A Co-production of Knowledge Approach to Monitor Change in the Biodiversity of Circum-Arctic Coastal Ecosystems

Jones, Tahzay[1]; Carolina Behe[2], Donald McLennan[3], Maria Arvnes[4], Susse Wesseberg[5], Liudmila Sergienko[6], Cyrus Harris[7], and Qaiyaan Harcharek[8], Sierra Fletcher[9], Sara Nichols[10,] Tom Christensen[11] , Kari Fannar Larusson[12]

[1] US National Park Service, Alaska, USA.

[2] Indigenous Knowledge/Science Advisor, Inuit Circumpolar Council, Anchorage, Alaska, USA.

[3] Canadian High Arctic Research Station, Cambridge Bay, Nunavut , Canada

[4] Norwegian Environment Agency, Trondheim, Norway

[5] Aarhus University, Copenhagen, DK

[6] Petrozavodsk State University, Petrozavodsk, Russia

[7] IK Holder, Maniilaq Association, Kotzebue, AK, USA

[8] IK Holder, hunter, anthropologist, Utqiagvik, AK., USA

[9] Nuka Research and Planning Group, Anchorage, AK., USA

[10] Nuka Research and Planning Group, Yarmouth, ME., USA

[11] *Aarhus University,* Denmark, CBMP co-Lead

[12] Kari Fannar Larusson, CAFF Secretariat

Corresponding Author – Donald McLennan (donald.mclennan@polar.gc.ca)

Abstract

Arctic coastal systems are among the most rapidly changing ecosystems in the world - changes that are creating important impacts on Arctic coastal biodiversity and ecosystem processes, on food security of Arctic coastal communities, and on indigenous cultural continuity. The Arctic Coastal Monitoring Plan is the Arctic Council's first initiative to develop a platform that will support a co-production of knowledge approach, and is an important step towards bringing together Traditional Knowledge (TK) and science into the assessment, planning and management of Arctic biodiversity. This process specifically includes involving Arctic peoples and their knowledge in the monitoring and analysis of Arctic biodiversity. Where it is appropriate, the successful development of effective monitoring programs will be formed through equitable partnerships with Indigenous Peoples that includes their knowledge across all aspects of monitoring activities and assessments.

Approved by the Arctic Council in 2019 the Arctic Coastal Monitoring Plan is one of four developed by the Circumpolar Biodiversity Monitoring Program (CBMP). The CBMP is the cornerstone programme for the Conservation of Arctic Flora and Fauna (CAFF) Arctic Council working group is an international network of scientists, government agencies, Indigenous organizations and conservation groups working together to harmonize and integrate efforts to monitor the Arctic's living resources.

The Coastal Monitoring Plan includes approaches to systematically utilize and include a co-production of knowledge process – approaches that support and extend our understanding of the state of, and changes in, Arctic coastal biodiversity. The Coastal Plan coined the term 'coastscape' to describe large, mappable segments of Arctic coasts with recurring physiographic features and processes, and where similar kinds of coastal terrestrial, marine and freshwater processes are interacting with these features and local climate to create a relatively predictable range of habitats that support characteristic populations of coastal species. With the inclusion of the coastal human communities that occur, coastscapes provide an ecological frame for designing monitoring programs and understanding observed changes in coastal FECs within an integrated ecological and social context. Through a series of international workshops that included both TK and science experts, the Arctic Coastal Monitoring Plan identified the changing drivers and stressors that are impacting Arctic coastal biodiversity, developed monitoring questions to focus program design, and developed a prioritized list of Focal Ecosystem Components (monitoring indicators). The Plan was approved by the CAFF Board in May 2019 and is now moving on to international implementation.

Further information:

- https://caff.is/coastal
- Coastal Monitoring Plan: https://www.caff.is/monitoring-series/473-arctic-coastal-biodiversity-monitoring-plan

Introduction

Arctic coastal systems are among the most rapidly changing ecosystems in the world - changes that are creating important impacts on Arctic coastal biodiversity and ecosystem processes, on food security of Arctic coastal communities, and on indigenous cultural continuity. The Arctic Council, made up of the eight Arctic States and six Permanent Participants (PPs), has directed the development of Arctic biodiversity monitoring through the Circumpolar Arctic Flora and Fauna Working Group (CAFF), Coastal Biodiversity Monitoring Program (CBMP). The recently completed CBMP Coastal Biodiversity Monitoring Plan takes a holistic approach and identifies seven types of typical coastal eco-physiographic settings called Coastscapes – settings that provide a social-ecological system frame for knowledge co-production through the use of science data and Traditional Knowledge (TK) in assessments of Arctic biodiversity.

The Arctic Coastal Biodiversity Monitoring Plan approved by the Foreign Ministers of the Arctic Council in May 2019 is an agreement across Arctic States to compile, harmonize and assess results from existing coastal biodiversity and ecosystem monitoring efforts, and to design a long term plan to comprehensively monitor and report change in Arctic coastal ecosystems. To acquire workshop reports, the monitoring plan, and other relevant publications go to https://www.caff.is/coastal/coastal-monitoring-publications.

The purpose of the Coastal Monitoring Plan is to organize a network of monitoring networks approach to synthesize and assess the status and trends of Arctic Coastal biodiversity as a contribution to international conventions and agreements on biodiversity conservation; providing policy and decision makers with comprehensive information on the status and trends of Arctic coastal biodiversity.

This Coastal Plan is the Arctic Council's first initiative to develop a platform that will support a co-production of knowledge approach, and is an important step towards bringing together Traditional Knowledge (TK) and science into the assessment, planning and management of Arctic biodiversity. This process specifically includes involving Arctic peoples and their knowledge in the monitoring and analysis of Arctic biodiversity.

Arctic Coastal Ecosystems

Complex and highly productive coastal ecosystems support a wide range of Arctic biodiversity including shorebirds and waterfowl, coastal fish, and marine mammals. Soft bottoms and shallow coastal water harbour important shellfish communities, which provide food for walrus and bearded seal, as well as for diving sea ducks. Extensive coastal mudflats provide invertebrate food for migrating shorebirds, rocky shorelines support rich intertidal and sub-tidal invertebrate, seaweed and fish communities, and coastal cliffs provide safe nesting habitat for large agglomerations of colonial seabirds.

Circum-Arctic human settlement is largely coastal, and includes the homelands of many Indigenous groups, as well as many non-Indigenous communities. Indigenous Peoples hold a close relationship to this environment, and rely on coastal species for the many aspects of food security, including health and wellbeing, culture, economics, and stability, as well as wildlife accessibility and availability. Recognizing humans as a part of the ecosystem, the Coastal Monitoring Plan acknowledges the interdependence of human coastal communities and the coastal ecosystems they rely on.

Stressors and drivers of change

Arctic coastal biodiversity is threatened by a diversity of environmental drivers and anthropogenic stressors and the list in Table 1 shows the input we received through the workshop process from both TK and science experts. Various combinations of stressors and cumulative impacts have the potential to

impact coastal biodiversity through their interactions in ways that are difficult to understand and predict. This uncertainty underscores the need for comprehensive and sustained monitoring of coastal ecosystems.

Direct/Indirect Changes in Environmental Drivers	Increasing Anthropogenic Stressors	Potential Biodiversity Impacts
• changes in relative sea level • seawater temperature and salinity regimes • sea ice phenology, distribution and thickness • increased storm frequency, intensity and duration • increased coastal erosion and altered sedimentation regimes • acidification of coastal waters • timing, duration and frequency of marine flooding, water temperature and salinity regimes in estuarine lakes and wetlands • water chemical parameters, e.g. DOC/POC, nutrients, pH, contaminants alkalinity/salinity • changes in storm frequency and intensity • amount of snow melt water on top of sea ice in spring	• ship-borne marine invasive alien species • shipping pollution including oils spills, noise, light, and marine debris (e.g. plastics) • community sewage • contaminants • oil and gas development • large scale commercial overfishing • channel dredging	• negative effects on the food security of coastal communities • seasonality changes in freshwater/saltwater inputs on timing of fish migration and possible increased health status from longer ocean feeding times • reduced security for marine mammal spawning areas • increased risk of disease • phenological mismatches due to changing seasonalities • negative effects of sea ice changes on seal, walrus and polar bear • changes in the number, composition, health and behaviour of resident and migratory birds • negative impacts of climate change on migration patterns, and on feeding and breeding areas • impacts on benthic species due to increased shoreline erosion and deposition, from changes in the timing and intensity of estuarine outflow patterns, e.g., turbidity, and from increased pollution and bioaccumulation of toxins • increased inundation by seawater on vulnerable coastal ecosystems • bio-fouling on infrastructure • negative habitat effects in southern wintering grounds • water quality on coastal wetlands • displacement of local species and altered food webs due to ingress of southern species • negative effects of changing ocean and nutrient circulation • increases in harmful algal blooms

Table 1: Summary of potential and observed impacts on coastal biodiversity resulting from changing environmental drivers and increasing anthropogenic stressors- summary of workshop inputs by TK and science experts.

To begin to deal with these issues, the Coastal Plan proposes to bring together an ecosystematic science approach and an Indigenous Knowledge holistic approach to co-produce knowledge of coastal ecosystems that we can use to design and implement coastal monitoring programs that can identify causal linkages to help predict change and reduce the potential for ecological surprise. Through a co-production of knowledge approach, evidence based information will be able to inform the proactive and adaptive decisions and policies needed to maintain the coastal biodiversity and sustainability of the Arctic.

Key Components of the Coastal Monitoring Plan

Traditional Knowledge[1]

Arctic coasts have been home to Arctic Indigenous Peoples for millennia, and have amassed a powerful depth of knowledge that continues to be built upon today. This knowledge holds its own methodologies and validation processes. Indigenous People's knowledge includes observation and monitoring practices, and ongoing assessments of coastal biodiversity. Where it is appropriate, the successful development of effective monitoring programs will be formed through equitable partnerships with Indigenous Peoples that includes their knowledge across all aspects of monitoring activities and assessments. The knowledge held by Indigenous Peoples holds a rich baseline that continues to be built upon today. This knowledge system embraces a holistic approach that includes a deep understanding of local and cumulative impacts, and a unique and useful understanding of drivers of change. The Coastal Monitoring Plan includes approaches to systematically utilize and include this knowledge – approaches that support and extend our understanding of the state of, and changes in, Arctic coastal biodiversity. CAFF, through implementation of the Coastal Monitoring Plan, is demonstrating a strong commitment to a monitoring approach that brings together both science and TK experts/representatives to monitoring, assess and report important changes in coastal ecosystems and biodiversity.

Coastscapes

The Coastal Plan coined the term 'coastscape' to describe large, mappable segments of Arctic coasts with recurring physiographic features and processes, and where similar kinds of coastal terrestrial, marine and freshwater processes are interacting with these features and local climate to create a relatively predictable range of habitats that support characteristic populations of coastal species. With the inclusion of the coastal human communities that occur, coastscapes provide an ecological frame for designing monitoring programs and understanding observed changes in coastal FECs within an integrated ecological and social context. A total of seven coastscapes were identified for the coastal Arctic - Fjords, Rocky

[1] The Arctic Council uses the term "Traditional and Local Knowledge." It is important to note that all the Permanent Participants and Indigenous participants contributing to the development of this plan prefer the term "Indigenous Knowledge".

The Ottawa Traditional Knowledge Principles defines Traditional Knowledge as - a systematic way of thinking and knowing that is elaborated and applied to phenomena across biological, physical, cultural and linguistic systems. Traditional Knowledge is owned by the holders of that knowledge, often collectively, and is uniquely expressed and transmitted through indigenous languages. It is a body of knowledge generated through cultural practices, lived experiences including extensive and multigenerational observations, lessons and skills. It has been developed and verified over millennia and is still developing in a living process, including knowledge acquired today and in the future, and it is passed on from generation to generation. Accessed on 7/30/19 - http://www.saamicouncil.net/fileadmin/user_upload/Documents/Eara_dokumeanttat/Ottawa_TK_Principles.pdf

Coasts and Sea cliffs, Lagoons and Barrier Islands, Estuaries, Eroding Shores, Low Gradient Soft Shores, and Ice Front Coasts. Based on discussions with TK and science experts, a general conceptual ecosystem model was developed for each Coastscape [Fig 1]. The models provide a pictorial summary of the coastscape and a space for showing interactions among FECs and key ecosystems processes, drivers and stressors.

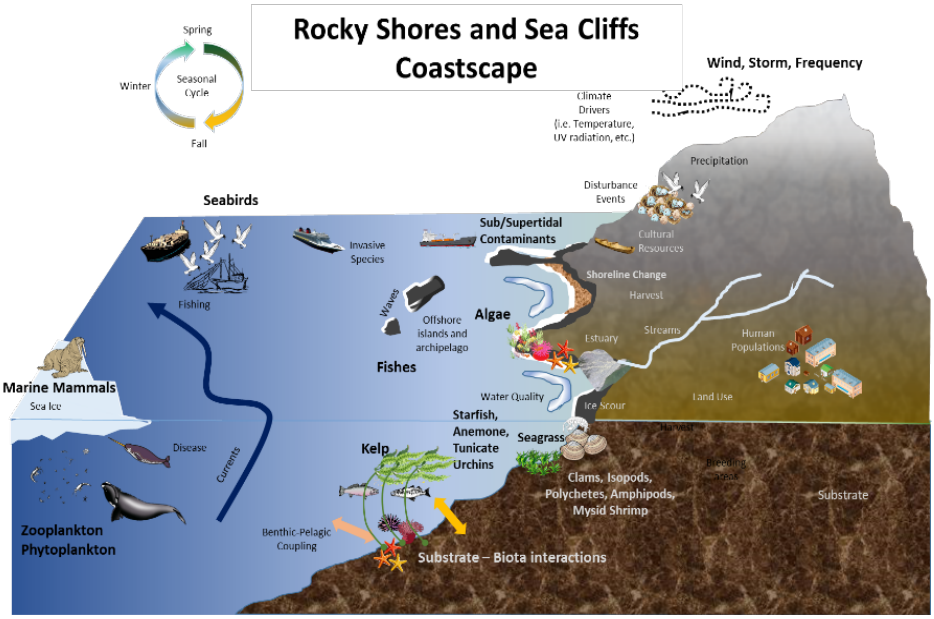

Figure 1: Rocky Shores and Sea Cliffs coastscape. Low gradient to steep coasts (including sea cliffs) with exposed bedrock to the waterline that frequently include rock pools, beaches and small wetlands.

Through the workshop process we used the coastscape conceptual models to:

- understand and communicate the main abiotic factors that drive habitat distribution and productivity for coastal biota;
- identify and prioritize the FECs;
- identify and address potential biodiversity threats, and;
- recognize the important role played by human cultures in coastal ecosystems.

Monitoring Questions

Monitoring questions are at the heart of any monitoring program and, through consultations with TK and science experts, the Coastal Plan identified the following general monitoring questions, as well as questions specific to identified knowledge clients of the Coastal Monitoring Plan:

1) What are the status and trends of Arctic coastal ecosystems in terms of their species composition and condition, new and invasive species, geographic distributions, thresholds with respect to climate drivers, phenological norms, and key processes and functions?

i) What are primary system drivers and stressors (biological, chemical, physical, and anthropogenic) and how are they influencing changes in coastal biodiversity and coastal ecosystem function?
ii) What are the cumulative effects of primary system drivers and stressors (biological, chemical, physical, and anthropogenic) to coastal ecosystems and biodiversity?

2) If Arctic coastal biodiversity and/or harvested foods for personal/community use are significantly impacted by any of these factors acting alone or together, which species are affected, how are they affected (mechanisms and drivers of change), where are they affected (geographically), and what is the expectation for the effects of these impacts in the near to medium future (5-20 years)?

3) How will measured and predicted changes in Arctic coastal biodiversity impact the mandated biodiversity obligations of local, Indigenous, territorial and federal governments?

4) Do the following factors (individually and/or cumulatively) significantly impact Arctic coastal ecosystems and associated biodiversity generally; and specifically, do they significantly impact the availability, abundance and quality of subsistence food for Arctic communities?
    - direct and indirect effects of climate change
    - oil and gas activities: exploration, drilling and extraction, and related infrastructure, shipping, and other transportation activities
    - mining activities: exploration, extraction, processing, and related infrastructure, shipping and other transportation activities
    - shipping: tourism and adventure cruising, community re-supply, industrial, military and research-related shipping
    - subsistence and commercial fishing
    - community activities: sewage disposal and other pollution, hunting, trapping, infrastructure, avoidance
    - long range and local contaminants: mercury (Hg) and persistent organic pollutants (POPs)
    - invasive alien species: especially marine invasive species

The development of these questions provided direction for the Coastal Monitoring Plan and criteria for selecting which components of coastal biodiversity to prioritize.

Focal Ecosystem Components, Attributes and Parameters

Continuing with CBMP monitoring approach, and in the context of the monitoring questions, TK and science experts were consulted at a number of workshops to help identify Focal Ecosystem Components (FECs) - key elements of Arctic coastal biota and ecosystems to monitor across participating countries. Regional ecosystem understanding and knowledge of existing programs also informed the selection of the FECs.

FECs were identified for the Coastal Plan by taking this input and implementing a prioritization process to identify FECs that were 'Essential' to support a coordinated monitoring approach across the coastal ecosystems of all participating countries – all other FECs were classed as 'Recommended'. The prioritization process was based on expert input, and assessed and rated each FEC in terms of its ability to answer program monitoring questions, and on other factors such as feasibility and the existence of ongoing monitoring, sensitivity to climate change, or vulnerability to stressors. FECs identified as Essential are listed across coastscapes in Table 2.

Essential FECs	Rocky Coast	Eroding Shores	Lagoons	River Estuaries	Low Gradient	Fjords	Ice Front
Waterfowl		X	x	X	x	x	
Seabirds: omnivores	x	X			x		
Seabirds: diving planktivore	x	X			x		
Seabirds: surface piscivores	x	X	x	X	x		x
Seabirds: diving piscivores	x	X	x		x		
Seabirds: benthivores	x	X	x	X	x		
Subtidal flora, intertidal macroalgae	x		x	X		x	
Pinnipeds	x				x	x	x
Whales				X	x	x	x
Pelagic fishes	x	X	x			x	x
Demersal fishes	x		x	X		x	x
Salmonids			x	X	x		
Phytoplankton	x	X		X		x	x
Meso- and macro-zooplankton		X					x
Benthos	x		x	X	x	x	x
Large herbivores					x		
Coastal wetlands			x	X		x	

Table 2. List of Essential Focal Ecosystems (FECs) across the seven Arctic coastscapes recognized in the development of the Coastal Monitoring Plan.

The CBMP also defines the way that we measure and assess FECs in terms of FEC Attributes and Parameters – Attributes being general categories of monitoring measurement, and Parameters the actual measures to be used. Coordinating these measures will make it possible to report across coastscapes and countries as the Coastal Monitoring Plan is implemented and reported in the State of Arctic Coastal Biodiversity Report (SACBR). Attributes and Parameters for coastal birds are noted in Table 3 and show a unique aspect of the Coastal Monitoring Plan where some parameters require TK expertise and others science expertise to report on the state of these FECs.

Monitoring Plan Implementation

Implementation of the Coastal monitoring plan will be conducted within each Arctic State. As the assessments are integrated for Arctic-wide reporting, the reports will be organized as an international, coastscape-focused approach. The Coastal Plan presents an umbrella approach to monitoring and reporting change in Arctic coastal biodiversity; that is, an international template that provides enough common direction (e.g., common FECs, co-production of knowledge where appropriate, coastscape/systems approach, data management, organizational structure) so that results can be integrated and reported internationally, but allowing for national monitoring approaches and variability in coastal systems.

POTENTIAL FEC	TYPICAL SPECIES
Coastal shorebirds/songbirds	all shorebirds/songbirds using coastal terrestrial ecosystems (coastal wetlands)
Coastal waterfowl	all geese and sea ducks using coastal ecosystems
Coastal raptors	white-tailed eagle, bald eagle
Seabirds: omnivores	glaucous gull, glaucous-winged gull, great black-backed gull, herring gull, ivory gull
Seabirds: diving planktivores	least auklet, dovekie
Seabirds: diving piscivores	common murre, thick-billed murre, Atlantic puffin, tufted puffin
Seabirds: surface piscivores	blacked-legged kittiwake, northern fulmar, Arctic tern
Seabirds: benthivores	black guillemot, pigeon guillemot, great cormorant, shag, pelagic cormorant

ATTRIBUTES	PARAMETERS
Diversity	Community Alpha diversity
	Species genetic diversity, sub-populations
	Spatial Structure
Abundance	Number
	Density
Phenology	Migration timing, routes, partial migration
	Life cycle events (breeding, nesting, rearing)
Demography	Growth rate and survival
	Reproductive rate
	Genetics and stock structure
	Age class distribution
	Sex distribution
Harvest and accessibility	Harvest statistics
	Subsistence hunting statistics
	Harvest usability
	Hunting strategies
	Success of food processing
	CuHE (distance, fuel, time)
Body Condition	Taste/texture/colour of fat, meat, organs, skin, scales, tongue, hair, feathers, stomach contents, egg-thickness, smell
	Lipid/fat amount, energy density
	Stress – cortisol levels, skittish animals
	Contaminants (Hg, POPs)
	Disease – frequency of outbreaks, die-offs, unusual mortalities, lesions, unusual mortality events

Table 3. Recommended Attributes and Parameters for coastal birds in the Coastal Monitoring Plan. Note the mixture of parameters requiring TK expertise and this science expertise.

The first task of the Coastal Plan is its implementation across participating States to produce the first 'State of Arctic Coastal Biodiversity Report' (SACBR). A report that will follow similar reporting for CBMP State of the Arctic Marine (https://www.caff.is/marine/marine-monitoring-publications) and Freshwater (https://www.caff.is/freshwater/freshwater-monitoring-publications) and Terrestrial (CAFF, in prep) reports. It will be developed from national syntheses of coastal monitoring data, and recent research information, with results assessed and reported using the approaches outlined in the Coastal Plan. The SACBR will not be able to comprehensively answer all monitoring questions for all FECs and will address those FECs where data are currently available, and work with partners to grow the program to begin to answer these overarching monitoring questions for all FECs across the circumpolar Arctic.