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# Proceedings of the Central and Arctic Regional Science Advisory Process to Select Indicators for the Tarium Niryutait Marine Protected Area (TNMPA)

**30-31 March and 13 April 2010**

**Freshwater Institute**
**Winnipeg, MB**

**Holly Cleator**
**Meeting Chairperson**

**Tanyss Wazny**
**Editor**

# Compte rendu du Processus de consultation scientifique régional du Centre et de l'Arctique concernant le choix d'indicateurs pour la zone de protection marine Tarium Niryutait (ZPMTN)

**les 30-31 mars et le 13 avril 2010**

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**Holly Cleator**
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**September 2010** | **Septembre 2010**

Canada

## Foreword

The purpose of these Proceedings is to document the activities and key discussions of the meeting. The Proceedings include research recommendations, uncertainties, and the rationale for decisions made by the meeting. Proceedings also document when data, analyses or interpretations were reviewed and rejected on scientific grounds, including the reason(s) for rejection. As such, interpretations and opinions presented in this report individually may be factually incorrect or misleading, but are included to record as faithfully as possible what was considered at the meeting. No statements are to be taken as reflecting the conclusions of the meeting unless they are clearly identified as such. Moreover, further review may result in a change of conclusions where additional information was identified as relevant to the topics being considered, but not available in the timeframe of the meeting. In the rare case when there are formal dissenting views, these are also archived as Annexes to the Proceedings.

## Avant-propos

Le présent compte rendu a pour but de documenter les principales activités et discussions qui ont eu lieu au cours de la réunion. Il contient des recommandations sur les recherches à effectuer, traite des incertitudes et expose les motifs ayant mené à la prise de décisions pendant la réunion. En outre, il fait état de données, d'analyses ou d'interprétations passées en revue et rejetées pour des raisons scientifiques, en donnant la raison du rejet. Bien que les interprétations et les opinions contenues dans le présent rapport puissent être inexactes ou propres à induire en erreur, elles sont quand même reproduites aussi fidèlement que possible afin de refléter les échanges tenus au cours de la réunion. Ainsi, aucune partie de ce rapport ne doit être considérée en tant que reflet des conclusions de la réunion, à moins d'indication précise en ce sens. De plus, un examen ultérieur de la question pourrait entraîner des changements aux conclusions, notamment si l'information supplémentaire pertinente, non disponible au moment de la réunion, est fournie par la suite. Finalement, dans les rares cas où des opinions divergentes sont exprimées officiellement, celles-ci sont également consignées dans les annexes du compte rendu.

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## SUMMARY

Under the *Health of the Oceans Initiative*, Fisheries and Oceans Canada (DFO) Science sector has been asked to provide advice on indicators and protocols for monitoring the conservation objective for the Tarium Niryutait Marine Protected Area (TNMPA). The conservation objective of the TNMPA is to conserve and protect Beluga Whales and other marine species (anadromous fishes, waterfowl and seabirds), their habitats and their supporting ecosystem. A science advisory meeting was held on 30-31 March 2010 and a follow-up meeting on 13 April 2010 to develop science advice on the selection of indicators and monitoring protocols for the TNMPA. Meeting participants included DFO Science and Oceans, Habitat and Species at Risk sectors and specialists from Natural Resources Canada, Fisheries Joint Management Committee and the universities of Manitoba and Dalhousie. The participants reviewed the proposed monitoring indicators and developed a new framework that contains 82 indicators. Recommendations for prioritizing the indicators were developed. It was decided that it was too early to develop monitoring protocols. They will likely be developed once DFO Oceans Programs Division decides which indicators they want to monitor. This proceedings report summarizes the relevant discussions and presents the key conclusions reached at the meetings.

The Science Advisory report and supporting research document resulting from the Advisory Meeting are being published on the DFO Canadian Science Advisory Secretariat Website at http://www.dfo-mpo.gc.ca/csas-sccs/index-eng.htm.

## SOMMAIRE

Dans le cadre de l'*Initiative pour améliorer la santé des océans*, on a demandé au secteur des Sciences de Pêches et Océans Canada (MPO) de formuler un avis sur des indicateurs et des protocoles permettant l'exercice d'une surveillance en regard des objectifs de conservation établis pour la zone de protection marine Tarium Niryutait (ZPMTN). L'objectif de conservation de la ZPMTN est de conserver et de protéger les bélugas et d'autres espèces marines (poissons anadromes, sauvagine et oiseaux marins), leurs habitats et les écosystèmes qu'ils habitent. Une réunion de consultation scientifique a eu lieu les 30 et 31 mars 2010; on a tenu une réunion de suivi le 13 avril 2010 pour élaborer des indicateurs et des protocoles de surveillance pour la ZPMTN. Parmi les participants à la réunion, mentionnons des représentants du secteur des Sciences du MPO et d'Océans, habitats et espèces en péril du MPO ainsi que de spécialistes de Ressources naturelles Canada, du Comité mixte de gestion de la pêche et des universités du Manitoba et Dalhousie. Les participants ont passé en revue les indicateurs de surveillance proposés et élaboré un nouveau cadre contenant approximativement 82 indicateurs. Des recommandations ont été formulées quant à l'ordre de priorité des indicateurs. On a convenu qu'il était trop tôt pour élaborer les protocoles de surveillance. Ceux-ci seront probablement élaborés lorsque le Programme des océans (MPO) aura choisi ses indicateurs de surveillance. Le présent compte rendu de la réunion résume les discussions pertinentes tenues au cours de cette réunion d'examen par des pairs et expose les principales conclusions formulées.

L'avis scientifique et les documents de recherche à l'appui produits au cours de la réunion de consultation scientifique sont publiés sur le site Web du Secrétariat canadien de consultation scientifique du MPO : http://www.dfo-mpo.gc.ca/csas-sccs/index-fra.htm.

## INTRODUCTION

Under the Health of the Oceans Initiative, Fisheries and Oceans Canada (DFO) Science sector has been asked by DFO Oceans Programs Division to provide advice on indicators and protocols for monitoring Marine Protected Areas (MPAs). In 1998, work leading to development of the Tarium Niryutait Marine Protected Area (TNMPA) began in the Beaufort Sea. The conservation objective (CO) of the TNMPA is to "*conserve and protect beluga whales and other marine species (anadromous fishes, waterfowl and seabirds), their habitats and their supporting ecosystem*". Development of indicators and monitoring protocols is necessary to demonstrate how effective the TNMPA is in achieving its conservation objective.

DFO Science held a meeting on 30-31 March 2010 with a follow-up meeting on 13 April 2010. The purpose of these meetings, as described in the Terms of Reference (Appendix 1), was to provide advice to DFO Oceans Programs Division on indicator selection and monitoring protocols for the TNMPA. Meeting participants (Appendix 2) included DFO Science, DFO Oceans Habitat and Species at Risk, Natural Resources Canada, Fisheries Joint Management Committee (FJMC) and universities of Manitoba and Dalhousie.

The meeting was convened at 8:30 AM on 30 March 2010. After a round of introductions, the Chair provided a brief introduction to the meeting. She explained that various experts within DFO Science had contributed to the development of a draft Research Document that outlined candidate indicators and monitoring strategies and protocols. The draft Research Document had been reviewed by Oceans Programs Division staff and comments have been provided to the meeting Chair. The purpose of the meeting was to peer review the draft Research Document and decide whether the proposed indicators and monitoring protocol were appropriate to monitor the CO of the TNMPA and, if not, to decide what work would need to be done to define appropriate indicators and monitoring protocols.

The Chair noted that the science advice resulting from the meeting would not include any socio-economic considerations.

## PRESENTATIONS

### TNMPA "ALL LIVING CREATURES IN THE OCEAN"

Presenter: Adrienne Paylor, DFO Oceans

TNMPA will be the first MPA to be designated in the Canadian Arctic. It was proposed as one of the first four pilot MPAs and has been over a decade in the making. It is hoped that TNMPA will be designated soon. Under the *Ocean Act*, MPAs are created to protect important fisheries, endangered species, unique habitats, high biodiversity and to fulfill the mandate of DFO.

The *Oceans Act* came into force in 1997 and allowed for the establishment of MPAs. The lack of guidelines for implementation created flexibility, but also some challenges. The Beaufort Sea Integrated Management Planning Initiative (BSIMPI) working group was asked to consider developing an MPA in the Mackenzie Delta under the *Oceans Act.* The Canadian Association of Petroleum Producers was also involved in the creation of the TNMPA, making it one of only a few MPAs in which industry has been involved from the start. DFO Oceans Programs Division also worked closely with local communities. Now it is necessary to define and clarify how we are going to protect the TNMPA.

The TNMPA was created in areas where Beluga Whales (*Delphinapterus leucas*) aggregate each summer in the southeastern Beaufort Sea and it consists of three separate and distinct sub-areas: Niaqunnaq (Shallow Bay), Okeevik (in Beluga Bay, east Mackenzie Bay near Kendall and Pelly Islands) and Kittigaryuit (Kugmallit Bay). The three areas are consistent with Zone 1a of the Beaufort Sea Beluga Management Plan, which sets out recommended guidelines and relies on voluntary compliance. All three areas within the TNMPA lie at the edge of the Mackenzie River Delta, within the Mackenzie River Estuary. With the Mackenzie Valley Gas Pipeline Project proposal there has been increased interest in the oil and gas potential of the area and pressure has been mounting to access these areas. MPA designation will provide regulatory protection for these important beluga aggregation areas and establish clear and consistent conditions and prohibitions to development activities.

Within the TNMPA, there are some pre-existing oil and gas rights, which created two different management zones. The Primary Protection Zone comprises 99% of the MPA. A Special Management Zone makes up the remaining 1% and is located in Okeevik to account for existing rights under Significant Discovery Licenses (SDLs). The TNMPA extends from the low tide water level down to 5 m in depth which is unique as most MPAs only extend down to 2 m.

Once the TNMPA has been designated, certain restrictions will be implemented to protect organisms and their habitat within the MPA and prevent activities that would cause disturbance. For example, within the Primary Protection Zone no oil & gas exploratory drilling or production facilities, mining of the sea bed, open water seismic or construction activities will be permitted. SDLs will be allowed within the Special Management Zone. Some exemptions will be allowed within the TNMPA: Inuvialuit harvesting; marine tourism; dredging for re-supply; licensed fishing; science and research; emergency, safety and sovereignty; and some hydrocarbon-related activities. MPA regulations ensure close scrutiny during the environmental assessment review process and serve to legislatively restrict the way these limited activities could be carried out in MPAs.

The FJMC, a co-management body within the Inuvialuit Settlement Region, will manage the TNMPA with input from communities and stakeholders and support from DFO. The TNMPA Management Plan will be revised on an ongoing basis. Monitoring will be based on the outcomes of this science advisory process while working with local resource managers and communities. The monitoring program will become part of the Management plan.

**SCIENCE ADVICE FOR THE TNMPA**
Presenter: Lisa Loseto, DFO Science

The presenter provided an overview of the first nine pages of the Research Document.

**TNMPA ecosystem and drivers**

The Mackenzie River is a defining feature of the Mackenzie shelf and estuary. The Mackenzie basin is approximately 1.8 million $km^2$ in size and includes parts of British Columbia, Alberta Saskatchewan, Yukon and Northwest Territories. The outflow from the Mackenzie River contributes 330 $km^3$/yr of freshwater to the Arctic (accounting for 60% of the Canadian contribution) and the largest source of suspended sediments.

The inner Beaufort Sea Shelf has little saltwater intrusion and is a freshwater lake where conditions are influenced by ice, flow and wind. The TNMPA has high turbidity and sediment loads that result in low light penetration, productivity and species assemblages at the lower trophic levels. Heavy ice

scouring also impacts the quality of benthic habitat. Waters within the TNMPA also have low zooplankton biomass but provide a nursery for anadromous/marine fishes.

The most recent population estimate for the Eastern Beaufort Sea Beluga Whale population is approximately 40,000. There are a number of hypotheses as to why belugas use the habitat in the TNMPA including calving, predator avoidance, moulting (by rubbing on the bottom) and feeding.

**Identification of threats**

Several threats, stressors and drivers affect the TNMPA. These include nearshore and offshore oil and gas development associated with the Mackenzie Gas Pipeline (MGP), exploration/seismic activities, climate change, contaminants, disease, ship traffic (noise), land-based activities, recreation and tourism and other activities such as subsistence hunting and fishing.

**Indicators for monitoring**

Various monitoring and research programs have taken place, or are underway, in the TNPMA and/or surrounding region to better understand the ecosystem, especially the biology and ecology of Beluga Whales, and processes associated with the physical and chemical environment. Prior to these recent studies other information was collected under the Northern Oil and Gas Action Program (NOGAP).

The overarching CO for the TNMPA is to protect Beluga Whales and marine species and their habitats and supporting ecosystems. The CO had undergone an “unpacking” exercise which created 30 specific sub-objectives of which five were selected by DFO and the FJMC. Experts within DFO Science were then asked to recommend potential indicators that would allow monitoring of the five sub-objectives. This process produced 35 candidate indicators included in the draft working paper circulated prior to the meeting.

A flow chart was presented (Figure 1) that summarized points relevant to the selection of appropriate and meaningful indicators for the TNMPA.

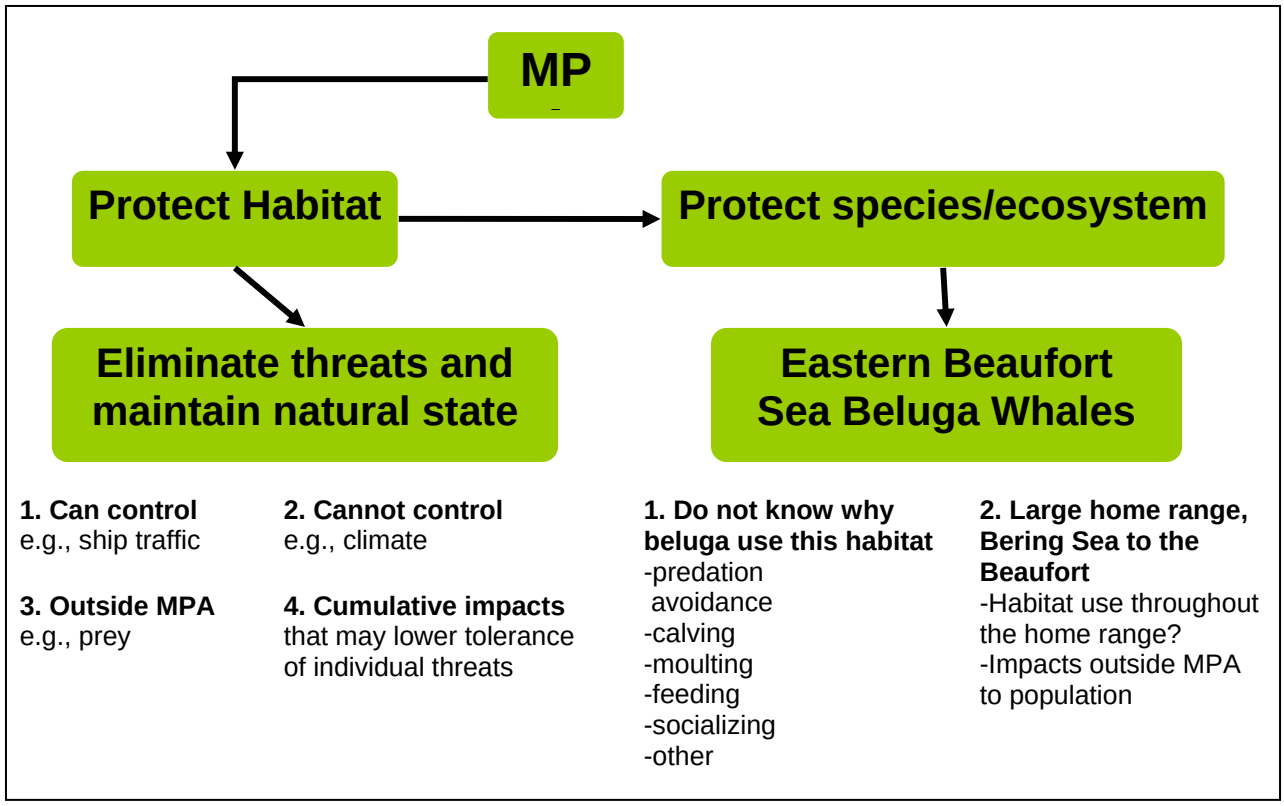


*Figure 1. Key points that relate to the TNMPA and are relevant to the selection of appropriate and meaningful indicators.*

## DISCUSSION

Suggestions were made for improvements to the Research Document during and following the presentation.

The Inuvialuit Final Agreement should be mentioned early in the document. A statement should also be included that traditional knowledge is not included in the Research Document but covered elsewhere.

### THE TNMPA ECOSYSTEM AND DRIVERS

Participants agreed this section should provide a brief summary of the current state of knowledge with TNMPA but identified that several key elements were missing. The TNMPA is strongly influenced by the Mackenzie River therefore more information about freshwater-terrestrial inputs to the TNMPA should be added. Information about early under-ice production, the bacterial portion of the food web, the importance of the light regime and how it is influenced by both inorganic and coloured organic material from terrestrial sources and how early production drives the system should also be included. An introduction to key fish species is missing. Hypothesis about why Beluga Whales use the TNMPA should also be added in this section.

## IDENTIFICATION OF THREATS

A number of suggestions were made regarding the threats section. Subsistence hunting and invasive species should be added as potential threats. Commercial fisheries in the Bering and Beaufort Seas should also be included as a threat because Beluga Whales spend nearly half the year in those waters where there are very large commercial fisheries. Diseases should include both endemic ones, that are already present and may become more prevalent and severe due to the effects of extrinsic stressors (e.g., climate change, oil and gas development and contaminants), as well as new diseases that will arrive with marine mammals from temperate areas moving further north in response to climate change. The Contaminants and Diseases category should include predators, parasites and competitors. Noise should be a separate threat category from shipping as it includes a range of sound sources.

Threats are not mutually exclusive thus they should be treated more as a web. For example, invasive species may arrive as a result of climate change. A short paragraph could be added to this section to address immediate versus short- or long-term threats. It was suggested that threats should be identified according to those that occur inside versus outside the TNMPA but participants decided that would be too difficult. Another approach would be to indicate whether threats were direct, indirect or cumulative for each indicator. At the most recent MGP meeting a primary recommendation was to establish a comprehensive aquatic monitoring program throughout the Mackenzie River and the Delta. A population model exists for marine mammals in certain regions. That should provide a starting point for how to address these cumulative impacts and their relationship to certain stressors.

Some threats can be controlled at the local level (e.g., noise resulting from anthropogenic disturbance) while others cannot (e.g., climate change). Participants indicated the need to monitor all threats to develop a more complete picture both inside and outside the TNMPA and to be more conservative about managing those that can be controlled. But in order to do this we need to demonstrate that there is a link between what we are controlling and what we cannot.

Prior to the meeting, Oceans Programs Division staff suggested developing a table to summarize each threat according to its level of risk and the time of year that it would be likely. This was not done during the meeting but would be a useful in the future.

## INDICATORS FOR MONITORING

Appropriate indicators are those that can measure changes and provide meaningful information about causation and response in relation to one or more stressors. The indicators must also provide useful information in relation to the five sub-objectives, which are components of the CO. Developing indicators is an iterative process. Another meeting may be needed in the future to reassess what the indicators are telling us, and if some need to be modified and/or new ones developed. Discussions about individual indicators should highlight what research needs to be done to make each indicator stronger and to understand cause and effect.

Participants agreed that indicators are needed to monitor the health of the Beluga Whale population.

There was some discussion about how to decide when a monitoring indicator should prompt a change in management to ensure that something is done before dangerous levels are reached. Appropriate indicators need to be developed first and then implemented, especially for those lacking baseline information. Threshold levels will be decided later.

The indicator screening table, that contained the original 35 candidate indicators, was presented as well as the four criteria and scoring regime. Participants discussed whether a new criterion should be added to measure the degree of connection between an indicator and the TNMPA CO, the five sub-objectives and a particular threat or change. It was decided it was possible to incorporate this element into the existing criteria. Participants discussed how to approach scoring the candidate indicators. The scientific expert(s) for a particular indicator would present their scoring recommendations for each criteria after which the rest of the group would discuss whether to accept or revise the suggested scores. It was noted that during the assessment process, the order and number of indicators may be revised. Deciding how to identify different elements in the evaluation table as an indicator, method, parameter or tool was discussed but no clear conclusions were reached.

The original candidate indicators 1-4 and 21-31 were scored based on in-depth discussions during which the criteria definitions and scores for the indicators were changed numerous times. These discussions identified several problems with the approach being used. The first four TNMPA CO sub-objectives were judged to be unattainable because we do not have the ability to “maintain” the biological and ecological components identified in those sub-objectives. It was decided to not use the five sub-objectives but instead to focus on the TNMPA CO. However the CO is quite broad, especially given the distribution of Beluga Whales and other potentially key species, so it is logical to monitor what is happening both inside and outside the MPA. The TNMPA is part of the much larger Canadian Beaufort Shelf ecosystem in the southeastern Beaufort Sea. Limiting the monitoring plan geographically to just the TNMPA would increase the likelihood of missing changing conditions and understanding why they are occurring and how to respond appropriately.

Participants also identified that the original 35 candidate indicators consisted of a mixture of ‘measures’ and ‘measuring tools’, along with duplicated and missing indicators and others that would benefit from lumping, splitting or re-grouping. The approach used to score the candidate indicators was found to be overly complicated, given the qualitative nature of the available information, and bogged down the evaluation process. It was thought that a better framework could be developed to present suitable indicators and how they relate to the CO.

A new table of indicators, which incorporated a hierarchical framework composed of a more detailed list of indicators, was developed (Appendix 3). Several guiding principles were used to develop the framework and indicators:

- an ecosystem-based approach that would permit monitoring at a spatial scale larger than the TNMPA in order to place findings from the TNMPA in proper context;
- a suite of indicators, not just one or two, to provide a better understanding of how, when and why key species use, and processes operate in, the TNMPA;
- a combination of indicators that relate to known threats to develop a more complete picture of how local and global stressors impact or drive processes in- and outside the TNMPA; and
- scientifically valid indicators that should provide useful information about the ecological health of the TNMPA.

Socio-economic and other considerations were given little weight in developing the framework and indicators.

Indicators were selected according to six main categories: ecosystem structure, ecosystem function, population structure of key species, heath of key species, the physical and chemical environment and noise and other physical stressors. Instead of scoring indicators, the table captured qualitative information about the current state of knowledge for each indicator, what work

needs to be done before it could be used and its priority level relative to other indicators in the table. A description of, and the rationale for, each indicator were not included in the table but are provided in Loseto *et al.* (2010). Most of the table was filled in during the March meeting based on information and advice provided by participants and group discussion. The section of the table related to the physical and chemical environment was filled in during a teleconference held on 13 April 2010. The follow-up meeting included a few of the March meeting participants and two key experts who were not able to attend the earlier meeting in person. Some information was added to the table by participants following the two meetings.

During the March meeting, key marine mammal and fish species within the TNMPA were identified for the indicators related to population structure and health: Beluga Whales, Ringed Seals (*Phoca hispida*), Broad Whitefish (*Coregonus nasus*) and ciscoes. Participants agreed that expert advice was needed to determine whether Ringed Seals should be included as a key species within the TNMPA. An expert, contacted following the meeting, confirmed that Ringed Seals occur in low densities within TNMPA, thus should not be considered a key species.

Several hypotheses have been posed to explain why belugas gather in the Mackenzie River Estuary, including the TNMPA, each summer. A number of the identified indicators would help to confirm what biological processes and/or habitat characteristics of the TNMPA are important for belugas.

Beluga Whales, Arctic Cod (*Boreogadus saida*) and Pacific Herring (*Clupea pallasii*) were identified as key species outside the TNMPA. Monitoring species and processes, and cross-ecosystem trophic sampling, on the Beaufort Sea Shelf would help to understand what is going on inside the TNMPA through linkages in the trophic structure between fishes and marine mammals, especially Beluga Whales. For example, cohort or vital rate analysis for Arctic Cod would help close the loop, though it may not be critical to understanding the MPA. The TNMPA monitoring program does not necessarily need to monitor all indicators, but participants thought it was useful to identify key indicators that should be monitored outside, as well as inside, the TNMPA. The TNMPA monitoring program should be integrated with similar activities that are or will be conducted, in some cases by other programs and organizations, in the Beaufort Sea Large Ocean Management Area (LOMA) and the Mackenzie River.

There was some discussion about who will acquire and analyze the data collected under the TNMPA monitoring program. Under the HOTO program, the directive from DFO Science managers in Ottawa is that Science will deliver advice on a scientifically sound monitoring design and Oceans will deliver the program. This exercise is not intended to put an extra burden on Science.

## HIGH PRIORITY INDICATORS

Participants prioritized indicators in the table on the basis of several factors. Scientific considerations were given most weight while recognizing that other factors come into play (e.g., logistics, finances, local community concerns/interest/participation). During the March meeting, highest priority was given to indicators that were directly related to beluga abundance and well-being, would build on research and monitoring efforts already underway, monitor several indicators through a single program, be non-invasive to target species and/or involve local communities. During the follow-up meeting on 13 April, the experts thought that priority should include all things that are relatively easy to measure and/or already being done. Four groups of indicators were identified as high priority (Appendix 3).

1. Indicators associated with the ongoing Hendrickson Island Beluga Study (HIBS)[1], including the proposed hunter sighting effort (Catch per Unit Effort) program, would provide useful ways to measure and monitor ecosystem structure, ecosystem function, and population structure and health of belugas in the TNMPA. It would be useful to have more than one sighting location to increase sample size and for comparison with other areas where similar aggregations occur to help explain why belugas use the TNMPA. Analyses using stable isotopes and fatty acids are highly informative about the food web and should be done at all levels of the trophic structure and should be started soon to establish baseline information on the environment.

2. Developing a fish sampling program within the TNMPA similar to the HIBS is needed. All indicators associated with the fish sampling program would provide useful ways to measure and monitor ecosystem structure, ecosystem function, and population structure and health of other key species in the TNMPA. Resources would be required for training, outreach and collection to educate people at fishing camps about how to collect samples and data. The Program would also need to partner closely with the FJMC, as is done for the Beluga Monitoring Program. Indicators for ciscoes would depend on identifying them to species. A complete list of fish species that occurred within TNMPA historically could be prepared quite easily based on latitude/longitude coordinates.

3. Basic measures of the physical and chemical environment are also needed. Indicators related to the timing of sea ice break-up, physical and biochemical oceanographic parameters, sea bed morphology and sediment mobility are considered to be the highest priority. A community program, that included schools, could be implemented.

4. Finally, monitoring anthropogenic noise in the TNMPA should be considered a high priority since it will be the first thing to change once the area is developed As belugas are highly vocal, their acoustic environment is likely important to their well-being. A bottom sensor to monitor acoustic disturbance could also be used to monitor physical and chemical attributes of the environment (e.g., temperature and salinity).

Indicators included in the table were, for the most part, those that would be monitored during the open-water season when beluga are present. The winter period should also be monitored as what happens during the cold season affects what happens during warmer months. Local communities could monitor during winter while travelling in the area. This point should be noted in the Research Document.

Some participants mentioned the need to monitor indicators every one to two years on an ongoing basis. Specific monitoring protocols can be developed in the future once decisions have been made by DFO Oceans Programs Division about which indicators they want to monitor.

**LITERATURE CITED**

Loseto, L., T. Wazny, H. Cleator, B. Ayles, D. Cobb, L. Harwood, C. Michel, O. Nielsen, J. Paulic, L. Postma, P. Ramlal, J. Reist, P. Richard, P.S. Ross, S. Solomon, W. Walkusz, L. Weilgart and B. Williams. 2010. Information in support of indicator selection for monitoring the Tarium Niryutait Marine Protected Area (TNMPA). DFO Can. Sci. Advis. Sec. Res, Doc. 2010/094. vi + 45 p.

[1] HIBS is an umbrella program that brings together research and monitoring programs conducted by DFO, FJMC BHMP and academia.

**APPENDIX 1: TERMS OF REFERENCE**

# Terms of Reference

# Advice on Indicator Selection and Monitoring Protocols for the Tarium Niryutait Marine Protected Area

**Regional Advisory Meeting (Central and Arctic)**
Freshwater Institute, Winnipeg, Manitoba

8:30 a.m. to 4:30 p.m. (Central Daylight Time) on March 30-31, 2010

Chair: Holly Cleator

## Background

Under the *Health of the Oceans Initiative*, Fisheries and Oceans Canada (DFO) Science sector provides advice in support of the management of Marine Protected Areas (MPAs). This includes identification of indicators, protocols and strategies that are to be incorporated into MPA monitoring plans. The identification of such indicators, protocols and strategies are to be based upon the regulatory conservation objectives set out for each particular MPA. The conservation objective of the Tarium Niryutait MPA (TNMPA) will be to conserve and protect beluga whales and other marine species (anadromous fish, waterfowl and seabirds), their habitats and their supporting ecosystem. The Tarium Niryutait MPA will strengthen, and complement the Beaufort Sea Beluga Management Plan (BSBMP) objectives, to ensure the long-term sustainable management of one of the world's larges summering stocks of beluga whales and their habitat. The proposed MPA would also support harvesting traditions central to the Inuvialuit culture in the communities of Aklavik, Inuvik and Tuktoyaktuk.
To aid in the development of indicators, the conservation objective was 'unpacked' into thirty sub-objectives. Five of these were chosen by the Fisheries Joint Management Committee (FJMC) and DFO to focus on because they relate to protection of the beluga population, the primary reason for establishing the TNMPA.

1. To maintain the spatial, temporal and annual variability of the beluga population.
2. To maintain the health and well-being of the beluga population.
3. To maintain the trophic structure.
4. To maintain the natural range of variability of the physical oceanographic features.
5. To minimize noise disturbance.

Monitoring biological and ecological indicators (and their respective threats) is essential to (a) developing a broader MPA monitoring program (which would include socio-economics), (b) tracking status, condition and trends to determine if the MPA is effective in achieving its conservation objectives, (c) aiding managers in the adjustment of the MPA management plan to achieve its conservation objectives and (d) reporting to Parliament and Canadians.

Selection of indicators and protocols for collection and analysis of data must be scientifically defensible. Science monitoring products are not intended to address non-biological/ecological aspects of monitoring (with the exception of threats as presented by human activities) so social,

economic or cultural indicators will not be examined. However, the creation of the MPA was largely based on community and co-management interests, thus indicators selected and the associated monitoring strategy must consider methods appropriate for both community-based participation and decision making.

## Objectives

The overall objectives of the meeting are to provide advice on indicators, protocols and/or strategies appropriate to monitor the beluga population and ecosystem health to assess whether the conservation objective for the Tarium Niryutait MPA is being met.

## Products

The Regional Advisory meeting will generate a proceedings report summarizing the deliberations of the participants. This will be published in the Canadian Science Advisory Secretariat (CSAS) Proceedings Series on the CSAS website. The advice from the meeting will be published as a Science Advisory Report and the working paper reviewed at the meeting, which provides the support for the advice, will be published as a CSAS Research Document.

## Participation

DFO Science, Oceans Habitat and Species at Risk, Fisheries and Aquaculture Management sectors, Fisheries Joint Management Committee and academia are invited to this advisory meeting.

## APPENDIX 2: MEETING PARTICIPANTS

| Name | Affiliation | E-mail |
|---|---|---|
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[2] Unable to attend meeting but provided review of documents before and after meeting.

## APPENDIX 3: TABLE OF INDICATORS

Table of indicators created during the 30-31 March and 13 April meetings. High priority indicators are highlighted in yellow.

| Species | Indicator | | Purpose | Historical information | Work needed |
|---|---|---|---|---|---|
| **1.0 ECOSYSTEM STRUCTURE** (shifts in trophic pathway) | | | | | |
| All | 1.1 Biodiversity | | | | |
| | 1.1.1 | Species lists | Measures biodiversity/ species richness by taxonomic group. | A species list was started for TNMPA (B. Stewart, unpubl. data). Current status of information varies by taxonomic group: completed for marine mammals, good information available for pathogens and fishes, not completed yet for benthos, phytoplankton or zooplankton. Seasonal information may be available for fish species within TNMPA. | Complete species lists for benthos, phytoplankton and zooplankton. Conduct desk analyses to determine extent of remaining work to develop lists for pathogens and fishes. Compare species lists spatially (in- versus outside the TNMPA) and temporally if/when information available. |
| | 1.1.2 | Biodiversity indices | Measures biodiversity/species richness by functional groups and/or ecosystem. | See indicator 1.1.1. Baseline information available for some taxonomic groups (e.g., fishes) but not yet analyzed from this perspective. | Perform computations to develop biodiversity indices by functional groups and/or ecosystem. Compare indices spatially (in- versus outside TNMPA) and temporally if information available. Assess levels of information by taxonomic group. |
| | 1.1.3 | Genomic and genetic analyses | Identifies invasive species and viruses. | Genomic testing is still in early development and has not been widely applied within the region, with the exception of the microbial community within the inshore portion of the Stamukhi lake. | Gather samples/data to investigate usefulness of genomic analyses for assessing biodiversity within TNMPA. |
| | 1.1.4 | Occurrence of unusual species | Identifies the arrival of competitors, predators, parasites and others. | Higher trophic level completed using historical information from observers. Several unusual species have been reported in recent years: Pacific salmon, Killer Whales, Stellar Sea Lions, Grey Whales and harmful algal blooms. Zooplankton paper nearing publication. | Enhance outreach to compile sighting information, at least for higher-trophic species, from communities. |
| | 1.1.5 | Surveys | Maps species use of specific habitat(s). | Some baseline data available for belugas within the TNMPA. Little distribution data available for other taxa. | Conduct surveys to map the distribution of species within the TNMPA and monitor for shifts in distribution. |

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| **All** | 1.2 Trophic structure | | | | |
| | 1.2.1 | Stable isotopes | Provides information about trophic structure of ecosystem from predator focus. | Samples available from 1000+ fish (over long time period) and 100+ marine mammals. Some phytoplankton, ice algae and zooplankton samples and data available. Samples for benthos (limited number) and sediment were collected and analyses underway. | Analyse fish and marine mammal samples and data. Collect missing fish species and lower trophic species not yet sampled. |
| | 1.2.2 | Fatty acids | Provides information about energy transfer within ecosystem. | Samples and data available for marine mammals, fishes and invertebrates. Samples for phytoplankton, benthos and sediment were collected and being analysed based on priority needs. | Analyse fish samples. |
| | 1.2.3 | Contaminant tracers | Maps food web and trophic structure. | Analysis of mercury (Hg) and persistent organic pollutants (POPs) for much of food web already completed. Data available for some beluga tissues since 1981; consecutive annual sampling began in 2001. | Desk analyses of specimen data. |
| **2.0 ECOSYSTEM FUNCTION** (energy flow) | | | | | |
| **All** | 2.1 Diet | | | | |
| | 2.1.1 | Stable isotopes | Provides information about diet and food web. | Considerable work has been done to understand beluga diet. Information about inferred diets available for fishes, belugas, zooplankton and others. Stable isotope samples were recently collected from particulate matter, phytoplankton, zooplankton, benthos and sediment from outside of the TNMPA. | Update/revise prey information. Collect inferred diets for fishes, belugas and others. Analyse archived fish samples. Carry out food web analysis. |
| | 2.1.2 | Fatty acids | Provides information about feeding relationships and food composition (quantity and quality). | Much work has been completed to date to better understand beluga diet. Zooplankton samples recently collected outside of the TNMPA. | Lab analyses of many prey items and collection and analyses of samples for missing species. |
| **All** | 2.1.3 | Stomach and intestine contents | Identifies sources of food for species at higher-trophic levels. | Data from Beluga Whales have been collected over many years. Some genetic approaches are available to determine prey species which have not been used yet. Samples of Arctic Cod stomachs from Beaufort Sea awaiting analysis. Some larval fish stomach analysis has been completed. Many Ringed Seal stomachs have been collected and some analysed. An analysis of a Bowhead Whale stomach has been completed. | Collect beluga intestines to provide examination of consumed prey over longer residence time. A number of key fish species (historical literature) can be updated with the new samples or start new diet analyses for key species in the TNMPA. |

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| | 2.1.4 | Contaminant tracers | Provides information about diet, energy flow and productivity. | Analyses completed for Hg and POPs for much of the food web so relatively comprehensive contaminant database available for belugas. | Field sampling to introduce temporal trends data. Lab analyses to add to the database. Desk analysis of current data. |
| | 2.1.5 | Calorimetry | Measures energy in organisms. | Little work on zooplankton in the area surrounding the TNMPA has been completed. Some work done on fishes. | Update beluga-based Dynamic Energy Model. Expand work. Could likely conduct desk analysis for belugas. |
| | 2.2 Biomass in relation to trophic level/group | | | | |
| | 2.2.1 | Contaminant tracers | Measures biomass for different trophic levels/groups. | Analyses completed for Hg and POPs for much of the food web so relatively comprehensive contaminant database available for belugas. | Much work needed to develop a model for energy flow/biomass using contaminants data for belugas. No biomass information available for fishes, except for some anadromous species. A major research effort would be required. |
| | 2.2.2 | Remote sensing of primary production | Measures primary productivity. | This tool can be used outside TNMPA. Background information available for outside TNMPA. Very little information available from inside TNMPA (ground truthing information) and difficult to obtain due to high sediment loads. | Desk analysis of background information. |
| | 2.2.3 | Zooplankton biomass | Measures secondary (and indirectly primary) productivity. | Some work completed outside the TNMPA and a little within the TNMPA near Tuktoyaktuk. | Summarize available data collected in the near-shallow regions to understand biota and appropriate collection method. Conduct field studies in TNMPA and lab analyses to create reference library/database of organisms and their fatty acids to detect changes in zooplankton and their biomass. |
| | 2.3 Age, size and sex structure | | | | |
| | 2.3.1 | Size spectrum within and among species | Measures changes in sizes of individuals within a species and sizes of species within assemblages. | Historical baseline information rather poor within the TNMPA. | Assess methods used to collect samples and then conduct substantial desk analyses of existing data. Explore potential for longer term research and monitoring applications. |
| **All** | 2.3.2 | Chlorophyll size fraction | Provides measure of primary productivity for different size classes of phytoplankton. | Samples have been collected from outside TNMPA, within the region. | Field studies using chlorophyll detectors and lab analyses of results. |
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| 3.0 POPULATION STRUCTURE OF KEY SPECIES | | | | | |
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| Beluga | 3.1 Distribution | | | | |
| | 3.1.1 | Sighting effort | Provides information about distribution. | Aerial surveys conducted in Mackenzie River Estuary historically to document distribution and are currently the most reliable method. | Hunter sightings of belugas from boats could be possible community-monitoring project. Conduct desk analysis to assess feasibility and reliability of boat-based hunter sightings. If promising, develop standardized method. Would require training of observers/recorders. Evaluation of satellite imagery as a tool. |
| | 3.2 Abundance | | | | |
| | 3.2.1 | Sighting effort | Measures abundance. | Aerial surveys have been used historically to estimate abundance and are currently the most reliable method. | Possible community monitoring project to obtain sightings of belugas on a catch-per-unit-effort (CPUE) basis. Conduct desk analysis to assess feasibility and reliability of indicator. If promising, develop standardized method. Would require training of observers/recorders. Evaluation of satellite imagery as a tool. |
| | 3.3 Size structure | | | | |
| | 3.3.1 | Morphometric data | Provides measure of population structure. | Many samples and size structure data available from Fisheries Joint Management Committee (FJMC) Beluga Harvest Monitoring Program (BHMP); some data have been worked up. Harvest samples are limited and biased due to small catch and the targeted harvest (though consistent over time) which may reveal changes over 5-10+ years. Growth model developed for belugas in Beaufort Sea. | Desk analyses of current data and ongoing community-based field sampling. Update and refine harvest collection. |
| | 3.4 Sex structure | | | | |
| | 3.4.1 | Gender data | Provides measure of population structure. | Few samples available from the BHMP; some data have been worked up. Harvest samples are limited and biased due to small numbers of females taken. | Lab analysis of samples. Update and refine harvest collection. |
| | 3.4.2 | Biopsy sampling | Can be used to determine gender in live animals. | Biopsy sampling has not been conducted in TNMPA to date. | It is logistically difficult to get close to whales to dart and may be considered culturally inappropriate by Inuvialuit. |

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| **Beluga** | 3.5 Age structure | | | | |
| | 3.5.1 | Aged teeth | Provides measure of beluga population structure. | Many samples available from the BHMP; some data have been worked up. Data limited to larger males and a relatively small catch. | Lab analysis of BHMP samples. Update and refine harvest collection. |
| **Broad whitefish** | 3.6 Distribution | | | | |
| | 3.6.1 | Capture effort | Provides presence-absence information about distribution. | Considerable inferred information within the TNMPA and direct and inferred information outside the TNMPA. | Ask local people if Broad Whitefish are regularly encountered and where they set nets. Develop community-based program. Once established, conduct desk analysis and ground truth results against scientific data from elsewhere. |
| | 3.6.2 | Otolith microchemistry | Differentiates habitat use between wholly- versus partially-marine areas. | Some baseline information available. | Need baseline signatures for physical habitat, increased precision for otolith microchemistry and increased number of samples to become a workable monitoring tool. Substantial background research needed. |
| | 3.6.3 | Stable isotope analysis | Provides information on use of freshwater versus marine environments. | Some baseline information available. | Desk analysis of samples from previous programs. Collect new samples for current representation. |
| | 3.6.4 | Acoustic tagging | Provides information about distribution of live animals. | None within the TNMPA. | This indicator may be considered culturally inappropriate by Inuvialuit. |
| | 3.6.5 | Phenology of life history | Provides temporal information about arrival in TNMPA each summer. | Considerable inferred information within the TNMPA and direct and inferred information outside the TNMPA. | Collection of field data by community members. Program would have to be initiated each year before the arrival of Broad Whitefish. Desk analysis of data needed once the program is set up. Ground truth program results against scientific data from elsewhere. |
| | 3.7 Abundance | | | | |
| | 3.7.1 | Capture effort | Provides a measure of abundance. | Considerable inferred information within the TNMPA and direct and inferred information outside the TNMPA. | Ask local people if Broad Whitefish are regularly encountered and where they set nets to evaluate usefulness of this indicator within the TNMPA. If warranted, develop community-based program to collect data on net locations, size of nets, soak times, number of fish caught, etc. Once established, conduct desk analysis and ground truth results against scientific data from elsewhere. |

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| **Broad Whitefish** | 3.8 Size structure | | | | |
| | 3.8.1 | Morphometric data | Provides measure of population structure. | Virtually no information within the TNMPA. Substantial information has been collected outside the MPA since the 1970s, particularly in freshwater upstream locations (delta fisheries). Likely the number of samples has been lower since 2000. Most historical data represent unbiased scientific sampling versus harvest sampling which has known bias. | Develop sampling regime for local fishers' harvest within TNMPA. Once established, conduct desk analysis and ground truth results against scientific data from elsewhere. |
| | 3.9 Sex structure | | | | |
| | 3.9.1 | Gender data | Provides measure of population structure. | See indictor 3.8.1. | Develop sampling regime for local fishers' harvest within TNMPA. Once established, conduct desk analysis and ground truth results against scientific data from elsewhere. |
| | 3.10 Age structure | | | | |
| | 3.10.1 | Otolith aging | Provides information about relationship between size and age of fish. | See indictor 3.8.1. | Otoliths acquired mostly from research programs but not routinely aged. Field data collection and analysis of archived and new samples. |
| **Least Cisco and Arctic Cisco** | 3.11 Distribution | | | | |
| | 3.11.1 | Capture effort | Provides presence-absence information about distribution. | Considerable inferred information within the TNMPA and direct and inferred information outside the TNMPA. | Ask local people if ciscoes are regularly encountered and where they set nets. Develop community-based program. Would need to train harvesters as to how to distinguish between the two species. Once established, conduct desk analysis and ground truth results against scientific data from elsewhere. A shift in ciscoes (from Least Cisco to Arctic Cisco) within the TNMPA would reflect a shift toward more marine influences. |
| | 3.11.2 | Otolith microchemistry | Differentiates habitat use between wholly- versus partially-marine areas. | Some baseline information available. | Need baseline signatures for physical habitat, increased precision for otolith microchemistry and increased number of samples to become a workable monitoring tool. Substantial background research needed |
| | 3.11.3 | Stable isotope analysis | Provides information on use of wholly- versus partially-marine areas. | Some baseline information available. | Desk analysis of samples from previous programs. Collect new samples for current representation. |

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| **Least Cisco and Arctic Cisco** | 3.11.4 | Acoustic tagging | Provides information about distribution of live animals. | None within the TNMPA. | This indicator may be considered culturally inappropriate by Inuvialuit. |
| | 3.11.5 | Phenology of life history | Provides temporal information about arrival in TNMPA each summer. | Considerable inferred information within the TNMPA and direct and inferred information outside the TNMPA. | Collection of field data by community members. Depends on identifying ciscoes to species. Program would have to be initiated each year before the arrival of ciscoes. Desk analysis of data needed once the program is set up. Ground truth program results against scientific data from elsewhere. |
| | 3.12 Abundance | | | | |
| | 3.12.1 | Capture effort | Provides a measure of abundance. | Considerable inferred information within the TNMPA and direct and inferred information outside the TNMPA. | Ask local people if ciscoes are regularly encountered and where they set nets to evaluate usefulness of this indicator within the TNMPA. If warranted, develop community-based program to collect data on net locations, size of nets, soak times, number of fish caught, etc. Depends on identifying ciscoes to species. Once established, conduct desk analysis and ground truth results against scientific data from elsewhere. |
| | 3.13 Size structure | | | | |
| | 3.13.1 | Morphometric data | Provides measure of population structure. | See indictor 3.8.1. | Develop sampling regime for local fishers' harvest within TNMPA. Depends on identifying ciscoes to species. Once established, conduct desk analysis and ground truth results against scientific data from elsewhere. |
| | 3.14 Sex structure | | | | |
| | 3.14.1 | Gender data | Provides measure of population structure. | See indictor 3.8.1. | Develop sampling regime for local fishers' harvest within TNMPA. Depends on identifying ciscoes to species. Once established, conduct desk analysis and ground truth results against scientific data from elsewhere. |
| | 3.15 Age structure | | | | |
| | 3.15.1 | Otolith aging | Provides information about relationship between size and age of fish. | See indictor 3.8.1. | Otoliths acquired mostly from research programs but not routinely aged. Field data collection and analysis of archived and new samples. |

| 4.0 HEALTH OF KEY SPECIES | | | | | |
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| **Beluga** | 4.1 Demographic rates | | | | |
| | 4.1.1 | Sighting effort | Potential for monitoring demographic rates (e.g., birth and death rates and changes in age structure). | No historical information known. | Conduct desk analysis to assess and develop indicator. Initiating a community monitoring project would require training of observers/recorders. Same indicator could be used offshore outside the TNMPA to detect number or cow/calf pairs. |
| | 4.1.2 | Survivorship curves | Provides information about population status. | Published data (Luque and Ferguson 2009 as cited in Loseto *et al.* 2010). | Desk analysis needed to assess and develop indicator. |
| | 4.1.3 | Biopsy sampling | Measures hormone profiles. | Biopsy sampling has not been conducted in TNMPA to date. | It is logistically difficult to get close to whales to dart and may be considered culturally inappropriate by Inuvialuit. |
| | 4.2 Levels of nutrition and condition | | | | |
| | 4.2.1 | Blubber thickness | Measures energy reserves. | Measurements of blubber thickness have been collected since 2001 and through the BHMP. Baseline available for blubber thickness quantity and preliminary data about blubber quality. | Desk analysis of historical data and develop updated plan for examining geographical variability of blubber thickness. If sufficient calves/yearlings are taken during the harvest, could infer health of mother during lactation and gestation. |
| | 4.2.2 | Lipid classes | Provides measures of blubber quality. | Historical samples are available for analysis. | Analysis of previously collected samples to establish baseline. |
| | 4.2.3 | Blood screening | Measures various biochemical factors (e.g., vitamin levels). | Blood samples archived since BHMP began. Analyses of vitamins and hormones have been completed for the past three years. | Lab and data analyses needed. Understanding of acute and chronic drivers is necessary in order to interpret data. |
| | 4.2.4 | Fatty acids | Provides measures of physiological condition. | Fatty acid data are available since 2004. | Analysis underway. |
| | 4.2.5 | Chronic stress impacts | Measures stress levels. | Some samples currently being measured using new genomic techniques since 2008. | Method development and analyses using new genomic techniques to determine the application and use of specific gene arrays. Method development to determine whether other types of samples (e.g., sloughed skin samples, feces and beluga blows) can be collected within the TNMPA to look for indicators of stress. |

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| **Beluga** | 4.3 Inter-annual stability of diet | | | | |
| | 4.3.1 | Fatty acids | Provides measures of food availability, quantity and quality over time. | Some samples have been collected as part of harvest collections. Data analysis completed since 2004 and published to a large extent. Older samples are available to build a historical database. There has been a temporal sequence analysis. | Lab and data analyses of older samples (e.g., try matching potential prey items with diet). |
| | 4.3.2 | Stomach and intestine contents | Provides diet information and identifies preferred prey. | Samples have been collected through the BHMP over many years, though they tend to be empty. In addition, anecdotal information is available. | Desk analysis of historical data to establish baseline. |
| | 4.3.3 | Stable isotopes | Provides information about diet within past 3-6 months. | Samples have been collected and analysed annually since the 1980s; Some publications have been produced. There has been a temporal sequence analysis. | Need ongoing monitoring annually as funds are available. Important to match with food web analysis. |
| | 4.4 Body burden of contaminants | | | | |
| | 4.4.1 | Persistent organic pollutants and mercury | Provides information about health, diet and foraging ecology. | Contaminants measurements (e.g., POPs and Hg) for certain tissues exist for belugas within the TNMPA since 1981; consecutive annual sampling began in 2001. Similar data exist for belugas from other Canadian sites. New contaminants are now being analysed (e.g., fluorinated compounds); old samples are being re-examined to understand when they entered the food web. | Ongoing monitoring as funds are available. Need toxicity endpoints linking back to environmental factors and an understanding of how to use contaminants as a tracer. |
| | 4.4.2 | Toxic effects of contaminants | Provides measures toxic injury in the form of endocrine, immune, reproductive and neurological effects. | Work underway since 2007; in the early stages of measuring hormones and toxicological endpoints using genomic and traditional methods. Health-related data collections were initiated at Hendrickson Island (within the TNMPA) in 2008. | Desk analyses, some lab analyses and some method development involving a cross-section of techniques to provide better linkage between burden of contaminants and changes in surrounding environment. |

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| **Beluga** | 4.5 Incidence of diseases and parasites | | | | |
| | 4.5.1 | Harvest collection | Provides information about incidence of emerging infectious diseases. | Data from BHMP samples available since early 1990s. Archival tissue and blood is available for *Brucella* and distemper research. *Brucella* has been monitored for many years. | Develop operational plan for belugas harvested at Kendall and Hendrickson islands (in the TNMPA), by collecting samples through the HIBS, similar to the comprehensive Health Assessment model being developed in the U.S. and Europe for terrestrial and aquatic animals as part of individual Species Management Plans. Develop a health effects assessment, following new initiative by Americans whereby a veterinarian conducts an overall health assessment of individual animals, to help set a benchmark and streamline sampling, analysis and interpretation of results. Any monitoring program should include monitoring for distemper in harvested whales. |
| | 4.5.2 | Biopsy sampling | Potential for determining incidence of diseases and parasites. | Biopsy sampling has not been conducted in TNMPA to date. | It is logistically difficult to get close to whales to dart and may be considered culturally inappropriate by Inuvialuit. |
| | 4.5.3 | Physical restraint | Potential for determining incidence of diseases and parasites. | No data available in the TNMPA using physical restraint to determine incidence of diseases and parasites. Physical restraint has been used to tag whales in the Beaufort Sea. | Could take samples while live-capturing and tagging belugas, an established technique, depending on condition of the animal. However, this technique may be considered culturally inappropriate by Inuvialuit. |
| **Broad whitefish** | 4.6 Reproductive success and natural mortality | | | | |
| | 4.6.1 | Life table analysis | Provides information about vital rates. | No information available within the TNMPA; samples taken outside the MPA. | Extrapolation of comparable information available for Broad Whitefish from outside the TNMPA. Assess the value of a dedicated sampling program (netting) within the TNMPA to gather a suite of indicators on health. Age structure analysis likely not worth trying at the scale of the TNMPA. |
| | 4.7 Levels of nutrition and condition | | | | |
| | 4.7.1 | Length-weight relationships | Provides measure of condition in an individual and overall health of the population. | Much of the baseline information available is from more interior freshwater locations though some of the individuals sampled may be using the MPA. | Assess the value of a dedicated Broad Whitefish sampling program (netting) to gather suite of indicators on health. |

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| **Broad whitefish** | 4.8 Inter-annual stability of diet | | | | |
| | 4.8.1 | Stable isotopes | Provides information about diet within past 3-6 months. | See indicator 1.2.1. Temporal series of samples available from fish that likely fed in, or moved through, the TNMPA. | Analysis of previously collected samples to track averages and variability, and analysis of temporal series of samples to provide baseline understanding of this indicator. Collect new samples for current representation if needed. |
| | 4.8.2 | Fatty acids | Provides measures of food availability, quantity and quality over time. | See indicator 1.2.2. | Analyses of previously collected samples to track averages and variability. |
| | 4.9 Incidence of diseases and contaminant loads | | | | |
| | 4.9.1 | Burden of diseases | Provides information about incidence of emerging infectious diseases. | No information available within TNMPA. | Collection of samples by community members or science programs. |
| | 4.9.2 | Burden of contaminants | Provides information about health, food web and ecosystem processes. | See indicator 1.2.3. | Further analysis of archived samples and collection of more samples if needed. |
| **Least Cisco and Arctic Cisco** | 4.10 Reproductive success and natural mortality | | | | |
| | 4.10.1 | Life table analysis | Provides information about vital rates. | No information available within the TNMPA; samples taken outside the MPA. | Extrapolation of comparable information available for ciscoes from outside the TNMPA. Assess the value of a dedicated cisco sampling program (netting) within the TNMPA to gather a suite of indicators on health. Age structure analysis likely not worth trying at the scale of the TNMPA. |
| | 4.11 Levels of nutrition and condition | | | | |
| | 4.11.1 | Length-weight relationships | Provides measure of condition in an individual and overall health of the population. | Using length-weight relationships to assess condition in ciscoes within the TNMPA would integrate freshwater and mixed, and perhaps marine, inputs though it may be difficult to interpret the results. Much of the baseline information available is from more interior freshwater locations though some may be using the MPA. | Assess the value of a dedicated cisco sampling program (netting) to gather suite of indicators on health. |

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| Least & Arctic Cisco | 4.12 Inter-annual stability of diet | | | | |
| | 4.12.1 | Stable isotopes | Provides information about diet within past 3-6 months. | See indicator 1.2.1. Some data exist for ciscoes temporally, and additional archival samples may also exist, from fish that likely fed in, or moved through, the TNMPA. | Analysis of previously collected samples to track averages and variability, and analysis of temporal series of samples to provide baseline understanding of this indicator. Collect new samples for current representation if needed. |
| | 4.12.2 | Fatty acids | Provides measures of food availability, quantity and quality over time. | See indicator 1.2.2. | Analysis of previously collected samples to track averages and variability. Collect new samples for current representation if needed. |
| | 4.13 Incidence of diseases and contaminant loads | | | | |
| | 4.13.1 | Burden of diseases | Provides information about incidence of emerging infectious diseases. | No information available within TNMPA. | Collection of samples by community members or science programs. |
| | 4.13.2 | Burden of contaminants | Provides information about health, food web and ecosystem processes. | See indicator 1.2.3. | Further analysis of archived samples and collection of more samples if needed. |
| **5.0 PHYSICAL AND CHEMICAL ENVIRONMENT** | | | | | |
| | 5.1 Timing of sea ice break-up | | | | |
| | 5.1.1 | Distribution and properties of ice and snow, and effects of wind | Measures a suite of parameters related to timing of sea ice break-up which influences arrival of belugas in the TNMPA in summer. | Sea ice data obtained through remote sensing has been available since 1970s though temporal distribution was spotty; wider coverage started in 1993 and continuous ice data has been available since 1996. Data collection of offshore wind fields also obtained through remote sensing. | Continued annual monitoring of sea ice development and break-up within and adjacent to TNMPA and desk analyses to establish baseline. Data collection of offshore wind fields through remote sensing. Better integration of these data with beluga behaviour and hunt information to better understand linkage between ice break-up and beluga movement into TNMPA and key variables that should be monitored. |
| | 5.1.2 | Timing and mode of Mackenzie River discharge and ice break-up | Measures ice break-up and discharge in the Mackenzie River which influences movement of landfast ice in the TNMPA and, thus, arrival of belugas in summer. | Mackenzie River discharge curves have been measured year-round for a number of years. Real-time water surveys have been conducted throughout the Mackenzie River Delta. | Ongoing measurement and analysis of discharge curves. Better integration of these data with TNMPA sea ice break-up data. |

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| 5.2 Physical and biochemical oceanographic parameters | | | | |
| 5.2.1 | Currents, temperatures, salinities, sediment loads, dissolved oxygen and chlorophyll *a* | Measures a suite of parameters related to oceanographic processes in the TNMPA that impact belugas and/or other components of the food web. | Almost no historical data available to use as a baseline. There are moorings in place near Kendall Island. Some historical data available for outside of the TNMPA: one mooring is located at the mouth of Kugmallit Bay in 15 m and another elsewhere in the Mackenzie delta. | Collect data during open water season using one sensor mooring per TNMPA sub-area and a "deep water" mooring (e.g., 20 m depth) outside the TNMPA. Remote sensing could measure turbidity and mixing. Use data in oceanographic models. Integrate results with biological/ecological information for TNMPA to better understand linkages between them. |
| 5.3 Sea bed morphology, sediment mobility and contaminant loadings | | | | |
| 5.3.1 | Bathymetry, substrate morphology and texture, coastline dynamics | Measures a suite of parameters related to the seabed that may affect use of the TNMPA by belugas or their prey. | Bathymetric information is 40 years out of date. | Develop baseline maps of seabed morphology (e.g., ice scourings, bedforms, ripple marks, hummocky beds), bathymetry, texture and mobility to provide inputs into models of oceanographic behaviour. Compare seabed maps with beluga use of the TNMPA to investigate possible relationships. Develop protocols for community-based coastal erosion monitoring program within TNMPA. |
| 5.3.2 | Burden of contaminants | Provides estimates of contaminant loads in sediments to aid in monitoring ecosystem health. | A baseline was attempted during the Northern Oil and Gas Action Program (NOGAP). Sediment samples are available from the Nahidik program that could be used for analysis. | Representative samples and cores should be obtained prior to start of significant industrial development to develop baseline. |
| 5.4 Sea level and tides | | | | |
| 5.4.1 | Sea level trends and tidal gauge measurements | Measures sea level change. | Tides have been measured at Tuktoyaktuk since the 1960s, except between 1998 and 2003. Velocity could be measured from tidal measurements. | Maintenance of tide gauge at Tuktoyaktuk. Collection of data on short-term water level fluctuations in the two western TNMPA sub-areas. |
| 5.5 Meteorology | | | | |
| 5.5.1 | Wind, temperature, humidity and radiation | Measures a suite of parameters that drive oceanographic conditions and associated seabed. | Automated weather stations collected data at Shingle Point and Tuktoyaktuk since the 1950s (stopped at Shingle Point in 1992) and at Pelly Island since 1994. | Maintenance of the automated weather stations and data collection of offshore wind fields through remote sensing. |

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| **6.0 PHYSICAL DISTURBANCE REGIMES** | | | | | |
| | 6.1 Noise | | | | |
| | 6.1.1 | Anthropogenic noise | Provides information about noise-related stressors that could disrupt beluga behaviour. | Underwater industrial noise recorded outside TNMPA in Beaufort Sea in 1976 (Ford *et al.* 1977 as cited in Loseto *et al*. 2010). Background noise levels of ship traffic recorded between 1980 and 1986 in vicinity of TNMPA. | Desk analysis of historical background noise data (Mackenzie Gas Pipeline reports). Try to roughly calibrate the number and size of ships operating with associated noise levels. Investigate use of recording data obtained from the Canadian Arctic Shelf Exchange Study (CASES) program. Investigate the potential to link the Automatic Identification System with vessel noise recorded by passive acoustic monitoring (PAM) bottom sensors. Investigate sound transmission in the TNMPA. Research should be extended outside the TNMPA to look for cumulative effects. |
| | 6.1.2 | Beluga vocalizations | Measures beluga vocalizations to assess potential impacts of anthropogenic noise. | Research on beluga vocalizations conducted outside TNMPA in Beaufort Sea in 1976 (Ford *et al.* 1977 as cited in Loseto *et al*. 2010). | Desk analysis of available literature to determine if beluga vocalizations are correlated with anthropogenic noise and whether collection of field data is required. If so, deploy PAM bottom sensors. Investigate possibility of correlating beluga echolocation with changes in their behaviour or changes in the physical environment. |
| | 6.2 Response to stressors | | | | |
| | 6.2.1 | Behaviour | Measures behavioural responses of belugas to potential stressors. | No historical information available for the TNMPA but two recent studies related to seismic activity (Ford 1977 and Millar *et al*.2005, as cited in Loseto *et al.* 2010), were conducted offshore of the TNMPA. | Assess the value of this indicator in the TNMPA and the logistical feasibility of available tools (e.g., aerial observations, D-tags, auditory brainstem response, hormone information from blow). |
| | 6.2.2 | Stress levels | Measures stress levels in relation to potential stressors. | Some samples currently being measured using new genomic techniques since 2008. | See indicator 4.2.5. Ongoing data collection may identify whether stress levels in belugas are increasing/changing over time within the TNMPA. It may be difficult to link stress levels with specific cause(s) of stress. It may be possible to correlate stress levels to presence or intensity of a stressor. |

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| | 6.2.3 | Injury or death | Measures extent of injury and manner of injury or death in belugas. | Post mortem examinations have been conducted on an intermittent case-by-case basis, on abnormal, stranded and "sick" belugas identified by hunters. | Develop baseline knowledge of pathologies and new diseases that may be present in harvested belugas for valid comparison with conditions and pathologies found in stranded animals. Develop health assessment method to determine whether live stranded belugas can be assessed for injuries/pathologies without involving difficult and invasive techniques which may be considered culturally inappropriate by Inuvialuit. |