CAFF
Conservation of Arctic Flora and Fauna

CIRCUMPOLAR BIODIVERSITY MONITORING PROGRAM

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DEVELOPMENT OF AN ARCTIC FRESHWATER BIODIVERSITY MONITORING PLAN

FRAMEWORK DOCUMENT

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Foreword

Canada agreed in 2008 to act as the lead country for the initial development of the Freshwater Expert Monitoring Group (FEMG) of CAFF'S Circumpolar Biodiversity Monitoring Program (CBMP). Prior to the first meeting of the FEMG Steering Group in May 2010, Canadian experts developed this document to provide a framework for the FEMG. "*Development of a Pan-Arctic Freshwater Biodiversity Monitoring Plan: Framework document*" was used as an important background document for the 1st international workshop of the FEMG that was held in Uppsala, Sweden on November 22-25, 2010, and it has provided important guidance for the activities and discussions of the FEMG.

1. EXECUTIVE SUMMARY

This document provides an overview on the development of a Freshwater Expert Monitoring Group (FEMG) for the Circumpolar Biodiversity Monitoring Program (CBMP) along with timelines for development of the FEMG. Considerations for monitoring Arctic freshwater biodiversity are discussed, including types of stressors, various approaches to monitoring, and criteria used to choose appropriate metrics to measure biodiversity status and trends. Canadian freshwater researchers took the lead to provide expert advice for this international initiative by developing: 1) recommendations of the spatial scale of monitoring needed for Arctic Canada; 2) a strategic list of metrics that should be monitored as well as standardized methods to be used; 3) a summary of existing and recent aquatic programs in the Arctic; and 4) discussions on issues surrounding data management and archiving.

Arctic biodiversity is under growing pressure from both climate change and resource development, however, monitoring programs remain largely uncoordinated and lack the ability to effectively monitor, understand and respond to biodiversity trends at the circumpolar scale. To meet these challenges, the Circumpolar Biodiversity Monitoring Program (CBMP) is working with partners to harmonize and enhance long-term Arctic biodiversity monitoring efforts in order to facilitate more rapid detection, communication and response to significant trends and pressures. Towards this end, the CBMP is facilitating an integrated, ecosystem-based approach to monitoring through the development of five Expert Monitoring Groups representing major Arctic themes (Marine, Coastal, Freshwater, Terrestrial Vegetation & Terrestrial Fauna). Each group will function as a forum for scientists, community experts and managers to promote, facilitate, share, and coordinate research and monitoring activities. In turn, this will faciliate improved and cost-effective monitoring that has a greater ability to detect and understand significant trends in Arctic biodiversity in a timely fashion.


Lawrence Hislop

The establishment of a FEMG is a logical approach for facilitating an integrated, ecosystem-based approach to the monitoring of Arctic freshwater biodiversity. An Arctic FEMG will support the development of a multi-disciplinary, integrated, pan-Arctic monitoring plan that identifies critical monitoring gaps and develops strategies to fill gaps. The output of this monitoring plan will serve to inform both the public as well as decision and policy makers from the local to the global level and will contribute to periodic assessments of the state of the Arctic fresh waters. The group will also serve as a forum for providing ongoing scientific and traditional knowledge (TK) input into enhancing current monitoring. The FEMG will make use of existing monitoring data, draw on expertise from both inside and outside the Arctic and from other relevant disciplines (i.e. climate science), incorporate both community- and science-based approaches, develop standardized protocols and analytical tools, and use existing and emerging technologies, such as remote sensing and genetic bar-coding, where appropriate. The FEMG will include and engage community, scientific, and indigenous experts. The group will not only work with existing research stations and monitoring networks to develop integrated, forward-looking monitoring programs, but also focus efforts on the retrieval and use of existing historical information, be it TK or archived scientific data.

Arctic freshwater ecosystems to be monitored by FEMG include all biotic components, processes, and services of lentic and lotic water bodies (ponds, lakes, and their tributaries, rivers and their tributaries) north of the treeline, *plus* more southerly water bodies entering this biogeographic boundary. Abiotic components that influence/drive biotic components, processes, or services, while not directly monitored by CBMP, will be taken into account as important in planning of monitoring and during interpretation of results. Abiotic and biotic components/processes that occur within wetlands and directly affect the aforementioned water bodies (e.g., terrestrial-aquatic linkages) should be considered in the monitoring efforts of FEMG.

The development of the FEMG will facilitate more powerful and cost-effective assessments of Arctic aquatic ecosystems. A central principle of the Freshwater EMG will be a focus on observing and understanding the cause of measured long-term change in the composition, structure, and function of Arctic lake, pond, and river ecosystems, as well as authoritative assessments of focal taxa species (e.g., key indicators, such as those that are ecologically pivotal, and/or charismatic taxa, or provide sensitive community biodiversity information).

While most Arctic biodiversity monitoring networks are national or regional in scope, there is much value in establishing circumpolar connections among monitoring networks. The development of a pan-Arctic, long-term, integrated freshwater biodiversity monitoring plan will facilitate circumpolar connections between national and regional research and monitoring networks, thereby greatly increasing the power to detect and attribute change for a reduced cost, compared to uncoordinated approaches. There are already a number of networks focused on aspects of Arctic freshwater biodiversity and ecosystems from which FEMG may draw. One of these networks, and a key building block for an Arctic Freshwater Expert Working Group, is the ABC-Net: Arctic Biodiversity of Chars – Network for Monitoring and Research. Additional networks include the coordinated research and monitoring efforts of Expert Monitoring Groups of the Conservation of Arctic Flora and Fauna (CAFF) and the Arctic Monitoring and Assessment Program (AMAP).

From January to April 2009 the Canadian Sub-Group of the FEMG developed objectives and a proposed framework for FEMG operation. This document represents results of these activities and was used to frame discussions for the Canadian workshop in December 2009, as well as the first international meeting of the FEMG in November 2010. The Canadian component of the FEMG conducted a small workshop in December 2009 to review and refine the background document and to develop a multi-year work plan for Canada's Arctic region. Key outputs from the national meeting of Canadian experts also informed the first international FEMG workshop.

2. INTRODUCTION

2.1 Coordination and integration of Arctic monitoring: the CBMP

Arctic biodiversity is under growing pressure from both climate change and resource development while established monitoring programs remain largely uncoordinated, lacking the ability to effectively monitor, understand and respond to biodiversity trends at the circumpolar scale. The maintenance of healthy Arctic ecosystems is a global imperative as the Arctic plays a critical role in the Earth's physical, chemical and biological balance. Maintaining the health of Arctic ecosystems is also of fundamental economic, cultural and spiritual importance to Arctic residents, many of whom maintain close ties to the land. *To meet these challenges, the Circumpolar Biodiversity Monitoring Program (CBMP) is working with partners to harmonize and enhance long-term Arctic biodiversity monitoring efforts in order to facilitate more rapid detection, communication and response to significant trends and pressures*.

The Arctic's size and complexity represents a significant challenge towards detecting and attributing important biodiversity trends. This demands an integrated, pan-Arctic, ecosystem-based approach that not only identifies trends in biodiversity, but also identifies underlying causes. It is critical that this information be made readily available to generate effective strategies for adapting to changes now taking place in the Arctic - a process that ultimately depends on rigorous, integrated, and efficient monitoring programs that have the power to detect change within a reasonable time frame.

Towards this end, the CBMP facilitates an integrated, ecosystem-based approach to monitoring through the development of five Expert Monitoring Groups representing major Arctic themes (Marine, Coastal, Freshwater, Terrestrial Vegetation and Terrestrial Fauna). These groups function as a forum for scientists, community experts and managers to promote, facilitate, share, and coordinate research and monitoring activities. In turn, the groups faciliate improved and cost-effective monitoring that has a greater ability to detect and understand significant trends in Arctic biodiversity in a timely fashion.

2.1.1 Importance of Arctic freshwater ecosystems

Arctic freshwater ecosystems (i.e., rivers, lakes and ponds) are under increasing stress from climate change, contaminants, introduced species, increased UV radiation exposure, and resource development. Climate change will directly and indirectly affect these systems and the biodiversity they support, including fish that provide food for Northerners. Many of these effects will be due to changes in the physical and chemical properties of freshwater systems (changing water temperature, thawing permafrost, changing ice cover extent and duration, altered hydrological processes and water balance), but will also involve the impact of growing competition from southern species expanding northwards as the result of ecosystem-restructuring. All of these stressors are expected to result in changes to freshwater fisheries around the Arctic, changing distributions of aquatic invertebrates, vertebrates and plants, and modifying ecosystem services to humans such as harvests from freshwater systems, drinking water, hydroelectric power, transportation and sewage disposal.

2.1.2 Arctic Freshwater Expert Monitoring Group (FEMG)

The establishment of a Freshwater Expert Monitoring Group (FEMG) is seen as a logical approach for facilitating an integrated, ecosystem-based approach to the monitoring of Arctic freshwater biodiversity. Creation of an Arctic FEMG will support the development of a multi-disciplinary, integrated, pan-Arctic monitoring plan (optimal sampling schemes, common parameters and standardized monitoring protocols, etc.) that identifies critical monitoring gaps, develops strategies to fill gaps, and inventories existing Arctic biodiversity monitoring activities. The output of this monitoring plan will serve to inform both the public as well as decision and policy makers from the local to the global level and will contribute to periodic assessments of the state of the Arctic fresh waters. The group will also serve as a forum for providing ongoing scientific and TK input into enhancing current monitoring. The FEMG will be expected to make use of existing monitoring and data, draw on expertise from both inside and outside the Arctic and from other relevant disciplines (i.e. climate science), incorporate both community- and science-based approaches, develop standardized protocols and analytical tools, and use existing and emerging technologies such as remote sensing and genetic bar-coding, where appropriate.

The FEMG will include and engage community, scientific, and indigenous experts. The group will not only work with existing research stations and monitoring networks to develop integrated, forward-looking monitoring programs, but also focus efforts on the retrieval and use of existing historical information, be it knowledge, archived scientific data or data collected in citizen monitoring programs.

2.1.3 Connections to local, national and global mandates

The outputs of a coordinated monitoring approach for Arctic freshwater ecosystems will serve a number of mandates at various scales (see Figure 1). The resulting information, as much as possible, will be provided at a local scale to serve local decision-making. This will be achieved partly through local-scale community-based monitoring approaches, but also through interpolation and modelling techniques to provide information that Arctic residents can use to make effective adaptation decisions.

The outputs will also be of direct value to national governments and departments who have a mandate for monitoring and reporting on the status of Arctic freshwater ecosystems. For example, within Canada this mandate is shared by a number of federal, territorial and provincial governments responsible for the management and monitoring of various aspects of northern aquatic ecosystems. The development of optimal sampling schemes and standardized and integrated approaches to monitoring will allow regional and national governments to better understand trends and the mechanisms driving those trends within their own region. Only through a structured and collaborative effort, can any one government or department have the ability to detect and understand trends experienced in their region and therefore, effectively respond to those trends. The Arctic Council will also be a direct beneficiary of the outputs of this collaborative effort. The outputs of the pan-Arctic integrated freshwater biodiversity monitoring plan will help populate Arctic Council assessments and raise issues facing Arctic freshwater ecosystems that require a coordinated, pan-Arctic or even global response.

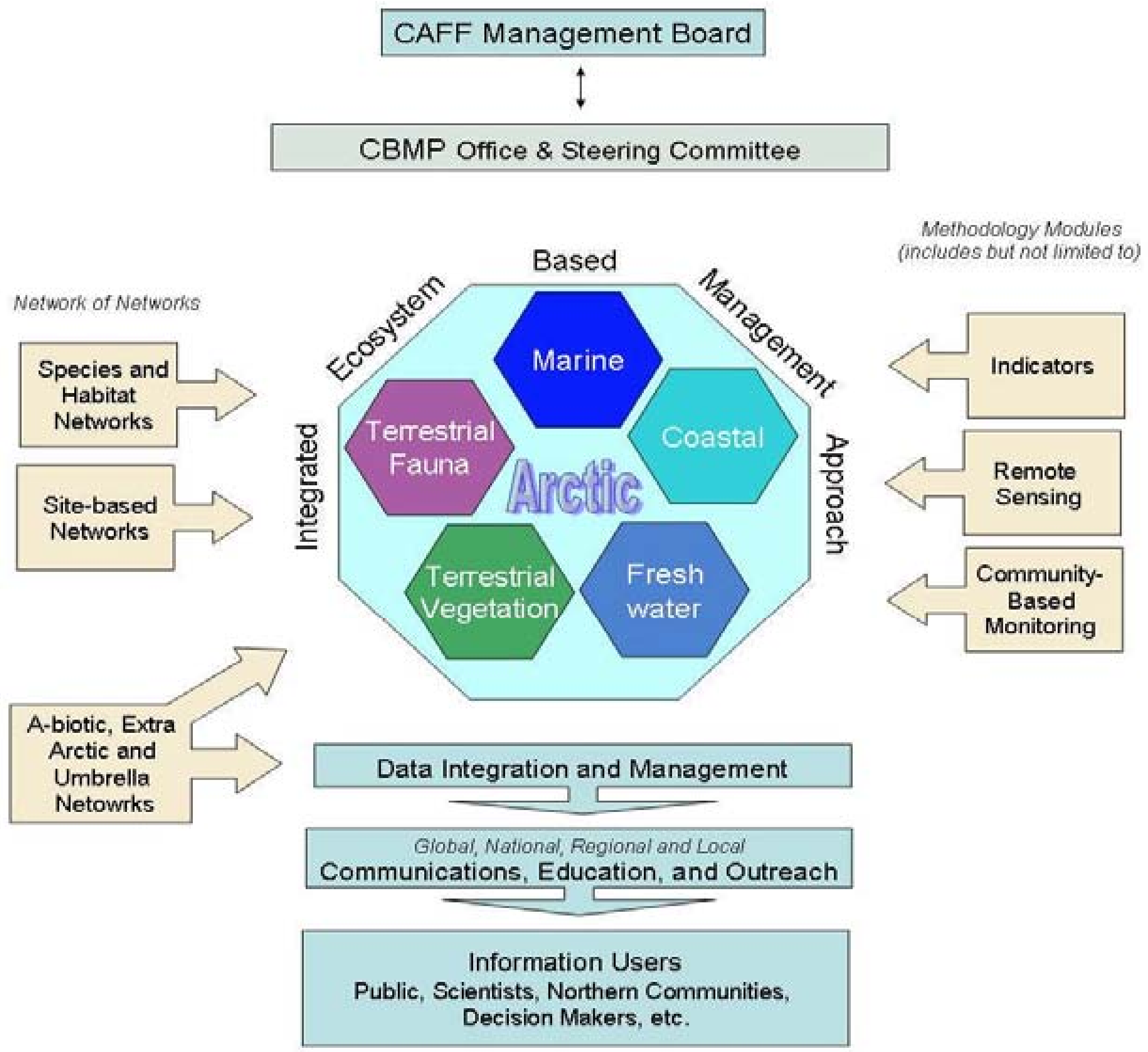

Figure. 1: Relationship of Expert Monitoring Groups to the Circumpolar Biodiversity Monitoring Program of the Conservation of Arctic Flora and Fauna.

2.1.4 Goals and objectives of the Freshwater EMG

The Freshwater EMG's goal will be to promote, facilitate, coordinate and harmonize freshwater biodiversity monitoring activities among circumpolar countries, and to improve ongoing communication amongst and between scientists, community experts, managers and disciplines both inside and outside the Arctic. Specifically, the FEMG's objectives are:

To develop a multi-disciplinary, integrated, pan-Arctic long-term freshwater biodiversity surveillance assessment that:

- Responds to identified science questions and user needs;
- Identifies an essential set of indicators for freshwater ecosystems that are suited for measurement and implementation on a circumpolar level;

- Creates a strategy for the use and organization of existing research and operational monitoring capacity and information (scientific, community-based, and TK);
- Establishes and promotes effective communication and linkages among Arctic freshwater researchers and monitoring groups;
- Identifies key abiotic parameters, relevant to freshwater biodiversity, that need ongoing monitoring;
- Addresses current gaps in coverage (elemental, spatial and temporal); and
- Identifies a core set of standardized protocols and optimal sampling strategies for monitoring Arctic freshwaters.

To facilitate implementation of the long-term monitoring plan and reporting on the state of circumpolar Arctic freshwater ecosystems by:

- Developing a global network of Arctic freshwater biodiversity monitoring sites through preparation of inventory lists, interactive maps and online forums;
- Establishing a state-of-the art biodiversity monitoring plan for the circumpolar Arctic focused on early warning of environmental change;
- Defining and standardizing efforts of sampling, data collection, and taxonomic identification;
- Assessing current status of biodiversity and biodiversity monitoring in the Arctic and forecasting future changes in Arctic freshwater biodiversity;
- Producing value-added integration among researchers and disciplines through assessments (e.g., Arctic Biodiversity Assessment), co-authored scientific publications, and data sharing;
- Deliver the information to stakeholders and contributors that provided TK (local communities), and scientific data (scientific community); and
- Preparing outputs to trigger policy response to changes in Arctic biodiversity through international synthesis reports and ad-hoc reports aimed at policy makers; and

To foster new research initiatives to improve environmental prediction for Arctic freshwaters.

2.1.5 Definition of Arctic freshwater ecosystems for the FEMG

Arctic freshwater ecosystems to be monitored by CBMP FEMG should include all biotic components, processes, and services of lentic and lotic water bodies (ponds, lakes, and their tributaries, rivers and their tributaries) north of the treeline, plus more southerly water bodies entering this biogeographic boundary. Abiotic components that influence/drive biotic components, processes, or services, while not directly monitored by CBMP, will be taken into account during the planning and result interpretation phase. The FEMG will endeavor to link to groups collecting such information. Abiotic and biotic components/processes that occur within wetlands and directly affect aforementioned water bodies (e.g., terrestrial-aquatic linkages) should be considered in the monitoring efforts of FEMG.

2.1.6 Benefits of contributing to a circumpolar, coordinated effort

The development of the FEMG will facilitate more powerful and cost-effective assessments of Arctic aquatic ecosystems. A central principle of the Freshwater EMG will be a focus on observing and understanding the causes of measured long-term change in the composition, structure, and function of Arctic lake, pond, and river ecosystems, as well as authoritative assessments of focal taxa species (e.g., key indicators, such as those that are ecologically pivotal, and/or charismatic taxa, or provide sensitive community biodiversity information).

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2.2 Overview of history and current status of FEMG

Planning for the FEMG has been ongoing since 2006. Three international CBMP workshops held in Anchorage (November 2006), Washington, DC (March 2008), and Vancouver (September 2008) helped establish the concept and development of five EMG's (terrestrial (flora and fauna), coastal, marine, freshwater). At the Washington, DC meeting, Canada agreed to act as the lead country for the initial development of the FEMG.

The above workshops led to the conceptual development of the FEMG. This was furthered by the development of a core working group that promoted two linked activities: a) international development of the FEMG through the extension and continuation of International Polar Year activities; and b) development within Canada of a parallel supporting national network. A preliminary planning meeting was held in December 2008 in conjunction with the *ArcticNet Annual Science Meeting* (Quebec City) to discuss the next steps in organizing an inaugural workshop and preliminary work plan (including the development of this document).

This document is based on ideas, discussions, and decisions made during and following these workshops. In addition, the Canadian subgroup of the FEMG held a small workshop in December 2009 to review and refine the background document and to draft a work plan prior to the first international FEMG workshop in November 2010 (2009-2011 Work Plan, Appendix I). The goals of the FEMG are as outlined in the introduction of this document.

3. PROBLEM FORMULATION

Information on biodiversity is sparse for the Arctic and many untested assumptions provide the only operational paradigms and context for long-term monitoring. While individual programs and efforts do exist, there is a lack of ecosystem-level integration of the current programs focused on aquatic biodiversity. Consequently, the 'bigger picture' is being missed, making it difficult to assess the impacts of known stressors to the Arctic (e.g., climate change, industrial development) and their consequences to humans. All recent assessments and reports (Arctic Climate Impact Assessment, International Conference on Research Planning II, Intergovernmental Panel on Climate Change) underscore that the Arctic will be affected most profoundly by climate change.

As a result of climate change, land-use changes such as industrial development (e.g., mining, oil and gas) are expected to increase in the Arctic. With increased development, a number of additional secondary effects on Arctic freshwater ecosystems are expected. Climate change can be seen as the overarching stressor that leads to and compounds effects of secondary (subsequent) stressors on Arctic freshwater ecosystems. Differentiating between natural variability and change (i.e., 'noise') and variability or change resulting from anthropogenic stressors (i.e., 'signal') is a key aspect underlying the development of effective remedial policy actions. This is made even more challenging as there are a multitude of stressors acting on the Arctic ecosystem on several spatial (local, regional, pan-Arctic, global) and temporal (pervasive, such as climate change) scales. Here we make an initial attempt to identify these Arctic Ecosystem stressors and the spatial extent of their effects Table 1.

Spatial integration is necessary to deliver meaningful information for this monitoring program. The CBMP's mandate is to measure biodiversity on an ecosystem level. A number of relevant aspects that need to be discussed prior to defining geographic scales are related to: 1) the nature of the ecosystem (size of ecosystem = river or lake); 2) geopolitical / societal region; 3) biogeographic region; and 4) the nature of stressor (e.g., for contaminants - point versus atmospheric source).

In order to have the monitoring program achieve relevant spatial coverage, a definition of region is necessary. 'Region' can be defined in several ways including political borders (territorial or settlements), socioeconomic categories, geologic regions, watersheds, or biogeography (Figure 2). Different regions will be affected by different stressors to differing degrees – in some cases, a given region could even serve as reference for another (e.g., a remote site could be used as reference site for one to be impacted by development). Monitoring should be performed in a way that allows comparisons among regions, and needs to be extended to suit a given region's specific issues or interests. While common metrics and standards need to be identified, the FEMG must also allow for regional variation in the monitoring to accommodate regional needs/issues and unique features.

Temporal aspects need to be considered by the FEMG. In order to detect changes to freshwaters on an ecosystem level, long-term temporal data are desirable. Data sets from the Arctic are rarely continuous and generally are produced during short-term investigations. Future monitoring work will need to identify sites where continuous data collections will be possible. New studies also often tend to lack linkages to previously collected archival data. This needs to be improved by accessing historic information (e.g., reports of past studies, photographs) to which the current status can be compared.

Table 1: Main stressors and expected responses of Arctic freshwater systems.

Stressor	Scale	Expected responses:	
		Abiotic Factors	Biotic Effects
Changing climate	Pervasive	- Temperature increases- Changes in precipitation and hydrological regime - Permafrost degradation - Nutrient enrichment	- Ecosystem processes - Community structure - Community function - Population dynamics - Biodiversity shifts
Human / land-use	Local / regional	- Permafrost perturbation - Changes in resource use (e.g., dam building) - Eutrophication - Contaminant inputs and fluxed	- Ecosystem processes - Population dynamics - Biodiversity (local) - Community structure and function
Industrial development	Local / regional	- Permafrost perturbation - Changes in resource use (e.g., dam building) - Eutrophication - Contaminant inputs and fluxes - Landscape changes	- Ecosystem processes - Population dynamics - Biodiversity (local) - Community structure and function

Three temporally distinct sources of information could be used: 1) paleo-records as longer and medium term records (e.g., lake sediments); 2) indigenous knowledge (TK or local knowledge) as a medium-term general record; and 3) recent or historical monitoring and/or scientific data. All of these should be used in discussions of where to develop a long-term monitoring site.

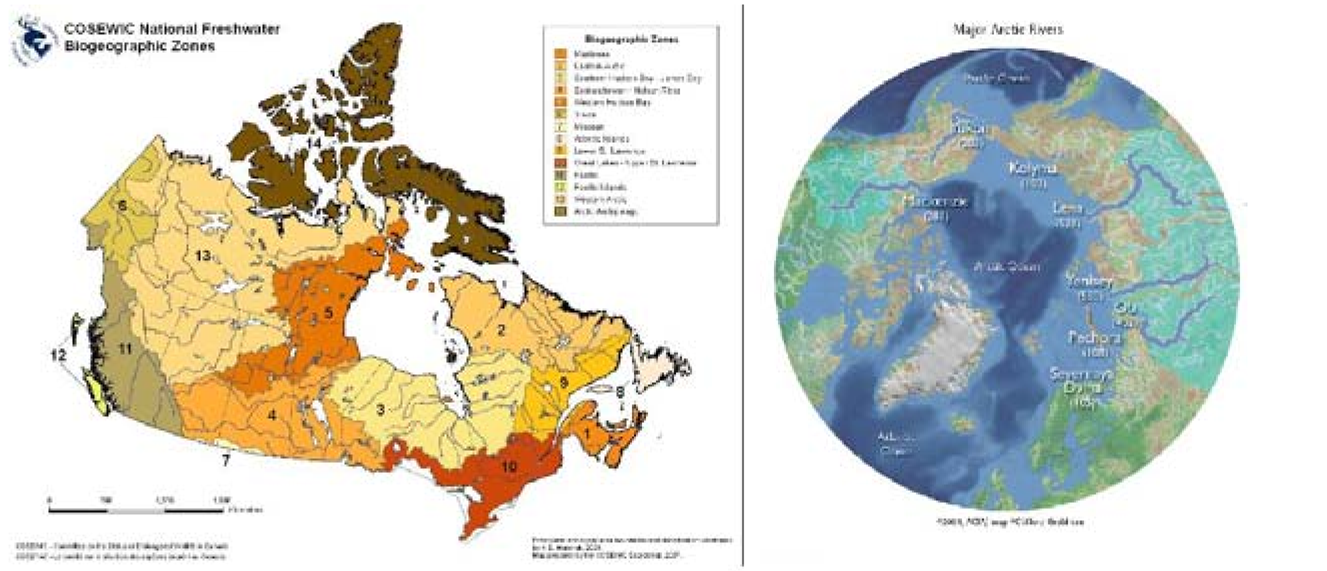

Fig.2 Biogeographic Zones are one possible way to define region, this would need to be expanded across the Arctic. Source: http://www.cosewicgc.ca

4. CONSIDERATIONS FOR MONITORING ARCTIC BIODIVERSITY

Biodiversity monitoring in the Arctic presents a number of challenges and limitations that are related to the large area and difficult (and costly) logistics. Key challenges and potential solutions to the monitoring of Arctic biodiversity are described below. Note that we define *parameters* as the measured biotic or abiotic entity of the ecosystem, *indicators* as the valued (and likely to be monitored) or pivotal components of the ecosystem (and thus likely to be good proxies of underlying changes); and *indices* as guides that indicate change. For example, Arctic char are good indicators, individual fish size is a measured parameter, and in a strict sense, size structure is an index.

4.1.1 Heterogeneity of Arctic freshwater ecosystems in time and space

Circumpolar Arctic ecosystems are highly heterogeneous (Table 2). Overcoming the large geographic distances between proposed monitoring sites will be a challenge. The metrics chosen for monitoring may need to be separated into intra-regional and inter-regional sets of metrics. Alternatively, monitoring may be reduced to using common ecological features and species as effective indicators.

4.1.2 Heterogeneity of stressors

Arctic freshwaters may be affected by many stressors on their own or in combination. Stressors include (but are not limited to) climate change, development (e.g., roads, population expansion), exploration of natural resources (e.g., non-renewable resources such as hydrocarbons; renewable resources such as fisheries) and contaminants. Sensitivity of an ecosystem to a stressor may vary, depending on intensity, frequency, and/or duration with which a stressor affects a system. For example, climate change may affect a system gradually until a certain threshold is exceeded. Moreover, the effect of multiple stressors is difficult to predict and represents a challenge for freshwater monitoring. Anthropogenic stressors as well as naturally changing biophysical components of the ecosystem can have a variety of effects when combined together, including antagonistic, additive or synergistic.

4.1.3 Cost-benefit of monitoring certain parameters

Sampling efficiency is important, especially when conducting monitoring in remote areas with high associated cost. Most ongoing research programs run on tight schedules and under financial constraints, thus any additional measures added to existing work need to be simple, repeatable, and effective. Where possible, monitoring should be conducted by Arctic residents (i.e., citizen science as a form of community-based monitoring).

4.1.4 Community-based monitoring

Involving local people in the program can help reduce cost while increasing the spatial and temporal components of the monitoring program. This will require provision for training in local communities, and a standardization of operating procedures and field manuals for non-expert users. Use and inclusion of *Indigenous and Traditional Knowledge* (terminology of Arctic council) will be necessary to ensure acceptance by northern communities and stakeholders, and to document recent observations and historical changes. This will provide important knowledge that may not be detected during routine monitoring programs.

Table 1: Main stressors and expected responses of Arctic freshwater systems.

Habitat type	- Standing water (lentic)
	- Flowing water (lotic)
Size of waterbody	- Size of lakes
	- Order of lake
	- Order of rivers
Biota	- Fishless or fish bearing
	- Fish community structure
	- Pelagic and benthic community structure
	- Trophic interactions and linkages
	- Species presence and absence
Region (defined above)	- Watershed
	- High versus low Arctic
	- Island versus mainland
	- Ecozone (climatic region)
Nature of changes	- Smooth versus catastrophic or stepwise events
Socio-economic aspects	- Proximity to communities and settlements
	- Importance to community
	- Proximity to exploration (ongoing or planned)
Cost of data acquisition	- Sampling effort and logistics
Site access	- Can species X be sampled frequently and extensively
	- Does a participating organization have a particular interest in the site (i.e., endangered species)?

5. MONITORING APPROACH FOR ARCTIC BIODIVERSITY

5.1 General overview of approaches in freshwater biomonitoring

The selection of approaches mentioned below affects the choice of metrics and scale (sections below).

1. Population approaches with focus on charismatic species or valued ecosystem component (VEC) (Indicator approach);
2. Ecosystem approaches with focus on biological communities and ecosystem function and services (mandate of CBMP) (Parameter and index approach).

The mandate of CBMP is to integrate information to the ecosystem level (ecosystem approach, 2 above), as conceptualized in Figure 3. Linking population and ecosystem approaches may be a valuable method to incorporate indicator species/ populations (e.g., charismatic species, country foods) and ecosystem approaches so that partners see the value of the partnership.

Research-based monitoring: Research studies can be adapted to also support monitoring programs by synchronizing areas of study, and maximizing information gathered during field programs. Further efficiencies could be realized by combining several studies, and thus results may be pooled to generate broader spatial and temporal measures of freshwater biodiversity that was not the original focus of the individual researchers.

Focused monitoring: This approach has the sole purpose of monitoring specific locations or ecosystems. Focused monitoring programs include compliance monitoring by industry or other focal groups.

Citizen-science based: All are welcome to engage in the monitoring by reporting ad-hoc. Being voluntary, success is limited to the number of interested citizens, their training and organization, and the duration of their interest. This interest depends on how well a community is engaged in the initial stages of setting up such a program. Citizen-science can be improved to the more focused community-based effort over time (e.g., when a certain change is observed – this can then be expanded to a focused, community-based monitoring.)

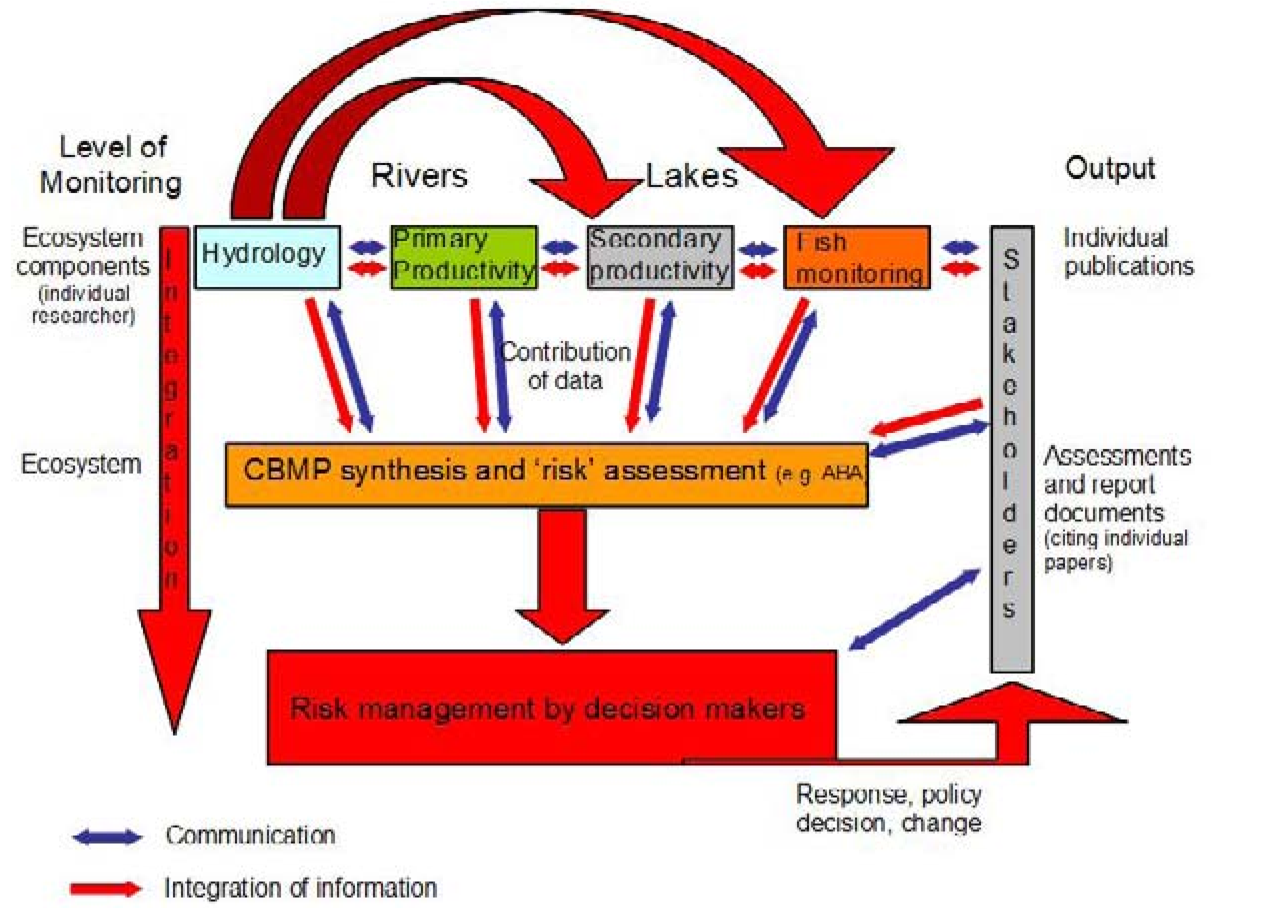

Figure.3 Conceptualized diagram of the CBMP approach to integrate information from individual programs to a holistic understanding of biodiversity on an ecosystem level.

Community-based: A group of stakeholders is involved in the monitoring program from selection of parameters to the endpoints of data interpretation and reporting, and decision making. This typically involves collection of basic scientific data (e.g., fish counts) useful in documenting changes. Many successful examples exist particularly in the south. A challenge will be to adapt, implement and fund such biodiversity focused monitoring programs in the north.

Traditional/local knowledge based: This monitoring approach collects information from Elders or other knowledgeable individuals regarding perceived or observed changes that were identified and transferred among generations of local people. Ideally, the FEMG will include participants who are well-versed in the practice of incorporating TK into contemporary science programs.

Table 3: Examples for metrics (parameters and indicators). This table can be expanded with examples at parameter, indicator and index levels of relevance.

Parameters

- Ice thickness (Ice On/Ice off), physical parameters, water chemistry (nutrients, ions, etc)
- Presence/Absence of species (invasive species)
- Monitoring of condition / parameter to detect change
- Species range / distribution limits (presence and absence)
- Diversity indices (e.g. Shannon-Weaver)
  Indices of species turnover

Indicators / nodal points

- Key species and interaction between species and their drivers (e.g. nutrient cycling)
- Structure and function of communities (algae, zooplankton, benthos, fish)
- Species range expansion
- Lake loss / de-watering (hydrological changes – evaporation/precipitation
- River courses / changes (water quantity – hydrological flow)

Perspectives of monitoring

- Population ecology and community composition of aquatic organisms
- Lower trophic levels community composition
- Structure and function of ecosystems (are effected?)

5.2 Inventorying and assessing existing capacity

Currently, there are a number of research stations and platforms across the Arctic that have supported many long-term research and monitoring programs and have collected a wide range of data. Therefore, these existing stations and networks provide a potentially cost-effective opportunity to initially implement a pan-Arctic freshwater monitoring framework and the monitoring plan should build upon this existing capacity. These efforts can be categorized into a) monitoring sites that measure one or few metrics over an extended time period or spatial area, and b) sites that integrate multiple metrics within a given ecosystem (e.g., a watershed). Gaps in spatial or temporal coverage, in metrics useful in a pan-arctic perspective, and potential linkages of existing information sources into useful local, regional and/or pan-arctic indices should be identified, and summarized to guide development of future monitoring programs.

5.3 Design of a monitoring program - methods and metrics

Many of the current methods used to measure biodiversity are common and well known, although there are also important developing methods such as genetic barcoding. It is necessary to standardize methods and approaches and particular metrics in order to produce comparable results that can be integrated into a circumpolar/pan-Arctic assessment. A basic selection of methods (not limited to) is presented below:

- Remote Sensing (multi-scalar)
- Censusing (developing new initiatives (i.e. Genetic barcoding)
- Fishery monitoring (benthic and pelagic invertebrates and algae, macrophytes, bacteria, waterfowl, aquatic mammals) and invertebrate bioassessment methods
- Stable isotope trophic measures (C, N) and hydrological measures (O,H)
- Stressor proxies (e.g., contaminants as tracers?)

5.3.1 Standardization of efforts

In order to produce comparable data on metrics on a pan-Arctic scale, measurements or collections need to be standardized, wherever possible. Standard operating procedures, and required training programs for sampling, data analysis, data management and status reporting need to be developed and distributed to individual groups.

5.3.2 Reference condition approach (RCA)

In order to detect changes in an ecosystem, the reference condition approach or (RCA) is one that is typically adopted. Sites/ecosystems are selected that represent natural (reference) conditions. These conditions are then compared over time to a site that may be affected or undergo change to establish baseline differences (before a stressor effects the system). The RCA could be used to either capture temporal changes (before/after), or spatial (development / construction or unaffected to varying degrees of affected). RCA is also used in a spatially comparative sense if one has a series of sites which are affected to differing degrees by a common driver/stressor; this is also possible if sites are affected to differing degrees by several different stressors.

Before and After Comparative approach: This may be a viable alternative to the RCA, particularly for point source stressors. It is necessary here to establish the baseline conditions (before impact/alteration), then assess the condition immediately/timely following an impact (after), as well as continue monitoring possible recovery of systems.

5.3.3 Frequency of observations/measurements

How often a given ecosystem should be sampled may depend on the stressor, as well as financial and logistical constraints. If the ecosystem is monitored – how intense is the monitoring (annual sampling / measurements, biennial, every 5 years)? If a population is monitored – how often is this necessary?

5.3.4 Uncertainty analysis (Spatial Variability)

Extrapolations from one system to the next (neighbouring or not) creates some uncertainty that needs to be addressed, for example: How well does the selected and monitored system reflect the conditions in other systems? How well does the reference site correspond to the site where impacts are being measured? There is considerable spatial diversity in the Arctic due to climatic and ecological gradients, there is also a diversity of freshwater ecosystems within the Arctic, and different freshwater habitats might be predicted to respond to ecological stressors differently and at different rates.

Peter Prokosch

6. DEVELOPMENT OF CIRCUMPOLAR FEMG EFFORTS

The development of an integrated monitoring plan for circumpolar freshwaters will be a major undertaking of the FEMG. The intent of the CBMP, as outlined in the introduction of this document, is to bring together existing sites, data sets and supporting information in a coherent and integrated way. The aim of the FEMG will be to identify the gaps in monitoring and suggest solutions that will limit their extent in the future. Initially, the FEMG will need to determine the key components of ecosystems that will be monitored. Metrics (parameters, indicators, indices) to be used for the program will need to be chosen, and the required spatial and temporal resolution required for assessments established. Once the framework of the monitoring program has been determined, and all available information gathered, a gap analysis can be conducted to determine what information remains to be collected. As an example of initial output, current projects could be geo-referenced (site specific) and mapped throughout the circumpolar Arctic. Such a map is available for U.S. NSF funded work: http://armap.org/ (Figure 4).

Circumpolar Arctic freshwaters are facing unique challenges through the interactions of natural and anthropogenic stressors such as climate change and industrial development. Biodiversity is expected to be affected; however a pan-Arctic monitoring strategy to identify these changes is not in place. The initial FEMG workshop will need to identify metrics and approaches to assess impacts of important stressors. These metrics and approaches could then be used throughout the network. Several of the key challenges that Arctic freshwater monitoring face includes the daunting heterogeneity of Arctic freshwater ecosystems in time and space; heterogeneity of exposure of stressors to biota; lack of research coordination; sparse spatial coverage of monitoring that is insufficient to detect long term trends; and lack of standardized sampling methods.

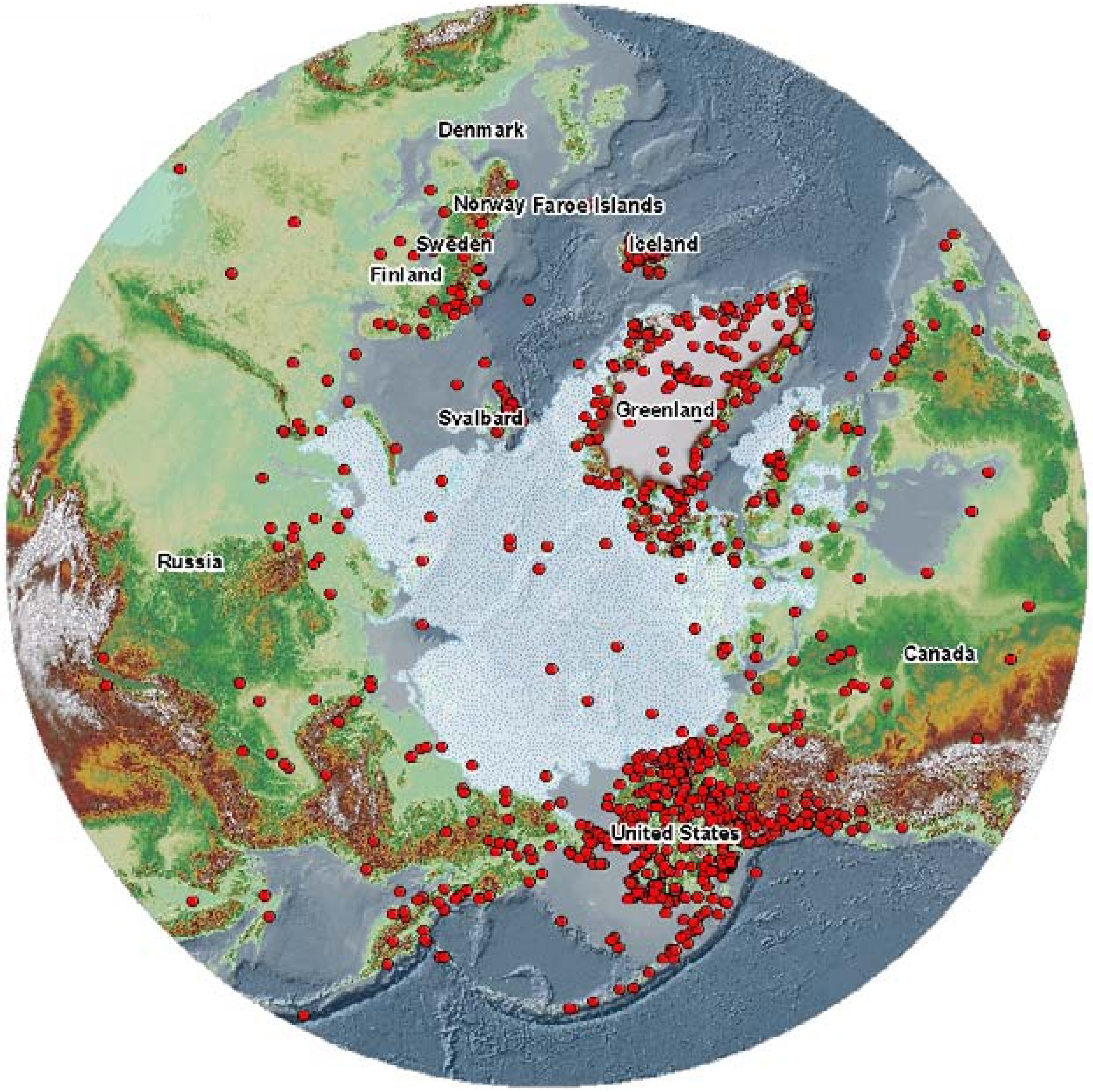

Figure. 4 Map of Arctic National Science Foundation Field Research sites.

7. APPENDICES

7.1 Appendix I: 2009 – 2011 Work Plan of CBMP-FEMG

JANUARY 2009

- Begin work on the background paper

APRIL 2009

- Complete background paper and send out for initial review
- Contact Canadian experts and arrange time and venue for workshop

JULY 2009

- Initiate list of international experts for Freshwater EWG and canvas international community for CBMP co-lead
- Establish Canadian network hub in affiliation with the Canadian Rivers Institute (University of New Brunswick)

OCTOBER 2009

- Workshop logistics and planning completed
- Organize special session for Oslo Science Conference, June 2010

DECEMBER 2009

- Hold 2 day workshop in conjunction with ArcticNet Conference in Victoria to organize Canadian input to FEMG

JANUARY 2010

- Complete draft FEMG work plan for 2009-2010 (work plan to include holding an inaugural meeting of international experts, timelines for completing a framework document of the FEMG, etc.) and work on FEMG framework

MARCH 2010

- Finalize FEMG framework and implementation plan with international FEMG co-lead

MAY 2010

- Inaugural meeting FEMG Steering Group; monthly teleconference intitiated

JUNE 2010

- Special session at Oslo Science Conference and meeting of FEMG Steering Group

NOVEMBER 2010

- Inaugural meeting of international FEMG; begin work on an integrated monitoring plan

FEBRUARY 2011

- FEMG presentation to CAFF Board at 13th Biennial Meeting in Akureyri, Iceland

MAY 2011

- Presentation on FEMG progress at "Arctic as a Messenger for Global Processes - Climate Change and Pollution" conference in Copenhagen, Denmark
- FEMG Steering Group meeting to finalize FEMG long-term work plan and develop agenda for 2nd Workshop to be held in Canada

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