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Central and Arctic Region

Canadian Science Advisory Secretariat
Science Advisory Report 2015/025

ANGUNIAQVIA NIQIQYUAM AREA OF INTEREST: MONITORING INDICATORS, PROTOCOLS AND STRATEGIES

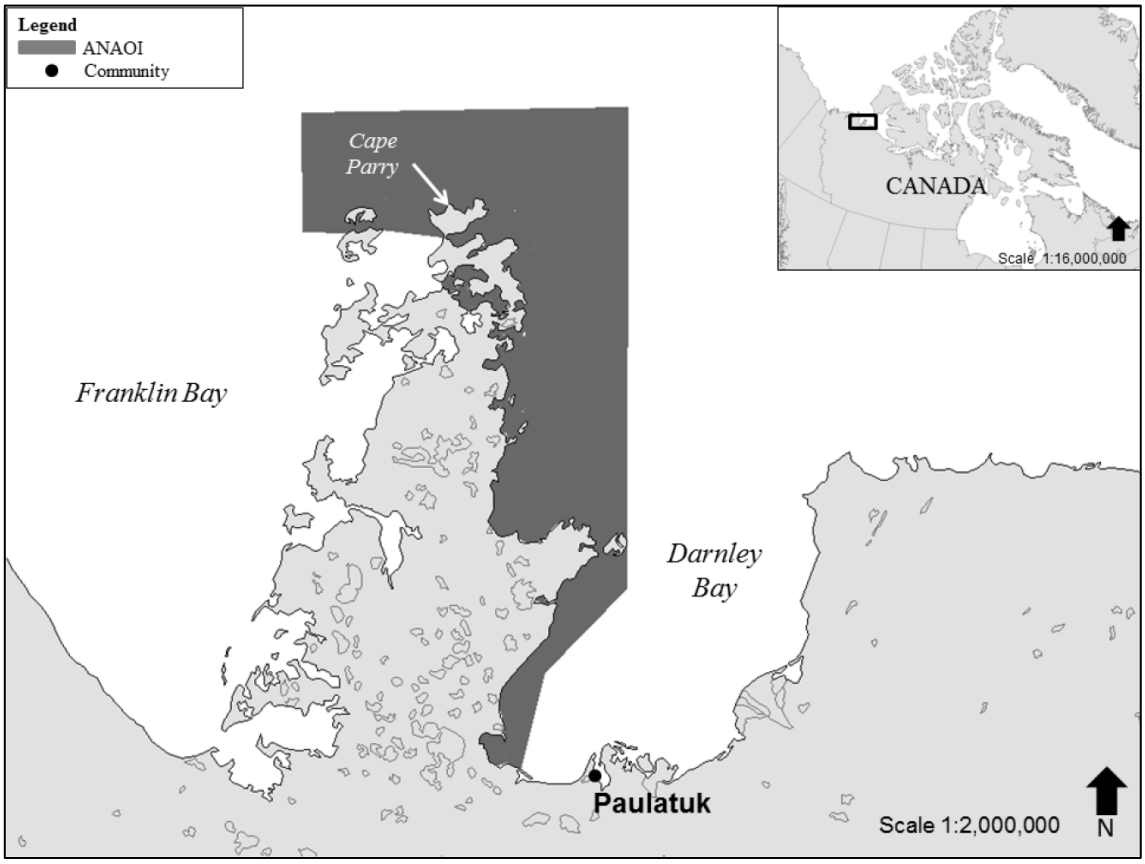

Figure 1. Map with the Anguniaqvia Niqiqyuam area of interest identified in charcoal.

Context:

Under the Health of the Oceans initiative, Fisheries and Oceans Canada (DFO) Science is required to provide support and advice on Marine Protected Areas (MPAs) to DFO Oceans Management. Currently, this includes the identification of indicators, protocols and strategies that are to be incorporated into MPA monitoring plans. Indicators, protocols and strategies are intended to allow DFO to evaluate whether the regulatory conservation objectives (COs) are being met for an MPA. Darnley Bay is located in the western Canadian Arctic within the Beaufort Sea Large Ocean Management Area and the Inuvialuit Settlement Region. A portion of Darnley Bay was nominated as an Area of Interest and is called the Anguniaqvia Niqiqyuam Area of Interest (ANAOI). For the ANAOI, one of the COs is "to maintain the integrity of the marine environment offshore of the Cape Parry Migratory Bird Sanctuary (MBS) so that it is productive and allows for high trophic level feeding by ensuring that the Cape Parry polynyas and associated sea-ice habitat, and the role of key prey species (e.g., Arctic Cod), are not disrupted by human activities.". DFO Science has been asked to provide advice on indicators, protocols and strategies to evaluate the CO for Cape Parry.

December 2015

SUMMARY

- Criteria should be followed for selecting appropriate indicators for monitoring the Cape Parry conservation objective (CO) and for establishing an effective monitoring program.
- The Cape Parry CO was broken down into its key components and two types of indicators were identified based on these elements.
- Thirteen ecological indicators were selected to directly evaluate the Cape Parry CO and five ecological indicators were selected to provide fundamental background environmental context for the Cape Parry ecosystem.
- Information on data availability, associated costs, and potential for community monitoring, monitoring methods, relevance to the CO, sensitivity and informativeness was provided for each indicator, to give additional context.
- The selected indicators are directly linked to the identified CO and are appropriate for monitoring the ANAOI ecosystem.
- The selected indicators already represent a prioritized short list of all possible indicators appropriate for monitoring the Cape Parry CO; if further prioritization and reduction in the number of indicators is required, additional scientific input is essential.

BACKGROUND

Darnley Bay is situated in the western Canadian Arctic within the Beaufort Sea Large Ocean Management Area (LOMA) and the Inuvialuit Settlement Region (ISR). The community of Paulatuk, Northwest Territories is located on the southern shores of Darnley Bay. In 2010, under the *Oceans Act*, Fisheries and Oceans Canada (DFO) Oceans program and a Marine Protected Area (MPA) steering committee nominated an Area of Interest in Darnley Bay, referred to as the Anguniaqvia Niqiqyuam Area of Interest[1] (ANAOI; Figure 1). The area is now being considered for designation as a MPA under the *Oceans Act*.

Conservation Objective

An ecosystem overview report was developed for the ANAOI (Paulic et al. 2012) and four priority areas were identified for marine protection (DFO 2011). The focus of the current report is the Cape Parry Offshore Marine Feeding Habitat (Figure 2), herein referred to as the Cape Parry priority area. The Conservation Objective (CO) for the area is as follows:

> "to maintain the integrity of the marine environment offshore of the Cape Parry Migratory Bird Sanctuary (MBS) so that it is productive and allows for high trophic level feeding by ensuring that the Cape Parry polynyas and associated sea-ice habitat, and the role of the key prey species (e.g., Arctic Cod), are not disrupted by human activities" (DFO 2011).

[1] The area was previously identified as the Darnley Bay Area of Interest.

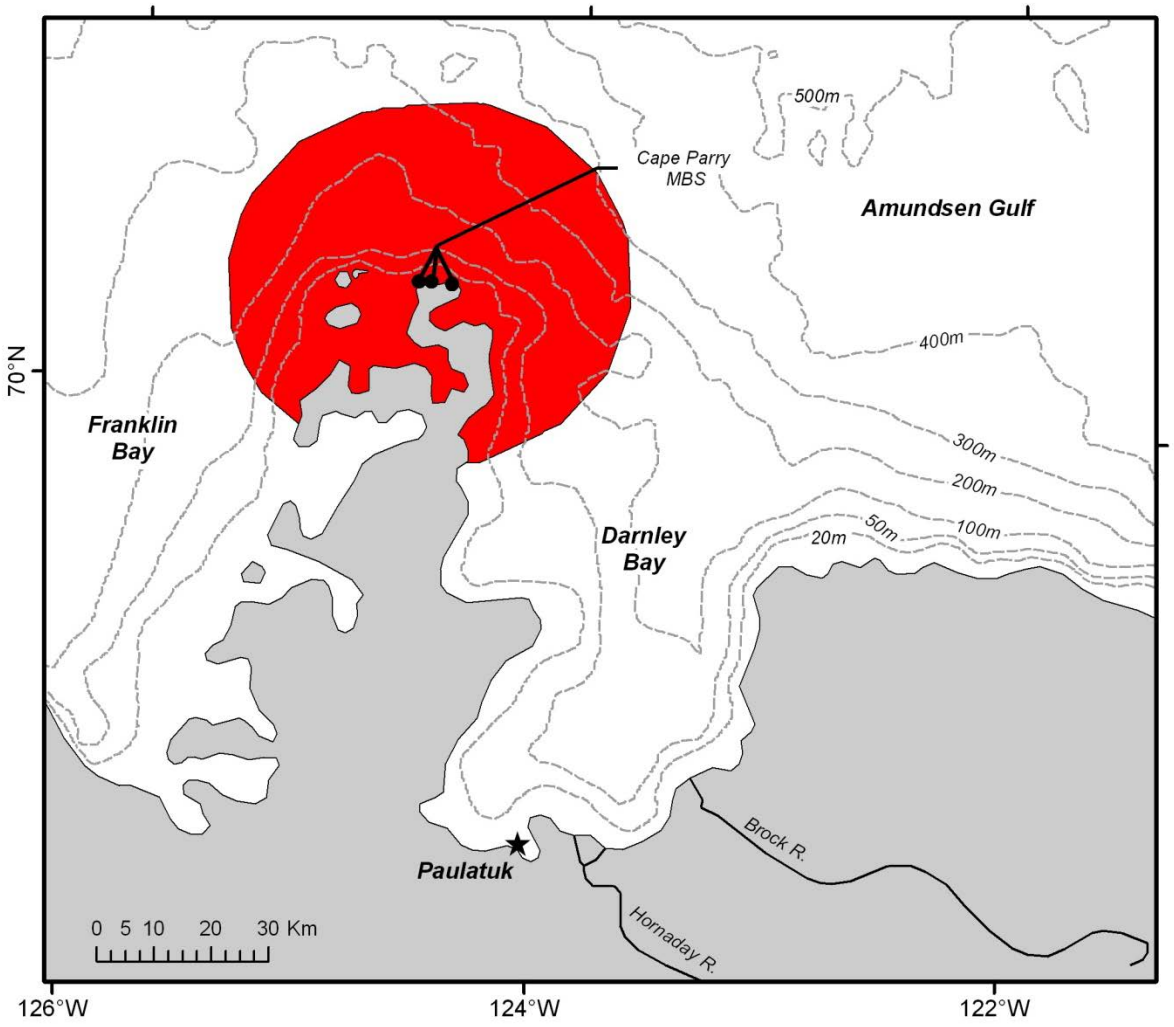

Figure 2. Cape Parry Offshore Marine Feeding Habitat priority area boundaries (in red) as defined in DFO (2011).

Purpose

In support of the Health of the Oceans initiative, DFO Science has been asked to deliver indicators, protocols and strategies for monitoring the CO for the Cape Parry priority area. The selected indicators, protocols and strategies may be incorporated into future monitoring and/or research programs in the area. This Science Advisory Report contains concise summary information that is useful to managers, including a description of the key components of an effective indicator and monitoring program and a brief description of the indicators that should be monitored within the ANAOI, along with their associated monitoring protocols and strategies. The detailed scientific background relating to indicators, protocols and strategies for the ANAOI can be found in the associated Research Document.

ASSESSMENT

DFO Science does not routinely conduct research on the identification and validity of indicators for marine protected areas. Expert knowledge and examples of other monitoring programs were used to help identify the indicators selected to monitor the ANAOI.

Criteria of an Effective Indicator

To successfully monitor whether the Cape Parry priority area CO is being met, indicators should satisfy the following criteria; specifically, indicators should be:

1. Sensitive; respond to a driver.
2. Reflective of processes/changes within the area.
3. Reflective of anthropogenic drivers or stressors within a relevant timeframe.
4. Able to provide information on multiple aspects of environmental integrity (ideally).
5. Most effective with appreciable baseline/historic data.
6. Relevant to the CO.
7. Based on scientific information but are not the explicit output of scientific research.
8. Easily developed and delivered in the field (ideally).
9. Easily detected; high signal to noise ratio.

Criteria of an Effective Monitoring Program

For a monitoring program to be successful, the following criteria should be satisfied. Specifically, a monitoring program should be:

1. Able to distinguish between anthropogenic and environmental factors.
2. Standardized, long-term and follow specific established protocols.
3. Dynamic rather than static; complementarity between hypotheses and data collection and analysis is required (e.g., hypotheses should be revisited regularly to incorporate new findings).
4. Based on detailed scientific hypotheses at the early stages of the monitoring program to achieve meaningful outcomes from data collection.
5. Assessed on a regular reporting schedule (e.g., report on progress every five years).
6. Incorporated with data analysis, the dissemination of results to both local and scientific communities and archiving of data/results in a standardized fashion.
7. Coordinated among scientific groups (e.g., Canadian Wildlife Service (CWS), DFO, ArcticNet).
8. Able to recognize the complexity of the system and be sensitive to seasonality.

Changes in the focus and technology of the monitoring program should only be implemented with great care to preserve the value of the time series. Given the high variability of the Arctic ecosystem, it may take several decades for a change to emerge from background variability.

Selection of Appropriate and Meaningful Indicators as Related to the CO

The Cape Parry CO was broken down into its key components and two types of indicators were identified based on these components (Appendix 1). Thirteen ecological indicators were selected to directly evaluate the Cape Parry CO (highlighted in green in Appendix 1) and five ecological indicators were selected to provide fundamental background environmental context for the Cape Parry ecosystem (highlighted in yellow in Appendix 1). Information on data availability, associated costs, potential for community monitoring, monitoring methods, relevance to the CO, sensitivity and informativeness, was provided for each indicator to give additional context. This information was not meant to form the basis for the selection of monitoring indicators for the ANAOI. All of the selected indicators are relevant to the Cape Parry CO, are informative and are sensitive to environmental change.

Indicators That Provide Background Environmental Context

Core Oceanography

Oceanographic data, such as temperature, salinity, depth, currents, etc., can be obtained using an ocean observatory and this indicator has the potential to be monitored by local community members (e.g., the Canadian Rangers Ocean Watch (CROW) program). Thus far, very limited baseline oceanographic data are available within the ANAOI (e.g., DFO's Northern Coastal Marine Program (conducted aboard the Nahidik), DFO's Salvelinus program). Although data from within the ANAOI is limited, baseline data from outside the boundaries (~ 100 km radius) do exist (e.g., Northern Coastal Marine Program [NCMP], Beaufort Regional Environmental Assessment [BREA], Canadian Arctic Shelf Exchange Study [CASES], Circumpolar Flaw Lead [CFL] study).

Benthic Habitat Distribution

Benthic habitat distribution should be monitored as a prerequisite for understanding benthic community composition (e.g., Buhl-Mortensen et al. 2012). Methods for monitoring benthic habitat distribution can include observations from local community members (e.g., presence/absence of beach erosion) along with acoustic surveys, bottom grabs, remotely operated underwater vehicle (ROV) and drop camera surveys, and mapping of benthic types. Baseline data on benthic habitat distribution are available within the ANAOI and within a 100 km radius of the ANAOI boundaries (e.g., NCMP, ArcticNet, BREA, Natural Resources Canada [NRCan], Canadian Hydrographic Service [CHS] and community observations).

Ice Structures, Thickness and Break-up Timing

Sea-ice provides important habitat for key species within the ANAOI (e.g., polar bears (*Ursus maritimus),* ringed seals (*Phoca hispida*)) and the timing of sea-ice break-up provides a good indication of ecosystem productivity on an annual basis. Sea-ice structures can be monitored using satellite radars and photographs from local hunters, whereas sea-ice thickness can be monitored using an ocean observatory mooring and ice charts. The timing of break-up can be monitored with photographs and reports from the Canadian Ice Service (CIS). Baseline data on sea-ice structures are available within the ANAOI and within a 100 km radius of the ANAOI boundaries from local/traditional ecological knowledge (LEK/TEK), polar bear surveys and satellite radar images. Baseline data on sea-ice thickness and sea-ice break-up timing are also available within the ANAOI and within a 100 km radius of the ANAOI boundaries from the CIS and LEK/TEK (for sea-ice break-up timing exclusively).

Indicators That Inform the Status of the CO

Under-ice, Ice-associated and Open-water Biota

Under-ice, ice-associated and open-water biota can all be monitored to measure ecosystem productivity, if sampling is continuous throughout the productive period. Because certain monitoring methods have drawbacks (e.g., high upfront costs associated with remote sensing and incomplete information from sediment traps), it is important to combine a suite of different methods when monitoring this group of indicators. Available methods include the use of an ocean observatory, sediment traps, remote sensing, moorings, gliders (for ice-associated biota), vessels (for open-water and under-ice biota) and biomarkers. There is also the potential for these indicators to be monitored by local community members. Baseline data are not available within the ANAOI but limited relevant data have been collected within a 100 km radius of the ANAOI boundaries through CASES and CFL.

Biodiversity of lower trophic level species

Lower trophic level species composition and functional diversity can be monitored to measure overall ecosystem health. Indicators can be monitored by local community members and/or by researchers where samples can be taken on-ice or using research vessels. Indicators can also be monitored using biomarkers. Baseline data are not available within the ANAOI but limited relevant data have been collected within a 100 km radius of the ANAOI boundaries through CASES.

Concentration of Nutrients

Nutrient concentrations can be monitored within the ANAOI to measure the productive capacity of the ecosystem. Nutrient concentration measurements can be taken from vessels or small boats (local monitoring component). Limited baseline data on nutrient concentrations are available within the ANAOI (e.g., NCMP) and within a 100 km radius of the ANAOI boundaries (e.g., NCMP, CASES, CFL).

Benthic Community Composition and Abundance

When incorporated with oceanographic data, data on benthic community composition (presence/absence) and abundance can provide important information on overall ecosystem health. This indicator can be measured using grabs, box cores, drop cameras and ROVs, and there is the potential for this indicator to be monitored by local community members. Currently, some baseline data are available within the ANAOI and within a 100 km radius of the ANAOI boundaries (e.g., NCMP, BREA).

Offshore Fish Community Composition, Structure, Function and Energetics

Data on offshore fish community composition, structure, function and energetics can provide important information on offshore prey species within the ANAOI, when integrated with oceanographic data. Monitoring could be both community-based through bird forage and marine mammal stomach content observations and/or vessel-based. Some baseline data are available within the ANAOI and within a 100 km radius of the ANAOI boundaries (e.g., NCMP, BREA). With the incorporation of new research, a target offshore fish species should be selected for monitoring the ANAOI ecosystem, as this would lower monitoring costs and enhance the data's relevance to the CO.

Inshore fish Community Composition, Structure, Function and Energetics

Data on inshore fish community composition, structure, function and energetics can provide important information on inshore prey species within the ANAOI, when integrated with

oceanographic data. Reports of odd looking species/individuals and odd behaviours should also be monitored as these characteristics are closely linked to environmental disturbances. This indicator can be monitored using methods similar to those for monitoring offshore fishes and it is important to select a target species following the incorporation of new research. Some baseline data are available within the ANAOI and within a 100 km radius of the ANAOI boundaries from historic local observations and DFO research programs.

Fish Diet Composition

Fish diet composition can indicate whether fishes are consuming benthic or pelagic prey and this indicator can be monitored by analyzing fish stomach contents (local community monitoring component), fatty acids, stable isotopes and contaminant tracers. Currently, some baseline data on fish diet composition are available within the ANAOI and within a 100 km radius of the ANAOI boundaries, from DFO research.

Presence/Absence, Semi-Quantitative Abundance and Timing of Capelin on Beaches

As Capelin (*Mallotus villosus*) appear to be a key prey species within the ANAOI, it is important to monitor the presence/absence, semi-quantitative abundance and timing of Capelin on ANAOI beaches. Visual surveys can be conducted by local community members to obtain data on this indicator. Baseline data on this indicator are available within the ANAOI and within a 100 km radius of the ANAOI, from historic local observations.

Marine Mammal Presence/Absence, Timing and Group Composition

Migratory marine mammals such as ringed seal, bowhead whale (*Balaena mysticetus*) and beluga (*Delphinapterus leucas*) play important roles in the ANAOI ecosystem (e.g., opportunistic foraging, habitat use of sea ice). Local community members can monitor marine mammal presence/absence, timing and group composition through observations and photographs (with the inclusion of standardized information on the date, location, species, etc.). Baseline data on this indicator are available within the ANAOI and within a 100 km radius of the ANAOI boundaries from surveys and satellite tracking of bowheads, beluga and ringed seals as well as from historic local observations; although, these observations are not yet compiled or quantified.

Marine Mammal Prey Items

Monitoring marine mammal prey items can provide an indication of why some marine mammals enter the ANAOI ecosystem (e.g., beluga). Researchers and local community members can monitor this indicator by examining the stomach contents of marine mammals (i.e., by photographs and/or preferably direct observations). Baseline data for marine mammal prey items are available within the ANAOI and within a 100 km radius of the ANAOI boundaries for both beluga and bearded seals (*Erignathus barbatus).* This was collected from a hunter harvest monitoring program co-managed by DFO, the community and FJMC for beluga and from local observations for bearded seals.

Anthropogenic Underwater Noise

As anthropogenic underwater noise can negatively impact many components of an ecosystem, it should be monitored to ensure that the roles of key prey species are not disrupted by human activities. Anthropogenic underwater noise can be monitored by local community members through short term instrument deployments or by researchers through the use of an ocean observatory, a mooring and/or short term deployments. To correctly interpret data, underwater noise will need to be compared against natural background variability. At present, baseline data are not available for this indicator.

Sources of Uncertainty

Some of the selected indicators require baseline research to fully determine their potential for detecting if the Cape Parry CO is being met. Without this information, it is difficult to predict their value as indicators for monitoring the ANAOI. Until this information is available, it may be prudent to develop a broad monitoring program that can be refined in the future.

Due to funding limitations, many uncertainties exist regarding the longevity of research programs that have been used to establish data on the selected indicators in this area of the ISR. Northern community members expressed their interest in collecting data on many of the selected indicators, and their incorporation into this monitoring program as citizen scientists could help ensure the longevity of consistent data collection. Incorporating northern community members into this monitoring program would also be beneficial as they have extensive knowledge of the ANAOI ecosystem and are able to collect data throughout the year.

CONCLUSIONS AND ADVICE

Two types of ecological indicators were selected for monitoring the ANAOI ecosystem. Thirteen ecological indicators were selected to directly evaluate the Cape Parry CO and five ecological indicators were selected to provide fundamental background environmental context for the Cape Parry ecosystem. Aside from a lack of baseline data, each indicator meets the criteria of an "effective indicator" for monitoring the ANAOI. It is important to note that the selected indicators already represent a prioritized short list of all possible indicators appropriate for the area. If further prioritization and reduction in the number of indicators is required, additional scientific input is essential. Future development of this monitoring program may also require additional scientific input.

OTHER CONSIDERATIONS

Although polar bears and seabirds were identified as important species within the ANAOI, they were excluded from the list of selected indicators because these species are outside the jurisdiction of DFO (polar bears and seabirds are the responsibility of Environment Canada, EC). Science advice regarding appropriate indicators, strategies and protocols for polar bears and seabirds should be developed by subject matter experts. In the future, monitoring efforts should be coordinated between DFO and EC to representatively monitor whether the Cape Parry CO is being met.

As with polar bears and seabirds, kelp beds were not included in the list of selected indicators for monitoring the Cape Parry CO because subject matter experts were not present. Indicators related to kelp beds may be considered for the TEK CO along the eastern coast of the Parry Peninsula.

Although most participants agreed that a successful monitoring plan should be dynamic rather than static, changes in the methodology of a monitoring plan generally increases background variability and therefore can make data analysis more challenging. If aspects of a monitoring plan must change, a sensible period of overlap between new and old approaches is important to minimize background variability.

SOURCES OF INFORMATION

This Science Advisory Report is from the regional peer review of the Anguniaqvia Niqiqyuam Area of Interest: monitoring indicators, protocols and strategies, held on February 19-21, 2014. Additional publications from this meeting will be posted on the DFO Science Advisory Schedule as they become available.

Buhl-Mortensen, L., Buhl-Mortensen, P., Dolan, M.F.J., Dannheim, J., Bellec, V., and Holte, B. 2012. Habitat complexity and bottom fauna composition at different scales on the continental shelf and slope of northern Norway. Hydrobiologia 685: 191-219.

DFO. 2011. Identification of Conservation Objectives and boundary delineation for the Darnley Bay Area of Interest (AOI). DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2011/009.

Paulic, J.E., Bartzen, B., Bennett, R., Conlan, K., Harwood, L., Howland, K., Kostylev, V., Loseto, L., Majewski, A., Melling, H., Neimi, A., Reist, J.R., Richard, P., Richardson, E., Solomon, S., Walkusz. W., and Williams, B. 2012. Ecosystem overview report for the Darnley Bay Area of Interest (AOI). DFO Can. Sci. Advis. Sec. Res. Doc. 2011/062. vi + 63 p.

APPENDIX 1: ANAOI INDICATORS BREAKDOWN

Table 1. Description of indicators and associated protocols and strategies for monitoring the Cape Parry CO. Indicators that directly evaluate the Cape Parry CO are highlighted in green and indicators that provide fundamental background environmental context for the Cape Parry ecosystem are highlighted in yellow. For the cost effective category, dollar signs were used to represent general associated costs; where one dollar sign is equivalent to $10,000+, two dollar signs are equivalent to $100,000+ and three dollar signs are equivalent to $1,000,000+. The category entitled relevance to the CO describes whether each ecological indicator is adequate for monitoring the Cape Parry CO. The column Indicator Sensitivity describes whether an indicator is susceptible to environmental disturbances; the column Usefulness of Indicator describes whether an indicator is useful for monitoring the Cape Parry CO; the column Local/External Representativeness documents if data for an indicator was collected within the ANAOI or outside the ANAOI. Acronyms used: Canadian Arctic Shelf Exchange Study (CASES), Circumpolar Flaw Lead (CFL) study, Canadian Coast Guard (CCG), Northern Coastal Marine Program (NCMP), Beaufort Regional Environmental Assessment (BREA), Canadian Rangers Ocean Watch (CROW), Natural Resources Canada (NRCan), Canadian Hydrographic Service (CHS), Fisheries and Oceans Canada (DFO), local/traditional ecological knowledge (LEK/TEK).

CO component	Indicator	Data Available within ANAOI	Data Available within 100 km of ANAOI	Local/ External Represen-tativeness	Cost	Potential for Community Monitoring	Monitoring Method	Relevance to CO	Indicator Sensitivity	Usefulness of Indicator
Ecosystem integrity (ice vs water; linkages)	Under-ice biota (chlorophyll size fractions)	No	Limited (CASES, CFL)	Local	Analysis $, collection $$ (coordinate with CCG programs)	Yes for surface samples	Ocean observatory, spring on-ice vessel-based, sediment traps (partial info), moorings, remote sensing (linked to sampling), biomarkers	Yes	Very	Yes, if sampling is continuous throughout productive period
	Ice-associated biota (chlorophyll size fractions)	No	Limited (CASES, CFL)	Local	Analysis $, collection $$ (coordinate with CCG programs)	Yes	Ocean observatory; spring on-ice sediment traps (partial info), moorings, gliders, biomarkers	Yes	Very	Yes, if sampling is continuous throughout productive period

CO component	Indicator	Data Available within ANAOI	Data Available within 100 km of ANAOI	Local/ External Represen-tativeness	Cost	Potential for Community Monitoring	Monitoring Method	Relevance to CO	Indicator Sensitivity	Usefulness of Indicator
	Open-water biota (Chlorophyll size fractions)	No	Limited (CASES, CFL)	Local	Analysis $, collection $$ (coordinate with CCG programs)	Yes for surface samples	Ocean observatory, spring on-ice vessel-based, sediment traps, moorings, remote sensing (linked to sampling), biomarkers	Yes	Very	Yes, if sampling is continuous throughout productive period
	Core oceanographic processes	Very limited (NCMP)	Limited (CASES, CFL, very limited from NCMP, BREA)	Both	Set-up $$, on-going $$	Some opportunities (e.g., CROW)	Ocean observatory	Yes, fundamental data on oceanographic processes and forcing; provides background context	Very	Yes, with ocean observatory
	Biodiversity (lower trophic levels, sp. composition, functional diversity	No	Limited (CASES)	Both	$	Yes, for surface	Spring on-ice, vessel-based, biomarkers	Yes	Yes	Yes
	Benthic habitat distribution	BREA, NCMP, Arctic Net (multi-beam, bottom grabs), community observations, NRCan, CHS	BREA; NCMP, ArcticNet (multi-beam, bottom grabs), community observations	Local	$-$$	Observations of beach erosion, kelp beds, sites selected for repetitive grabs	Acoustic surveys, bottom grabs, ROV, drop camera (and other ground truthing); mapping benthic types (prerequisite for better using community composition data)	Yes, fundamental data; provides background environmental context	Substrate relatively insensitive (unchanging) at broad scale; local anthropogenic effects (e.g., anchor drags, net footprints observable on shorter timeframes and scales; bottom fauna changes)	Yes

CO component	Indicator	Data Available within ANAOI	Data Available within 100 km of ANAOI	Local/ External Represen-tativeness	Cost	Potential for Community Monitoring	Monitoring Method	Relevance to CO	Indicator Sensitivity	Usefulness of Indicator
Marine productivity (nutrients, alga, higher trophic levels)	Concentrations of nutrients	Very limited (NCMP)	Limited (CASES, CFL, very limited from NCMP)	Both	$ (if combined within larger program)	Yes	Spring on-ice, vessels, small boats	Yes	Yes	Yes
	Benthic community composition (presence-absence) and abundance	Some (BREA, NCMP)	Some	Local	$-$$	Yes	Grabs, box cores, drop camera, ROV	Yes	Yes	Yes if integrated with oceanographic info
Prey spp. (e.g., forage fishes)	Offshore fish community composition, structure, function, energetics	Some (BREA, NCMP)	Yes (BREA, NCMP)	Both	Vessel-based $$$		Vessel-based (periodic), bird diets (annual)	Yes	Yes	Yes if integrated with oceanographic info
					Community-based $-$$	Yes, bird forage observation; mammal stomach contents		Yes	Limited by foraging strategies and search images	Yes if integrated with oceanographic info
	Inshore fish community composition, structure, function, energetics (target sp. TBD)	1960s survey, Jim Johnson, DFO (Brown Harbour 2014)	Jim Johnson, DFO (Bennett Point), TEK	Local	$	Yes	Trap nets, gillnets	Yes	Yes	Yes if integrated with oceanographic info

CO component	Indicator	Data Available within ANAOI	Data Available within 100 km of ANAOI	Local/ External Represen-tativeness	Cost	Potential for Community Monitoring	Monitoring Method	Relevance to CO	Indicator Sensitivity	Usefulness of Indicator
		Historical location observations	No	Local	$-$$	Yes (cod at Cape Parry in summer fishery); reports of odd species or odd looking individuals (hybrids, deformities, lesions, etc.), odd behaviours (life history changes)	TBD; 1-3 years	Yes	Yes	Yes if integrated with oceanographic info
	Fish diet composition: benthic vs. pelagic sources	Jim Johnson, DFO (Bennett Point and Brown Harbour)	Jim Johnson, DFO (Bennett Point)	Local	$$	Yes (e.g., char diets in southern part of bay)	Stomach contents, fatty acids, stable isotopes, contaminant tracers (e.g., Hg, transfer pathways and magnitudes; can then serve as indicator)	Yes	Yes	Yes
	Presence/absence, semi-quantitative abundance and timing of Capelin on beaches	Historic local observations	Historic local observations	Local	$-$$	Yes	Visual survey, location and date	Yes	Yes	Yes
Marine mammals (predators)	Presence/absence, timing and group composition (reason for presence)	Local observations but not compiled or quantified; surveys and satellite tracking (bowhead, beluga, ringed seal; small sample size)	Local observations but not compiled or quantified; surveys and satellite tracking (bowhead, beluga, ringed seal; small sample size)	Local	$-$$	Yes; reports of odd occurrence (species, appearance, etc.)	Long-term, standardized, date, location, species, photographs	High	Medium	Limited

CO component	Indicator	Data Available within ANAOI	Data Available within 100 km of ANAOI	Local/ External Represen-tativeness	Cost	Potential for Community Monitoring	Monitoring Method	Relevance to CO	Indicator Sensitivity	Usefulness of Indicator
	Marine mammal prey items	Harvest program for beluga, local observations for bearded seal	Harvest program for beluga, local observations for bearded seal	Both	$	Yes	Stomach contents (frozen stomachs preferred; alternative photographs with location and date)	Yes	Medium	No for change in area but yes for change in use
Polynyas and ice habitats	Ice structures (pressure ridges, etc.)	Not convenient but radar data available since mid-1990s ; TK ; polar bear surveys	Not convenient but radar data available since mid-1990s ; TK ; polar bear surveys	Local	$	Yes (January on during winter hunting), photographs with location and date	Radar data; hunter observation (with photographs, dates, location; detailed report similar to existing beluga data collection)	Yes, fundamental data; provides background environmental context; helps interpret remote sensing data, even if mooring located outside ANAOI	High	Yes
	Ice thickness (relevance to light penetration, in combination with snow thickness)	Ice charts	No systematic measuremen ts except at Cape Parry (ended 1979); ice charts	Local	$-$$	Yes (e.g., CROW), snow thickness measuremen ts (including drifts)	Ice charts, ocean observatory, mooring	Yes, provides background environmental context; helps interpret remote sensing data, even if mooring located outside ANAOI	High	Yes
	Ice leads, break-up and timing	Ice service (need to work with raw images), TK	Ice service (need to work with raw images), TK	Both	$-$$	Yes, during hunting	Reports, photographs with location and date	Yes, fundamental data; provides background environmental context; helps interpret remote sensing data, even if mooring located outside ANAOI; also movement pathway and foraging	Yes	Yes, break-up timing relates to seal fitness and reproduction and availability of seals to polar bears (and polar bears to hunters)
Human impacts (compared against natural variability and changes)	Anthropogenic underwater noise	No	No (eastern Amundsen Gulf)	Local	$-$$	Yes, target short-term deployment	Ocean observatory mooring; short term deployments	Yes	Yes	Yes

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