Integrating Activities for Advanced Communities

Task 4.1: Documenting the effects of extreme weather events on the seasonal timing of species migration, range changes and biodiversity.

Project No. 871120– INTERACT

H2020-INFRAIA-2018-2020

Start date of project: 2020/01/01

Duration: 48 months

Due date of deliverable: 2021/03/31

Actual Submission date: 2021/05/31

Lead partner for deliverable: CAFF

Author: Barry, Tom

Dissemination Level		
PU	Public	X
PP	Restricted to other programme participants (including the Commission Services)	
RE	Restricted to a group specified by the Consortium (including the Commission Services)	
CO	Confidential, only for members of the Consortium (including the Commission Services)	

Table of Contents

© INTERACT consortium

Publishable Executive Summary

The purpose of Task 4.1 was to consider the effects of extreme weather events on the seasonal timing of species migration, range changes and biodiversity in the Arctic's freshwater and terrestrial ecosystems; and inform how impacts of extreme events on biodiversity might be incorporated within the Circumpolar Biodiversity Monitoring Programme (CBMP). In order to do it we identified the types of extreme events that potentially can have a big influence on Arctic Biodiversity for instance by affecting the seasonal timing of migrations, distribution patterns, ecological shifts, and invasive species pathways. This entailed conducting a dedicated and systematic review of the scientific evidence of extreme event impacts on the terrestrial Arctic biota. Review of the scientific literature highlighted a research bias towards single-events studies and a lack of focus on impact recovery. It also found that extreme events are a key facet of climate change research with impacts on biodiversity expected to be particularly severe in the Arctic. Building upon this review Key Findings and recommendations were made on bridging current knowledge gaps by taking advantage of the established pan-Arctic long-term monitoring network, the Circumpolar Biodiversity Monitoring Programme (CBMP) in order to better define what is considered extreme in terms of events and ecological impacts; move beyond single-impact studies and spatial scales of observation; and consider predictive modelling to address ecosystem-level impacts.

© INTERACT consortium

1. Introduction

The purpose of Task 4.1 was to consider the effects of extreme weather events on the seasonal timing of species migration, range changes and biodiversity in the Arctic's freshwater and terrestrial ecosystems; and inform how impacts of extreme events on biodiversity might be incorporated within the established pan-Arctic long-term monitoring network the Circumpolar Biodiversity Monitoring Programme (CBMP). To inform recommendations for how this might be done; a dedicated and systematic review of the scientific evidence of extreme event impacts on the terrestrial Arctic ecosystem was conducted. Building upon this review Task 4.1 developed Key Findings and recommendations on bridging current knowledge gaps by taking advantage of the CBMP. The outcomes of this task will feed into ongoing work that is informing research, monitoring and policy frameworks related to extreme events and Arctic biodiversity.

2. Knowledge on impacts of extreme events

Upon starting this task, it was discovered that a dedicated and systematic review of the scientific evidence of extreme event impacts on the terrestrial Arctic ecosystem was lacking. To fill this gap in knowledge, Task 4.1 provides a comprehensive overview of the available scientific literature focused on extreme events and their ecological impacts on terrestrial Arctic biota. This includes an overview of the different extreme events studied, the ecological impacts detected, the focal species or taxonomic groups studied, the methods employed, and whether or not impact recovery was quantified in the studies.

A literature search was performed through the Institute for Scientific Information (ISI) Web of Science database in which considered all literature published prior to February 2021 and which had a focus on the impacts of extreme events on the Arctic's terrestrial ecosystem. A total of 42 published studies were found that investigated the ecological impacts of extreme events on terrestrial biota in the Arctic (Figure 1). While the number of published studies on the topic has grown over the last 25 years, a significant linear increase was not detected.

- Most studies reviewed quantified the impact of a single extreme event on a specific Focal Ecosystem Component (FEC).
- Three (7%) documented impacts of a single extreme event on multiple FECs;
- Four (9%) considered multiple extreme events and their impacts on a single FEC; and
- Two (5%) found multiple ecological impacts on a single FEC from a single event.

The total number of ecological impacts reviewed was larger than the number of published studies and although the study area locations were scattered across the Arctic, there was a spatial bias towards more impacts investigated in certain areas such as Alaska, Svalbard, the Nordic countries, and Greenland. Relatively few impacts were quantified in Russia and Canada and one study was found with a circumpolar focus. By synthesizing current scientific evidence and knowledge, research gaps and priorities were identified in the field of extreme event-based research in the Arctic. Building upon this review providing Task 4.1 then developed Key Findings and recommendations on bridging current knowledge gaps by taking advantage of the CBMP. The literature review has been submitted to the Journal *Earth's Future* and is currently undergoing peer review.

© INTERACT consortium

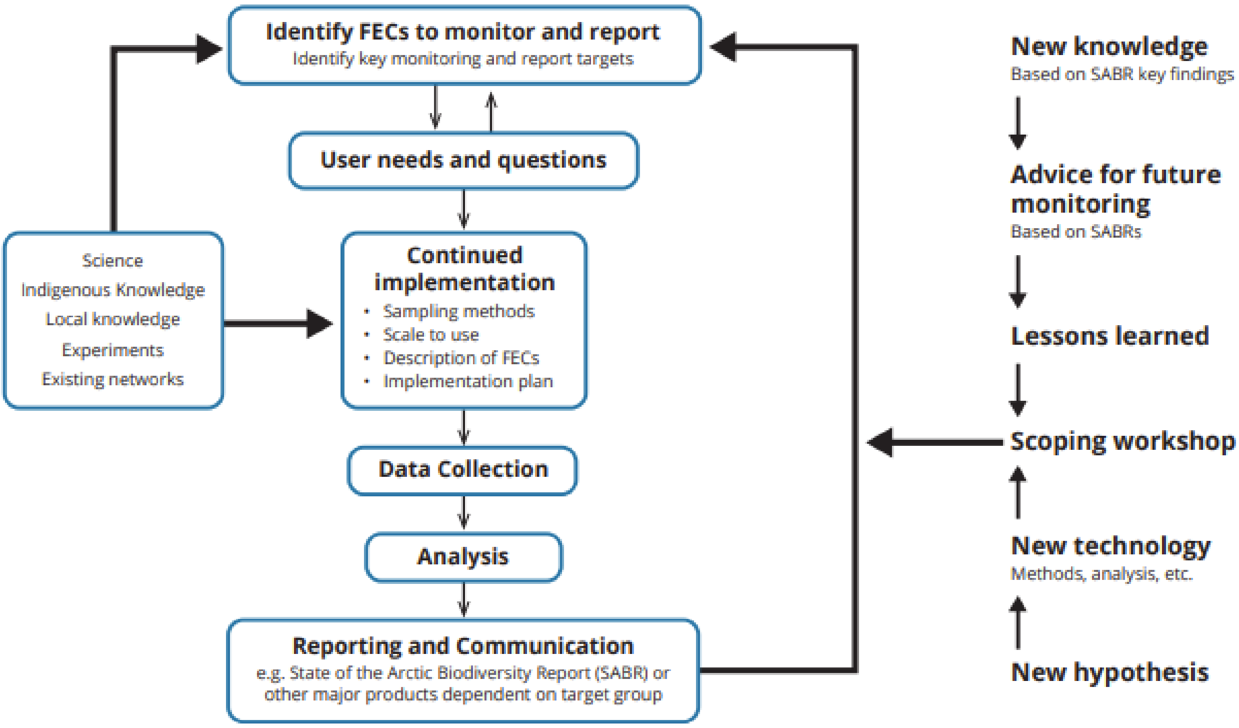
3. Circumpolar Biodiversity Monitoring Programme (CBMP)

The Circumpolar Biodiversity Monitoring Program (CBMP) is the biodiversity monitoring program of the Conservation of Arctic Flora and Fauna (CAFF), the biodiversity working group of the Arctic Council. The overall goal of the CBMP is to facilitate more rapid detection, understanding, prediction, communication, and response to the significant biodiversity-related trends and pressures in the Arctic. CBMP does this by:

- Standardizing, coordinating, and enhancing existing Arctic monitoring efforts;
- Collecting and harmonizing relevant biodiversity data, including increasing data accessibility, thereby improving the ability to detect and understand significant trends; and,
- Reporting to, and communicating with, key decision makers and stakeholders, thereby enabling effective conservation and adaptation responses to changes in Arctic biodiversity.

CBMP creates a platform to inform policy and decision-making at the global, national, regional, and local levels and improve understanding of Arctic biodiversity. The CBMP's four Arctic Biodiversity Monitoring Plans, one for each ecosystem (Coastal, Freshwater, Marine, Terrestrial), follow the steps required for an adaptive (question-based) ecosystem-based monitoring program (Figure 2). This ecosystem-based approach integrates information across ecosystems, species, and their interactions. Each plan identifies Focal Ecosystem Components (FECs) which may indicate changes in the ecosystem and/or the environment. The CBMP seeks to aggregate the best available scientific, Indigenous, and local knowledge whenever possible to inform our perspectives.

© INTERACT consortium



4. Findings

A wide variety of extreme events were found to occur throughout the Arctic and considerable effort has been taken over the past twenty-five years to document and quantify associated ecological impacts on FECs within the terrestrial environment. Review of the scientific literature highlighted a research bias towards single-events studies and a lack of focus on impact recovery. It found that extreme events are a key facet of climate change research with impacts on biodiversity expected to be particularly severe in the Arctic, and that:

- Studies varied greatly in scale and data collection methods ranging from fine-scale experimental studies to circumpolar modelling efforts.
- The majority of research effort was biased towards quantifying ecological impacts of a few extreme event types (e.g., rain-on-snow events) and, more generally, focused on single-events studies that were based on relatively short-term field campaigns.
- Opportunistic post-hoc investigations following third party (non-scientific) observations, were also common and are an important starting point for the process of gaining basic knowledge.
- Documented impacts of events on arthropods and freshwater fish were under represented, highlighting a known research gap in climate change research in the Arctic.

- Despite the dominance of single event studies identified through the review, these were mostly well-designed and therefore provide important insight on the types of impacts or responses that are possible and, moreover, they allow for theory and hypothesis development. Equally valuable in this respect are 'no-effect' studies though only two were identified, which may reflect a distressing scientific focus on publishing data that is "high impact and novel".
- Logistical constraints associated with working in remote and often inaccessible areas in the Arctic certainly hinders the design and implementation of coordinated research and collection of data before, during, and after extreme events.
- It remains unclear why ecological impacts are often species- or group-specific, what the involved mechanisms are, and whether extreme event-induced ecological impacts are important drivers of long-term population trends/changes.

5. Recommendations

As climate change continues to put pressure on Arctic biodiversity, improved and coordinated effort to monitor potential impact over extended temporal and geographic gradients is critical. Studies of extreme events in northern regions can be somewhat opportunistic and uncoordinated, with logistical constraints associated with working in remote and often inaccessible areas in the Arctic hindering the design and implementation of coordinated research and collection of data before, during, and after extreme events. It remains unclear why ecological impacts are often species- or group-specific, what the involved mechanisms are, and whether extreme event-induced ecological impacts are important determinants of long-term population trends/changes. Indeed, the literature review highlighted numerous ecological impacts of extreme events in the Arctic, but a minority of studies reported on the state or recovery of the system after the event.

With this in mind, the CBMP biodiversity monitoring plans that aim to improve the ability to detect and report on long-term changes in biodiversity across the entire Arctic, coupled with the network of field stations provided by the International Network for Terrestrial Research and Monitoring in the Arctic (INTERACT) provides a platform to facilitate detection and documentation of the impacts of extreme events on biodiversity; and tackle knowledge gaps. Below we provide recommendations that follow from the findings of the literature review and hopefully benefit the design and effectiveness of future research and science-based monitoring efforts.

6. Better define what is considered extreme in terms of events and ecological impacts

There is a general lack of agreement on what constitutes and defines an extreme event and whether or not an ecological impact is even. A key advantage of long-term monitoring programmes is that they offer the opportunity to collect continuous baseline data on climatic conditions and biodiversity that is needed to objectively and quantitatively assess whether a climatic event and impact was indeed extreme (i.e., conditions or abundances observed are at the edge of their statistical reference distributions at a particular time or place). While this approach is adopted in some science-based monitoring stations implementing it across a pan-Arctic network of research

© INTERACT consortium

stations will provide critical data on variation in the occurrences of extreme events and their impacts. Overall, consistent definitions, quantification and clear communication of extreme events will enhance the understanding and management of potential impacts.

7. Move beyond single-impact studies and spatial scales of observation

As extreme climatic events impact biodiversity and peoples livelihoods, there is a strong scientific and socioeconomic need to go beyond single-event studies. Long-term monitoring programmes provide the temporal resolution and data needed to start quantifying patterns and drivers of natural variability of biodiversity and to improve the possibility of following multi-event impacts. Equally important is spatial monitoring and replication to increase the likelihood of collecting biological data from areas that did not experience the extreme events. To achieve a more holistic understanding, a combination of research methods where baseline data from long-term monitoring programmes is complemented with evidence from field studies, opportunistic observations, remote sensing, experimental data, models, and, where possible, local ecological knowledge is recommended. Especially valuable, in this respect, are long-term experiments or dedicated field studies that can identify potential lag effects, feedbacks and interactions of extreme event impacts and to assess system recovery. Implementing multiple study designs into Arctic monitoring networks will be critical to better understand the impacts of the range of extreme events that occur across multiple spatial and temporal scales.

8. Consider predictive modelling to address ecosystem-level impacts

Empirical data and evidence on the impacts of extreme events on biodiversity are often geographically and taxonomically idiosyncratic. The direction of extreme event impacts in the Arctic sometimes differed within and between FECs and across extreme events. This highlights that the predictability of local responses to extreme events is low, and more empirical data is required to better understand the mechanisms and processes involved. Predictive modelling is a useful means to tackle some of these current knowledge gaps. Empirical data derived from long-term monitoring programmes combined with remote sensing facilitates the development of hindcasting and forecasting models to assess previous and future conditions over large geographic areas and temporal scales. While modelling entire ecosystems is clearly a demanding task, statistical models that can incorporate multiple data streams derived from long-term monitoring programmes to assess ecosystem dynamics and state changes are already available. As more empirical data becomes available and informs a better understanding of the processes and drivers underlying extreme events and their impacts, these models can be used to iteratively evaluate and progress current evidence and knowledge.

© INTERACT consortium

9. Conclusions

The CBMP has recently completed its first integrated reporting for Freshwater and Terrestrial ecosystems through a series of State of the Arctic reports generated from implementation of the CBMP Freshwater and Terrestrial monitoring plans. The development of these reports has led to the initiation of scoping processes to inform how these monitoring plans might need to be revised and updated based upon lessons learned during their implementation. The recommendations listed above to better define what is considered extreme in terms of events and ecological impacts; moving beyond single-impact studies and spatial scales of observation; and considering predictive modelling to address ecosystem-level impacts will be used to inform these scoping processes and the updating of the CBMP monitoring plans. When updating CBMP Monitoring plans to include considerations of extreme events and collection of data to inform further analyses it will be important to keep in mind the following:

- Consistent, long-term monitoring is essential and ecosystem/community-wide monitoring is crucial in order to understand the full extent of perturbations;
- Before-during-after monitoring is needed in order to know the baseline, the impact, and the recovery;
- An adaptive monitoring approach is essential in order to be able to incorporate new events and their related ecological effects;
- A system is where ad-hoc monitoring can be implemented across stations in response to an extreme event; and
- A common (model) framework is needed to help align the various data streams (from scientific to Indigenous) .

10. Supporting documentation

CAFF. 2018. Circumpolar Biodiversity Monitoring Program Strategic Plan 2018-2021. CAFF Monitoring Series Report No. 29. Conservation of Arctic Flora and Fauna, Akureyri, Iceland. ISBN: 978-9935-431-71-4.

CAFF. 2017. Work Package 7: Improving and harmonizing biodiversity monitoring workshop report International Network for Terrestrial Research and Monitoring in the Arctic (INTERACT) Rif Field Station, Raufarhöfn, Iceland August 22-24, 2017

CAFF. 2018. Work Package 7: Improving and harmonizing biodiversity monitoring workshop report International Network for Terrestrial Research and Monitoring in the Arctic (INTERACT). Data management workshop, Akureyri, April 2018

CAFF. 2018. Work Package 7: Improving and harmonizing biodiversity monitoring International Network for Terrestrial Research and Monitoring in the Arctic (INTERACT). *Aarhus University, Copenhagen, April 25-26, 2018*

CAFF. 2019. Work Package 7: Improving and harmonizing biodiversity monitoring workshop report International Network for Terrestrial Research and Monitoring in the Arctic (INTERACT) Rif Field Station, Raufarhöfn Iceland June 11-12, 2019

Christensen, T., J. Payne, M. Doyle, G. Ibarguchi, J. Taylor, N.M. Schmidt, M. Gill, M. Svoboda, M. Aronsson, C. Behe, C. Buddle, C. Cuyler, A.M. Fosaa, A.D Fox, S. Heiðmarsson, P. Henning Krogh, J. Madsen, D. McLennan, J. Nymand, C. Rosa, J. Salmela, R. Shuchman, M. Soloviev, and M. Wedege. 2013. The Arctic Terrestrial Biodiversity Monitoring Plan. CAFF Monitoring Series Report Nr. 7. CAFF International Secretariat. Akureyri, Iceland. ISBN 978-9935-431-26-4

Culp J.M., W. Goedkoop, J. Lento, K.S. Christoffersen, S. Frenzel, G. Guðbergsson, P. Liljaniemi, S. Sandøy, M. Svoboda, J. Brittain, J. Hammar, D. Jacobsen, B. Jones, C. Juillet, M. Kahlert, K. Kidd, E. Luiker, J. Olafsson, M. Power, M. Rautio, A. Ritcey, R. Striegl, M. Svenning, J. Sweetman, M. Whitman. 2012. The Arctic Freshwater Biodiversity Monitoring Plan. CAFF International Secretariat, CAFF Monitoring Series Report Nr. 7. CAFF International Secretariat. Akureyri, Iceland. ISBN 978-9935-431-19-6

© INTERACT consortium