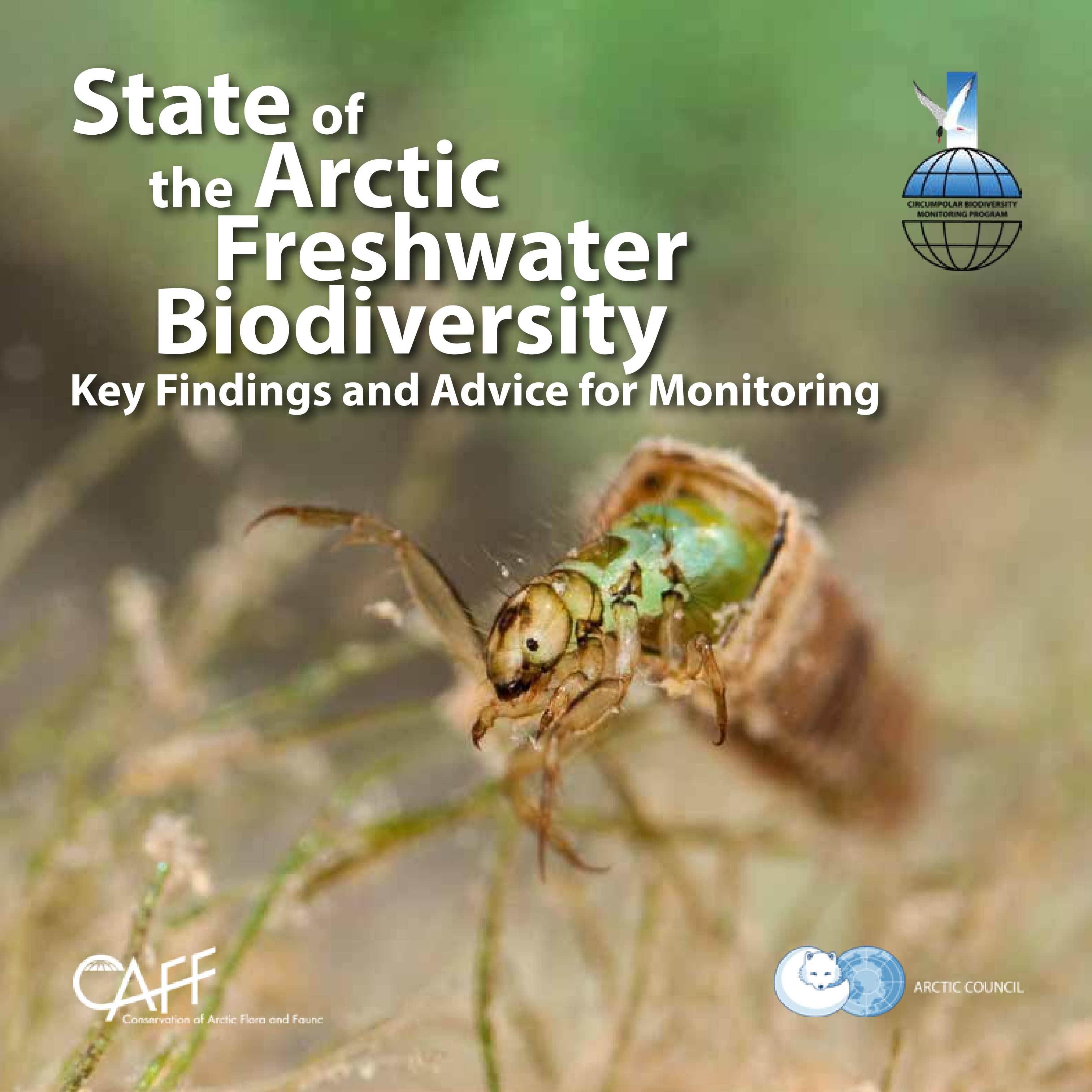
State of the Arctic Freshwater Biodiversity

Key Findings and Advice for Monitoring



CIRCUMPOLAR BIODIVERSITY MONITORING PROGRAM

CAFF Conservation of Arctic Flora and Fauna

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State of the Arctic Freshwater Biodiversity: Key Findings and Advice for Monitoring

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The report and associated materials can be downloaded for free at: **www.arcticbiodiversity.is/freshwater**

Cover photo: *Brachycentrus subnublius*, a casemaking caddisfly/Jan Hamrsky

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- Environment and Climate Change Canada
- Faroese Museum of Natural History
- Finnish Ministry of the Environment
- Ministry of Nature and Environment, Government of Greenland
- Icelandic Institute of Natural History
- Norwegian Environment Agency
- Ministry of Natural Resources and Environment of the Russian Federation
- Swedish Environmental Protection Agency
- United States Department of the Interior, Fish and Wildlife Service

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- Aleut International Association (AIA)
- Arctic Athabaskan Council (AAC)
- Gwich'in Council International (GCI)
- Inuit Circumpolar Council (ICC)
- Russian Association of Indigenous Peoples of the North (RAIPON)
- Saami Council

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*Arctic Char (*Salvelinus alpinus*) in a Greenlandic River. With increasing climate change and human development, cold-water endemic species unique to the Arctic, such as Arctic char, may suffer regional losses with the potential for local extinctions in extreme cases. Photo: Dan Bach Kristensen*

Introduction

The ***State of the Arctic Freshwater Biodiversity Report*** (SAFBR), is a product of the ***Circumpolar Biodiversity Monitoring Program*** (CBMP) Freshwater Group of the Arctic Council's ***Conservation of Arctic Flora and Fauna*** (CAFF) Working Group. The SAFBR provides a synthesis of the state of knowledge about biodiversity in Arctic freshwater ecosystems (e.g., lakes, rivers, and associated wetlands), identifying detectable changes and important gaps in our ability to assess biodiversity across a number of Focal Ecosystem Components (FECs; see Box 1): fish, benthic macroinvertebrates, zooplankton, planktonic algae, diatoms (algae), and macrophytes. The overall goal of the SAFBR is to assess the current status and trends of freshwater biodiversity of FECs across the Arctic on a circumpolar scale.

Freshwater ecosystems are closely connected to the surrounding landscape, and climate change and land-use alterations affect their physical, chemical and biological conditions. Rivers and lakes host diverse communities of microscopic plankton, plants, invertebrates, and fish which are interrelated in food webs. Changes affecting these populations act as indicators of human-induced disturbances to the ecosystem. Freshwaters also provide important ecosystem services, such as drinking water, fish production, and hydropower, which makes them key elements in Arctic landscapes.

The SAFBR represents the first circumpolar assessment of freshwater biodiversity across the Arctic. Snapshots of the present state of knowledge and trends for each FEC are provided. By locating and compiling available data and information from all Arctic countries, it also provides an important first step towards identifying knowledge gaps in circumpolar biodiversity monitoring efforts.

The **Arctic Freshwater Biodiversity Monitoring Plan** is a framework developed by Arctic freshwater ecosystem and species experts to compile, harmonize, and compare results from existing freshwater biodiversity and ecosystem monitoring efforts in the Arctic. This work is coordinated under the **Circumpolar Biodiversity Monitoring Program** (CBMP) of the Arctic Council's **Conservation of Arctic Flora and Fauna** (CAFF) Working Group. The CBMP is a network of scientists and Traditional and Local Knowledge holders, governmental bodies, Indigenous organizations and conservation groups, working to harmonize and integrate efforts to monitor the Arctic's living resources.

The CBMP freshwater program focuses on lake and river ecosystems, as well as associated wetlands, and builds a foundation for establishing a long-term monitoring framework for Arctic freshwaters. This framework is designed to facilitate more rapid detection, communication and response to significant trends in Arctic water quality and biodiversity.

Key elements of the freshwater ecosystem, called **Focal Ecosystem Components** (FECs), were initially identified by a diverse set of stakeholders involved in this effort. Changes in FEC status could indicate changes in the overall freshwater environment. For the purposes of reporting and analysis, freshwater monitoring stations across the Arctic were classified on the basis of the terrestrial ecoregion in which they were found (Fig 1). These ecoregions reflect temperature and vegetation differences across the Arctic, and stations are grouped on the basis of local climatic conditions.

Water milfoil, Myriophyllum alterniflorum, *a macrophyte in spring pond.*
Photo: Mps197/Shutterstock.com

Based on the results of the SAFBR, these general trends have been identified:

- Arctic freshwater ecosystems (e.g., lakes, rivers, and associated wetlands) are highly threatened by climate change and human development, which can alter the distribution and abundance of species and affect biodiversity and the ecosystem services on which many Arctic peoples depend.
- Patterns of biodiversity vary across the Arctic, but ecoregions that have historically warmer temperatures and connection to the mainland generally have higher biodiversity than those with cold temperatures (high latitude or altitude) or on islands far from continental mainland.
- Temperature is the overriding and predominant driver for most FECs, but climate, geographical connectivity, geology, and smaller-scale environmental parameters such as water chemistry are all important drivers of Arctic freshwater biodiversity.
- Available long-term monitoring records and research data indicate that freshwater biodiversity has changed over the last 200 years, with shifts in species composition being less dramatic in areas where temperatures have been more stable.
- Existing data are not sufficient to describe biodiversity patterns in all ecoregions, and increased sampling is required to improve understanding of biodiversity change.
- Better coordination and harmonized sampling, sample processing, and data storage for data from across the Arctic will improve our ability to detect and monitor changes in the ecoregion's freshwater biodiversity.

Advice for future monitoring of freshwater ecosystems includes the need for: better coordination, standardization of methods, increased use of emerging technologies (such as remote sensing and DNA barcoding), improved consideration of Traditional and Local Knowledge (TLK), better engagement with local and Indigenous communities, and a commitment to support continued development and maintenance of the CBMP-Freshwater database and monitoring efforts in Arctic freshwaters.

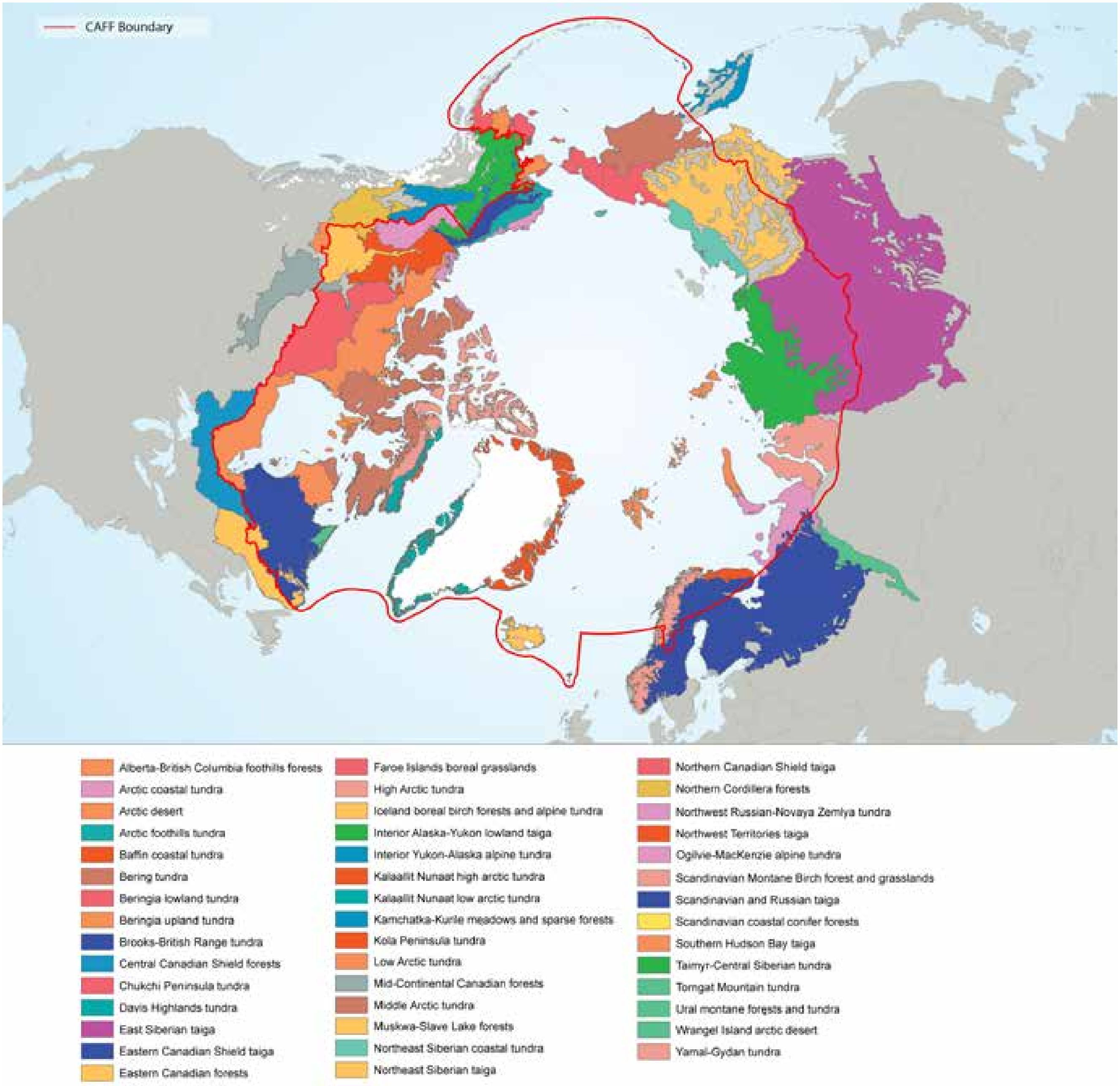
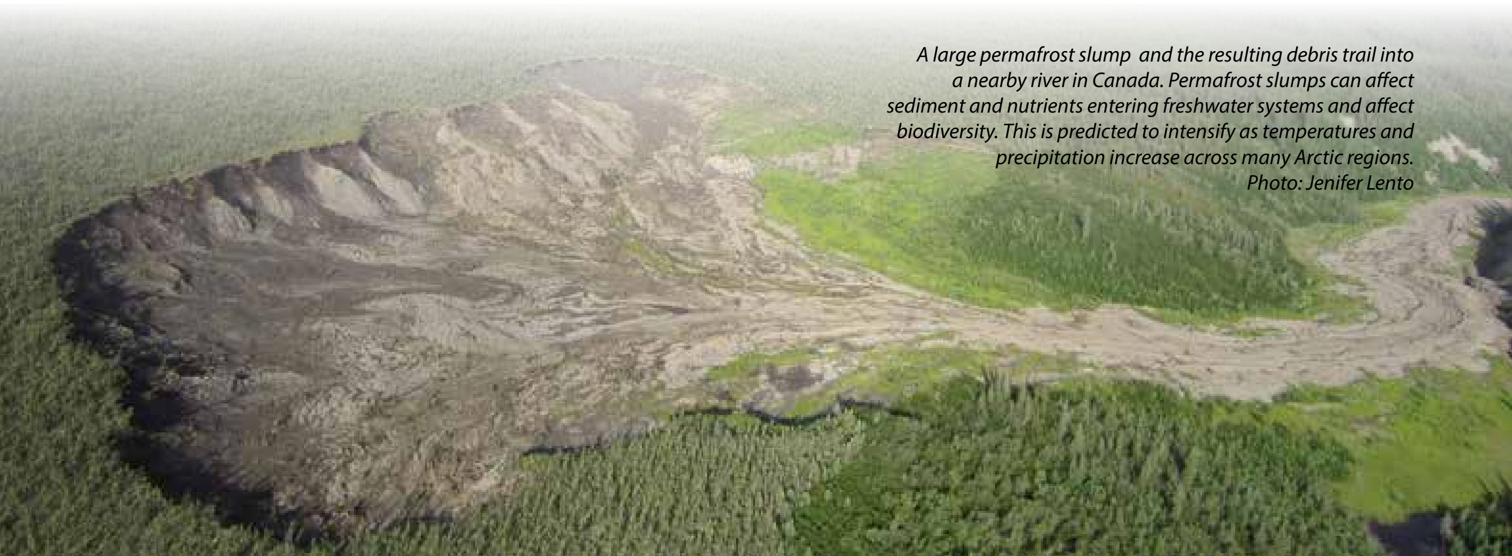


Fig 1: Terrestrial ecoregions included in the Arctic.

Key Findings

Arctic freshwater ecosystems are highly threatened by climate change and human development which can alter the distribution and abundance of species and affect biodiversity and the ecosystem services on which many Arctic peoples depend.

- Long-term trends of increasing water temperature and decreasing ice cover in freshwater systems have been observed in many areas of the Arctic. Warmer and wetter climate will generally lead to higher concentrations of dissolved organic matter, minerals, and nutrients. Furthermore, impacts related to human population growth (e.g., from increased infrastructure, development, and resource exploration/exploitation) have the potential to contribute to further degradation and nutrient enrichment of freshwater systems in the Arctic.
- These changes could significantly affect lake and river ecosystem processes, causing decreased light penetration in lakes, nutrient enrichment, and sedimentation, and leading to changes in biodiversity, occurrence, and biomass of Arctic species.
- With continued warming, the boundaries of Arctic climatic zones (e.g., sub-, low, and high Arctic, as defined by the Arctic Biodiversity Assessment) are expected to shift and cause an overall reduction in the spatial extent that can be considered part of the Arctic ecoregion, based on temperature and vegetation conditions.
- Warmer water temperatures in Arctic rivers and lakes may lead to an increase in overall biodiversity as southern species expand their ranges northward, but the highly cold-adapted and cold-tolerant species that currently inhabit the Arctic will be at risk due to competition from non-native species and face possible extirpation when their thermal tolerances are exceeded.
- Cold-water endemic species unique to the Arctic, such as Arctic char, may suffer regional losses with the potential for extinctions in extreme cases.



A large permafrost slump and the resulting debris trail into a nearby river in Canada. Permafrost slumps can affect sediment and nutrients entering freshwater systems and affect biodiversity. This is predicted to intensify as temperatures and precipitation increase across many Arctic regions. Photo: Jenifer Lento

Anadyr River, Chukotka Autonomous Region, Russian Federation. Photo: Andrei Stepanov/Shutterstock.com

Patterns of biodiversity vary across the Arctic, but ecoregions that have historically warmer temperatures and connections to the mainland generally have higher biodiversity than those with cold temperatures (high latitude or altitude) or on remote islands.

- Fennoscandian lakes (in particular, inland non-mountainous regions) are biodiversity hotspots for macrophytes, zooplankton, benthic macroinvertebrates, and fish in lakes. Lakes in Coastal Alaska are most diverse with regards to diatom and phytoplankton species and among the most diverse ecoregions for fish in the Arctic. Ecoregions in Canada, Greenland, Iceland, and Russia were less diverse for many of the lake biotic FECs.
- Fennoscandia, coastal Alaska, and western and southern Canada have the most diverse ecoregions across riverine diatoms, benthic macroinvertebrate, and fish FECs.
- The warmer climate in Fennoscandia and southern ecoregions of Canada as well as the strong geographical connectivity to the mainland explains the overall high biodiversity of these areas. Similarly, high connectivity of the Alaskan coastal region and lack of ice cover in the last glaciation may have contributed to high biodiversity of many FECs.
- Biodiversity in mountainous and alpine ecoregions of North America and Fennoscandia is generally lower than that of surrounding ecoregions for both lakes and rivers. This likely reflects harsh environmental conditions generally found in mountainous regions or possibly the effect of dispersal barriers to species such as migrating fish.
- Biodiversity is lower on remote islands where movement and introduction of species can be limited; this is particularly evident in Greenland, Iceland, the Faroe Islands, Svalbard, and Wrangel Island.

Temperature is the overriding and predominant driver for most FECs, but climate, geographical connectivity, geology, and smaller-scale environmental parameters such as water chemistry are all key drivers of Arctic freshwater biodiversity.

- Biodiversity of benthic macroinvertebrates in rivers and lakes decreased at higher latitudes, particularly above 68°N. This northward decline in diversity was strongly related to decreasing maximum summer temperatures, indicating that tolerance for cold temperatures limits the number of benthic macroinvertebrate species that can inhabit the high Arctic.
- Latitudinal trends were weaker for other FECs, but high-latitude lakes and rivers showed differences in diversity and composition of fish, plankton, diatoms, and macrophytes compared to lower-latitude systems. The differences reflected temperature and precipitation gradients as well as barriers to movement, glaciation history, and bedrock geology, which affects water chemistry.
- Cyanobacteria species, of which some are toxin-producing, were most abundant in lakes during the warmest years on record. As temperatures continue to increase, cyanobacteria blooms can be expected to become more common.

Available long-term monitoring records and research data indicate that freshwater biodiversity has changed over the last 200 years, with shifts in species composition being less dramatic in areas where temperatures have been more stable.

- Long-term fish monitoring records from Iceland indicate declining abundance of Arctic char and increasing dominance of Atlantic salmon and brown trout since the 1980s. At the same time there has been an increase in spring and fall water temperatures that might affect spawning and hatching time of Arctic char.
- Diatoms in lake sediment cores show shifts in community composition over the last 200 years, with changes in the dominant species that reflect changes in the temperature zones in the water column of lakes.
- Changes in diatom composition over the last 200 years were weakest in eastern Canadian coastal ecoregions (e.g., northern Labrador and Quebec) where temperatures have historically been more stable with less evidence of warming.

Existing data are not sufficient to describe biodiversity patterns in all ecoregions, and increased sampling is required to improve understanding of biodiversity change.

- Differences in composition among stations were most often due to finding new species, which suggests that additional sampling (more stations) is required to accurately estimate the number of species present in Arctic freshwater systems.
- Better coordination and harmonized sampling, sample processing, and data storage across the Arctic will improve our ability to detect and monitor changes in freshwater biodiversity.
- There is a substantial lack of data for large parts of the North American and Russian Arctic and few long-term data sets for Arctic lakes and rivers.
- Differences in sampling methods, sample processing, and data storage limit spatial comparisons, for example, where different lake habitats (shallow or deep water) are sampled or vastly different sampling equipment or approaches are used.

The larval stage of non-biting midges (Chironomidae) occurs in aquatic environments. Chironomidae are cold-tolerant and are therefore the dominant benthic macroinvertebrate group in many Arctic freshwater systems. Because they are so abundant, they are an important component of aquatic and terrestrial food webs, and provide food sources for fish and other organisms. Photo: Jan Hamrsky

Status of Monitoring

The SAFBR builds on the Arctic Freshwater Biodiversity Monitoring Plan and the Arctic Biodiversity Assessment. It is an important first step towards better understanding and management of our living resources in Arctic freshwater environments. The SAFBR helps identify the limitations of what existing and available biodiversity monitoring is able to tell us about the Arctic environment and provides a path forward for improving knowledge. Monitoring the status and trends of Arctic biodiversity and attributing causes of change are challenging. Complexity, logistics, funding, international coordination, natural variability, and availability of expertise and technology combine to limit available data and knowledge.

The Arctic Freshwater Biodiversity Monitoring Plan recommended that participating institutions develop common, standardized protocols for Arctic freshwater monitoring as well as for appropriate storage and archiving of biological data collections. With these recommendations as a baseline, the SAFBR provides an overall status of the monitoring of lakes and rivers.

Researchers collect aquatic invertebrates from small ponds on the Arctic Coastal Plain, Alaska. Photo: Christian Zimmerman, USGS

Daphnia longispina
Photo: Dieter Ebert

Key Findings: monitoring

- All countries have data sets that allow for identification of baseline levels for most FECs, but only a few countries (such as Finland and Sweden) have an extensive spatial coverage and very few countries have long time series. Data collection was not exhaustive, and there are likely additional data that exist for each country that may contribute to the assessment of freshwater biodiversity; however, significant gaps will remain even with a more extensive search of existing data sources.
- Instruments such as the European Water Framework Directive promote routine monitoring of lake and river FECs. But where a country, ecoregion, or FEC is not covered by such instruments, monitoring is irregular, has poor spatial coverage, or is absent.
- The vast expanse of the Arctic region in some countries (e.g., Canada, Russia) and the high monetary cost and logistical constraints associated with sampling in some regions (e.g., northern Canada and Russia, Greenland, Svalbard, Faroe Islands) limits the possibility of routine monitoring. This leads to sparse sample coverage in space and time, particularly where funds are not secure.
- In countries where routine government monitoring is limited or does not occur, data must come from other sources (e.g., academic research), where unsecure funding often leads to single-event sampling, meaning that change over time cannot be examined.

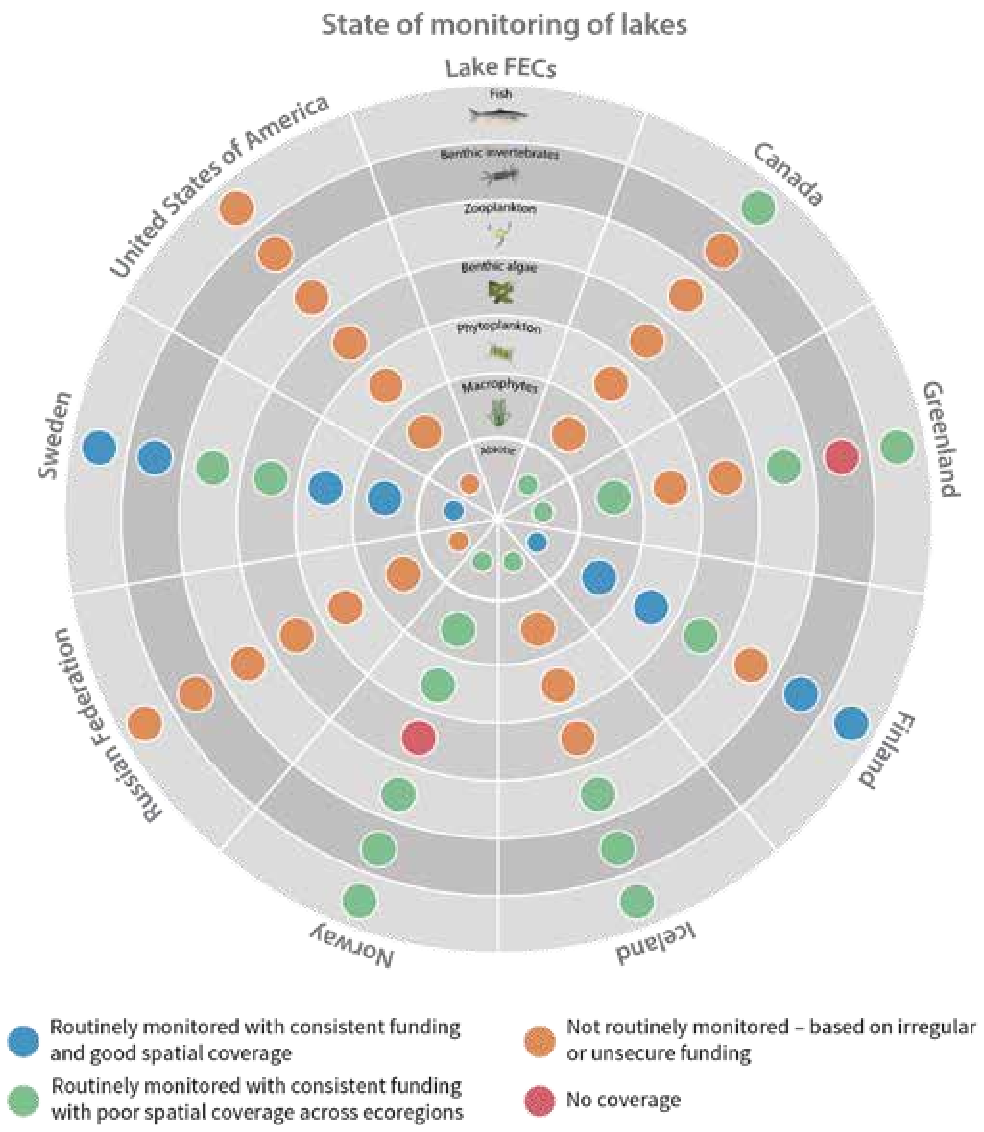


Fig 2: Current state of monitoring for lake Focal Ecosystem Components (FEC) in the Arctic regions of each country

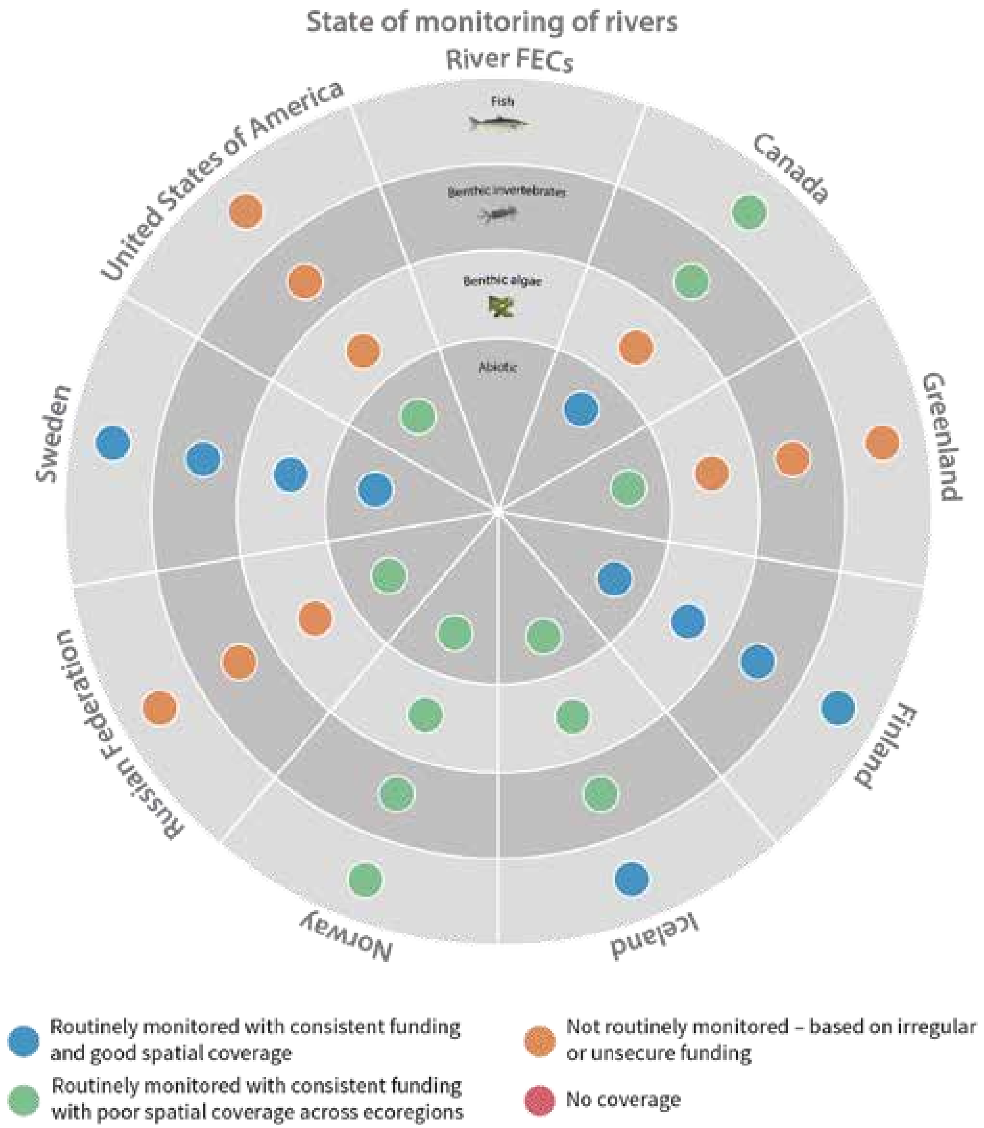


Fig 3: Current state of monitoring for river Focal Ecosystem Components (FEC) in the Arctic regions of each country.

Advice for monitoring

The SAFBR stresses the need to establish a circumpolar network of key monitoring stations across Arctic countries for time-series monitoring and better spatial coverage. Such a network would supply high-quality data that can be used to quantify change in water quality and biodiversity of Arctic freshwaters. This monitoring network should have representative coverage across the Arctic and take advantage of ongoing and past monitoring.

This monitoring network could be designed as a hub-and-spoke model, i.e., one central hub or station with regular monitoring and a number of spokes, or distant stations, at which monitoring is less frequent. Such a network could include both freshwater and terrestrial monitoring efforts. Existing sampling locations (and field stations) that already have a sampling history should be blended with new locations in areas with poor monitoring coverage or without a sampling record.

There is an urgent need to provide the infrastructure necessary to maintain and update the freshwater database (at CAFF's Arctic Biodiversity Data Service) in the long term. This infrastructure should also include routines for the regular updating of this database (e.g., by interfaces that allow more direct communication with government databases).

Monitoring Methods

- Harmonize sampling approaches among countries and select appropriate sampling methods and equipment to balance between maintaining consistency and comparability with historical data and alignment with common methods used across the Arctic.
- Use a regionalized approach based on ecoregions to guide the spatial distribution of sample stations and, ultimately, provide better assessments.
- Ensure spatial coverage of sampled ecoregions is sufficient to address the overarching monitoring questions of the CBMP across the Arctic and provide sufficient replication.
- Maintain time series at key locations, and fill gaps where monitoring data are sparse.
- Develop supplementary monitoring methods that provide better standardized estimates of biodiversity to maximize the likelihood of detecting new and/or invasive species.
- Make use of recent advances in emerging technologies, including environmental DNA (eDNA) methods and remote sensing approaches.
- Standardize data storage practices and provide access through a common data source like GBIF.

Achnanthidium minutissimum, *a common planktonic algae. Photo: Chris Carter*

Traditional Knowledge (TK)

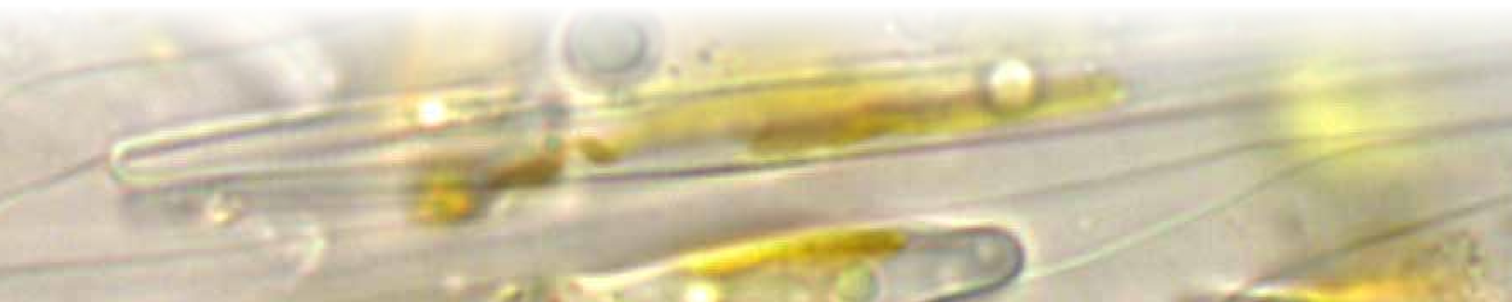
- Engage with Indigenous communities to work towards identifying and integrating their TK into efforts to assess Arctic freshwater biodiversity, including change over time.
- Incorporate TK as an integral part of circumpolar monitoring and observational networks.

Citizen Science

- Engage local communities in monitoring activities through citizen science and incorporate local knowledge as an integral part of future circumpolar monitoring and observational networks.
- Interact with local communities to enhance outreach to the public (youth in particular) and develop common observational tools.
- Provide material for training and educational purposes for local residents at all age levels.

Monitoring Design and Assessment

- Establish a circumpolar monitoring network based on a hub-and-spoke model in remote areas.
- Increase focus on the response of biotic communities to environmental changes by designing monitoring to address impact hypotheses developed in the CBMP-Freshwater Plan.
- Ensure that the CBMP Freshwater group continues to serve as the focal point for the development and implementation of Arctic, freshwater biodiversity monitoring.
- Provide resources to maintain and build the CBMP freshwater database for future assessments in order to maximize the benefits of this database.
- Efforts should be made to document and preserve data from short-term research projects, research expeditions, industrial, university and government programs and to make these data accessible to the public.
- Status assessments of Arctic lakes and rivers must explore the close association of biodiversity with spatial patterns of physical and chemical quality of aquatic habitats that can drive biological systems.
- The CBMP-Freshwater database allows the identification of predominant sampling approaches across the Arctic and should be used to inform the development of harmonized monitoring approaches.
- Where valuable long-term data series exist, these should be given high priority in monitoring programs, to continue to provide data for the detection of long-term trends and changes in biodiversity.



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