD (Conductivity, Temperature, and Depth) instrument (Loseto et al. DFO unpubl. data). Some historic data on plankton and oceanographic conditions are also available (e.g., Grainger 1975; Grainger and Lovrity 1975).

In 2010, the zooplankton community was sampled at each station using two types of nets. Four replicates were taken with a fine mesh (80 µm) net that was towed vertically from about 1 m above the bottom to the surface and preserved with a 5% (final concentration) solution of formaldehyde in sea water (taxonomic analysis) or frozen (stable isotopes and fatty acids). A 500 µm net was towed horizontally 5 times at each station, at a towing speed of 2 knots for a 20 minute deployment. Volume of water filtered was calculated using a flowmeter (installed at the mouth of the net). All larval/juvenile fishes (ichthyoplankton) were removed from the samples and preserved in a 5 % formaldehyde solution in seawater.

Benthos

As a whole, there are few historical and recent benthic data available for the Western Arctic region (Kenchington et al. 2011). Most sampling has occurred on the shelf or in deeper water, although some nearshore sampling has been conducted (e.g., F.F. Slaney & Co. Ltd. 1974, 1975; Conlan et al. 2008). Benthic sampling has been conducted in Tuktoyaktuk Harbour and near Toker Point in 2008 under the Canadian Aquatic Invasive Species Network (CAISN), which applied a variety of benthic sampling methods (K. Howland, pers. comm., DFO, Winnipeg). Visual sampling (i.e., scuba-diving) was not found to be an effective method due to poor clarity in the water column. In 2010 and 2011, the ACES program surveyed the benthic community using similar techniques as the CAISN program. The 2010 methodology for benthic sampling can be found in detail in Walkusz et al. (DFO unpubl. data). Under the ACES program, a Petit Ponar grab sampler (15 cm x 15 cm) was deployed five times at each station, and samples were sieved on a 500 µm bucket sieve. Samples were then preserved with a 5 % formaldehyde solution in seawater for taxonomic analysis or frozen for analyses of stable isotopes, lipid classes and granulometry (grain size) (Walkusz et al. DFO unpubl. data). At some stations, it was not possible to collect a good sample because of the “sloppy” nature of the sediment, and it was noted that more efficient sampling techniques may be required to sample deeper in the sediment. In 2011, a benthic dredge was used in shallow waters (< 2 m depth) (Loseto et al. DFO unpubl. data). Most collected material was a mixture of mud, stones and wood. Larger pieces were removed by hand and the remainder was sieved manually in shallow water to expose biota. Samples were separated manually by eye and immediately frozen. The procedure was successful in collecting large sample sizes of bivalves, small isopods, and benthic worms.

The MPA sub-areas are found within the inner-shelf region of the larger Beaufort Shelf. This area receives 100% seasonal ice scouring and/or ice grounding (Lewis and Blasco 1990; Blasco et al. 1998). Organisms have evolved to adapt to this annual scouring (Carmack and MacDonald 2002), and therefore the nearshore benthic community is replaced on an annual basis. Surveys should therefore be conducted as late in the open-water season as possible, to allow for maximum growth of the benthic community. The inner shelf zone is a relatively unstable benthic habitat (Loseto et al. 2010), and the spatiotemporal variability in benthic communities should also be considered in the sampling design.

Fish

A variety of methods are used to census fish populations (e.g., hydroacoustic assessment, baited traps, standardized trawls, net sets), and all approaches have associated biases that have to be considered (Polunin et al. 2009). Different methods have different strengths and weakness, and no single gear type will be able to meet all of the monitoring needs of the MPA. An index netting program could build upon current and past research conducted in the region, and include both scientific research projects and CBM. A number of fisheries research projects have been conducted or are on-going in the nearshore region. Many of the past field sites are found outside the MPA sub-areas but were located in the general vicinity. These studies provide baseline data and important information for survey plan development (e.g., Bray 1975; Percy 1975; Corkum and McCart 1981; Bond 1982; Lawrence et al. 1984; Bond and Erickson 1987, 1989; Harwood et al. 2008).

Trap-netting will be the most appropriate choice for monitoring the nearshore fish community. This method is relatively repeatable, will capture the greatest number of fish (and presumably the greatest species diversity), and allow fish to be sampled and then released alive with some retained for lethal sampling if needed (ensuring random selection of any fish killed). Trap nets are not the best way to sample all species of interest, and they will have to be supplemented with other gear types (e.g., gill nets) as appropriate and necessary.

The nearshore fish community was a particular focus of the ACES program and a variety of sampling methods were used. In 2010, combinations of shore- and vessel-based surveys were conducted (Walkusz et al. DFO unpubl. data). Shore-based sampling included trap-netting, gill-netting, and seining conducted using a 5.8 m inflatable Zodiac. Small trap nets were effective at capturing adult fish across a range of species and size classes, and seine deployments were mainly effective at capturing juveniles and small-bodied species. Shoreline and offshore gill nets were also deployed. Vessel-based sampling with a 3 m benthic beam trawl was hampered by equipment issues and safety factors. Juvenile fishes were also collected in the horizontal-tow zooplankton net. Seine nets were also hand-deployed from shore and towed alongshore manually for 20 to 50 m.

The primary objective in 2011 was to work with local fishers to collect samples and supporting biological data from subsistence gillnet catches (Loseto et al. DFO unpubl. data). This field program was run in conjunction with the Subsistence Fishery Harvest Monitoring (gill netting) and the Dolly Varden Char Projects, however, the main goals of the 2011 ACES program were to provide training to support long-term CBM and to evaluate indicators for cumulative impact monitoring. Overall, the 2011 sampling program met and in some cases exceeded target sample size goals for most major fish species. Some additional scientific sampling was conducted to supplement subsistence catches with a broader range of age/size classes and species. Catches in monitored subsistence gill nets were discontinuously distributed throughout the study area. Some fishers would consistently catch large numbers of Arctic Cisco, while others with similar nets in other locations would consistently catch nothing (Loseto et al. DFO unpubl. data). For effective monitoring of subsistence harvests, it is important to keep track of multiple fishers to collect accurate records of fishing effort, location, and fish harvested. It was also recommended that automated sensors be used for environmental measurements (e.g., salinity, temperature) at gill net deployments, as this would eliminate delays in collecting samples and speed up processing (L. Loseto, pers comm., DFO, Winnipeg). In order to monitor the success of the TNMPA the monitoring program should build upon other CBM-based projects and continue to expand the ACES program into other MPA sub-areas (e.g., fishing and Beluga monitoring to start in 2012 at the Okeevik MPA sub-area (L. Loseto, pers comm., DFO, Winnipeg)).

Marine Birds

Seabirds and waterfowl are identified in the CO for the TNMPA, and the development of effective monitoring tools is important. Seabirds are effective indicators for monitoring marine ecosystems (Diamond and Devlin 2003; Montevecchi 1993; Piatt et al. 2007). Marine birds and waterfowl fall outside of DFO's area of management responsibility, and external expertise is needed (e.g., Environment Canada, Government of the Northwest Territories, consultants) for survey development and data collection. Marine birds are large, mobile, highly visual, readily identifiable; local knowledge and observations can be an important source of monitoring for this species group.

A number of survey methods are available, and boat-based strip and line transects are most commonly used in monitoring for impact assessments (Witt et al. 2012). Aerial surveys have been used to monitor seabird populations in marine ecosystems (e.g., Certain and Bretagnolle 2008), but they would not be cost-effective for the small MPA sub-areas (they could be useful for offshore surveys in the greater Beaufort Sea region). It is possible for seabird observations to be collected during Beluga aerial surveys, but this increased effort will make data collection difficult. Surveys should be designed around the variable with the highest variance, so that this variance can be constrained to the greatest extent possible (Macleod et al. 2010). If the variance around seabird surveys is lower than that around marine mammal surveys, as was suggested by those authors, combined surveys will have to be optimized for Beluga. Combined marine mammal and bird surveys have been conducted from small vessels in Arctic regions (Diemer et al. 2011; S. Ferguson, pers. comm., DFO, Winnipeg), but boat-based Beluga surveys are not likely to be effective in the TNMPA (see Sighting Effort, Indicators 3.1.1 and 3.2.1). Dedicated surveys will be the most effective way to collect robust data in support of this aspect of the MPA CO.

Suitable options for dedicated marine bird surveys include boat-based transects or point counts. The Canadian Wildlife Service (CWS) has developed standardized protocols for pelagic seabird surveys from moving (e.g., fishing or seismic vessel) and stationary (e.g., oil rig, supply vessel on stand-by) platforms (CWS 2006, also see Gould et al. 1982 for a similar protocol). These protocols have been developed for offshore surveys on large platforms, but they can be applied to small-boat surveys in nearshore regions (e.g., Diemer et al. 2011). One of the biggest difficulties with using small boat platforms is the low height of the observer, which increases the difficulty of measuring distances (typically 300 m). Distances can be estimated during ship-board surveys using a slide caliper (CWS 2006), or 7 x 50 binoculars with reticle markings (Lerczak and Hobbs 1998; Kinzey and Gerrodette 2001; Moulton and Mactavish 2004).

Line transects (i.e., moving platform) and/or point counts (i.e., stationary platform) could be used for monitoring marine birds in the TNMPA. Static point count surveys could be conducted at established stations (e.g., the ACES 2010 stations, Figure 2), with on-effort line transects during transits between stations. One advantage of static stations is that observations could be conducted in conjunction with other monitoring programs, such as recording noise levels (see Anthropogenic Noise Indicator 6.1.1). Abundance estimates (by species, group, foraging guild, etc.) can be derived from moving or static data using standardized methods (Greenwood and Robinson 2006).

Surveys can also be conducted along shorelines, using either static counts or short walking routes. The British Columbia Coastal Waterbird Survey, a citizen-scientist monitoring program (Badzinski et al. 2006), is a useful starting point for protocol development. The Program for Regional and International Shorebird Monitoring (PRISM) (Bart et al. 2005) also provides important information for shorebird monitoring protocols. One advantage of shoreline surveys is that data on beached birds can also be included. Surveys of beach-cast birds provide important information for monitoring ecosystem health and impacts to seabird populations (e.g., oiling, net entanglement) (e.g., Wiese and Ryan 1999). Several on-going citizen-scientist programs can provide guidance on protocols, including the Coastal Observation and Seabird Survey Team (COASST) (Hamel et al. 2009; Litle et al. 2007) and the Seabird Ecological Assessment Network (SEANET) (Harris et al. 2006; Vargo et al. 2006).

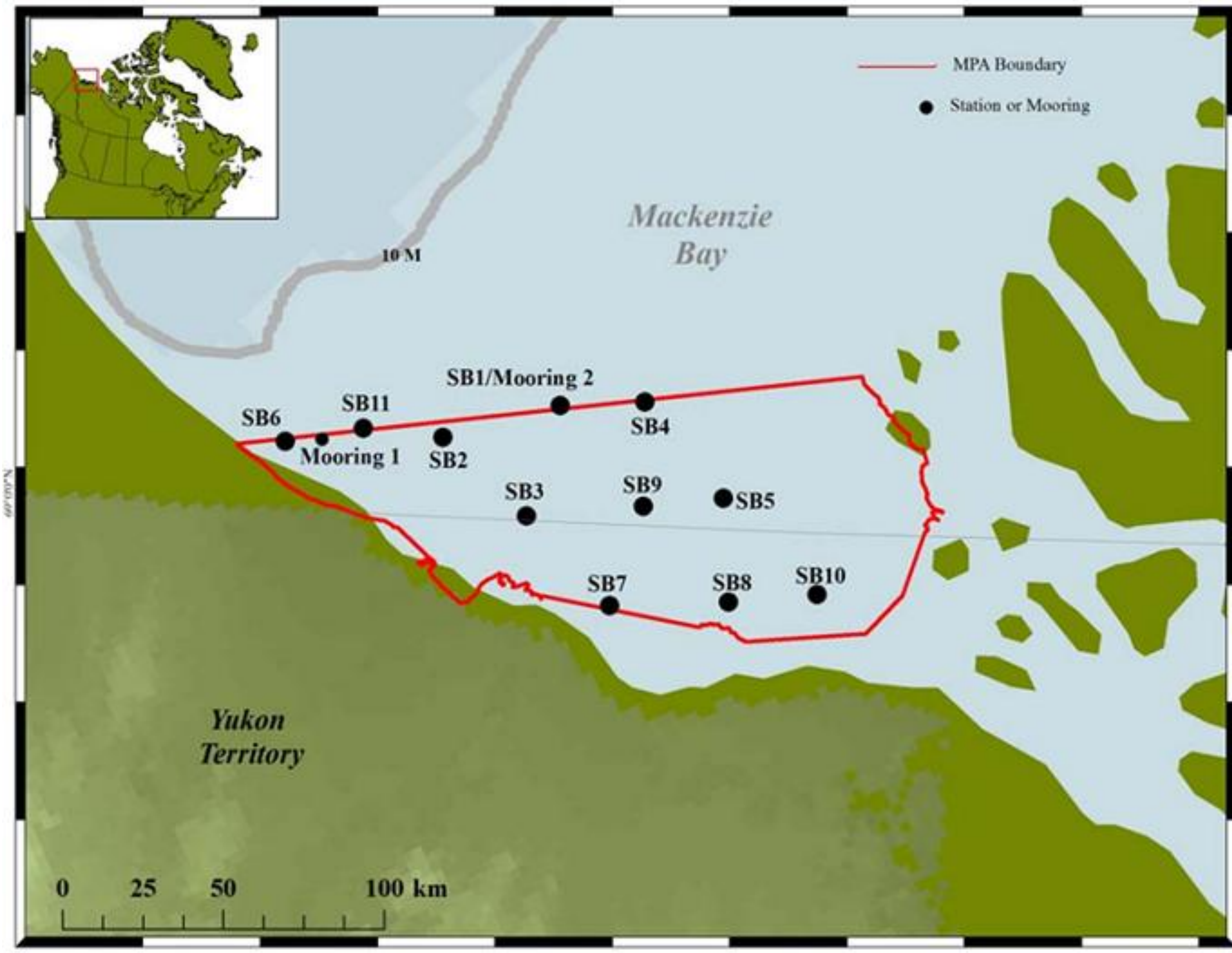

Figure 2. Sampling stations used by the ACES program in 2010 (from Walkusz et al. DFO unpubl. data).

Sighting Effort (Indicators 3.1.1 and 3.2.1)

Belugas are a species of considerable socio-economic, cultural and ecological interest in the Canadian Beaufort Sea, and Beluga conservation is a primary component of the CO for the TNMPA. The importance of Beluga to the region and its residents is reflected in the large volume of research conducted and the fact that two of the five selected indicators are directly linked to this species. Methods to monitor cetacean distribution and abundance are similar, and both indicators are therefore reviewed together in this discussion of protocols and strategies (see Loseto et al. 2010).

Strategy

A variety of tools are available for marine mammal sampling and monitoring (Macleod et al. 2010; Gill et al. 2011). The best choice of monitoring technique(s) for any situation will be determined by research objectives and priorities, local conditions, and the resources available. A coordinated monitoring effort for the TNMPA will likely require the use of multiple methods, many of which have been used, or are currently in use, in the local area (e.g., aerial surveys, satellite tagging, hunt sampling, acoustic monitoring, CBM). Macleod et al. (2010) reviewed mammal monitoring techniques, and noted that systematic sighting surveys are the standard for estimating density and abundance. Aerial surveys are generally more cost effective than ship-based methods because they cover large areas relatively quickly.

There is growing interest is the use of passive acoustic monitoring (PAM) as an alternative to visual detection methods. PAM detects cetaceans by the distinctive sounds they emit during communication, foraging and geolocation (e.g., echolocation clicks and whistles) (Mellinger et al. 2007). PAM can also be a cost-effective way to collect long-term, seasonal information on cetacean presence and relative abundance (Witt et al. 2012), but these methods have a number of caveats regarding data quality and usefulness and are unlikely to generate estimates of absolute abundance (Macleod et al. 2010). Options for PAM include echolocation (click) detectors (e.g., Bailey et al. 2010) and broadband recording devices. Broadband sound recording devices (e.g., Autonomous Underwater Recorder for Acoustic Listening-Model 2 (AURAL M2)) can also be used to collect data on Beluga and other marine mammals (e.g., Bowhead, seals) that fall outside the detection range of echolocation detectors. Units can be programmed to sample using flexible duty cycling to collect biological sounds over an extended period of time (e.g., months). These devices also provide important information on anthropogenic noise and the ambient sound field (see Anthropogenic Noise Indicator 6.1.1).

Protocol

Visual surveys combined with distance sampling techniques (Buckland et al. 2001) are the most statistically robust methods available for estimating cetacean abundance (Macleod et al. 2010). Loseto et al. (2010) suggested that these indicators could best be monitored using aerial surveys or from stationary sighting stations or boats, and the discussion focuses on these options. Beluga abundance and distribution in the MPA will best be monitored with aerial surveys, as there is an existing protocol and a long history of survey coverage (Loseto et al. 2010). Aerial surveys in the Mackenzie delta started in 1972 in response to oil and gas development, and survey lines were standardized in 1977 (Norton and Harwood 1986). Standardized survey lines (3 km or 5 km spacing) occur in all three TNMPA sub-areas (Figure 3). A large database on Beluga abundance and distribution is available from surveys conducted in 1977-1985 and 1992 (Norton and Harwood 1986; Harwood et al. 1996), and a summary of these surveys (L. Harwood, pers. comm., DFO, Yellowknife) will provide a comprehensive baseline for these two indicators. Continued trend monitoring will need to occur and surveys should be conducted for a 2-3 year period once every decade. Decadal-scale surveys should provide adequate power to detect trends in relative abundance (c.f., Macleod et al. 2010). Conducting surveys in successive years (2-3 year period) will provide important information on inter-annual variability. A survey is currently planned for 2013 that will repeat the aerial survey methods from in 1977-1985 and 1992 (L. Harwood, pers. comm., DFO, Yellowknife). Follow-up surveys for 2014 and 2015 could be planned so that the recommended temporal sampling scheme is maintained. It should be noted that monitoring of Beluga abundance and distribution will also need to consider a larger spatial scale than the TNMPA, and surveys should extend throughout the nearshore region (i.e., using the lines in Figure 3, Norton and Harwood 1986) and into the offshore region (e.g., 2007 surveys, L. Harwood, pers. comm., DFO, Yellowknife).

In addition to the aerial surveys that follow the standardized transect in Figure 3, sea-ice reconnaissance surveys will also be important when considering Beluga distributions in early spring, the timing of entrance into the Mackenzie Estuary and habitat use (Loseto et al. 2011b). This survey method uses a systematic zigzag approach along the ice edge in addition to a reconnaissance ice edge survey.

With respect to the methodology of aerial surveys, Macleod et al. (2010) suggest that double platform aerial surveys be given preference since data can be corrected for perception bias and used to calculate absolute abundance, with negligible cost differences. Such a design will be difficult however in the TNMPA, for reasons related to line spacing, water turbidity, and the large number of whales observed (i.e., difficult to collect angle readings given the “busy” nature of the surveys). However, these factors also assist in trend monitoring, as statistical power is usually better for relative abundance measures (versus absolute abundance), for abundant species, and in smaller survey areas.

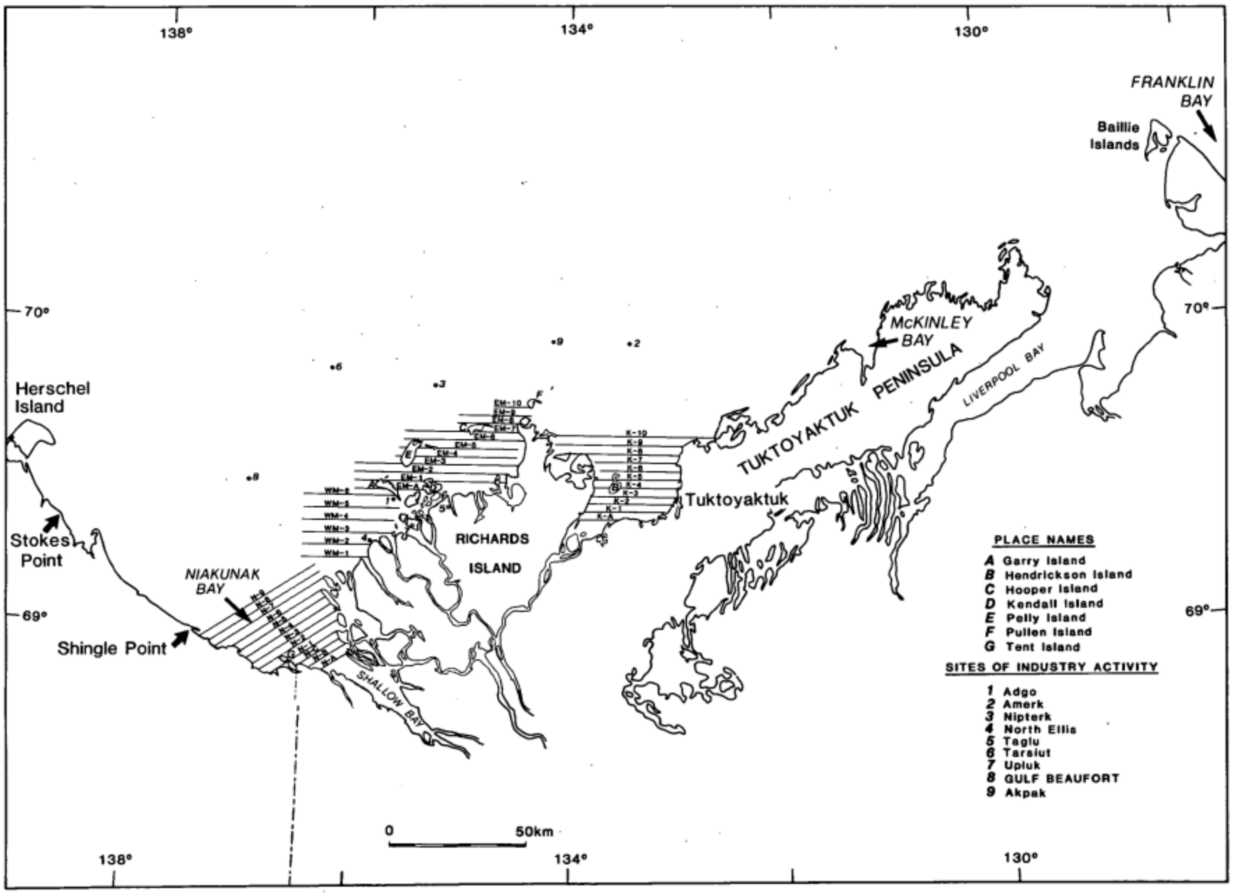

Figure 3. Standardized track lines for beluga aerial surveys in the Mackenzie delta (from Norton and Harwood 1986).

Boat-based surveys have been conducted for Beluga in other areas of the Arctic (e.g., Diemer et al. 2011). Small-boat surveys would provide increased local participation, and could allow additional data collection (e.g., focal follows for behavioural studies). Such methods are expected to be difficult in the TNMPA due to the high turbidity within the water column, and are considerably less effective than aerial surveys. Similarly, there are limited opportunities for shore-based surveys, using theodolites to track whale movements and potentially monitor boat disturbance and movement patterns.

Biological sampling of hunter harvests is another valuable monitoring tool for Beluga, and there is a long-running program in place at Hendrickson Island (Kugmallit Bay) that started in 1977 and was standardized in 1980 (Harwood et al. 2002). Hunter harvest monitoring (as currently conducted) will not provide information on sighting effort per se, but can provide valuable data on changes to Beluga reproductive biology and body condition. Another potential monitoring tool would be a CBM-based approach to measure catch per unite effort (CPUE) for Beluga harvesting activities (i.e., catch and/or sightings per unit effort, measured as hours of hunting effort). No hunter sightings have been recorded within the TNMPA to date, and such a CBM-based project would require training of observers and recorders (Loseto et al. 2010).

Options for PAM include echolocation detectors, which monitor Beluga clicks only, and broadband recording devices that, while more expensive, will collect a much wider range of data for monitoring. Beluga will echolocate in the shallow waters of the estuary, but detection range is short and clicks are highly directional. Click detection devices could have some future application to Beluga monitoring in the TNMPA, for example indication of Beluga feeding events, although more research on Beluga echolocation behaviour is required (E. Chmelnitsky, pers. comm., DFO, Winnipeg). Broadband devices are a better option (see Anthropogenic Noise Indicator 6.1.1), and they are currently being used in the TNMPA. The 2010 ACES field program collected acoustic data on Beluga in Shallow Bay (Walkusz et al. DFO unpublished data). Whale vocalizations and ambient noise were recorded using two methods. A portable hydrophone was deployed over the side of the Beaufort Explorer at each station (minimum of 30 minutes), with 12 recordings. An autonomous underwater recorder (AURAL M2) was also deployed with the eastern oceanographic mooring, which recorded continuously for a total of 152.5 hours (Chmelnitsky DFO unpublished report). The portable hydrophone kit was also opportunistically used during the Hendrickson Island (Kugmallit Bay) Beluga monitoring program when whales were seen in the area, and 24 recording tracks (10 minutes each) were made. In 2011 the AURAL was again deployed in Shallow Bay. The 2012 ACES program will deploy three AURALs, one in each MPA sub-area (L. Loseto, pers. comm., DFO, Winnipeg).

The CO for the TNMPA includes the conservation and protection of Beluga habitats and their supporting ecosystem. Studies should examine the relationships between environmental conditions (e.g., sea ice, sea surface temperature, bathymetry, primary productivity) and Beluga distribution to develop a baseline with continued trend monitoring following future surveys (see Loseto et al. 2010).

<u>Anthropogenic Noise (Indicator 6.1.1)</u>

A number of anthropogenic activities can impact marine habitats (e.g., resource extraction, effluent discharge, ocean dumping) and species (e.g., fishing, hunting, behavioural disturbance, noise), to varying degrees, directly or indirectly (see Jamieson and Levings 2001). There is increasing global recognition of the impacts of anthropogenic underwater noise on a range of marine taxa, including marine mammals, fishes and invertebrates (Horowitz and Jasny 2007; Slabbekoorn et al. 2010; André et al. 2011). Noise impacts include immediate, short-term disturbances, but also the possibility for chronic, long-term effects, depending on the frequency of noise, energy emitted, and species' auditory ranges (Slabbekoorn et al. 2010). The use of sound is critical to many aspects of marine mammal life history, and sound is used as a primary means for underwater communication (Wartzok and Ketten 1999). Anthropogenic underwater noise can interfere with many important biological functions, for example, affecting a whale's ability to detect the calls of conspecifics, forage, or navigate through their environment (NRC 2003, 2005; Southall et al. 2007). PAM of spectral noise levels should occur throughout the TNMPA and surrounding areas, and include ambient noise, ship and aircraft traffic, oil and gas exploration (e.g., seismic) and development, and Beluga vocalizations (Loseto et al. 2010).

<u>Strategy</u>

Monitoring of ocean noise in the MPA requires knowledge of both noise sources and background (ambient) noise levels (Hildebrand 2009). Knowledge of the ambient sound field is needed to assess impacts of anthropogenic noise on ecologically and culturally important marine mammals and fishes (Gill 2005; Slabbekoorn et al. 2010; Witt et al. 2012). In recent years there has been increasing recognition of noise impacts on marine wildlife, and global research efforts have similarly grown. Acoustic data are collected using a variety of platforms and deployment modes, including cabled, fixed autonomous, and mobile (drifting, towed, gliders, hand-held) systems.

For MPA monitoring, devices will need to record in a frequency band that captures cetaceans, ships, and ambient noise. The International Quiet Ocean Experiment (IQOE), a new program to describe ambient noise, is developing protocols to characterize ocean soundscapes and develop a baseline understanding of the global sound field (Boyd et al. 2011). The IQOE reviewed the frequency bandwidth used in fixed autonomous recorder deployments, using a variety of instruments, including AURALs. AURAL deployments typically record in the 1 Hz - 16 kHz or 1 Hz - 32 kHz frequency bands. For example, the ArcticNet research program deployed AURALs throughout the Canadian Arctic recording at a 1 Hz-16 kHz frequency range, and in 2010, AURALs deployed at Shingle Point within the TNMPA were recorded at a 32 kHz sampling rate. A minimum 10 kHz broadband for AURAL and other device deployments in the MPA is necessary based on the IQOE range of frequencies.

Protocol

PAM with broadband recording devices (AURALs) is currently being conducted in the TNMPA, as described above, and this work should be continued and expanded. Loseto et al. (2010) identified a number of research needs relevant to this indicator, including the development of an ambient noise baseline. On-going work will provide information on current noise conditions, and some historic information is also available. Beluga vocalizations and underwater industrial noises associated with dredging, artificial island construction and ship noise were recorded near the Kittigaryuit sub-area in the summer of 1976 (Ford 1977). Noise levels related to ship traffic and other activities were also recorded from 1980-1986 and the data may be available in Mackenzie Gas Pipeline reports (Loseto et al. 2010). Brouwer et al. (1988) summarized this industrial activity for the 1980-1986 period (seismic surveys, vessel movements, and site-specific activities).

An analysis and assessment of historical background noise data can be conducted, if archived data are available (Loseto et al. 2010). Information on historic shipping activity and port usage (Brouwer et al.1988; Chan et al. 2012) could be used as a proxy for noise levels. A history of vessel use within the TNMPA would provide important information on changes to noise levels over time. Such a history could include information on the types of vessels that use the MPA sub-areas (e.g., small locally-owned boats, barges, sealift) and changes in the size and type of vessels used over time (e.g., diesel versus gas, freighter canoes versus whale boats). Historical data may be available in anthropological and socio-economic studies and economic surveys which would also be a good opportunity for community-based research, including elder recollection of the history of local boat use and monitoring of current boating patterns in the area. Information on the number and size of ships operating in the TNMPA could be used with published information on sound generation to roughly calibrate anthropogenic activity with associated noise levels (Loseto et al. 2010).

Recording anthropogenic noise may be challenging in the TNMPA due to the shallow water, which results in poor propagation of low frequency noise (< 1 kHz) and reduced detection distance. Detection will also be influenced by ocean waves and wind that will create background noise. Loseto et al. (2010) suggested research to investigate whether sound transmission in the TNMPA is attenuated by shallow water and the muddy nature of the seafloor.

CONCLUSIONS

A total of 82 indicators have been developed for the TNMPA (DFO 2010a, b; Loseto et al. 2010), and five (Table 1) have been selected by DFO Oceans programs division for development of protocols and strategies to monitor the success of the CO. The CO for the TNMPA is to conserve and protect Beluga Whales and other marine species (anadromous fishes, waterfowl and seabirds), their habitats and their supporting ecosystem. Selected indicators relate to ecosystem structure and biodiversity (species lists and surveys), population structure and abundance of Beluga (sighting effort – distribution and abundance), and anthropogenic noise as an ecosystem stressor.

This report includes some general recommendations for a monitoring plan, information on other monitoring programs that are relevant to the TNMPA, and specific advice for each of the five selected indicators. Kenchington (2010) distinguished between data collection, where long-term standardization is imperative, and data analysis, which can and should be upgraded to new and better analysis methods as they become available. This document therefore emphasized sampling techniques and protocols, and not methods of data analyses. The level of development of the various protocols varies by indicator. For example, Beluga aerial survey techniques are well established, there is a wealth of internal (i.e., within-DFO) expertise, and an extensive baseline is available from past surveys. Conversely, there is little baseline data available for anthropogenic noise. Survey protocols will need additional development, but these must be refined based on management needs and stakeholder concerns (e.g., selection of focal species for surveys).

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