RIF Field Station

Rif Field Station Ecosystem Monitoring

Freshwater and Terrestrial Monitoring Plan

May 2018

Developed with the direction of the Circumpolar Biodiversity Monitoring Program (CBMP) as part of INTERACT Work Package 7

CAFF Conservation of Arctic Flora and Fauna

INTER ⇄ ACT

CIRCUMPOLAR BIODIVERSITY MONITORING PROGRAM

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Introduction

Threats such as climate change, anthropogenic disturbance, resource extraction and over-exploitation are putting increased pressure on ecosystems in Arctic regions. This calls for a stronger emphasis and action when it comes to surveillance and monitoring of these fragile ecosystems. Understanding these complex dynamics, determining trends and developing adequate responses is difficult since long-term monitoring data from across the Arctic is often lacking. Scientific research and monitoring is also the basis for further policy development at national, regional and global level.

The Circumpolar Biodiversity Monitoring Program (CBMP) is the cornerstone program of the Conservation of Arctic Flora and Fauna (CAFF), the biodiversity working group of the Arctic Council. The CBMP is an international network of scientists, government agencies, Indigenous organizations and conservation groups working together to harmonize and integrate efforts to monitor the Arctic's living resources. CBMP experts are developing four coordinated and integrated Arctic Biodiversity Monitoring Plans to help guide circumpolar monitoring efforts. Results will be channelled into effective conservation, mitigation and adaptation policies supporting the Arctic. These plans represent the Arctic's major ecosystems; *Marine*, *Freshwater*, *Terrestrial* and *Coastal*.

Rif Field Station (RFS) has been chosen by the *International Network for Terrestrial Research and Monitoring in the Arctic* (INTERACT) as one of three stations that will implement the Freshwater and Terrestrial Arctic Biodiversity Monitoring Plans to test their requirements and protocols. The two other stations involved in this work package, called "*Improving and harmonizing biodiversity monitoring*", are the Canadian High Arctic Research Station (CHARS) in Cambridge bay, Canada and the Zackenberg station in Greenland.

RFS and its research area are located in Melrakkaslétta peninsula in the Northeast of Iceland. The peninsula is an easily accessible lowland area classified as Low Arctic, which makes it very well suited for such research activities. In addition, with RFS being in its initial phases in an area with very little established monitoring, the station offers a unique opportunity to serve as a model for how to use the protocols of the CBMP program to set up successful biodiversity monitoring. In this way, monitoring at the station will provide a valuable contribution to ecological monitoring in Arctic regions.

Rif Field Station monitoring plan

In the following pages the details of the RFS monitoring plan will be described, including aims and objectives, environmental characteristics of the area, key monitoring components and questions, implementation plan and selected focal ecosystem components.

Linkage to CAFF and other circumpolar monitoring plans

Monitoring approaches at RFS will be informed by, be coordinated with, and directed by the monitoring approaches outlined in the Circumpolar Biodiversity Monitoring Plans for terrestrial and freshwater ecosystems. Specifically, this monitoring plan for Rif takes direction from the following:

- Arctic Terrestrial Biodiversity Monitoring Plan (CAFF Monitoring Series Report no. 8, 2013), developed by the terrestrial expert monitoring group of the CBMP.
- Arctic Freshwater Biodiversity Monitoring Plan (CAFF Monitoring Series Report no. 7, 2012), developed by the freshwater expert monitoring group of the CBMP.

Aims and objectives

The overarching aim of monitoring at RFS is to understand and communicate change in freshwater and terrestrial biodiversity, in the context of ecosystem composition, structure and physical processes in the Arctic. The monitoring plan will build on and test selected terrestrial and freshwater components of the CBMP along with the Zackenberg station in Greenland and CHARS in Canada.

The specific objectives of the monitoring plan are:

- To provide useful and timely information to decision-makers and all Icelanders on the effects of climate-driven change on selected components of biodiversity in and around RFS
- To ensure that monitoring results can contribute to and inform Icelandic policy, regulations and international commitments, including CBMP, CAFF, and INTERACT, as well as the different institutions involved in the Icelandic monitoring framework
- To aid the process of building an efficient working interface between CBMP and INTERACT
- To serve as a model for ecological monitoring in Arctic regions by implementing the requirements and protocols listed within the CBMP program from the beginning
- To develop and define the Rif research area as safe and accessible for scientists
- To link research and monitoring nationally and internationally while also supporting the local community
- To involve community based monitoring, which will employ local citizens, create science capacity in the community and make significant contributions to the monitoring program
- To communicate research and monitoring results to communities, government decision makers and involved research networks
- To seek ways to make data accessible and thus maximize the benefits gained through monitoring

Connection to Iceland's policies and international commitments

Iceland occupies a unique position in the Arctic as a large portion of the country's economic zone lies within its boundaries. Increased activity leads to new opportunities but also creates new challenges when it comes to the environment as well as traditional lifestyle.

The current governmental policy emphasizes the need for environmental protection as well as for increased research, monitoring and innovation in connection with identifying and addressing the potential effects of climate change. According to the policy, the fragile ecosystems of the Arctic should always be given the highest priority. Nordic cooperation is also deemed highly important and Arctic matters, which touches upon almost all aspects of Icelandic society, and are considered a priority within the foreign policy. Iceland will be taking over the chairmanship of the Arctic Council in 2019-2021 and will strongly emphasize the global goals of the United Nations within this platform as well as climate and marine issues. In accordance with the approved Icelandic Arctic policy, special attention will be placed on Indigenous rights and gender equality (Stjórnarráð íslands, 2017).

Iceland is part of various international cooperative agreements that concern this monitoring plan, as well as the country's research and monitoring commitments as a whole. For example, special attention must be given to the Convention of Biological Diversity (CBD), the Ramsar Convention on Wetlands and the Bern Convention on the Conservation of European Wildlife and Natural Habitats. Cooperation also includes activities taking place within INTERACT, CAFF, and the Nordic Council of Ministers.

Development and implementation

The development and implementation of the monitoring plan will be divided into three phases:

1. ***Pilot phase (2017-2019):*** Work within this phase will be aimed at the planning process, i.e. mapping the area, determining monitoring components, consulting with relevant parties, collecting and organizing existing data and establishing a database for current and future research and monitoring. Some overlapping with the second developmental phase described below may occur.
2. ***Implementation phase (2019-2020):*** Implementing the Rif monitoring plan requires building and strengthening science collaboration and partnerships with the relevant institutions involved in terrestrial and freshwater monitoring in Iceland.
3. ***Establishment phase (2020-):*** To ensure long-term sustainability, implementations, continued development, usefulness and scientific relevance of the monitoring plan, a science committee will be established, based on the collaborations and partnerships developed through phase 1 and 2. The continuation of the station and its monitoring and research activities will further be secured through a steering committee including local government, relevant institutions and more.

Research and monitoring area: Characteristics

Melrakkaslétta lies between two wide-open fjords: Öxarfjörður in the west and Þistilfjörður in the east. Rif Field Station's facilities are located in the village of Raufarhöfn, 15 km southeast of the research area. The Rif site, which will host the intensive monitoring site at the station, includes the northern most point of Iceland, Rifstangi. The area reaches approximately 20 km inland from the shoreline, which lies only 3 km south of the Arctic Circle.

The northern part of Melrakkaslétta is very open and thus highly exposed to the cold northerly winds. The annual average temperature over the period 2006 to 2016 was 3,43° C in Raufarhöfn; -0,25°C in February and 8,75° C in July. Annual average precipitation for the same period was 650 mm (Icelandic Meteorological Office, 2017) with fog frequenting the coastline and bringing humidity inland. The area lies on the eastern edge of the northern volcanic zone of Iceland. Two Holocene fissure swarms, originating from active central volcanoes in the interior of Iceland, extend north to the peninsula. One of the fissures ends in the Cape Rauðinúpur, an old volcano on the northwest coast of Melrakkaslétta peninsula, while the other extends into the valley of Blikalónsdalur. Blikalónsdalur is a rift valley, reaching some 20 km inland from the north coast.

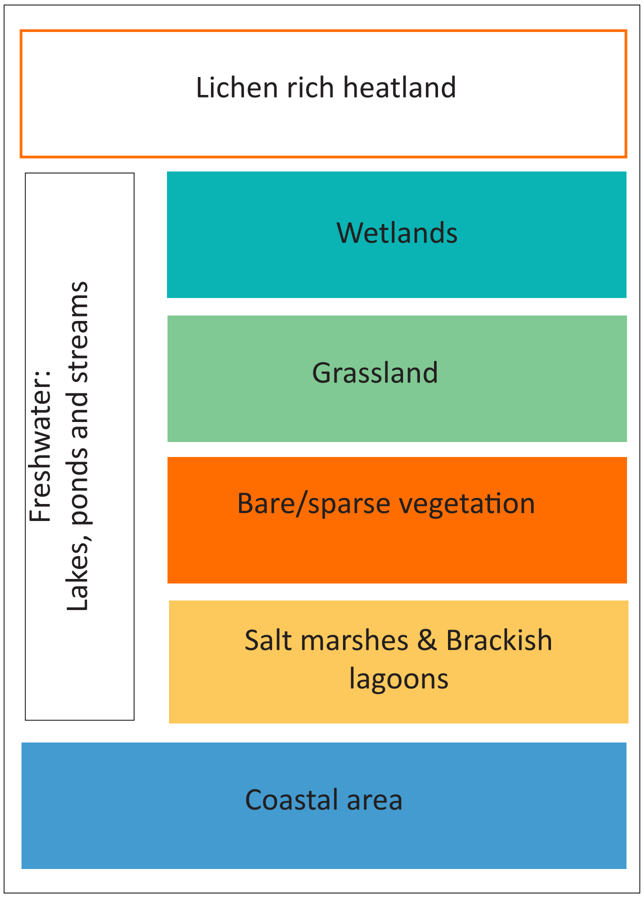

Figure 1. Habitat types found within Rif Field Station's research and monitoring area.

The greater part of Melrakkasléttа's bedrock is built of grey basalt from the Pleistocene period but young tuff (palagonite) is characteristic of the westernmost part of the peninsula. This is especially prevalent north of the village Kópasker (Sæmundsson, 1977). Water penetrates easily through the western part's young bedrock, resulting in scarce surface water. The water flows as groundwater instead, emerging as spring water close to the shore or where faults and fissures cross the surface. The older bedrock in the north-eastern part is less permeable, creating numerous freshwater lakes, ponds and rivers that extend from the coast and further inland, with surface water being most abundant in the area close to Raufarhöfn (Albertsson et al., 2003). For most of the lagoons, lakes and rivers, only limited information exists regarding their environmental condition and biota.

Figure 2. Habitat map of Melrakkaslétta peninsula. Provided by the Icelandic Institute of Natural History.

Low average summer temperatures along with fog and humidity affect the area's vegetation, with plants of arctic origin being characteristic (Steindórsson, 1941). Lichen rich heathland is common, especially further inland (Albertsson et al., 2003). In some parts of the peninsula, a narrow strip of cultivated land can be found close to the coast, especially on the eastern side. The vegetation of Melrakkaslétta peninsula has been classified as Low Arctic, which is a result of various environmental factors, including climate (Elven et al., 2011; Wasowicz et al., 2013). Most of Melrakkaslétta peninsula has little evidence of soil erosion. On the western part however, where the bedrock is predominantly young tuff, one can find highly eroded areas with very fragmented vegetation (Arnalds et al., 1997).

Of terrestrial mammals found in Melrakkaslétta the Arctic fox (*Vulpes lagopus*) is the only native species, having colonised Iceland long before any human residency. The mink is believed to have arrived in around 1960 after having escaped from mink farms in southwest Iceland in the early 1930's (Skírnisson et al., 2004). The wood mouse (*Apodemus sylvaticus*) and house mouse (*Mus musculus*) inhabit the area but those species are thought to have arrived in Iceland with the first human settlers (Skírnisson et al., 2004).

Geographical location, harsh climate that shapes the vegetation, diverse wetlands and rich shores results in a rich and diverse birdlife in Melrakkaslétta. At least 53 species of birds have been found breeding in the region, of which 47 nest on an annual basis. Seabirds, waterfowl and waders are characteristic. The geographical location of Melrakkaslétta and its rich shorelines are particularly important for migrating waders on their way to breeding sites in Greenland and Arctic Canada in spring. The birds use the shores to rest and refuel by putting on fat reserves for their continued migration farther north.

Melrakkaslétta has for many years been listed as an important territory for conservation in Iceland, especially as habitat for many bird species, although the area has never been protected according to the Nature Conservation Act (Environment Agency of Iceland, 2013). Tourism is a growing industry and opportunities connected to nature tourism, e.g. birding, are excellent. Bird related tourism is becoming popular in Iceland with the north-eastern areas of the island being very well suited for such activities. In recent years there has been substantial work related to the promotion of bird related tourism in the region through the development of the project Birding Trail Northeast Iceland, which e.g. is located along the coast of Melrakkaslétta (Atvinnuþróunarfélag Þingeyinga, 2013). The Arctic nature, harsh environment, isolation and abandoned farmhouses make the area a unique place to visit, and Melrakkaslétta is likely to become an attraction for travellers in the near future. Therefore, it is important that tourism development is done in a responsible manner that considers the fragile nature of the area.

Key monitoring components

The main emphasis of the terrestrial plan is on monitoring key species and processes across plant and animal populations in the area's terrestrial and freshwater ecosystems. This will include intra and inter-annual variation, resilience, and long-term trends with a focus on biodiversity, abundance and composition, phenology, reproduction, and predation. The Freshwater plan emphasizes monitoring of freshwater systems, which will include ponds, lakes, their tributaries, and associated wetlands, as well as rivers, their tributaries, and associated wetlands.

The plan focuses on selected Focal Ecosystem Components (FECs) of terrestrial and freshwater ecosystems, which have been determined by the CBMP. FECs are defined as biotic or abiotic processes, which are ecologically pivotal, charismatic, or sensitive to changes in biodiversity (adapted from Gill et al. 2011).

The Melrakkaslétta Peninsula has been defined as the RFS Extensive Monitoring Area. The Rif site will serve as the core of intensive monitoring supported by a network of satellite sites located throughout the peninsula. The Intensive Monitoring Area includes coastal and upland focal areas where long–term, hypothesis-based experiments can be established (figure 3). The monitoring will be established along a gradient based on distance from the coastline and/or vegetation changes. Habitat types within the Intensive Monitoring Area are further presented in figure 4.

The satellite sites (as shown in figure 3) are necessary to collect data on rare ecotypes and for certain aspects of the freshwater monitoring. The Coastal Focal Zone will target the marshes and brackish lagoons located along the coastline, while the Upland Focal Zone includes a matrix of upland heath and wetlands linked to freshwater basins and streams.

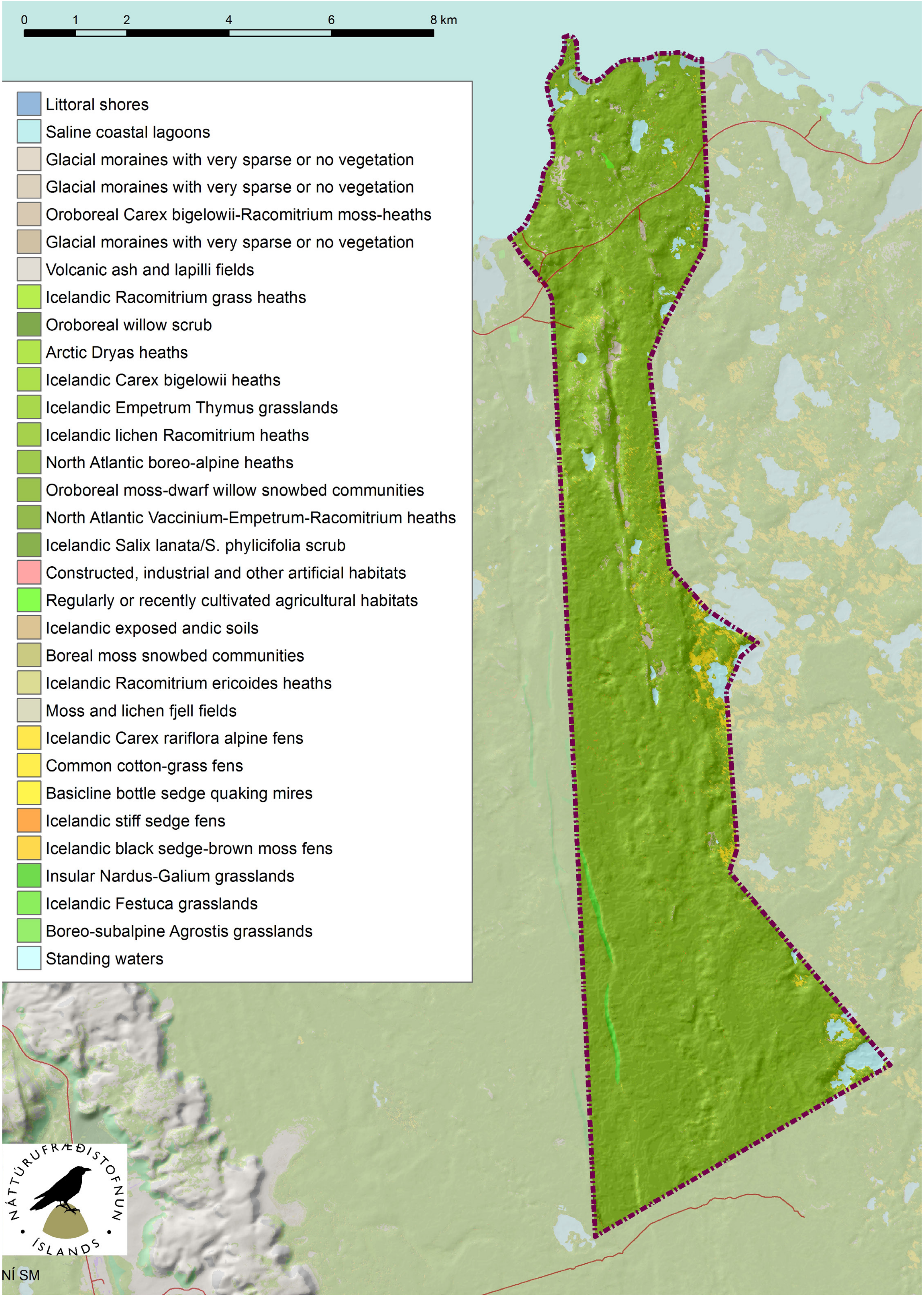

Figure 4. Habitat type map of the Rif site, which will serve as the intensive Monitoring Area. Map provided by the Icelandic Institute of Natural History.

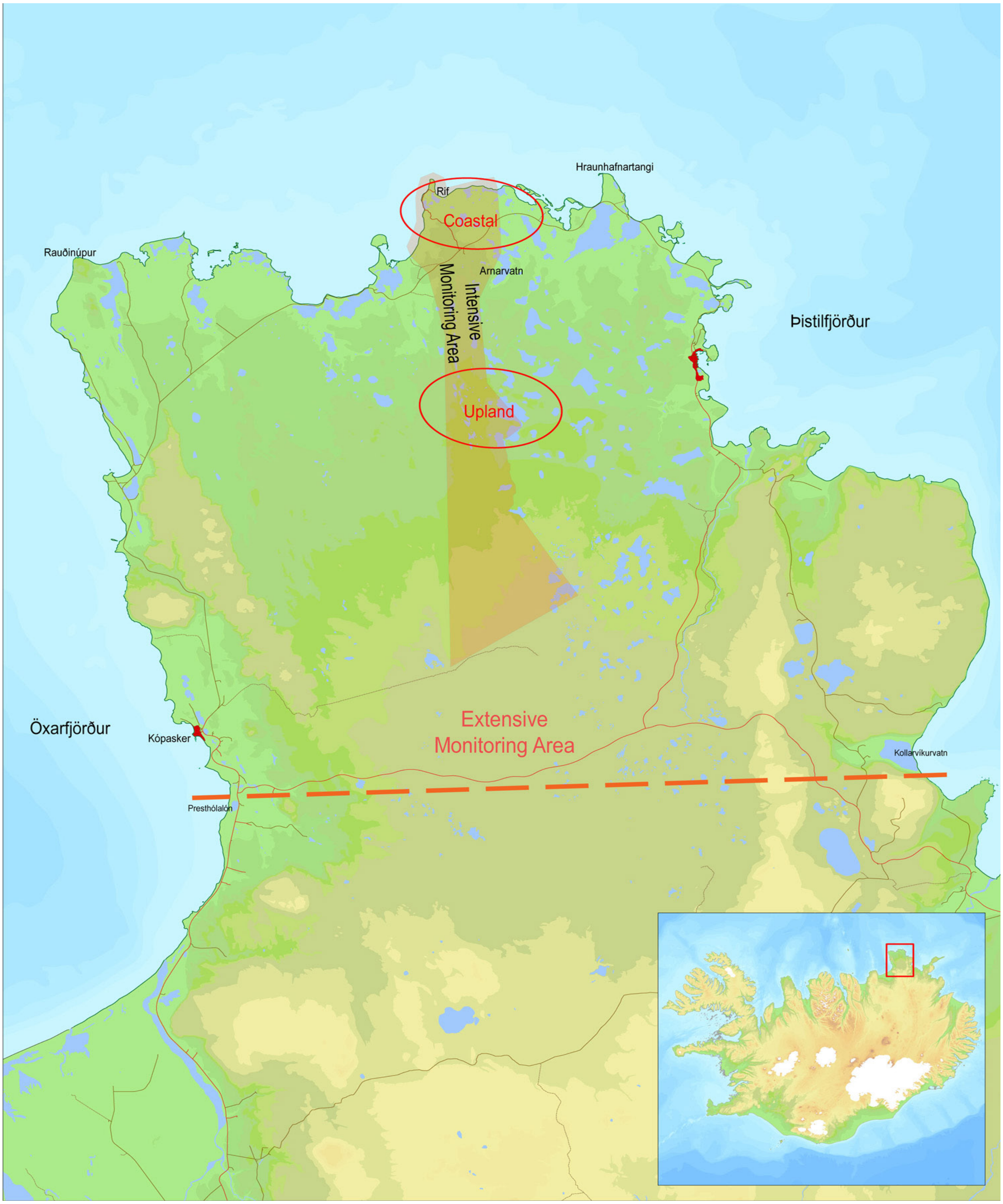

Figure 3. RFS Extensive Monitoring Area and Intensive Monitoring Area with focal zones (coastal and upland) for establishing long-term, ground-based hypothesis-based monitoring of terrestrial and freshwater exosystems and biota.

Collaboration and partnerships

Monitoring will be carried out as much as possible in collaboration with the six research institutions forming the backbone of Rif Field Station: Northeast Iceland Nature Research Institute, University of Akureyri, Stefánsson Arctic Institute, Icelandic Institute of Natural History, Agricultural University of Iceland and University of Iceland. In addition, to ensure the necessary expertise and professionalism regarding the freshwater component of the plan, the intention is to collaborate with the Icelandic Marine and Freshwater Research Institute. The plan will also focus on including community-based monitoring and local data sources as much as possible. Special attention will be put on making sure that the research and monitoring conducted in connection to this plan will complement and provide value for ongoing local and national efforts.

Ecosystem Monitoring Questions

The RFS monitoring plan intends to contribute to answering the ecosystem monitoring questions listed below, which are adapted from those put forward by the terrestrial and freshwater expert monitoring groups of the CBMP.

Terrestrial ecosystems

- What is the status, distribution and condition of focal species, populations, communities, landscapes/ecosystems and key processes/functions that occur in the Rif area?
- What kind of changes are these focal species, populations, communities, landscape/ecosystems and processes/functions facing and where?
- Which primary environmental and anthropogenic drivers are influencing terrestrial biodiversity and ecosystem functions, and how?
- Which areas can be considered of high ecological importance (including e.g. resilient and vulnerable areas, related to the FECs) and where are drivers having the greatest impact?

Freshwater Ecosystems

- What is the status of freshwater biodiversity in the Rif area?
- Are alpha and beta biodiversity changing, and if so, are they increasing or declining, and are species moving or disappearing?
- What are the primary environmental and anthropogenic stressors causing the observed change in biodiversity?
- Are boundaries of the Arctic zone in the RFS Extensive Monitoring Area shifting?

The proposed FECs for both terrestrial and freshwater ecosystems at Rif are addressed in Appendix A. The importance of the ecosystem approach will be stressed in all aspects of the plan.

Monitoring priorities: Establishment of baseline data

As a first step in establishing the CBMP terrestrial and freshwater monitoring at RFS, baseline information will be collected to understand relevant work that has been carried out. This will help develop an understanding of species and ecological processes to inform the monitoring. The first step will be to gather, archive and organize existing information on the terrestrial and freshwater ecosystems and biota located in Melrakkaslétta. This will target the Intensive Monitoring Area while also including the Extensive Monitoring Area (as shown in figure 3, page 8). In addition, mapping of all existing and potential environmental stressors and drivers will be a priority.

Relating to equipment, the priority is to establish a climate monitoring station at the RFS Intensive Monitoring Area. This will be done in collaboration with the Icelandic Meteorological Office (IMO - Veðurstofa Íslands) and will fall under their network, database and interface, which will be accessible to all users of the Rif Field Station. The IMO follows international standards and collaborates with the World Meteorological Organization (WMO).

The climate station will include a good variety of sensors and provide a broad spectrum of information that will feed into the monitoring as well as individual research projects. The selected location will include a mosaic of two ecotypes; heathland and wetlands. The station will be placed in an inland terrestrial area as a contrast to the two other climate stations within the Rif Extensive Monitoring Area, which are located on the coast. Parameters measured will include: air temperature and humidity, soil temperature and moisture, wind direction and speed, precipitation, solar radiation, snow, and greening through the use of NDVI sensors.

Terrestrial monitoring priorities

For terrestrial ecosystems within RFS Extensive Monitoring Area, the focus will be set on the following components:

- Establishment of a baseline map database of terrestrial ecosystems
- Development of a remote sensing baseline data library
- Examination of existing vegetation and other relevant data
- Location and mapping of habitats of key animal species in the area including:
    - Key migratory bird areas
    - Key nesting/wintering areas for resident birds, and;
    - Known fox dens and territories

To collect information on plant and animal species, monitoring partnerships will be formed with related institutions with data relevant to the Rif Extensive Monitoring Area. A second goal is to include citizen science and local knowledge to collect information on relevant observations such as species arrival dates and species counts. This information will be compiled in a RFS State of Biodiversity report.

The CBMP Terrestrial Plan has four categories – Vegetation, Arthropods, Birds and Mammals. As a starting point, the RFS monitoring plan will focus on two of those, i.e. vegetation and birds. An arthropod monitoring program has already been established, and therefore some vegetation plots will be located to overlap so that changes in abiotic and biotic drivers can be linked to potential monitored changes in arthropod communities. Spatial replications will be added along gradients for both vegetation and arthropod monitoring.

Special attention will be given to minimizing environmental impact of monitoring on vegetation by deploying board walks and other protective measures from the beginning. Benefits of drone monitoring will also be explored.

Freshwater monitoring priorities

For the freshwater ecosystems in RFS Extensive Monitoring Area, the focus will be set on the following components:

- Establishment of a baseline map database of hydrology, including the delineation of watersheds boundaries as possible. The map should include flow directions and quantify discharge.
- Development of a remote sensing baseline data library, and;
- Examination and summation of existing freshwater data

To collect information on hydrology in the area, monitoring partnerships will be formed with relevant institutions with available data from the region. Monitoring of landscape-level change (C-flow and nutrients) will be a priority, as these reflect the gradual change in land-use, vegetation cover, grazing pressure, atmospheric deposition and so forth. Water chemistry (abiotic FECs) can be considered the template for freshwater biodiversity, and thus serves as an early warning indicator of ecological change.

In addition, the aim is to include citizen science and local knowledge to collect information, e.g. regarding freezing and thawing events, and snow melt.

Freshwater monitoring at Rif will take note of and be informed by the EU Water Framework Directive, which Iceland is in the process of implementing according to Act no. 36/2011 on Water Management1. The Directive should lead to legal management and protection of water across administrative boundaries, integrated management independent to specific municipal policy, and a timed action plan to improve and maintain water quality. According to the act on water management this includes rivers, lakes, estuaries, lagoons, salt marshes, ground water and glaciers (Environment agency of Iceland, 2012).

The RFS monitoring plan and its implementation will contribute to the objectives of the EU Water Framework Directive by reporting on the ecological condition of water catchment areas in Melrakkaslétta. This will be based on exploring the effects of the four main stressors on Icelandic waters that have been predefined within the Act on Water management within RFS Extensive Monitoring Area: pollution, physical changes, construction, and biological effects (Environment agency of Iceland, 2012).

1 Lög nr. 36/2011 um stjórn vatnamála: https://www.althingi.is/lagas/nuna/2011036.html

Monitoring establishment: Implementation plan

Project	Description	Attribute and parameters	Responsibility	Timeline
Rif monitoring and research database	Collect, tabulate, and assess existing data relevant to terrestrial and freshwater research and monitoring in the area; Collaborate with related institutions.	*Not applicable*	Rif Field Station	**Sept 2017 – Sept 2018**
Mapping database	Establish a baseline terrestrial map database Mapping of important bird habitats Establish a baseline hydrology map database	*Not applicable*	Rif Field Station, CAFF and Aarhus university	**Sept 2017 – August 2018**
Determine National and International importance	Define connections among Rif and CBMP/INTERACT WP7, Iceland's commitments, climate change, and an increased need for monitoring; highlight the role of CHARS and Zackenberg.	*Not applicable*	CAFF and Rif Field Station with input from rest of WP7	**May 2018**
Monitoring of abiotic parameters	Install climate station, establish research and monitoring database and accessible interface	Air temperature, pressure and humidity, soil temperature and moisture, wind direction and speed, precipitation, snow cover and greening (NDVI sensors)	Rif Field Station and the Icelandic Meteorological office	**July 2018**
Arthropod monitoring	Continue already established project (2017) with pitfall traps and Malaise tents in two different habitat types and three locations inside the Rif Intensive Monitoring Area (IMA)	Abundance and diversity; Presence/absence	Rif Field Station and the Icelandic Institute of Natural History	**June 20th – Aug 30th 2018**
Vegetation monitoring	Install monitoring squares that overlap the existing arthropod monitoring; focus on parameters requiring basic methods	Diversity, composition, abundance, spatial structure, and phenology (e.g. flowering) Presence/absence of non-native species	Rif Field Station and the Icelandic Institute of Natural History	**Spring/summer 2018**
Animal monitoring	Acquire knowledge from local observers and hunters and relevant institutes on fox and mink in the area	Abundance, health, phenology, den position, hunting	Rif Field Station	**Autumn/winter 2018**
Bird monitoring	***Heathland birds:*** Continuation and expand this monitoring project within the Rif IMA; sharing of data	Abundance, density, species diversity	Rif Field Station and Northeast Iceland Nature Research Centre	**Spring/summer 2018**
	Gyrfalcon and Ptarmigan: Continue and strengthen monitoring, data sharing and collaboration	Abundance, density, demographics, productivity, phenology	Rif Field Station and the Icelandic Institute of Natural History	**Spring/summer 2018**
	Shore birds and passerines: Strengthen partnerships with local bird enthusiasts (Citizen science) - collect existing data; secure continuation of monitoring efforts	Breeding bird census - abundance, density, demographics, productivity, phenology, habitat selection and migration patterns	Rif Field Station, Northeast Iceland Nature Research Centre	**Spring/summer 2018**
Freshwater monitoring	Establish a collaborative relationship with the Icelandic Marine and Freshwater Institute and Kópavogur Natural History Museum. Explore optimal first steps regarding monitoring establishment at Rif; Discuss and determine achievable monitoring attributes and parameters	*Abiotic:* Water temperature, hydrological and ice regime (break-up and freeze-up) water quality (e.g. turbidity, color, nutrients, conductivity) *Biotic:* Diversity and abundance (zoo plankton, zoo benthos, macrophytes and fish)	Rif Field Station, the Icelandic Marine and Freshwater Institute & Kópavogur Natural History Museum	**Sept 2018**

Data management

As in any monitoring program the data generated is the key program asset. The establishment of an appropriate data management policy and system plan is therefore a necessary and important part in the planning process. Such a management plan needs to make sure that data is compatible with other networks and institutions.

Data for RFS will be managed in collaboration with the institutes involved, and with the CAFF secretariat. The Zackenberg Research Station, CHARS, and Aarhus University will further aid in the development of the Rif Field Station Data Management Plan (RFS DMP). The goal of the RFS DMP is to ensure that data on selected FECs defined within the CBMP are documented, made accessible and preserved for future use. This process will make use of the Arctic Biodiversity Data Service (ABDS), which is the online data portal being developed by the CBMP.

The ABDS accesses, integrates, analyzes, and displays biodiversity information from many circumpolar sources. This system accepts geo-referenced data at various spatial, temporal, and taxonomic scales (e.g., populations, regions, nations, circumpolar, biomes, habitats) allowing users to explore relationships and factors driving change. The ABDS provides a dynamic source for up-to-date Arctic biodiversity information and emerging trends and serves as a focal point and common platform for all participating networks (see abds.is).

The DMP will provide descriptive details of the data collection and processing procedures to be applied at RFS and will comprise the following components:

- ***Data Management Principles:*** describing the data management principles and guidelines for management of data from RFS
- ***Data collection:*** describing data collection, storage, and processing at RFS
- ***Data handling:*** describing how data from RFS will be delivered to the ABDS

The DMP will focus on baseline managing being conducted by RFS and will not seek to archive data from all research activities conducted by others. Rather, it will ask for these data to be made accessible and that access details will be provided to RFS. To further aid the development of the DMP, CHARS data management principles and guidelines will be used to inform those of RFS. As the data management plan is part of INTERACT Work Package 7 it is important that it remain generic enough so that it can apply to stations other than RFS, e.g. within INTERACT.

Concerning data management and interface for the Rif climate station, Rif Field Station will collaborate with the Icelandic Meteorological Office (IMO) as the station will fall under their network. The IMO follows international standards and collaborates directly with the World Meteorological Organization (WMO). Through a special interface created for Rif Field Station, all users of the station will be able to download the available raw data upon request.

The data format and management will feed into other CAFF and Arctic Council initiative as well as into the INTERACT network.

Monitoring outcomes

To ensure the sustainability and growth of the Rif Station, monitoring outcomes of the terrestrial and freshwater monitoring plans will serve several mandates at various scales. A key contribution that Rif can make to partner institutions is to bring together and analyze background data, and data from other institutions, that can provide important ecological context that would not be otherwise available, and that will add value to their programs. These data will become more valuable over the years. The resulting information, as much as possible, will be communicated effectively locally, nationally, and internationally to serve decision-making, support related research, and potentially provide a 'control' area for assessing the impacts of regional industrial developments. The information gathered will also be of direct value to national and regional governments as optimal sampling schemes and standardized, integrated approaches to monitoring will allow them to better understand trends and the mechanisms driving them.

Integrating research and monitoring is very important and RFS is in a unique position to do just that from the beginning. The RFS monitoring plan, its development and implementation, will be closely linked to and informed by independent research projects within the area through the station's users, thus benefitting from their shared data, knowledge, and ideas. These research projects will in turn benefit from the ongoing monitoring and the supporting information and data it provides. This will ensure the continued development and adaptation of the monitoring plan, its protocols and implementation process.

Rif Field Station is a new, self-governing institution with limited resources, but with important links to other Icelandic research institutions and universities and monitoring at Rif will have to be implemented in consultation and cooperation with these important partners. This cooperation prevents, contributes to increased efficiency of monitoring efforts, and effectively optimizes government investments in ecosystem research and monitoring. The implementation will also be planned and implemented in collaboration with INTERACT, CAFF, the CBMP expert network and the other two research stations involved in this project, i.e. Zackenberg in Greenland and CHARS in Canada.

This monitoring plan is believed to be of significant value for the development of the CBMP and as such it will contribute to the facilitation of circumpolar connections between national and regional research and monitoring networks. This will in turn greatly increase the power to detect and attribute change for a reduced cost compared to multiple, uncoordinated approaches.

Next steps

For the future development of Rif Field Station research and monitoring plan the following items will be further defined:

- Conceptual model
- Placement of monitoring plots
- Improved access to upland area
- Utilization of the climate gradient from coast to upland area
- How to minimize disturbance due to monitoring, e.g. need for boardwalks, tracking activities etc.
- RFS clients, their needs, requirements and how best to serve them
- Use of different technology, e.g. drones and photography

These steps will take place within the implementation phase of the research and monitoring plan and should be developed and finalized for 2020.

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Appendix A: Suggested monitoring indicators at Rif based on the CBMP terrestrial and freshwater plans

Vegetation monitoring

Table 1. Proposed monitoring indicators (FECs) for vegetation. Lichens, mosses and vascular plants will be monitored in relation to species diversity, community composition, abundance and phenology as well as herbivory. Includes only attributes seen as "essential" for monitoring and only those methods classified as basic in protocol complexity.

FEC	Monitoring area	Attribute	Parameter	Method	Frequency
All plants (Species, life form groups, communities). Includes monitoring of forage species	*Or habitat(eco)type*	Diversity, composition and abundance	% Cover by life form or species	Point intercept/line point intercept	Every 3-5 years
			Canopy gap	Line intercept	
			Alpha diversity	Plot species list and plot photograph	
			Height of representative life forms	Mean of 5 representative plants	
			Beta/gamma diversity	Medium resolution remote sensing	Every 10 years
		Diversity and spatial structure	Pattern: fragmentation/ Connectivity	Remote sensing	Every 5 years
			Area: Total area by community		
			Distribution of communities		
		Phenology	Date of flowering (species)	Direct observation	Annual
			Date of senescence (species)	Direct observation	Annual

Rare species, species of concern		Abundance	Presence/absence; number of individuals/ population size	Direct count observations	Every 10 years

Non-native species Lupine		Abundance	Presence/absence	Direct count observations	As required
			Population size	Direct count observations	As required
		Spatial structure	Extent	Remote sensing	As required

Medium-sized predators (Arctic fox)		Abundance	Number, density	Den surveillance	Annually
		Health	Prevalence	Harvest records	Every 3-5 years
		Phenology	Parturition; breeding	Surveys, local knowledge (hunting)	Annually

Small predators (mink) Non-native species		Abundance	Number density	Cue counts, land-based surveys, local knowledge (hunting)	Annually

Animal monitoring

Table 2. Proposed animal monitoring indicators (FECs). Includes only attributes seen as "essential" for monitoring and only those methods classified as basic in protocol complexity.

FEC	Monitoring area	Attribute	Parameter	Method	Frequency
Birds	*Or habitat(eco)type*				
Herbivores (geese, swan, ptarmigan)		Abundance	Population size, number, habitat selection	1) Various aerial and ground surveys 2) Non-breeding census 3) Banding (capture-mark-recapture) 4) Citizen science, local knowledge, hunting numbers	Annually or as required
		Spatial structure	Local density; presence/absence, habitat selection, migrating patterns	1) Various aerial and ground surveys 2) Non-breeding census 3) Banding (capture-mark-recapture) 4) Citizen science, local knowledge	Annually or as required
		Demographics, productivity and phenology	Propensity; clutch size; brood size; age ratio; nest success; breeding behaviour; phenology	1) Banding (capture-mark-recapture) 2) Hunter collected: wing surveys 3) Site-specific studies 4) Egg collectors	Annually or as required
Insectivores (shorebirds, passerines)		Abundance	Population size, numbers, habitat selection	1) Non-breeding surveys: flyway 2) Observations - passerines 3) Single-species surveys 4) Local knowledge	Annually or as required
		Spatial structure: distribution	Local density; presence/absence, habitat selection, migration patterns	1) Citizen science, local knowledge 2) Banding and tracking studies (for migration patterns)	Various (annual to continuous)
		Demographics, productivity and phenology	Propensity; clutch size; brood size, age ratio; nest success; breeding behaviour; phenology	1) Specific projects 2) Citizen science, local knowledge 3) Non-breeding ground surveys (juvenile ratios)	Annually or as required

Arthropd monitoring

Table 3. Proposed arthropod monitoring indicators (FECs). Includes only attributes seen as “essential” for monitoring and only those methods classified as basic in protocol complexity.

FEC	Monitoring area	Attribute	Parameter	Method	Frequency
Terrestrial arthropods	Or habitat(eco)type				
Blood feeding: Diptera	Heathland, wetlands, freshwater	Diversity	Species richness (estimates)	Larvae collection in aquatic habitats, sweep net samples for adults	every 3-5 years
Pollination: Hymenoptera	Heathland, grassland	Diversity	Species richness (estimates)	Flower visitation, observations, sweep nets, passive sampling	Annually
		Spatial structure	Presence/absence	Visitations per unit time; timed sweep-net surveys	Annually
		Ecosystem functions and processes: pollination success, fruit set and yield	Fruit set and seeds	Some focal surveys required; community knowledge	Every 3-5 years
Food prey for vertebrates (esp. birds): Araneae, Diptera		Diversity	Species richness estimates	Standard grids of pan and/or pitfalls	Every 3-5 years
		Abundance and productivity	Relative number per trap	Standards grids of pan and/or pitfalls	Annually if possible where bird studies are conducted
		Phenology	Seasonal activity patterns	Standard grids of pitfalls – sampling over entire active season from snowmelt to snow arrival	Annually if possible where bird studies are conducted
Decomposers and nutrient cycling: Soil mesofauna and macro-invertebrates		Diversity	Species richness (estimates)	Soil and turf cores taken on site, returned to laboratory for extraction (high environmental impact for long-term monitoring, needs consideration)	Every 3-5 years
		Abundance	Density estimates, i.e. number per standard soil core	Numbers calculated per m^2 at specified depth (high environmental impact for long-term monitoring, needs consideration)	Annually
		Spatial structure	Presence/absence		Annually first; 3-5 years afterwards

	Herbivores: Lepidoptera, Aphididae, Hemiptera, Coleoptera		Diversity	Species richness	Opportunistic collection of adults and/or standardized sweep samples	Annually first; every 3-5 years afterwards
			Spatial structure	Presence/absence	Opportunistic collection of adults; standardized sweep samples; standardized beat-sheet sample/systematic surveys of plants for larvae.	Annually first; every 3-5 years afterwards
			Ecosystem functions and processes: herbivory	Plant damage	% Leaf area lost, index of leaf damage, leaf minor damage	Annually if possible

Freshwater ecosystem monitoring

Table 4. Biotic and abiotic freshwater monitoring indicators (FECs) selected for inclusion in Arctic freshwater monitoring by the freshwater expert monitoring group of CBMP. Only showing FECs that might be considered applicable within the Rif freshwater monitoring plan.

FEC	Ecosystems	Attribute	Parameter	Method	Frequency
Biotic FECs					
Zoo plankton	Lakes and rivers	Diversity, abundance	Species richness, relative number per sampling	Mesh, 250 µm is recommended as small chrionomids make up a large share of the fauna	Seasonal sampling initially (monthly, May-October) Annually after that (late summer) or as required
Phytoplankton	Lakes and rivers	Diversity, abundance	Species richness, relative number per sampling	Mesh, 250 µm is recommended as small chrionomids make up a large share of the fauna	Annually (late summer) or as required
Zoo benthos	Lakes and rivers	Diversity, abundance	Species richness, relative number per sampling	Samples from submerged stones, kick-sampling method, core samples	Annually (August/Sept) or as required
Phyto benthos	Lakes and rivers	Diversity, abundance	Species richness, relative number per sampling		
Fish	Lakes and rivers	Diversity, abundance	Species richness, relative number per sampling	Gill netting for different habitats (littoral, profundal and pelagic zone), electrofishing for juvenile fish in littoral zone	Every 3-5 years
Macrophytes	Lakes	Diversity, abundance, distribution		Standard methods developed for Scandinavia	Every 3-5 years
Alien and/or invasive species	Lakes and rivers	Occurrence, abundance	Species richness, relative number per sampling		Every 3-5 years
Abiotic FECs					
Water temperature regime	Lakes and rivers			Manual measurements, thermistor and data logger measurements, remote sensing (surface)	

Hydrological and ice regimes	Lakes and rivers	Phenological events	Record timing of break-up and freeze-up (lakes), trends in winter ice growth, snow cover on ice	Measurement of lake levels and surface area, community based monitoring, direct observation	Annually
Water quality	Lakes and rivers		Recommended: TP, TN, DOC, CDOM, pH, alkalinity, conductivity, major ions, TSS, dissolved oxygen	Subsurface water sampling, or on-site measurements of water column chemistry	
Climatic regime	Lakes and rivers		Incoming light, temperature, wind, precipitation	Weather station and paleolimnological studies to provide information about current and past climate	
Active layer (and permafrost)	Lakes and rivers		Active layer depth	Field surveys or remote sensing techniques (also for surfaces affected by wind erosion)	

Appendix B: Current and existing research within the RFS Extensive Monitoring Area

Table 5. Already established, ongoing or planned bird monitoring projects in the area that can be built on, integrated, or adapted to the CBMP terrestrial monitoring plan.

FECs/species group	Attribute & parameters	Method	Frequency	Responsibility/data collection
Birds*				
Herbivores: Rock ptarmigan (Lagopus muta)	Population index, fecundity/reproduction, age composition (spring & hunting season), abundance, demographic parameters	Counting, age estimates based on appearance and size, hunting numbers	Annually	Icelandic Institute of Natural History
Carnivores: Gyrfalcon (Falco rusticolus)	Nesting population, fecundity/reproduction, nesting phenology, Food composition, numerical response and functional response (to ptarmigan population change)	Visitations on established territories	Annually	Icelandic Institute of Natural History
All migratory birds	Migration patterns	On the ground observations	Annually, since 2001	Guðmundur Örn Benediktsson (supported by Northeast Iceland Nature Research Centre)
Piscivores: Loons	Abundance, migration patterns, nesting phenology, fecundity/reproduction, food composition (chicks)	On the ground observations	Annually, since 2012	Ævar Petersen & Guðmundur Örn Benediktsson (for the Ministry for Environment and Natural Resources)
Waders	Species diversity	On the ground observations	Annually	Guðmundur Örn Benediktsson for the Icelandic Institute of Natural History
Waders: Oystercatchers	Migration patterns, nesting phenology, nesting population, fecundity/reproduction	On the ground observations	Annually, since 2001	Guðmundur Örn Benediktsson for the Icelandic Institute of Natural History
Waders: Sanderlings	Migration patterns, nesting population		Annually, since 2010	Guðmundur Örn Benediktsson for the Icelandic Institute of Natural History and AnimalTrack
Herbivores: Geese, swans	Migration patterns	On the ground observations	Annually, since 2001	Guðmundur Örn Benediktsson for the Icelandic institute of Natural History
Heathland birds	Abundance, diversity	Counting on predetermined locations	Annually, since 2015	Northeast Iceland Nature Research Centre
Common shelduck	Nesting population, fecundity/reproduction, nesting phenology	On the ground observations	Annually	Northeast Iceland Nature Research Centre
Seabirds	Nesting population, abundance, diversity	Counting, on the ground observations	-	University of Iceland

*in addition, bird species composition near the village of Kópasker has been recorded 8-9 times per year from 2013. Winter population counts have been performed for the same area for the last 4 years and once for the whole of Melrakkaslétta peninsula.

Table 7. Already established, ongoing or planned arthropod monitoring projects in the area that can be built on, integrated, or adapted to the CBMP terrestrial monitoring plan.

FECs	**Attribute & parameters**	**Method**	**Frequency**	**Responsibility/data collection**
Vegetation				
All terrestrial plants	Abundance, species diversity and more	Intense monitoring areas; 1 x 1m squares in different ecotypes. Connected to arthropod monitoring	Every 5 years	Rif Field Station & Icelandic Institute of Natural History

Table 8. Already established, ongoing or planned freshwater monitoring projects in the area that can be built on, integrated, or adapted to the CBMP freshwater monitoring plan.

FECs	**Attribute & parameters**	**Method**	**Frequency**	**Responsibility/data collection**
Biotic and Abiotic FECs				
Biotic: Zoo plankton, zoo benthos, macrophytes and fish	Diversity and abundance	Sampling from water column, protocols to be determined	Annually for three years, every 3-5 years after that	RFS, aided by the Icelandic Marine and Freshwater Research Institute & Kópavogur Natural History Museum
Abiotic: Water temperature, hydrological and ice regime, water quality	Ice break-up and freeze up; turbidity, color, nutrients, conductivity etc.	Sampling from water column, protocols to be determined; Citizen science and local knowledge	Annually for three years, every 3-5 years after that	RFS, aided by the Icelandic Marine and Freshwater Research Institute & Kópavogur Natural History Museum

Appendix C: Implementation Plan and Timeline for Work Package 7

The important steps that will be taken during the development and implementation process of the monitoring plan are listed here below along with the responsibility of different tasks and timeline.

Table 9. Timeline for the development and implementation process of Rif Field Station's monitoring plan.

Task	Responsibility	Timeline
Identify and confirm: – Proposed FECs to be monitored at Rif – Methods for monitoring selected FECs that will provide most relevant data for the CBMP	RFS and WP7 coordinating group	**Aug 24th 2017**
Plans and documents for monitoring in CHARS and Zackenberg delivered to Rif station manager, submission of comments on the Rif monitoring plan	Station managers/scientific leaders of Zackenberg and CHARS	**Sept 15th 2017**
Provide a starting point for text on international linkages of Rif monitoring plan	CAFF secretariat and CBMP co-leads	**Sept 30th 2017**
Raufarhöfn workshop report with overview of the meeting and its outcomes including decisions, advice, actions and responsibilities.	RFS, CAFF secretariat and CBMP co-leads	**Oct 10th 2017**
Other INTERACT WPs: Connections and benefits	CBMP co-leads	**Nov 1st 2017**
1st INTERACT WP7 teleconference	RFS and CAFF secretariat	**Nov 10th 2017**
A sales document for Rif and the CBMP/INTERACT WP7 focusing on connections to Iceland's commitments, climate change, increased need for monitoring etc. Highlight the role of CHARS and Zackenberg.	CAFF secretariat and RFS with input from all members of INTERACT WP7	**Dec 20th 2017**
Identify possible ways to include local knowledge and community-based monitoring	RFS with input WP7 coordinating group	**April 15th 2018**
Data management strategy in connection with ABDS for the selected focal ecosystem components in cooperation with CBMP, INTERACT, CAFF, CHARS and Zackenberg	CAFF secretariat and Rif station with input from WP7 coordinating group	**April 15th 2018**
Identify and map already established monitoring projects in the area that fit to the requirements of the CBMP and that can complement the proposed monitoring plan at Rif	RFS and related institutions	**March 2018**
Copenhagen workshop report with overview of the meeting and its outcomes, including decisions, advice, actions and responsibilities	CAFF secretariat and WP7 coordinating group	**May 2018**
RFS Monitoring Plan: Version 1 finalized and released	RFS and WP7 coordinating group	**May 2018**
Coordination of monitoring activities within the area and establishment of cooperation with involved research institutions	RFS and related institutions	**June 2018**
Communications plan for RFS	RFS, CAFF secretariat and WP7 coordinating group	**June 2018**
RFS mapping database completed	CAFF secretariat and RFS	**Sept 1st 2018**
RFS Data Management Plan – draft completed	CAFF secretariat, Aarhus university, RFS and WP7 coordinating group	**Sept 30th 2018**
Long-term funding/business plan for Rif and its monitoring	RFS and CAFF secretariat with input from WP7 coordinating group	**March 2019**
User manual for implementing CBMP at INTERACT stations	CAFF secretariat CBMP co-leads and input from WP7 coordinating group	**Jan 2020**
Report describing the flow of data from the field to Arctic Council assessments, monitoring and reporting activities	CAFF secretariat and CBMP co-leads with input from WP7 coordinating group	**Jan 2020**
Updated publication on Arctic terrestrial biodiversity for the Encyclopedia of Biodiversity	To be determined	**Jan 2020**

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