Scoping outline for AMAP-CAFF joint-work on *Climate change impacts on Arctic ecosystems and associated climate feedbacks*

This document is the scoping outline of a joint AMAP and CAFF work on climate effects on Arctic ecosystems and feedbacks. The document reflects input provided by the extended scoping advisory group and has been revised and elaborated by a small nominated expert group. The document provides inputs for consideration in the AMAP and CAFF workplans for 2021-2023.

CONTEXT & CHARGE

In its report to Ministers in 2019, Senior Arctic Officials directed AMAP and CAFF to "scope stepwise work to jointly review and assess climate impacts on Arctic marine, freshwater and terrestrial ecosystems and ecosystem feedbacks to climate" *[SAO Report to Ministers 2019].* The report states that "Understanding how climate change will affect ecosystems and ecosystem services is key to human livelihoods in the Arctic. From the policy perspective, an assessment of how climate change affects species and ecosystems upon which Arctic residents depend, particularly indigenous peoples, has been identified as a high priority within AMAP." *[SAO Report to Ministers 2019].*

AMAP and CAFF formed an advisory committee, organised a workshop and developed a draft scoping paper. Subsequently, a small project committee was established to advance the work. Figure 1 illustrates the organizational framework within which the scoping process was undertaken. The outcomes presented below focus on elements that the project committee consider feasible to implement in 2021-2023. These outcomes will be considered by AMAP and CAFF to provide the basis for decisions regarding activities to be included in their 2021-2023 work plans.

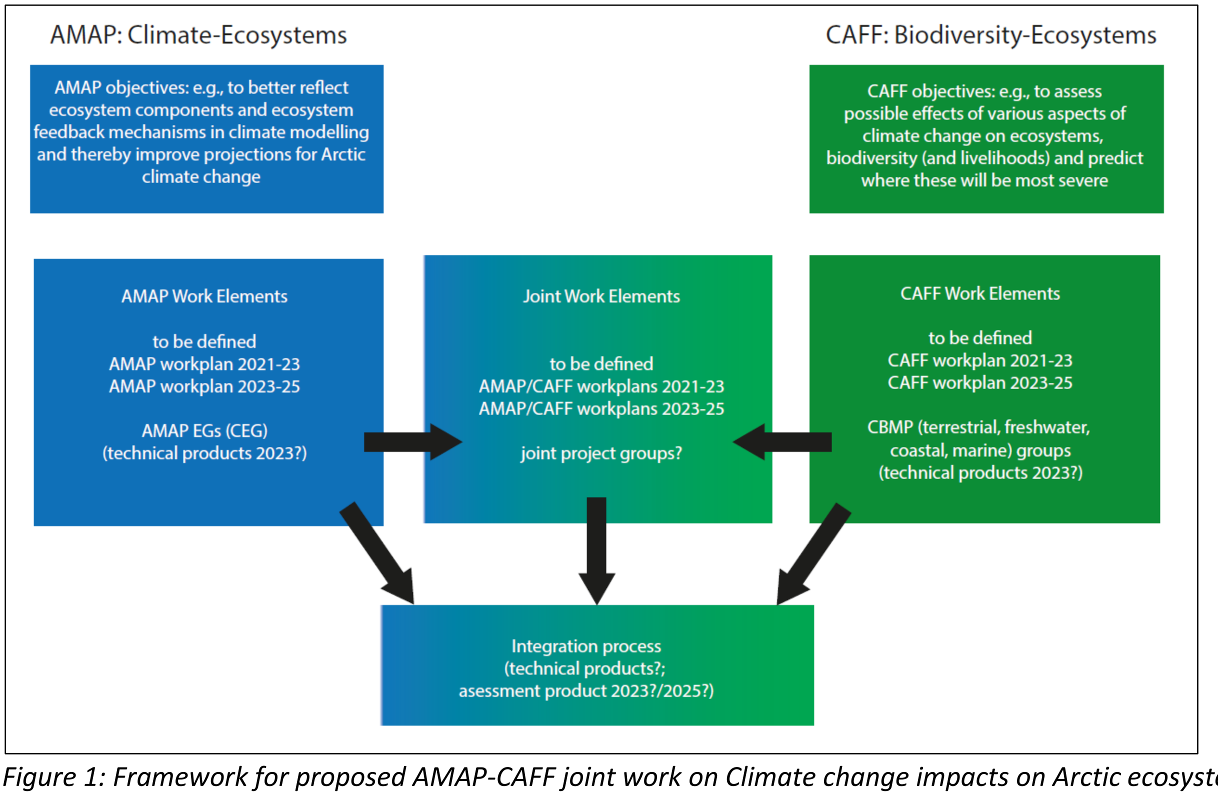

Figure 1: Framework for proposed AMAP-CAFF joint work on Climate change impacts on Arctic ecosystems and associated climate feedbacks

OBJECTIVE & APPROACH

Climate change is currently altering Arctic ecosystems and biodiversity. These ecosystem changes feed back to the climate system, with a potential to dampen or accelerate local to regional changes in climate and greenhouse gas emissions. The resulting impacts on ecosystem services, livelihoods and well-being are accelerating and will have far-reaching consequences for Arctic communities. The over-arching objective of the joint activity is to:

Assess how climate change affects Arctic ecosystems and feedbacks and inform strategies for adaptation and resiliency.

CONCEPTUAL FRAMEWORK

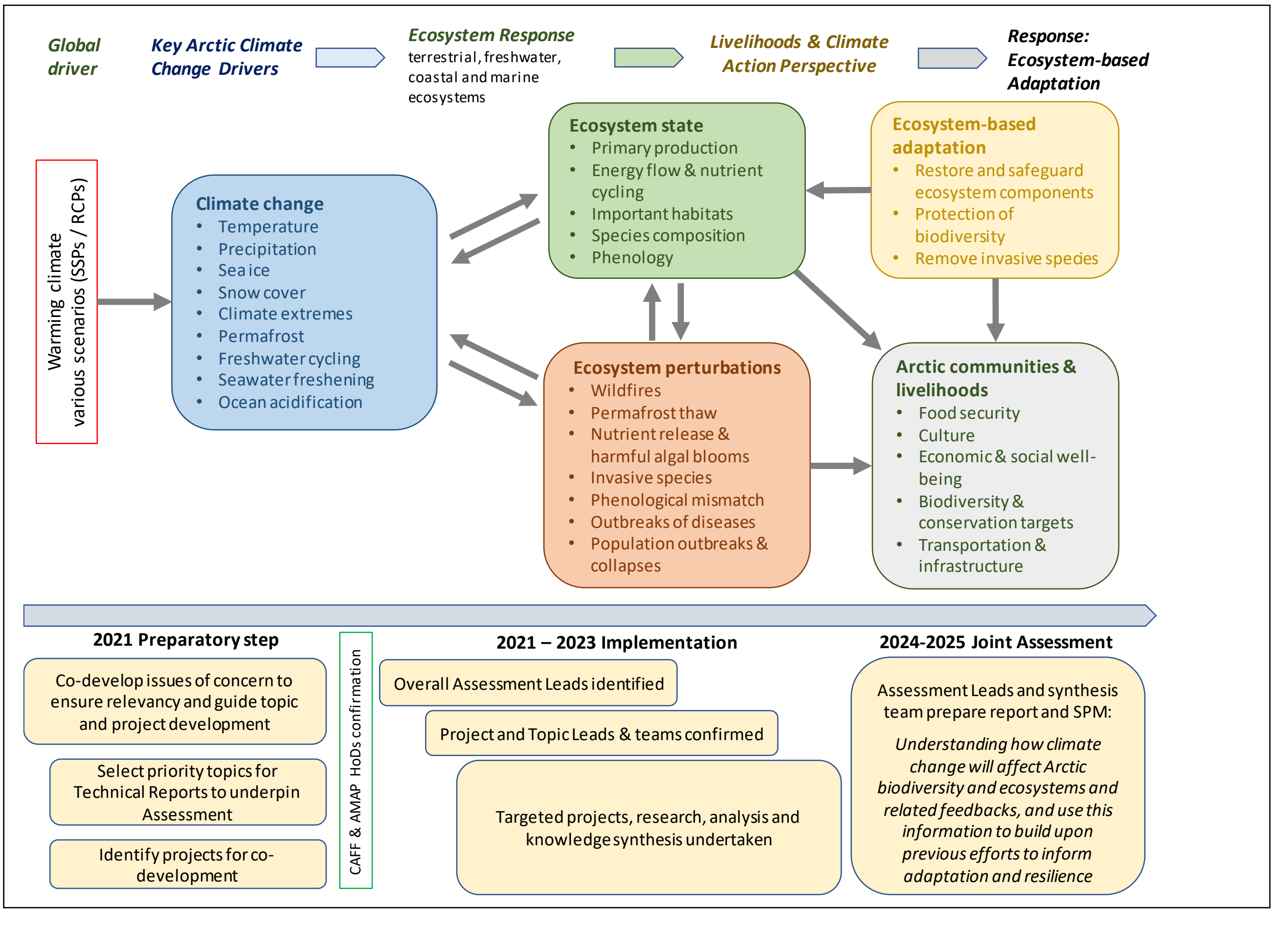

Figure 2: Conceptual framework and timeline for AMAP-CAFF joint work on Climate change impacts on Arctic ecosystems and associated climate feedbacks.

A conceptual framework has been developed to guide the joint AMAP-CAFF climate-ecosystem work (Figure 2). The climate-ecosystem linkages are described as interactions between greenhouse gasses, Arctic climate, the ecosystem state and ecosystem perturbations. Climate-change induced ecosystem changes impact Arctic communities, and ecosystem-based adaptation strategies could help people to adapt to the adverse effect of climate change.

Arctic climate -The increased concentration of atmospheric greenhouse gasses has profound effects on a range of regional climatic and physical features fundamental to the state of Arctic ecosystems. Observed changes include [*SWIPA* 2017]:

- increased temperature in air and water
- increased and changed pattern of precipitation
- reduced and changed pattern in ice and snow cover

- increased frequency and intensity of climate extremes
- permafrost thawing
- increased and changed freshwater cycling
- seawater freshening and stratification
- ocean acidification.

State of Arctic biodiversity and ecosystems -The changes in physical environment cause changes in the fundamental characteristics of Arctic ecosystems. Changes can be seen in major ecosystem processes such as [*ABA* 2013, *SWIPA* 2017]:

- primary production -e.g., changes in composition of plant species, increased phytoplankton growth and greening or browning of the Arctic tundra
- energy flow -e.g., changed flow from the benthic to the pelagic parts of marine ecosystems
- nutrient cycling -e.g., increased release and cycling of nutrients due to permafrost thawing and changing freshwater systems
- important habitats -e.g., reduced sea-ice habitat and shrubification of the tundra
- species composition and biodiversity -e.g., poleward expansion of species (borealization) and changes in the abundance of species of relevance to Arctic communities, including top predators
- phenology -e.g., changes in the seasonal rhythm of the ecosystem such as earlier onset of spring

These changes might occur gradually, as a slow response to changes in the physical environment, or abruptly when the system has reached a tipping point. Depending on mechanisms such as positive feedbacks in the system, the changes might be irreversible.

Ecosystem perturbations - Changes in ecosystem characteristics are likely to erode resilience, making the system more vulnerable to ecosystem perturbations, most notably from climate induced extremes. For example, increased release of nutrients enables blooms of harmful algae in aquatic ecosystems, changes in tundra vegetation enables increased severity and frequency of wildfires, changes in phenology causes mismatch between predators and prey resulting in population collapses, and changes in species composition enables the establishment of invasive species. Several such ecosystem perturbations have increased in frequency and intensity in recent decades and have often been attributed to a combination of reduced ecosystem resilience and episodes of climate extremes. Such perturbations include [*ABA* 2013, *SWIPA* 2017]

- wildfires
- abrupt permafrost thaw
- rain on snow
- nutrient release
- harmful algal blooms
- invasive species
- phenological mismatch
- outbreaks of diseases
- population outbreaks or collapses.

Ecosystem perturbations could link back to the ecosystem state causing shifts in the fundamental characteristics of ecosystems. The probability of unexpected and abrupt ecosystem shifts is expected to increase as climate continues to change, ecosystem resilience erodes, and perturbations intensify.

Ecosystem-climate feedback - Ecosystems have a critical role in regulating global, regional and local climate by providing sources and sinks of greenhouse gasses, providing sources of aerosols affecting temperature and cloud formation, enhancing evapotranspiration important for cloud formation and precipitation, affecting surface albedo, and affecting micro climate through shelter and regulation of local temperature and humidity. Climate induced ecosystem changes could impact these regulatory mechanisms, resulting in ecosystem-climate feedbacks [*SWIPA* 2017]. Primary production, carbon cycling, vegetation cover and vegetation disturbances (through e.g., insect outbreaks and wildfires) are key ecosystem processes that could be involved in such feedbacks. The feedbacks can be negative (cooling) through e.g., increased carbon uptake and increased albedo, or positive (warming) through e.g., carbon release and reduced albedo. The feedback loops can be complex and scale-dependent, resulting in both negative and positive feedbacks. For example, climate induced expansion of shrubs in the tundra could include feedbacks such as increased uptake of carbon in the vegetation (*cooling*), release of stored carbon from permafrost thawing (*warming*), changes in local temperature, snow cover, soil insulation and humidity (*cooling* and *warming*) and reduced albedo (*warming*).

Arctic communities and ecosystem-based adaptation - Climate induced ecosystem changes are increasingly impacting the livelihoods and well-being of Indigenous Peoples and Arctic communities. Impacts include changes in food security, economic and social well-being, cultural preservation, safety, human health, transportation, infrastructure, biodiversity and conservation targets [*AACA reports* 2017]. Ecosystem-based adaptations to climate change involve local ecosystem-based strategies and approaches that reduce the vulnerability of the human communities to the impacts from climate change. Such approaches could include strategies to restore and safeguard biodiversity and important ecosystem components, protect the ecosystems from additional human pressures, and eradicate pests and invasive species.

The joint work proposed here, will encompass policy-relevant assessments of each element and linkage represented in the conceptual framework, covering Arctic marine, coastal, freshwater and terrestrial ecosystems. The proposed work will follow a stepwise approach starting with a preparatory step in 2021 that emphasizes co-design in the framing of the questions to guide development of technical reports, projects and the joint assessment; implementation of the project and assessment work (2021-2023); and to eventually compile a joint AMAP/CAFF assessment (2024-2025). The end-product will be responsive to the Arctic Council States' and Permanent Participants (PPs) priorities regarding climate change, ecosystem resilience and conservation of biodiversity.

PP ENGAGEMENT

During the preparatory step, PPs will be engaged to:

- co-develop questions and topics relevant to Indigenous Peoples as well as other Arctic residents.
- further develop and modify the conceptual framework to include a co-production of knowledge approach
- guide the selection of study areas/regions and the selection of indicators and topics for technical reports and projects
- identify and develop case studies for co-production of knowledge, especially related to societal consequences and ecosystem-based adaptation to climate change.

CO-PRODUCTION OF KNOWLEDGE

Co-production of knowledge will be an important part of this assessment and will entail case-studies organized and implemented through collaboration between Indigenous Knowledge holders and scientists at local/sub-regional scales. These projects could for example identify climate induced ecosystem changes affecting the livelihoods and well-being of Indigenous Peoples and elucidate possible strategies to mitigate adverse effects and adapt to change. These projects will contribute with results of importance for policymaking and will bring in important perspectives from Indigenous Peoples.

KNOWLEDGE SYSTEMS

This assessment will utilise different knowledge systems, including Indigenous Knowledge as well as knowledge from local communities. The knowledge obtained from particularly Indigenous Knowledge will contribute to reaching the overall aim of the assessment, contribute to the fulfilment of the Arctic Council's Icelandic Chairmanships goal to enhance constructive cooperation and make Arctic Council assessments increasingly relevant to the people living in the Arctic states.

MANAGEMENT AND COORDINATION OF ACTIVITIES

It is proposed that implementation of the joint activity will be managed by a project steering committee comprising the AMAP and CAFF Chairs and Executive Secretaries and a few experts representing the AMAP

Climate or SLCF Expert Group and CBMP. Status of the work will be reported to AMAP and CAFF at their HoDs/Board meetings. Any adjustments to activities would be decided by agreement between AMAP and CAFF HoDs.

During the preparatory step (2021), in order to facilitate a broader understanding of the effects of climate change on Arctic ecosystems in all aspects, AMAP and CAFF will coordinate and consult with other AC WGs concerning their information needs and links to related activities.

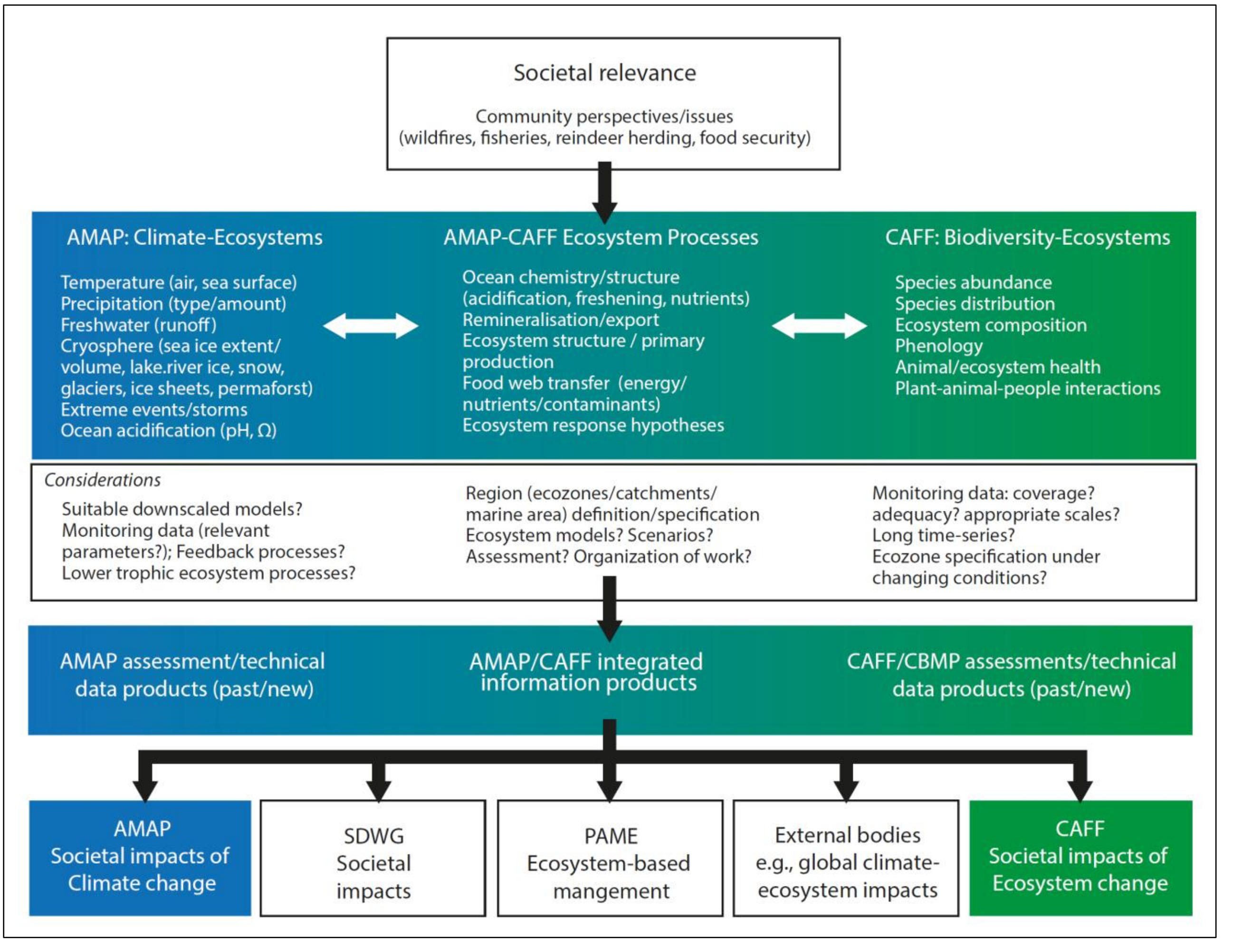

Figure 3: Joint-work elements and linkages to other AC and external initiatives addressing societal impacts.

STEPWISE WORKFLOW, PROVISIONAL TIMELINE AND OUTPUT

Step 1 – Preparatory Activities (2021)

Goal: *Co-design and prepare a detailed workplan for the joint AMAP-CAFF climate-ecosystem work.*

- Elaborate and modify conceptual model according to input from PPs and develop policy relevant questions to guide the assessment work . This could also include policy relevant questions and knowledge gaps identified in previous AMAP-CAFF workshops, from the Scoping Advisory Group (Annex C) and previous AC projects.
- Identify issues of concern that are of particular relevance to Indigenous Peoples and local communities in relation to ecosystem-climate linkages to ensure societal relevance of proposed work and specification of geographical areas where these concerns are the greatest. The AACA work is particularly relevant as a basis for this task.
- Establish data rich subject areas and geographical regions suitable for further consideration in project implementation work by:

  - Identifying geographical areas in freshwater, coastal, marine and terrestrial ecosystems where sufficient data is available. Availability of long-time series data for both key climate and ecosystem variables is emphasized in this connection. Geographical areas could be ecoregions or catchment areas.
  - Identifying regions with the best potential for downscaling model output and/or having meteorological data (including extreme events).
- Select priority topics for technical reports or articles to underpin the assessment.
- Identify and develop case studies for co-production of knowledge targeting societal consequences and ecosystem-based adaptation to climate change.

Product: Detailed implementation plan describing the topics, relevance, available datasets, methods, case studies and assessment products.

Step 2 – Implementation (2021-2023)

Goal: *Implementation of the joint workplan to answer the AMAP-CAFF climate-ecosystem objective.*

- Implement AMAP, CAFF and joint work to explore climate change-ecosystem linkages in relation to identified topics focusing on identified geographical areas:
  - Compile and synthesize relevant literature and scientific reports.
  - Consider existing AMAP and CAFF data and information products. This is likely to involve down-scaling of AMAP information (from circumpolar Arctic to sub-regional) and up-scaling some CAFF information (from local to sub-regional). Focus would be on compiling and synthesizing relevant information from existing data products.
  - Apply downscaled climate models to test their ability to reproduce past observations in relevant geographical areas; and project possible ecosystem responses not only to gradual warming but also extreme events with respect to e.g., temperature and precipitation.
- Implement case studies for co-production of knowledge with a special emphasis on societal consequences of climate change and possible ecosystem-based adaptation to climate change.

Products: Technical reports, project reports, scientific articles, special journal issues, policy-summaries and communication and outreach products.

Step 3 – Follow-up (2023-2025)

Goal: *Completion of* joint work from step 2, and preparation of:

- Joint AMAP/CAFF assessment on climate change impacts on Arctic ecosystems, with components describing climate change impacts and ecosystem feedbacks to climate for 1) freshwater; 2) terrestrial; 3) coastal; 4) marine ecosystems; and 5) an overall assessment based on each of these 4 components.

Product(s): *2025 Joint Science Assessment and SPM, with related communication / outreach products.*

ANNEX A: SCOPING PROCESS

The scoping process has been informed by discussions between the AMAP Heads of Delegation (HoDs), CAFF Board, and input from members of AMAP, CAFF/CBMP expert groups. A Scoping Advisory Group established to provide input to the scoping process (Annex B) held teleconferences in September and October to review the content of the scoping document. A Scoping workshop was held on September 10-11 where ca. 90 experts participated and provided input into the scoping process addressing issues such as areas for possible joint work. The results of that workshop were further discussed at an AMAP Climate Expert Group tele-meeting (15-17 September) where CAFF/CBMP members also participated. A first draft of a scoping document was developed in November 2020, and a small group of experts (Annex C) was established to finalize the scoping document by the end of January 2021. The group has developed a broad conceptual framework for the proposed work, delineated the elements to be included and discussed how knowledge co-production can be achieved. Indigenous knowledge holders and permanent participants (PP) have not played an active part in the scoping process, and the conceptual framework presented might therefore not represent their view. To adjust and fill the framework with content, the framework has been kept relatively flexible and open-ended and co-production of knowledge will be an important part of the preparatory part of the proposed work (step 1, 2021).

ANNEX B: Membership of Extended Scoping Advisory Group

Mora Aronsson (Sweden, CBMP Terrestrial)

Richard Bellerby (Norway, AMAP CEG)

Gilbert Castellanos (USA, CAFF)

John Cheechoo (ICC)

Tom Christensen (Denmark, CBMP)

Torben Røjle Christensen (Denmark, AMAP CEG)

Catherine Coon (USA, CBMP)

Joseph Culp (Candada, CBMP Freshwater)

Martin Forsius (Finland, AMAP)

Willem Goedkoop (Sweden, CBMP Freshwater)

Lis Jørgensen (Norway)

Nadine Kochuten (AIA)

Vladimir Krever (WWF)

Melanie Lancaster (WWF)

Libby Logerwell (USA)

Johanna Mård (Sweden, AMAP CEG)

Debbie Martin (Canada)

Elizabeth McLanahan (USA, PAME)

Donald McLennan (Canada, CBMP Marine)

Christine Michel (Canada, AMAP CEG)

Palle Smedegaard Nielsen (Greenland, AMAP)

Irina Onufrenya (WWF)

Frans-Jan Parmentier (Norway, AMAP CEG)

Anna Marja Persson (Saami Council)

Cecilie von Quillfeldt (Norway, CAFF)

Sunna Björk Ragnarsdóttir (Iceland)

Martin Sommerkorn (WWF)

John Walsh (USA, AMAP CEG)

Muyin Wang (USA, AMAP CEG)

Ram Yerubandi (Canada, AMAP CEG)

ANNEX C: Membership of small expert group

Name	Organisation	State/PP	Email	Comment
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Palle Smedegaard Nielsen	Government of Greenland	Kingdom of Denmark	pasn@nanoq.gl	Able to participate if needed
Per Fauchald *(Lead)*	Norwegian Institute for Nature Research	Norway	per.fauchald@nina.no	
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Johanna Mård	Department of Earth Sciences, Uppsala University	Sweden	johanna.maard@geo.uu.se	
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Gilbert Castellanos	USFWS	US	Gilbert_Castellanos@fws.gov	

Annex D – Advisory Group suggestions and comments concerning Policy-relevant questions

Note: The suggestions listed below were made by the scoping advisory group and should not be considered a comprehensive, definitive or agreed set of policy-relevant questions. Defining the policy-relevant questions that would be addressed in the joint work will be part of the Step 1 activity.

The advisory group identified a number of **knowledge gaps** that may determine possibilities to answer overarching questions. These give rise to further PRQs including:

- What is the current knowledge concerning major direct (temperature, precipitation, acidification, etc.) and indirect (changes in hydrology, light conditions, nutrient availability, wildfires, etc.) effects on Arctic ecosystems, and their impact on ecosystem interactions? [*Note: Information to answer this question can be extracted from previous AMAP/CAFF assessments*]

- How do changes in sea ice and other climate-driven changes in abiotic parameters affect population sizes, densities and distributions of higher trophic levels (including marine mammals and seabirds), and how can this information contribute to improved data-driven sustainable management of Arctic living resources? [*Note: This question is at the core of CAFF biodiversity assessment work*]

- Can long-term data series be identified or developed to aid better understanding of trends in order to fill knowledge gaps and build the foundation for a better understanding of key processes and interactions? [*Note: A comprehensive review/overview of existing monitoring data in relation to information required to enable more holistic assessments in the future is a necessary prerequisites to initiating new monitoring programs or adding new parameters in a cost-effective manner. A better understanding of how climate drivers interact and influence ecosystems and changes on different spatial and temporal scales is a key element in such an evaluation*].

The advisory group noted additional PRQs concerning **interactions**, including:

- How will climate change impact complex ecosystem interactions and couplings between ecosystems?

- How do climate-driven abiotic changes affect ecosystem interactions, biological production and biodiversity? [*Note: addressing potential impacts on ecosystem services is outside the scope of the work currently envisaged for the joint project*]

Specific PRQs have been identified concerning **'climate-ecosystem-climate' feedback mechanisms**:

- What are the major ecosystem interactions and the current knowledge on climate-ecosystem feedback mechanisms? What are the observed and anticipated climate feedbacks (changes of albedo, hydrological cycle, carbon cycling, methane emissions)? What are the major knowledge gaps and how can they be addressed? Are feedback mechanisms adequately described in climate models? [*Note: addressing these complex feedback mechanisms in climate modelling is a key element in work undertaken by AMAP*].

- How do different Arctic ecosystems feedback to the climate system and how do changes in their coupling amplify/reduce those feedback loops? To what extent do climate-ecosystem feedback mechanisms present new knowledge about Arctic ecosystems?

- Can climate-ecosystem feedback mechanisms lead to acceleration towards tipping points of ecosystems? If so, what role do climate-ecosystem feedback mechanisms play in reaching tipping points? Have Arctic ecological tipping points already been exceeded? Do changes happen gradually or abruptly and are new ecosystem tipping points approaching?

- How do climate-ecosystem feedback mechanisms differentiate from direct effects of climate change on ecosystems? How significant are feedback mechanisms compared to direct pressures on Arctic ecosystems? Is this estimate expected to alter within the time spans currently addressed in climate modelling work (e.g. to 2050, 2100)?

The envisaged work focuses on climate-ecosystem connections and therefore would not extend into areas addressing multiple **drivers of ecosystem change**; however, it could potentially contribute to that work and address parts of the following PRQs suggested by the Advisory Group:

- How significant are climate-ecosystem impacts compared with other primary system drivers influencing changes in ecosystems functions, and what is their contribution to the cumulative effects of these drivers?

- How many ships can pass through the Bering Strait, across the Central Arctic Ocean to the Fram strait, without compromising the ecosystem, including the native population along the coast (food security and safety/health) and other human residents. [*Note: this question would be outside of the scope of the work currently envisaged for the joint project*]