Integrated Arctic Observation System

Research and Innovation Action under EC Horizon2020
Grant Agreement no. 727890

Project coordinator:
Nansen Environmental and Remote Sensing Center, Norway

Deliverable 4.3

Lessons learned on community-based observing parameters

Piloting of community-based and citizen science observing to inform decision-making in Greenland and Svalbard

Start date of project:	01 December 2016	Duration:	60 months
Due date of deliverable:	31 May 2020	Actual submission date:	25 May 2020
Lead beneficiary for preparing the deliverable:		NORDECO	
Person-months used to produce deliverable:		13,3 pm	

Finn Danielsen, Michael K. Poulsen (NORDECO), Lisbeth Iversen (NERSC), Martin Enghoff (NORDECO), Zeinab Jeddi, Mathilde B. Sørensen (UiB), Peter Voss (GEUS)

Version	DATE	CHANGE RECORDS	LEAD AUTHOR
1.0	10/01/2020	Outline	Finn Danielsen
1.1	24/04/2020	Draft	Finn Danielsen
1.2	24/05/2020	Reviewed and final version	Martin Enghoff
1.3	25/05/2020		Finn Danielsen
1.4	28/05/2020	Technical review and submission	Kjetil Lygre

Approval	Date:	Sign.
X	28 May 2020	Stein Sandven Coordinator

USED PERSON-MONTHS FOR THIS DELIVERABLE					
No	***Beneficiary***	***PM***	***No***	***Beneficiary***	***PM***
1	NERSC	***3***	**24**	TDUE	
2	UiB	***2***	**25**	GINR	
3	IMR		**26**	UNEXE	
4	MISU		**27**	NIVA	
5	AWI		**28**	CNRS	
6	IOPAN		**29**	U Helsinki	
7	DTU		**30**	GFZ	
8	AU		**31**	ARMINE	
9	GEUS	***0.8***	**32**	IGPAN	
10	FMI		**33**	U SLASKI	
11	UNIS		**34**	BSC	
12	NORDECO	***7,5***	**35**	DNV GL	
13	SMHI		**36**	RIHMI-WDC	
14	USFD		**37**	NIERSC	
15	NUIM		**38**	WHOI	
16	IFREMER		**39**	SIO	
17	MPG		**40**	UAF	
18	EUROGOOS		**41**	U Laval	
19	EUROCEAN		**42**	ONC	
20	UPM		**43**	NMEFC	
21	UB		**44**	RADI	
22	UHAM		**45**	KOPRI	
23	NORCE		**46**	NIPR	
			47	PRIC	

DISSEMINATION LEVEL		
PU	Public, fully open	X
CO	Confidential, restricted under conditions set out in Model Grant Agreement	
CI	Classified, information as referred to in Commission Decision 2001/844/EC	

EXECUTIVE SUMMARY

In the Arctic, it is a priority of governments and Indigenous peoples' organizations to increase the spatial and temporal coverage of environmental observations. One solution is to enhance community-based and citizen science observations.

We piloted a series of people-based observing activities in Disko Bay, Greenland, and in Svalbard. Our aims were to examine the feasibility of specific community-based and citizen science observing and networking activities and, at the same time, to assess their potential for wider use. We assessed the observing activities against six criteria: (1) the cost, (2) the need for expertise, (3) the ability to detect trends, (4) the ability to support decision-making, (5) the potential for enhancing local stakeholder capacity, and (6) the capacity to inform international monitoring. The results of our tests are presented and discussed in this report. The key findings are summarized below.

In Disko Bay, fishing and hunting are the most important livelihoods whereas, in Svalbard, it is tourism and science. In both areas, the susceptibility to natural disasters is increasing, and landslides and earthquakes have recently led to loss of lives. Through dialogue with civil society organizations, research institutions and the local authorities, we identified five community-based and citizen science observing and networking activities which we co-facilitated with many partners in Disko Bay and Svalbard between 2016 and 2019:

- Garage-type geophone devices to observe natural hazard events
- Expedition cruise operator-based observing
- Focus group discussions with fishermen and hunters
- Interviews and workshop dialogues to inform urban development
- Linking social science climate research with the needs of the decision-makers.

Citizen seismology. We tested the use of four garage-type geophone devices, two in each area, over two years. We compared the citizen-generated seismic data from the geophones with existing scientist-executed seismic sensors. In Disko Bay, the citizen geophones enabled the location of 23 events and improved the location of 209 events, thus significantly improving our understanding of the cryo-generated and tectonic events that occurred in the area whereas, in Svalbard, it was impossible to find suitable locations for the instruments. Citizen seismology may be useful in Arctic communities where the buildings are constructed on bedrock and trusted relationships exist between government agencies, scientists and the local residents. If seismic events detected by the geophones are discussed with the communities and the authorities, citizen seismology may help build community awareness of natural hazards and contribute to improved decisions on safety.

Expedition cruise operator-based observing. Cruise guests already make observations of the environment in the Arctic but the number of attributes observed and the volume of records are limited and very few of the observations are used by decision-makers. We initiated a dialogue about coordinated expedition cruise operator-based observing with the expedition cruise industry, scientists, and the authorities. Together, we tested the use of six citizen science programs among six cruise operators in Disko Bay and Svalbard for one cruise season. A total of 165 people contributed observations, mostly bird checklists to eBird and marine mammal encounters with photos to Happywhale. Cruise guests and cruise guides can contribute large volumes of

observations from areas visited by expedition cruises during the Arctic cruise season, April to September. Enabling factors may include: (1) equipping cruise vessels with tablets that allow for easy upload of records, (2) prompt feedback to observers and decision-makers directly from the citizen science programs through the use of digital platforms, and (3) a well-funded intermediate organization facilitating communication. Further work is necessary to fully understand the feasibility and potential of coordinated expedition cruise operator-based environmental observing in the Arctic.

Focus group discussions with resource users. In Disko Bay, we tested focus group discussions with fishermen and hunters for monitoring and managing living resources as part of the PISUNA program (*Piniakkanik Sumiiffinni Nalunaarsuineq*). A total of 30 fishermen and hunters summarized observations, from 4,287 field trips, of 33 attributes, including sea-ice and climate/weather, plus 10 fish, 11 mammal and 10 bird taxa, over four years. The community members used the observations as a basis for submitting 197 management proposals to the local and central authorities. Focus group discussions with resource users are useful where community members depend on living resources for their livelihood and where government policies are supportive of collaborative resource management. To achieve their full potential, focus group discussions require government staff time and funds to be prioritized for supervising the fishermen's and hunters' monitoring and for making decisions and taking action on the basis of the management proposals.

Networking for people-based observing. In Svalbard, we initiated a dialogue with local actors on environmental observing so as to build trust and long-term collaboration while addressing both ethical, democratic and cultural dimensions. We facilitated interviews and organized workshop dialogues to inform urban development. We also co-established a digital platform for linking social science climate research with the needs of the decision-makers, thereby promoting experience exchange, coordination and communication. The initiatives contributed to important community dialogues during the Covid-19 crisis in Svalbard.

From observation to action. The three piloted activities that involved field-based data-gathering in Disko Bay and Svalbard represent approaches with varying levels of participant and scientist involvement and with different linkages to decision processes and action. The geophones case is an example of automated data collection with Arctic residents. The role of the participants is limited to installing the geophones and providing electricity and Internet. The expedition cruise operator-based observing is an example of human production of data by visitors to the Arctic. The observers are cruise guests and guides, and their role is limited to making observations and taking measurements and photos. In both cases, if the data is to inform decision-making, it will need to be interpreted and analyzed by scientists and the findings made available to the appropriate decision-making bodies. In the third tested field-based data-gathering activity, the focus group discussions with resource users, the participants not only submit records to scientists but they also themselves interpret and discuss their records, and propose management interventions to the authorities. In this case, communicating findings and proposing decisions are in-built components of the monitoring process.

Table of Contents

1. Introduction

One of the conclusions of the 2nd Arctic Science Ministerial in Berlin in October 2018 was that there is a need to enhance collaboration and coordination of efforts on *"Arctic observations of all types, spanning from community-based observatories to high-tech autonomous systems, and to increase their spatial and temporal coverage"* (The Joint Statement of Ministers 2018[1]).

With support from the European Union Horizon 2020 Program, the Integrated Arctic Observation System Project aims to extend and improve existing and evolving observing systems that encompass land, air and sea in the Arctic (INTAROS, intaros.eu). INTAROS involves 49 institutions from 20 countries. The INTAROS project was developed to both contribute to implementing the European Union Arctic Policy and to assist in the creation of an efficient Arctic Observation System. Efforts would broadly address issues to extend, improve and unify existing and evolving systems in the different regions of the Arctic.

One of the project components focuses on enhancing community-based observing and citizen science in the Arctic. Key activities include: knowledge exchange workshops, exploring opportunities to inter-weave existing community-based monitoring programs in the Arctic with scientists' monitoring efforts, and piloting tools in Disko Bay, Greenland and in Svalbard to support decision-making and capacity building.

This report presents the lessons learned on piloting of community-based observing and citizen science to inform decision-making in Greenland and Svalbard. Firstly, we describe the theoretical framework, what we did and why (Chapters 2 and 3). Secondly, we summarize what the outcome was and why (Chapter 4). We conclude with a discussion of what we have learnt from this (Chapter 5) and we discuss the prospects for positive developments for Arctic observing (Chapter 6).

We intentionally did not predefine community-based and citizen science observing but adopted an inclusive approach that encompassed activities with different levels of community and citizen involvement. We distinguished community-based and citizen science observing networks from scientist-executed observing networks by the involvement of community members or citizens in one or more steps of the observing process.

[1] Available at https://www.iarpccollaborations.org/uploads/cms/documents/asm-2-joint-statement.pdf

2. Background

In this chapter, we describe the theoretical basis for the piloting of community-based and citizen science observing and networking activities. We describe the expectations from the project document and we present the rationale for the selection of the pilot communities. We also provide the reasoning behind the selection of the observing tools that we have piloted.

2.1 Expectations

Our activities were guided by the activity descriptions in the INTAROS project document (Sandven et al. 2016). In the project document, it was spelled out that we would: "*identify community-based variables (...) that are relevant for communities and citizens to support local and national decision-making processes"*. Moreover, *"the variables will be identified in dialogue with indigenous and other civil society organizations and local authorities in the focal communities"*.

The project document also included a list of provisional variables. These were: changes in sea-ice, snow cover, permafrost thawing, land and marine ecosystems, earthquake hazards, air temperature, air humidity, wind speed, atmospheric pressure, water level, and oceanographic profiles of salinity and temperature.

The project document specified that we would: *"establish (the) tools (...) on the ground, and pilot their use among 15-20 community members and volunteers in each community over a two-year period"*. We would "*test the ability of the tools to provide knowledge products that are salient, credible, and legitimate to local and national decision-makers*". These activities would be undertaken in "*close cooperation with the Office of the Governor of Svalbard and with Qaasuitsup Municipality (from 2018, renamed Qeqertalik and Avannaata municipalities) in Greenland*". Moreover, in Greenland, the activities would: *"build on, and further strengthen, the network of community monitors established by the (...) PISUNA (Piniakkanik Sumiiffinni Nalunaarsuineq) program*" (Links: http://www.pisuna.org/; https://eloka-arctic.org/pisuna-net/).

2.2 Rationale for the selection of the pilot communities

We focused the piloting of community-based and citizen science observing networks on two Arctic communities, located in Disko Bay, Greenland, and Svalbard. These communities were chosen on the basis of three criteria:

(1) Communities where a process to develop community-based and citizen science observing programs is underway;

(2) Communities where good prior relations and mutual knowledge on participatory research and capacity building already exist between the partners and with government and community-level authorities and institutions, and where the project therefore has substantial potential for achieving quick results and constructive experiences of direct relevance for an Arctic Observing System and for local and national decision-making;

(3) Communities in countries that have some degree of policies enabling good governance and solving of issues of rights over land and resources, which is important for successful community observing efforts.

The pilot areas of Disko Bay and Svalbard share a number of common features. Both areas: (1) are high-risk regions in terms of climate change impacts and loss of biological diversity, (2) can potentially benefit significantly from community-based observing and citizen science programs in terms of enhancing resilience and adaptation to climate change through improved governance, and (3) are characterized by economies in which institutional set-ups and available funding would benefit from efficient and low-cost observing programs at local levels. It was envisaged that the site-based activities would contribute significantly to moving community-based observing and citizen science programs forward in the communities in both pilot areas.

2.3 Local context

In this section, we describe the dialogue we have had with local stakeholders in Greenland and Svalbard. We also present the reasoning behind the selection of the observing tools that we have piloted.

In Greenland, discussions have been held both at central and local level. At the central level, in Nuuk, discussions have been held with staff of the Greenland Association of Fishermen and Hunters (KNAPK) and the Ministry of Fisheries, Hunting and Agriculture. At the local level, we have had discussions with community members (Akunnaaq, Attu, Kangarsuatsiaq, Kitsissuarsuit, Qaanaaq), school teachers, scientists, and staff of Qeqertalik and Avannaata municipalities in the towns of Aasiaat and Ilulissat. In Greenland's Disko Bay[2], the land and seascapes are vast and used by a relatively sparse population living in scattered coastal settlements. Utilization of marine and terrestrial living resources forms an all-important mainstay for the majority of people in the settlements. The people in the settlements are *de facto* managers of the landscapes through their use of resources. The distribution and abundance of living resources are changing rapidly (Post et al. 2009, Meltofte 2013). The status of a wide range of key resources and their changing abundance has a very direct impact on the incomes and lives of ordinary people in the municipalities (Nuttall 2009). Sustaining incomes from living resources and ensuring a sustainable use of the living resources, as well as successfully adapting to the changes in abundance of resources and adjusted management regulations, depends on knowledge of the status of resources (Riedlinger and Berkes 2001). This requires continuous observation of the environment and an associated continual reshaping of management interventions. Scientist-based monitoring of the environment is taking place but scientist knowledge of the environment is incomplete and conventional scientific monitoring is logistically difficult and relatively costly. However, local fishermen and hunters make on-the-job observations of the environment all year round through which to make use of first-hand knowledge of changes in the living resources (Danielsen et al. 2014). Their observations and knowledge are, however, not consistently quantified and analyzed and, when they are used for resource management, it is mostly due to legally required public hearings or sometimes as a contribution from the central government to negotiations in international environmental agreements. At the same time, the Government of Greenland has a policy of promoting user knowledge in the management of living resources (Greenland Government 1999), a policy that remains to be transferred into a systematic approach in practice.

[2] Excerpt from Danielsen et al. 2017.

In Svalbard, there are no indigenous people, and it has been important for us to approach many actors to secure broad knowledge on research and monitoring priorities and to generate ownership. Government decision-making is strongly framed by Norwegian and international agreements and regulations (Kaltenborn et al. 2020). The Governor is the head of overall planning and development in Svalbard. Discussions have been held with the Governor's Office, the Local Council, the business association, the school, the church, the youth club, the library and the University Center in Svalbard (UNIS), plus its Safety Center. Through information and discussions by email, phone calls and visits, we intended to: (1) build understanding, trust and capacity among the actors, (2) anchor the intentions of the project, (3) improve our understanding of local needs, local planning challenges and local democracy, and (4) explore the potential for co-creating observing networks for improved decision-making. The project has sought a role as 'facilitator' between local community and research on climate change and adaptation strategies, data collection and scientific and local knowledge and, through this process, increased information and knowledge-sharing and collaboration. The project has taken part in many meetings of the Local Council in Svalbard. A number of topics of great importance were discussed at these meetings, including climate change mitigation and adaptation, clean water, waste management, tourism and future job possibilities. For example, many houses in Longyearbyen need to be demolished due to the increased frequency of snow avalanches and landslides. Melting permafrost and increased precipitation and flooding are challenging the conventional way of constructing buildings on timber poles hammered into the permafrost ground in Longyearbyen. The possibility of new building areas is thus a planning and development topic of great concern both for the safety and well-being of the inhabitants, as well as a technical challenge. The project has also revealed a need to support decision-making processes in Svalbard for better collaboration and coordination around research on climate change mitigation efforts, climate adaptation and social issues connected to this.

Both in Greenland and in Svalbard, natural disasters such as landslides and earthquakes are likely to increase with the changes in the climatic conditions in the Arctic (e.g., Dahl-Jensen et al. 2004; Hestnes et al. 2016). In Greenland, recent earthquakes and especially the 2017 landslide north of Disko Bay (Clinton et al. 2017) have highlighted the safety issues related to seismic events. Likewise, in Svalbard, a snow avalanche in Longyearbyen in 2015 led to the loss of two lives (www.snoskred.no), and strong precipitation events have led to several mudslides in recent years. The permanent seismological network is not dense in the Arctic due to: (1) difficult access to the area, and (2) earthquakes represent less risk to this region than others due to the sparse population (Voss et al. 2019; Jeddi et al. 2020). Recent technologies have improved access to the Arctic; however, undertaking seismic research and monitoring is still expensive and demanding both logistically and technically. In both communities, it is therefore a high priority of the authorities to obtain a better understanding of ways to monitor and respond to natural hazard events.

In both pilot communities, many areas are visited only by expedition cruise ships each year (Wagner et al. in review). Expedition cruises are self-contained and thus differ from conventional tourism cruises, which are dependent on land infrastructure such as buses (Van Bets et al. 2017). The expedition cruise industry grew after the breakdown of the Soviet Union, when many Russian ships became available at an affordable price. Since then, many 100 – 500 passenger vessels have been and are being built[3]. Expedition cruise operators, guides and passengers regularly visit the remote areas of Svalbard and Greenland. They may find it

[3] Ilja L. Lang, Association of Arctic Expedition Cruise Operators (AECO) pers. com., see http://www.intaros.eu/media/1635/2019-report-aeco-workshop-v4.pdf (Poulsen et al. 2019:7).

meaningful to contribute to monitoring of the environment yet few attempts have been made to improve and expand the environmental monitoring efforts of expedition cruise ships in the Arctic.

Previously, community members have been involved mostly as informants or observers in research activities in Greenland (e.g., Lennert 2017; Flora et al. 2019; Cuyler et al. 2020; Nielsen et al. 2020). Local people have successfully been involved in counting breeding Eider Ducks *Somateria mollissima* in several areas for almost two decades (Merkel 2016) and hunters report their catch annually via the Greenland hunting and catch registration system, *Piniarneq* (e.g., Flora et al. 2019). In Svalbard, visitors have been involved in citizen science projects with the University Center in Svalbard, UNIS (e.g. https://www.unis.no/can-cruise-tourists-become-citizen-scientists/), expedition cruise operators like Hurtigruten, and the Polar Citizen Science Collective.

2.4 Piloted community-based and citizen science observing activities

With the considerations in Section 2.1-2.3 in mind, it was therefore considered a high priority to pilot the following community-based and citizen science observing and networking activities in Disko Bay and Svalbard:

1) Garage-type geophone devices to observe natural hazard events
2) Expedition cruise operator-based environmental observing of multiple variables
3) Focus group discussions with fishermen, hunters and environmentally-interested people to observe changes in marine and terrestrial ecosystems, resource uses and threats in Disko Bay
4) Interviews and workshop dialogues to inform urban development in Longyearbyen
5) Linking social science climate research in Svalbard with the needs of the decision-makers.

In Chapter 3 we describe each of these activities.

3. What we did and why

In the preceding chapter, we explained the background to the pilot activities in Disko Bay, Greenland, and in Svalbard. In this chapter, we elaborate on how we undertook each of the community-based and citizen science observing activities and why.

3.1 Garage-type geophone device

Below we describe the garage-type geophone system and how it was used in Disko Bay and Svalbard. Large parts of this material have also been published by Jeddi et al. (2020) under CC BY 4.0 license[4].

The Raspberry Shake geophone system

We chose the Raspberry Shake instrument for citizen seismological monitoring in the pilot areas. The Raspberry Shake seismograph is an all-in-one, plug-and-go solution for seismological applications, which can detect and record short-period (0.5–15 Hz) earthquakes. It was developed by OSOP, S.A. in Panama and integrates geophone sensors, digitizers, period-extension circuits and a computer into a single enclosure (see https://raspberryshake.org/). The units used in Disko Bay are both equipped with vertical geophones; in Svalbard one uses a vertical geophone and one uses three orthogonal geophones. The performance of Raspberry Shakes has been evaluated in several studies with the conclusion that they are suitable to complement existing networks for studying local and regional earthquakes (e.g., Anthony et al. 2018; Manconi et al. 2018; Hicks et al. 2019). The instruments are also becoming increasingly popular as an educational tool for teaching and public science exhibitions. Raspberry Shake is low cost (approximately US $340), easy to install/maintain and has near real-time data transmission. Power and an Internet connection are the only technical requirements. Even if there is no Internet, the instrument still has internal data storage. An additional requirement, which is valid for all seismological monitoring, is that the instrument needs to be at a quiet location with little man-made and natural noise and with good coupling to the ground, preferably to bedrock. Information on online Raspberry Shake sensors can be seen through a website where data can also be displayed (see https://raspberryshake.net/stationview/).

Greenland geophone case

In Disko Bay, we based the establishment of the seismographs on the existing network of fishermen, hunters and authorities in PISUNA where experienced community members keep track of changes in the status of living resources, discuss and interpret their observations, and propose management interventions to the authorities (Danielsen et al. 2014). In April 2018, two families living in the village of Akunnaaq (Figure 1B, 1D and 1E) and the town Aasiaat installed geophones in their basements. These were named AKUG and ASIG. The installation instruction was simply to place the instrument on bedrock, connect the instrument to their Internet router via the LAN cable and power up the unit. The units automatically connected to the Raspberry Shake server and started uploading data. The ASIG sensor was moved to a new location in Attu in 2019 due to the host getting rid of his mobile phone and Internet. The new site is called ATTUG. AKUG was therefore recording between April 2018 and July 2019, ASIG monitored data between April 2018 and December 2018 and then ATTUG was monitoring between June 2019 and December 2019.

[4] https://creativecommons.org/licenses/by/4.0/

Svalbard geophone case

It was decided to deploy two sensors in Svalbard in July 2018. To accommodate the technical requirements for deployment (access to power and Internet), as well as the citizen science perspective of the study, we wished to locate them within the town of Longyearbyen. To maintain the educational value of having these instruments in town, several public places were approached (e.g., the library, school, church, Svalbard Museum, Radisson Blu Polar hotel, Svalbard art gallery, the fire station, airport and so on). However, unexpectedly, only two places could fulfil our basic technical requirements, provide appropriate locations for the sensors (on the ground floor of the building) and were willing to host the instruments: Svalbard Museum and Radisson Blu Polar hotel. Due to the high cost and limited availability of indoor areas in Longyearbyen, the main reason for rejecting our request was a lack of space, despite the fact that these instruments do not take up much room (Figure 1C and 1F). The fact that nearly all buildings in Longyearbyen (and Svalbard) are built on poles (timber poles hammered into the permafrost ground), in order to provide a stable foundation for the building in the permafrost, turned out to be a major challenge. Such locations provide poor coupling to the ground and will thus result in much higher noise levels than installation in buildings on firm ground. Both Svalbard Museum and Radisson Blu Polar hotel, which were our only options in Longyearbyen, are built on poles. Both sensors were installed in July 2018, in close collaboration with our hosts. In Svalbard Museum, a corner of an abandoned office was used to set up the instrument and launch the recording. The host also provided a lid to protect the instrument (Figure 1F). The other instrument was installed in a storage room in Radisson Blu Polar hotel. We had access to data in near real-time and immediately noticed the high level of noise in both locations, as expected. However, further effort to find alternative locations were not successful. The monitoring was therefore continued at the initial locations.

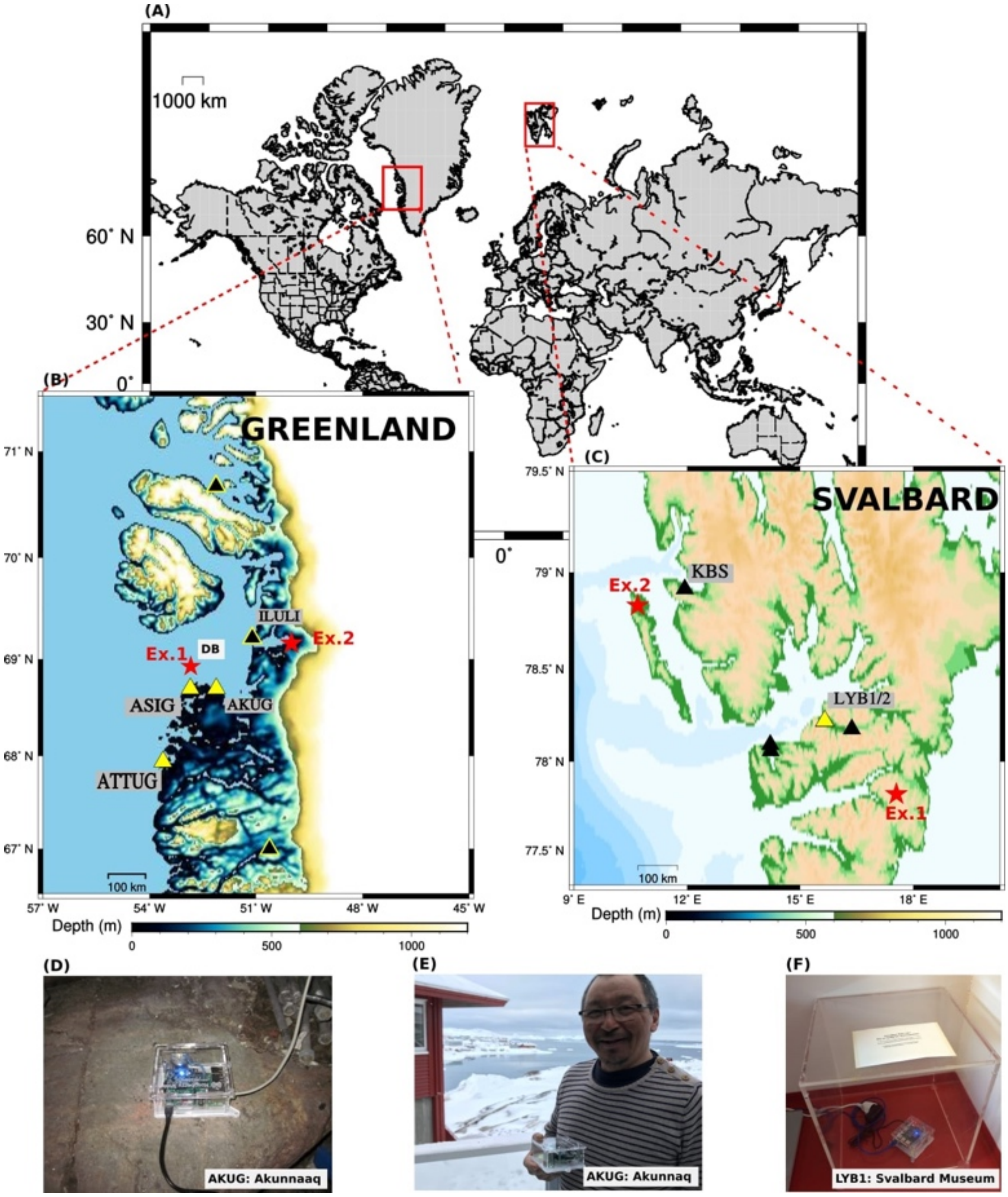


Figure 1. (A) Location map. The two study areas are shown with red boxes. (B) Map of west Greenland. Citizen seismology sensors and permanent stations are shown with yellow and black triangles, respectively. 'DB' refers to 'Disko Bay'. 'Ex.1' and 'Ex.2' are the location of two events in Figure 7B-C. (C) Map of Svalbard. Citizen seismology sensors and permanent stations are shown with yellow and black triangles, respectively. 'Ex.1' and 'Ex.2' are the location of two events in Figure 8D-I. (D) Sensor installed in Akunnaaq, Greenland (Photo: G. Nielsen). (E) Gerth Nielsen, Akunnaaq, before installing citizen seismology sensor on the rock below his house (Photo: F. Danielsen). (F) Sensor installed in Longyearbyen, Svalbard Museum. The Raspberry Shake is covered with a glass lid. Bathymetry in panels (B) and (C): ETOPO1 taken from National Oceanic and Atmospheric Administration (NOAA) (Amante and Eakins, 2009). Written informed consent was obtained from the individual in Figure 1E for publication in this report. (Figure from Jeddi et al. 2020 under CC BY 4.0 license[5]).

[5] https://creativecommons.org/licenses/by/4.0/

3.2 Expedition cruise operator-based environmental observing

In Svalbard and Greenland, expedition cruises visit remote parts that other people, including fishermen, hunters, scientists and local authorities, rarely reach. On most expedition cruises in the Arctic, some guests engage in citizen science (CS) programs, thereby contributing to environmental observations and monitoring. This is usually done *ad hoc* by especially interested expedition cruise guests and cruise guides (Wagner et al. in review). In order to increase observing in difficult to access regions of the Arctic, we decided to look further into the possibilities of enhancing the observing activities that tourist expedition cruises can engage in.

In dialogue with the Association of Arctic Expedition Cruise Operators (AECO), we contacted >70 cruise operators, met with representatives of six cruise operators, and organized a Cruise Expedition Monitoring Workshop on improving and expanding the environmental monitoring efforts of cruise ships in the Arctic. The workshop was held in Svalbard at the University Center (UNIS) on March 7-8, 2019 (proceedings available at: https://intaros.nersc.no/content/cruise-expedition- monitoring-workshop).

Figure 2. Participants in the Cruise Expedition Monitoring Workshop in Svalbard March 7-8, 2019.

The workshop offered an opportunity for cruise operators, citizen science programs, local government and scientists in the Arctic to come together to exchange experiences and perspectives and discuss the potential for cruise expedition-based environmental monitoring. The cruise operators of AECO had been briefed on the possible field testing of CS programs during 2019 and six of the operators that had shown an interest were invited to present at the workshop. At the workshop, it was agreed to test the use of different CS programs on cruise expeditions during the 2019 Arctic cruise season. Some workshop participants were worried that there would too little time to prepare for testing during 2019 and recommended not starting from scratch but rather looking at a selection of CS programs already in use in the Arctic. The CS programs needed to cover different spheres/biomes and monitoring objects/attributes so that they would appeal to cruise guests with different interests. Moreover, it should be possible to use the CS methods both on moving ships and during short breaks (< 1 hour) and in a variety of Arctic habitats. It was suggested to install tablets (iPads) for data recording on all ships. Photo-documentation was mentioned as important, e.g. for documenting the status of historical and cultural sites.

A short manual was prepared and sent to the workshop participants for comment on 26 April 2019. A revised version was circulated on 4 June 2019, and a letter requesting progress updates on 1 July 2019. The following CS programs were selected to take part in the Pilot Cruise Expedition Monitoring 2019:

1. eBird
2. Happywhale
3. Secchi Disk Study
4. Cloud Observations (GLOBE)
5. Tidal Glaciers Hot Spots for Top Predators
6. Plastic Debris on Arctic Shores (IO PAN)

We initially also planned to test a citizen science program on Cultural and Historical Site Photography. At the Cruise Expedition Monitoring Workshop, there was broad agreement on the need for collecting photos and notes of cultural and historical sites. Many of these sites seem to be rapidly undergoing changing conditions. With representatives of Hurtigruten, we therefore searched for a suitable existing CS program that we could adapt for this purpose in the Arctic but we were unable to find any. We therefore had to abandon the piloting of a citizen science program on Cultural and Historical Site Photography.

Below is a short description of each of the six CS programs, including the method, what the observations are used for, and the feedback provided to the observers.

Citizen Science Program 1: eBird

The eBird program of the Cornell Lab of Ornithology uses an online database of bird observations. eBird data document bird distribution, abundance, habitat use, and trends through checklist data. Contributors enter bird species, numbers observed, location and time via a mobile app or a website. In return for contributions, the observers are given access to a website providing ways to explore and summarize own contributions and, to some extent, the contributions of other users. The users are rewarded with lists of the birds they have recorded.

Citizen Science Program 2: Happywhale

Happywhale is a web-based CS platform for recording marine mammals led by the US-based Polar Citizen Science Collective. Contributors enter photos of marine mammals, preferably photos clearly showing the identifying traits specific to each species, via a mobile app or a website. With sighting histories of individually recognizable whales, scientists can estimate population trends. In return for photos, the contributors are sent updates when each of “her/his” individual marine mammal is spotted around the world. The users can also track the individuals on their personal Happywhale page.

Citizen Science Program 3: Secchi Disk Study

A secchi disk is a round white 30 cm diameter disk which is lowered into the water to measure the secchi depth; the depth beneath the surface when the disk just disappears from your sight. It is used for measuring how clear the seawater is as a proxy for plankton density. The Secchi Disk Study is a web-based CS platform for recording secchi disk data led by the UK-based charity The Secchi Disk Foundation. Contributors enter secchi depth records via a mobile app or a website (Seafarers et al. 2017). In return, the contributors’ records will appear on a map at the website in <48 hours. The phytoplankton in the sea account for >50% of all photosynthesis on earth and, through the food web they support, they underpin the marine food chain. Living at the surface of the sea, the phytoplankton are particularly sensitive to changes in sea surface temperature.

Citizen Science Program 4: Cloud Observations

Cloud Observations is a web-based CS platform for photos of clouds in the atmosphere led by the National Aeronautics and Space Administration (NASA). Contributors enter photos of clouds via a mobile app or a website. Cloud observations help scientists understand clouds from below (the ground) and above (from space). Clouds affect the overall temperature and energy balance of the earth and play a role in controlling the planet's long-term climate. In return, the contributors' photos will appear on the website. This is part of the GLOBE Observer Program, which also covers, e.g., Mosquito Habitats and Land Cover.

Citizen Science Program 5: Tidal Glaciers as Hot Spots for Top Predators

This program gathers photographs and notes on wildlife near tidal glaciers and collects surface water samples. The program is led by the Institute of Oceanology of the Polish Academy of Sciences (IO PAN). Large concentrations of seabirds and marine mammals are observed near glacier cliffs associated with turbid meltwater. The violent outflow of meltwater kills the marine plankton and concentrates it close to the surface, where it makes easy prey for fish, birds and mammals. Very little is known about this phenomenon. Contributors email photos and send water samples by mail to IO PAN. In return, the observations are placed on the project web page.

Citizen Science Program 6: Plastic Debris on Arctic Shores (IO PAN)

This program is gathering photos of the plastic that is washed ashore and the fauna attached to the plastic. Plastic debris acts as a vector for species dispersal. Little is known about the scale of this problem, especially in the Arctic region. Contributors email their photos to IO PAN. In return, the photos are placed on the project web page.

3.3 Focus group discussions with resource users

In collaboration with Qeqertalik and Avannaata municipalities located along the west and northwest coast of Greenland, the Greenlandic Ministry of Fisheries, Hunting and Agriculture has promoted a simple, field-based system, PISUNA, for monitoring and managing resources which is based on observations in the field made by local resource users. It has been developed specifically to enable Greenlandic fishermen and hunters to document trends in living resources, to propose management decisions themselves and to take an active role in stewardship of the living resources.

The system to promote local involvement in monitoring and management of living resources was initiated in communities in Greenland in 2010, starting in settlements in the area around Disko Bay and Uummannaq Fjord and expanding to the extreme North around Upernavik and Qaanaaq. It was implemented with a focus on monitoring a range of different important living resources and resource-impacting activities[6]. While the participatory monitoring and management system has been active for around six years in some areas, it has only been active for one to two years in others.

Formats and procedures for capturing local information and promoting participation have been tested as a way of facilitating the use of local knowledge in resource stewardship. The formats

[6] Excerpt from Danielsen et al. 2017

utilized are “easy to use” matrices that members of community monitoring groups fill out together every three months. They capture information on trends in observations and in use of resources/species. The matrices encourage self-interpretation of the observed changes in resources and, at the same time, they promote discussion and agreement on relevant resource management actions.

The communities that take part in the participatory monitoring and management activities are spread out over most of the inhabited coastal area of North West Greenland and they have been selected based on the interest expressed by people in the settlements. In each of these communities, a Natural Resource Committee (NRC) has been established, selected through village meetings and consisting of six to ten of the most experienced and interested local hunters, fishermen and other people with knowledge of the environment and resources. The monitoring focus is decided locally and, typically, eight to twelve different important living resources are selected, the use of which constitutes a key aspect of the interaction between people and the landscape.

When members of the NRC are in the field, they collect data by observing living resources and resource use. At quarterly meetings of each committee, the data are summarized, discussed and interpreted and possible management initiatives emanating from the results are considered. The proposed management decisions and the supporting data and analyses are forwarded to the municipal and national authorities. From time to time, the NRC members present their monitoring results at a community meeting to obtain input and feedback from the entire community. Fundamentally, the system is designed so that local people who know the landscape and have first-hand knowledge of the resources can use their knowledge to propose management interventions as an aspect of practical resource stewardship.

The management proposals from the NRCs relate to how, from a local perspective, living resources can be managed better so as to ensure effective and sustainable utilization and stewardship of the resources. Some of the management proposals can be acted upon locally but most need municipal or national approval. Upon receipt of the management proposals, staff of the municipality present them to the municipal Fisheries and Hunting Council, which then makes recommendations to the municipality. When the municipality approves a management proposal, it will often require the publication of a municipal ordinance. Municipal staff draft the ordinance and submit it to the Ministry of Fisheries, Hunting and Agriculture for technical scrutiny and possible ministerial signature.

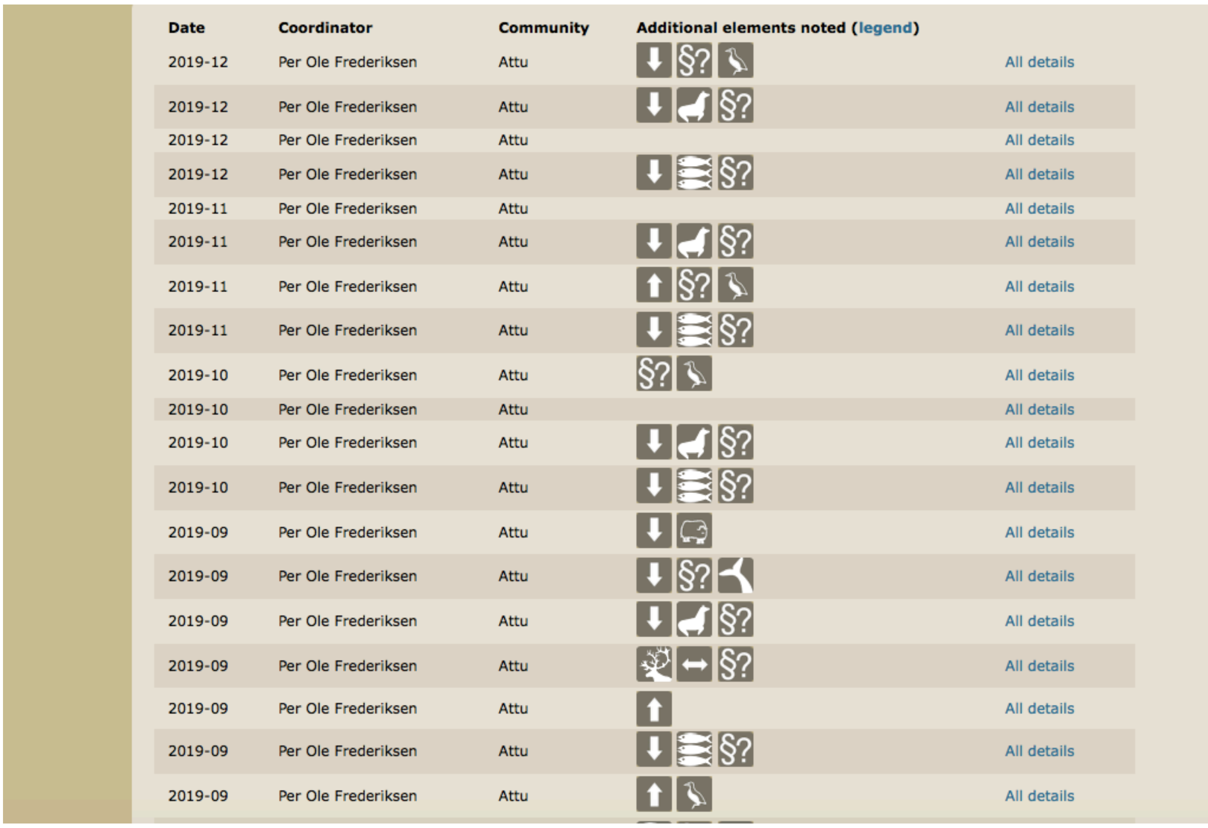
This participatory monitoring and management has been facilitated through the development of observing and reporting formats, which are used by the NRCs involved. People in the settlements are participating in the system on a voluntary basis and they do so because they have an interest in how the resources are being managed. Furthermore, they see the system as a way of getting their knowledge used in management decisions that have an impact on their livelihoods and of shaping the way in which stewardship of the resources is undertaken.

PISUNA was initially developed by the Greenland government with funding from the Nordic Council of Ministers and the EU. During the INTAROS project, we have piloted focus group discussions with fishermen and hunters in Disko Bay and assisted the PISUNA actors through supervision and capacity-enhancement as summarized in Table 1.

Table 1. INTAROS assistance provided to PISUNA for piloting focus group discussions with fishermen and hunters.

Activity	Description
Supervision of PISUNA actors	We supervised the PISUNA actors through Skype or physical meetings on a weekly basis. We assisted KNAPK (Greenland Association of Fishermen and Hunters) in the development of a scaling-up plan for PISUNA with local and central authorities. We assisted Avannaata Municipality in planning PISUNA expansion and assisted the Natural Resource Committees in Kangarsuatsiaq and Qaanaaq. We facilitated documentation of the status of management decisions emanating from PISUNA. We organized community meetings in Attu, and assisted volunteers and government staff in their preparations for international conferences. Finally, we enabled a biology student, Simone G. Hansen, University of Copenhagen, to be able to compare PISUNA findings with scientist data.
Improvement of web interfaces	With the assistance of ELOKA (Exchange of Local Observations and Knowledge for the Arctic) and UAF-IARC (University of Alaska Fairbanks, International Arctic Research Center), we updated and considerably expanded the PISUNA.org website and the searchable, web-based database of observations and management proposals, PISUNA-net. On a quarterly basis, we translated PISUNA data and supervised their incorporation into PISUNA-net. At PISUNA.org, the observations and recommendations from the PISUNA Natural Resource Committees are available in the original, unedited format as they were reported from the PISUNA Natural Resource Committees. The completed forms are available in English in the PISUNA-net database.
UArctic course for public natural resource managers	With the Greenland Climate Research Center and other partners, we developed and convened a course in collaborative resource management and monitoring in the Arctic, to our knowledge the first of its kind. We trained 25 government resource managers from all 5 municipalities of Greenland, three ministries, civil society associations and a research institute. The course curriculum is freely available at the UArctic home page (https://www.uarctic.org/media/1600608/curriculum-overview-pdf.pdf).

Figure 3. Natural Resource Committee meeting in the village of Attu.



Date	Coordinator	Community	Additional elements noted (legend)	
2019-12	Per Ole Frederiksen	Attu		All details
2019-12	Per Ole Frederiksen	Attu		All details
2019-12	Per Ole Frederiksen	Attu		All details
2019-12	Per Ole Frederiksen	Attu		All details
2019-11	Per Ole Frederiksen	Attu		All details
2019-11	Per Ole Frederiksen	Attu		All details
2019-11	Per Ole Frederiksen	Attu		All details
2019-11	Per Ole Frederiksen	Attu		All details
2019-10	Per Ole Frederiksen	Attu		All details
2019-10	Per Ole Frederiksen	Attu		All details
2019-10	Per Ole Frederiksen	Attu		All details
2019-10	Per Ole Frederiksen	Attu		All details
2019-09	Per Ole Frederiksen	Attu		All details
2019-09	Per Ole Frederiksen	Attu		All details
2019-09	Per Ole Frederiksen	Attu		All details
2019-09	Per Ole Frederiksen	Attu		All details
2019-09	Per Ole Frederiksen	Attu		All details
2019-09	Per Ole Frederiksen	Attu		All details
2019-09	Per Ole Frederiksen	Attu		All details

Figure 4. Screenshot of PISUNA-net 2019 data (Link: https://eloka-arctic.org/pisuna-net/).

.

3.4 Qualitative interviews and workshop dialogues

In Svalbard, we have considered it a high priority to help link top-down and bottom-up initiatives in research and monitoring by enabling a process of co-creation of community-based and citizen science observing activities. We have initiated a dialogue and collaboration with local actors addressing both ethical, democratic and cultural dimensions for building trust and long-term collaboration. We have sought to ensure coordination of efforts and resources and to strengthen capacity building. We have held dialogue meetings, undertaken interviews and co-organized presentations and workshops. We have discussed local needs, opportunities, planning and decision-making. Analytically, our focus has been on co-creation and placemaking, where we have tried to strengthen the three broadly known dimensions of sustainable development with a fourth dimension: democracy and participation, as shown conceptually in Figure 5.

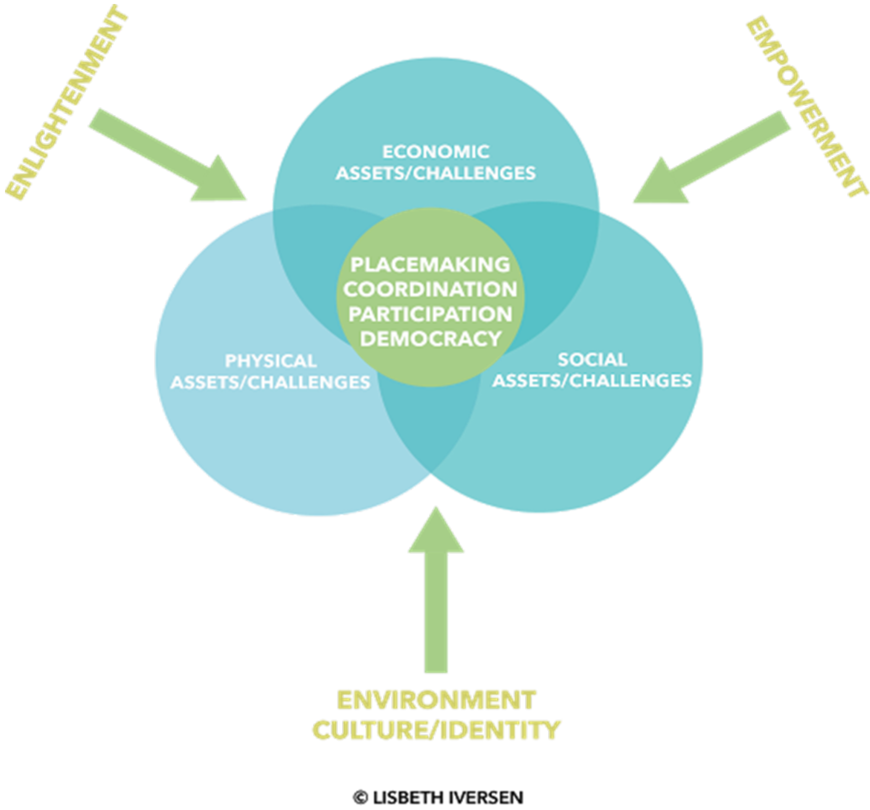


Figure 5. Conceptual overview of how, in Svalbard, through dialogue with many actors on environmental observing, we have tried to strengthen the three broadly known dimensions of sustainable development with a fourth dimension: democracy and participation.

As part of a research school connected to the Useful Arctic Knowledge project and INTAROS, we arranged a workshop in Dec. 2018 with the NUNATARYUK project and UNIS. The aim of the workshop was to initiate a dialogue on knowledge, challenges and possibilities related to climate, nature and the environment in Svalbard. A central question asked was how research on climate and the environment can be of use to the local community in Longyearbyen. Different local actors were invited to give short statements about what they see as the most important challenges and possibilities related to climate, nature and the environment within their sector, as well as what knowledge is needed, and this formed the basis for the workshop discussions. Proceedings from the workshop are available on the web (Link: http://www.intaros.eu/media/1549/report-from-workshop-v5-1-final.pdf).

We also organized a workshop and dialogue meeting with local community members in Svalbard at UNIS on March 7-8, 2019. The aim of this event was, through dialogue between key actors, to discuss opportunities for a better use of 'citizen science' and community-based monitoring for sustainable development in Svalbard, and to make socially relevant information available in order to contribute to the best possible development of the community, business and tourism in Svalbard.

3.5 Linking climate change data-collecting and research with the local needs

In Svalbard, we have contributed to developing a network of social scientists and a digital platform for exchange of experiences, coordination and communication and to promoting demand-driven social science research in Longyearbyen. With other researchers studying the human dimensions of the dynamic changes underway in Svalbard, we co-created the Svalbard Social Science Initiative, SSSI. The aim of the network is to create linkages among social scientists working with issues related to Svalbard, establish a platform for coordinating research activities and facilitate communication with local communities and other scientists. The platform provides a venue for sharing research and publications as well as creating opportunities to coordinate with each other and local residents. We co-established a digital platform for the network and, as of May 2020, it had 10 active members and 7 associate members (link: https://www.svalbardsocialscience.com/).

4. What was the outcome and why

In Chapter 3, we described how we undertook each of the community-based and citizen science observing activities and why. This chapter presents the results of the piloting of these activities in Disko Bay, Greenland, and Svalbard.

4.1 Garage-type geophone device[7]

The Greenland geophone case

Since the first data became available on the Raspberry Shake server, the data has been analyzed together with data from the permanent seismological stations in Greenland. The quality of data was first assessed by computing hourly Power Spectral Density for the entire deployment period using Seisan software (Ottemöller et al. 2018). The Power Spectral Density of seismic recording is defined as the power of the signal distributed over a range of frequencies and it is the primary method by which all seismometers are specified in terms of noise. The data were plotted as Probability Density Functions for the vertical component of the deployments in Greenland (Figure 6, A-D). The poor performance of the Raspberry Shake for long period signals (>10s) is to be expected due to the bandwidth limitations of those sensors. At higher frequencies, the instrument's self-noise results in levels lower than the New High Noise Model of Peterson (1993) and the noise distribution is very similar at the three locations. AKUG's self-noise is always below the high noise model at high frequencies, whereas ASIG shows windows with noise above the high noise model. ATTUG has a small band around 10 Hz with slightly higher noise level.

The two CS sensors showed very useful information and their signal-to-noise ratio was comparable to permanent sensors in the frequency range above 4.5 Hz. For some events, the CS sensors were closer to the epicenter than any of the permanent stations (Figure 7A) and for some events a location of the event would not have been possible without the CS sensors.

During the period from 20 April 2018 to 23 September 2019, 280 events were observed on the recordings of the CS sensors. Thirteen of those events were observed on only 1 or 2 seismic sensors and 48 were observed on fewer than 4 seismic sensors. The CS sensors thereby contributed to an acceptable location of 232 events. By relocating the 280 events without the observations from the CS sensor, we find that 71 events were observed by fewer than four seismic stations. The CS sensors enabled the location, by four or more stations, of 23 events and improved the location of 209 events.

The Disko Bay area is subject to high glacial activity from the nearby outlet glaciers. During calving (breaking of ice from the glacier edge) or other movement of the cryosphere, seismic signals detectable at long distances may be generated (Podolskiy and Walter 2016). Of the 280 events observed on the CS sensors, 53 have been classified as of cryospheric origin, mainly from glacial activity during calving or from other displacements of glaciers or sea-ice. The classification is done manually during analyses based on frequency content of seismic events, epicenter location and analyst experience. The remaining events have been presumed to be of tectonic origin. Figure 7A shows a map of the two types of events located using CS sensors and

[7] Jeddi et al. 2020

an example of such events (Figure 7B-C). In the first example (Figure 7B), a seismic recording classified as a tectonic event is shown where the two CS units are nearest to the epicenter. In this case, having highest signal-to-noise ratio on the P-phase, the two CS sensors improves the event location. Figure 7C shows an example of a cryo-generated event.

The Svalbard geophone case

The quality of data was assessed similarly for the Longyearbyen installations (Figure 8A-B) through self-noise analyses. However, in this case, the high frequencies also suffer from very high levels of noise, exceeding the New High Noise Model of Peterson (1993) in LYB2 (Radisson Blu Polar Hotel). The Svalbard Museum installation (LYB1) is slightly better and this is probably because of the lid used to cover the instrument, in addition to the building itself. The high noise levels confirm that the buildings in Longyearbyen, which are built on poles in the permafrost, are inappropriate for seismic monitoring. A similar quality assessment was performed for one of the nearby permanent stations (KBS) for comparison (Figure 8C).

Initially, it was planned to have a live view of the recordings in the museum and in the hotel to share the data with the public (mainly students and tourists). However, the high noise levels meant that few events were visible in the collected data, and it was decided to abandon the idea of public displays. Figure 8D-I shows two examples of local events with a local magnitude of 4.5 and 3.6, respectively, which are recorded on the CS sensors as well as at the closest permanent station (KBS).

Discussion of the piloting of geophones

Monitoring of seismic activity in western Greenland has been ongoing for more than 100 years (Gregersen 1982) not due to local earthquakes but because of Greenland's unique location for observing earthquakes on a global scale due to the low level of man-made noise. However, this is to our knowledge the first time in Greenland that geophones have been established in communities and setup by local residents. In recent years, earthquake monitoring has shown its value both for the understanding of the geological structures (e.g., Darbyshire et al. 2017) and for the detection of new events such as felt earthquakes, landslides (e.g. Clinton et al. 2017) and cryo-seismic phenomena (e.g., Clinton et al. 2014). The cryo-generated events (e.g., Nettles and Ekstrom 2010) have raised awareness globally due to their possible connection to climate change. The location of felt earthquakes and especially the 2017 landslide north of Disko Bay (Clinton et al. 2017) have increased the focus on the importance of local seismic monitoring in western Greenland.

The CS sensors provided valuable improvements in the location of seismic events in western Greenland and, in some cases, unique recordings on first motion of seismic waves, which are important for understanding the causal mechanisms behind events. Furthermore, the CS sensors gave important information on the seismic noise level at the three sites (Figure 7). Such measurements are necessary before any temporary/permanent deployment of seismic sensors; however, it would have been very expensive to cover the travel costs of performing the noise test using temporary deployments of scientific sensors. Hence, future deployment of broadband seismic sensors may be selected on the basis of these noise analyses.

Our test of seismological CS in western Greenland encountered only a few challenges: One seismic sensor was moved to a new settlement because the host cancelled their Internet subscription. We asked the Raspberry Shake community to change the location of the unit on the website but that was unfortunately not currently possible. The units stopped transmitting data from time to time, which required manual power cycling. The Internet usage by the seismic sensors was not easy to estimate. In Greenland, Internet is often paid by usage, since flat rate systems have only recently been introduced. The data rate is therefore important for the host of a CS system, since it will affect the cost of Internet.

On the other hand, we have the Longyearbyen case which faced extraordinary challenges in producing useful seismic data. The town of Longyearbyen developed due to the coal excavation in the surrounding mountains, and it was built by the mining industry over the past century up to 1990. The town has now evolved into a varied business community with tourism, research and education being its main industries (Misund 2017). Due to the fragile Arctic surroundings, strict zoning and planning regulations have been implemented in Longyearbyen, and very limited space is available for construction. UNIS is one of the main institutions in Longyearbyen. A large proportion of the Longyearbyen population is affiliated to UNIS, either as employees or students, and a wide range of Arctic research is conducted. These points make Longyearbyen a special place where many people are already engaged in research in some way, and may therefore be more reluctant to participate in citizen seismological studies. In addition, indoor space is limited and expensive, and therefore finding a quiet 0.5m by 0.5m corner is challenging.

Based on the experience of deploying four CS sensors in Longyearbyen and in western Greenland, it has become clear that local factors are driving the level of success in such deployments. With the limited availability of appropriate locations (i.e. buildings not on poles) in Longyearbyen, combined with the high cost of indoor space, finding suitable locations for the instruments proved impossible. This was probably strengthened by the strong presence of research environments in Longyearbyen, making people less likely to engage in “yet another research project”. In Greenland, in contrast, stable locations providing high signal-to-noise ratios were obtained at each site. The CS conducted in western Greenland therefore provided high-quality data for the observation of seismic events in the region.

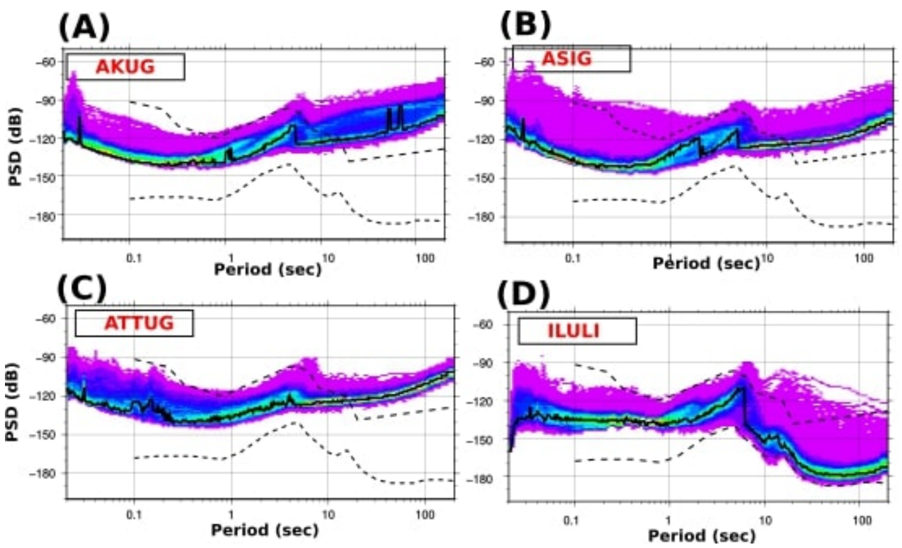


Figure 6. (A-D) Hourly probability density functions of the vertical component for AKUG, ASIG, ATTUG and ILULI installations, respectively. The dotted black lines show the global New High and Low Noise Models for seismic monitoring stations of Peterson (1993), respectively. The solid black curve is the mode value of the spectrograms.

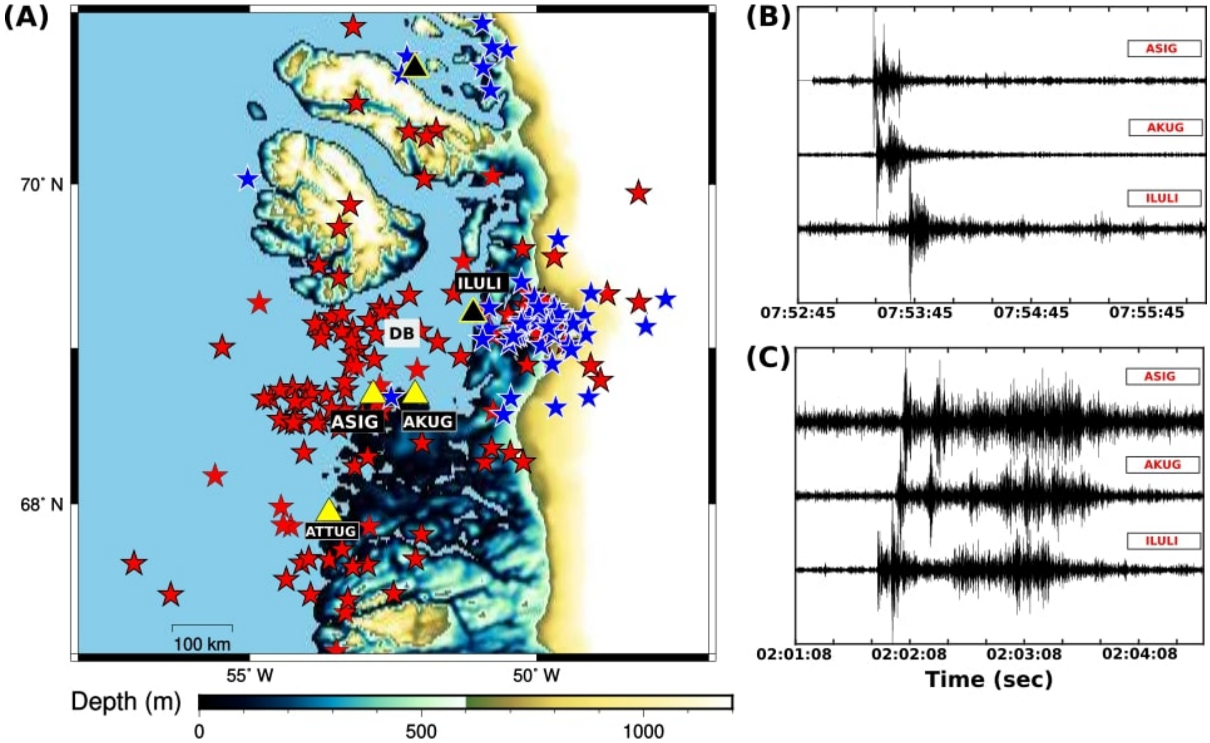


Figure 7. (A) Map of west Greenland. Blue stars indicate events thought to be generated by glacial activity and red ones are classified as tectonic events. The CS sensors are the yellow triangles and permanent stations are black triangles. Three CS sensors and the closest permanent station to those deployments are marked with a label. 'DB' refers to 'Disko Bay'. Bathymetry: ETOPO1 taken from National Oceanic and Atmospheric Administration (NOAA) (Amante and Eakins, 2009). (B) Example of tectonic-originated seismic recording on 4 May 2018, 5-10 Hz bandpass. Location of the event is shown on Figure 1B as 'Ex.1' (latitude: 68.93N, longitude: 52.84W). (C) Example of cryo-originated seismic recording on 21 May 2018, 5-10 Hz bandpass. Location of the event is shown on Figure 1B as 'Ex. 2' (latitude: 69.15N, longitude: 50.00W).

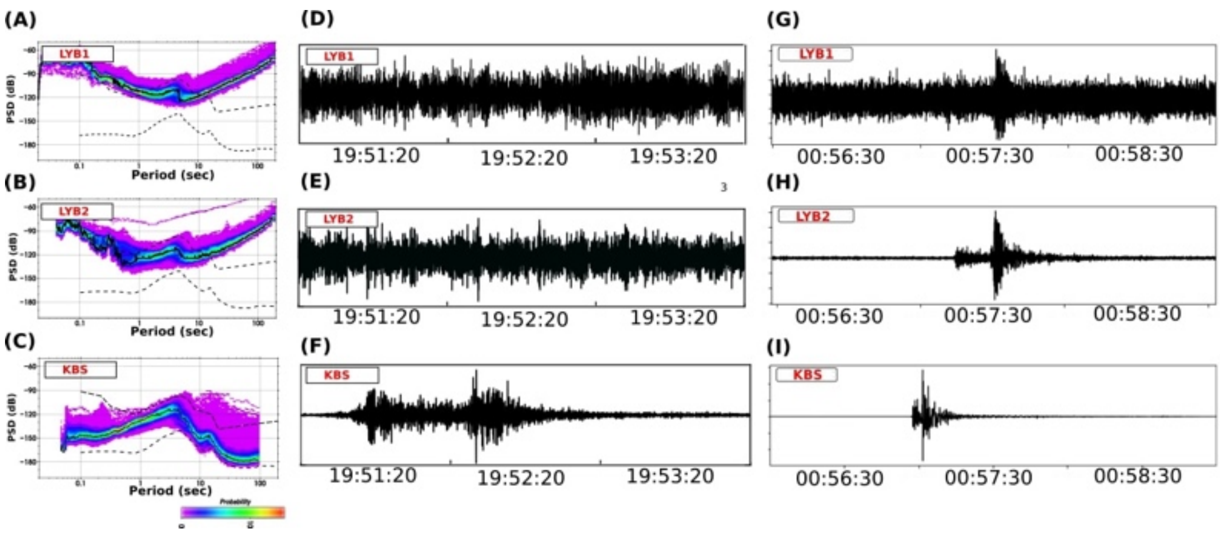


Figure 8. (A-C) Hourly probability density functions of the vertical component for LYB1, LYB2 and KBS, respectively. The dotted black lines show the global New High and Low Noise Models for seismic monitoring stations of Peterson (1993). The solid black curve is the mode value of the spectrograms. (D-F) Example of seismic waveform on 28 October 2019, 3-15 Hz bandpass. The event is not observed on either CS sensor. Location of the event is marked as 'Ex. 1' in Figure 1C (latitude: 77.23N, longitude: 17.96E). (G-I) Example of seismic waveform on 18 October 2019, 3-15 Hz bandpass. Only one of the CS sensors recorded the event clearly. Location of the event is marked as 'Ex. 2' in Figure 1C (latitude: 78.83N, longitude: 10.69E).

4.2 Expedition cruise operator-based environmental observing

We tested the use of six CS programs with expedition cruise operators for one cruise season. Below we describe the results based on data obtained from the individual CS programs. Because of the Covid-19 crisis the expedition cruise operators were unable to contribute to this report. For each CS program, we describe the data obtained by the CS program from Svalbard and Greenland during 2019, and we provide examples of the findings.

Citizen Science Program 1: eBird

We extracted information from the eBird online database (April-May 2020). The information was kindly reviewed by Dr Ian Davies of eBird. The findings are described below.

In 2019, a total of 705 checklists of birds were submitted from Svalbard and 265 from Greenland. The checklists comprise observations of bird species, numbers observed, location and time. The checklists covered bird observations between 6 March and 14 September 2019 in Svalbard and between 9 February and 12 October 2019 in Greenland. In Svalbard, the observations were mainly from the sea and coastal areas of the western part of Spitsbergen, with fewer from Nordaustlandet. In Greenland, most observations were along the west coast from Disko Bay and southward.

Which species were recorded? The checklists submitted to eBird for 2019 comprised 62 bird species in Svalbard and 57 species in Greenland. During 2019, a total of 755 photos of bird species were attached to 157 checklists (22%; *n* = 705 checklists) from Svalbard, and 141 photos were attached to 47 checklists (18%; *n* = 265 checklists) from Greenland. The records of four globally red-listed species were supported by photographic documentation (Svalbard: Long-tailed Duck, Steller's Eider, Atlantic Puffin; Svalbard and Greenland; Black-legged Kittiwake; *sensu* World Conservation Union 2020; latin names in Annex 1).

Who made the observations? During 2019, checklists were submitted by 76 individuals for Svalbard and 15 for Greenland, with no overlap between the two areas. In Svalbard, we were able to explore the background of those who reported sightings to eBird during 2019. The figures are minimum numbers. The 69 contributors with information indicating home country came from >15 countries, mostly from the US (34 persons; *n* = 69 persons). Most of the contributors were men (men 51; women 25, *n* = 76 persons). A minimum of 17 of the contributors had a university degree and 10 were cruise expedition guides.

Since the first eBird record from Svalbard in 2002, eBird has received 2,802 checklists of birds from Svalbard comprising information about 89 bird species (May 2020). As examples, we show the geographic distribution of records of Pink-footed goose *Anser brachyrhynchus* and Atlantic puffin *Fratercula arctica* in Svalbard (Figure 9AB). The total number of eBird checklists from Greenland since 2005 is 1,100, representing information on 76 bird species. In Figure 10, we show the geographic distribution of records of White-tailed eagle *Haliaeetus albicilla* in Greenland (Figure 10). Overall, the eBird database comprises checklists of 89 species in Svalbard and 76 species in Greenland. In Svalbard, the three most frequently observed species are Black-legged Kittiwake, Northern Fulmar and Glaucous Gull, whereas in Greenland they are Northern Fulmar, Glaucous Gull and Raven, Figures 11 and 12. In Annex 1, we provide a systematic list of bird species and the number of checklists they appear on in the eBird database. Six of the species from Svalbard and 4 from Greenland in the eBird database are considered globally red-listed by IUCN, belonging to the "Vulnerable" category (World Conservation Union 2020). All 18 bird species categorized as Red-Listed for Svalbard (Henriksen and Hilmo 2015) have records from Svalbard in eBird's database. Likewise, 52 of the 53 bird species categorized as nationally red-listed in Greenland (Boertmann 2007) have records from Greenland in eBird's database; the exception is Barrow's Goldeneye *Bucephala islandica*.

Who can use eBird's web-based database? Everyone who contribute a checklist can explore and summarize their own contributions (using "My eBird") and, to some extent, other users'(using "Explore") at the website of eBird. All data are free to use on request for any non-commercial purposes related to basic and applied research and education. Below is an example of the information that can be obtained from the website. This example is Pink-footed goose *Anser brachyrhynchus* in Svalbard. First, we use the "explore-function" and type the species name and thereafter change the default region "World" to "Svalbard". Now we can see that eBird holds 583 Svalbard records of Pink-footed Goose and that 49 of these are documented by photographs. Phenology is shown using a weekly bar chart, see example of a screenshot in Figure 13. We cannot ask which of the 583 records are from 2019. We can use search filters for the photos. There are filters for location, date, sex, age, behavior, breeding, etc. We are not allowed access to the same type of search filters for all 583 records.

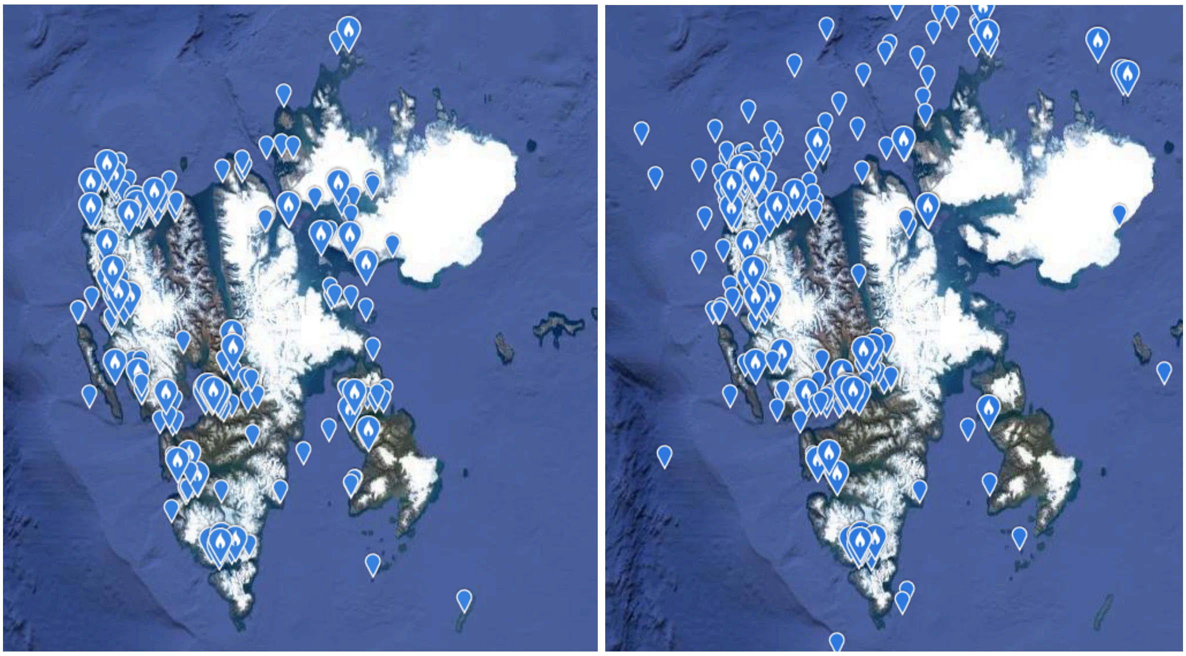


Figure 9. Records of (A) Pink-footed goose *Anser brachyrhynchus* (left: *n* = 583 records) and (B) Atlantic puffin *Fratercula arctica* (right; *n* = 622 records) from Svalbard 2002-2019 in the eBird database. Records highlighted with a white flame are from eBird hotspots, areas with "many" checklists.

Figure 10. Records of White-tailed eagle *Haliaeetus albicilla* from Greenland 2005-2019 in the eBird database (*n* = 68 records). Records highlighted with a white flame are from eBird hotspots, areas with "many" checklists.

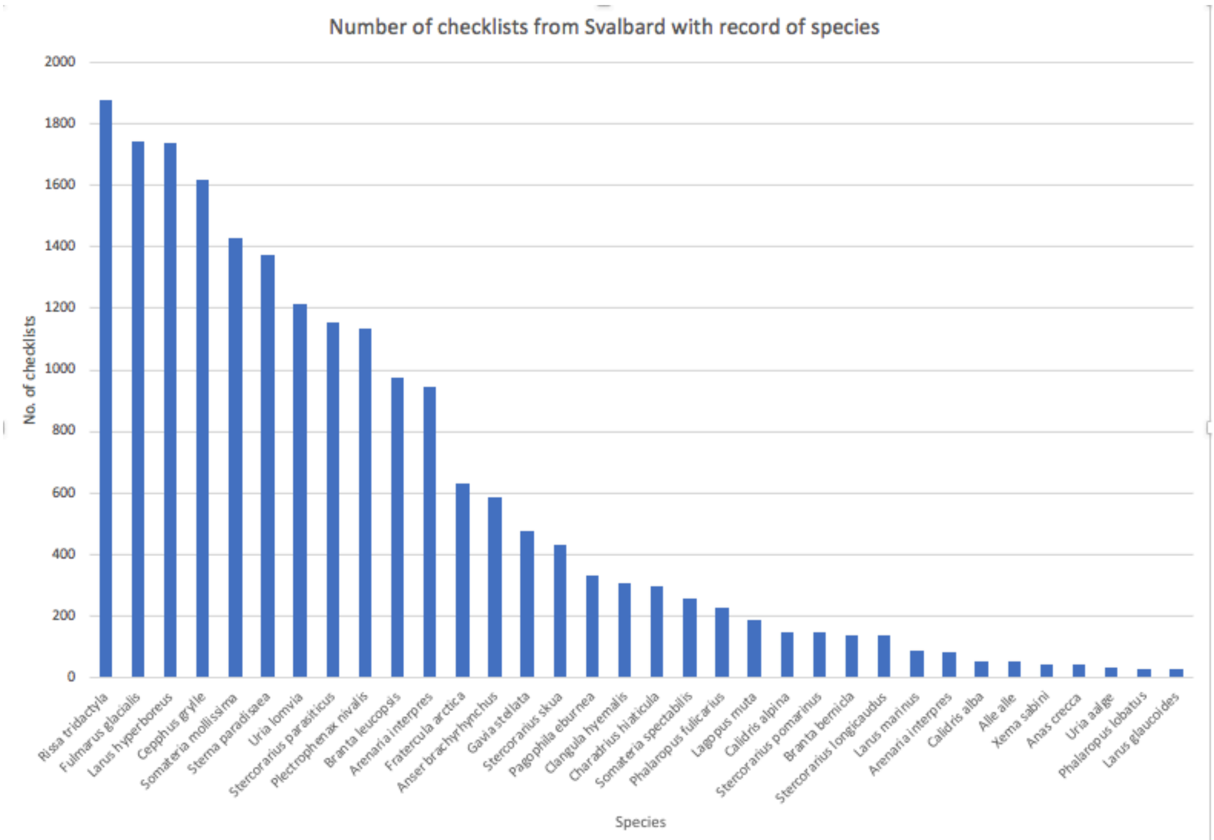


Figure 11. The number of checklists per bird species in Svalbard for the most frequently recorded species 2002-2019 (Source: eBird database; extracted May 2020).

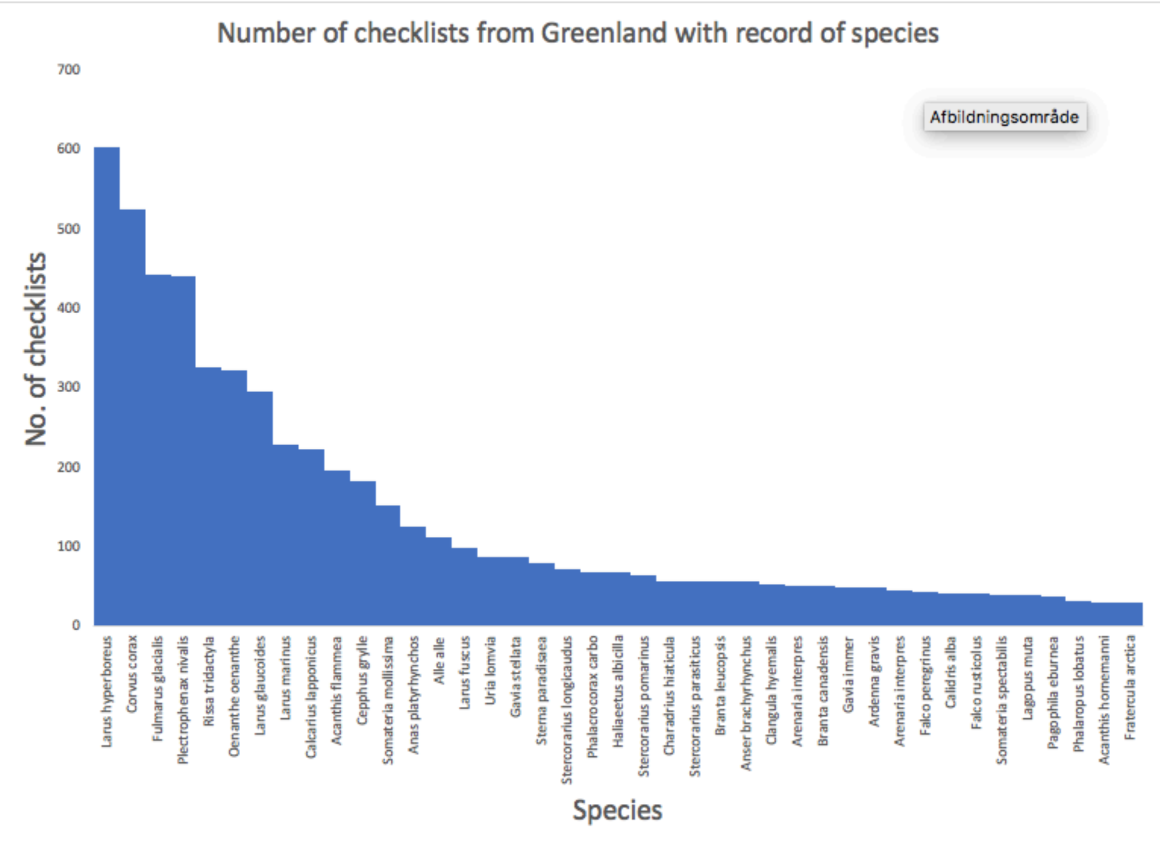


Figure 12. The number of checklists per bird species in Greenland for the most frequently recorded species 2005-2019 (Source: eBird database; extracted May 2020).

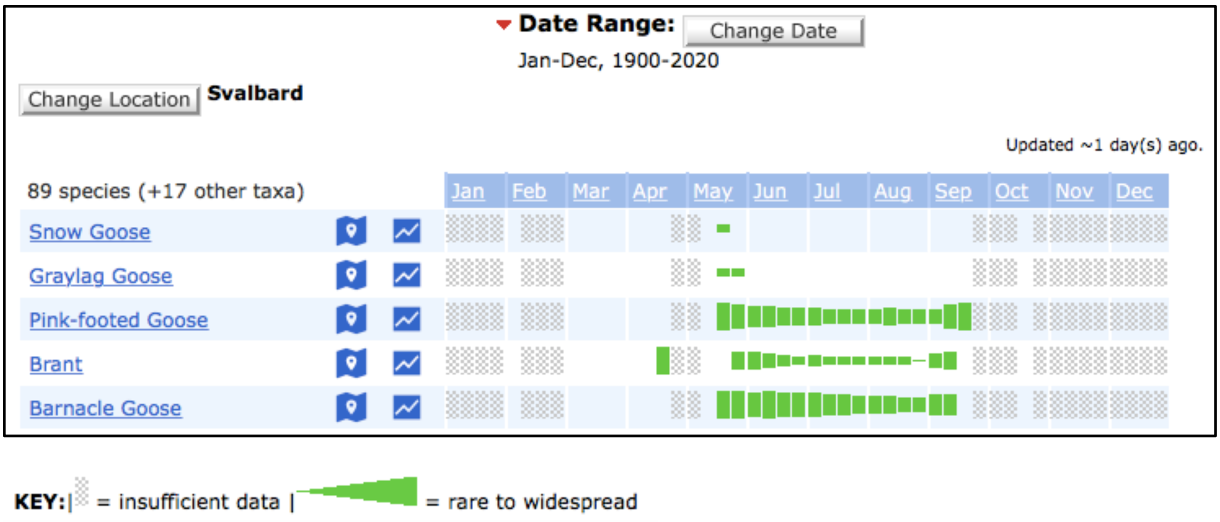


Figure 13. Screenshot from the eBird website showing the weekly abundance of five goose species in Svalbard 2005-2019 (Source: eBird database; extracted May 2020).

Citizen Science Program 2: Happywhale

We obtained information from the Happywhale online database (April-May 2020). The information was kindly reviewed by Dr Ted Cheeseman of Happywhale and the Polar Citizen Science Collective. The findings are described below.

We extracted information by going to happywhale.com and selecting “Browse”, selecting “Date” = “Custom”, “Between” and enter in “1/1/2019” and “12/31/2019”. Then we typed “Svalbard” under “Location” or used “Current Map Bounds” to indicate the area of interest. Finally, we selected “Search”. The result is a map showing Svalbard with indications of 85 encounters of 14 species of marine mammals. An encounter with a marine mammal comprises one or more photos of the animal, and data on the location and time of the observation. Examples of photos are shown in Figures 14 and 15. Of the 85 encounters in Svalbard, 81 are of 13 species close to Svalbard while 4 are closer to Bear Island and Greenland.

Figure 14. Bowhead Whale sighted by “Barnaby” on 24 June 2019 northwest of Spitsbergen, Svalbard, when sailing with Lindblad/National on board Geographic Expeditions. Photo from David Hone. Date confirmed from vessel track.

Figure 15. Sperm Whale sighted by "MTurcot" on 1 August 2019 near Tasiilaq (Ammassalik), East Greenland.

Worldwide, 16,806 encounters including photos of marine mammals were submitted to Happywhale in 2019. A total of 81 encounters were from Svalbard and 60 were from Greenland. The encounters encompassed marine mammal observations made between 27 May and 3 September 2019 in Svalbard and between 22 May and 13 September 2019 in Greenland. In Svalbard, the observations were mainly from coastal areas of the western part of Spitsbergen and only a few were from Edgeøya and Nordaustlandet (Figure 16). In Greenland, 41 of 60 of the observations were from Disko Bay, Figure 17.

Which species were recorded? The 2019 encounters comprised 13 species in Svalbard and 7 species in Greenland (Table 2). The three most frequently observed species were in Svalbard: Humpback Whale (22 encounters), Blue Whale (16) and Polar Bear (9); Greenland: Humpback Whale (51 encounters), Northern Bottlenose Whale (3) and Polar Bear (2). Seven of the species are globally red-listed by IUCN (World Conservation Union 2020) and one is data deficient (Table 2). Six species recorded in Svalbard are red-listed in Svalbard or Norway and one is data deficient. One species recorded in Greenland is red-listed in Greenland and 3 are data deficient. The encounters included 27 individually recognizable marine mammals, 11 in Svalbard and 16 in Greenland. The individually recognizable animals were all Humpback whales identified using photos of unique identifiable markings on the flukes (tail).

Who made the observations? Information on encounters of marine mammals was submitted by 70 people during 2019 (Svalbard 40 people; Greenland 34 people; with a 4-person overlap between the two areas and two people reporting from two different vessels in Svalbard). The information was submitted by guides and guests on board at least 14 different vessels in Svalbard and 14 in Greenland. We have only been able to explore the background to a few of those reporting to Happywhale in 2019. The contributors came from >19 countries, mostly from the USA (40 persons; n = 95 persons with known home country). Most of the contributors were men (men 34; women 26, no data on gender 10; n = 70 persons). A minimum of 8 of the contributors had a university degree in the natural sciences and 7 were cruise expedition guides.

Overall, since the first record submitted to Happywhale from Svalbard in 2007, Happywhale received 259 encounters including photos of marine mammals from Svalbard 2007-2019 comprising information on 14 marine mammal species and 43 individually recognizable marine mammals. The total number of Happywhale encounters from Greenland 2007-2019 is 261 encounters, representing information on 9 marine mammal species and 103 individually recognizable marine mammals.

Who can use Happywhale's web-based database? All users can explore and summarize their own contributions and, to some extent, those of other users. Below are examples of the information that can be obtained from the Happywhale website for Blue whale *Balaenoptera musculus* in Svalbard 2007-2019, Figure 18. We also provide examples of the distribution of Happywhale records of Humpbacked Whales *Megaptera novaeangliae* in Disko Bay in 2019 (Figure 19), and marine mammal sightings during one voyage from Svalbard to the neighboring islands Franz Josef Land in 2019 (Annex 2).

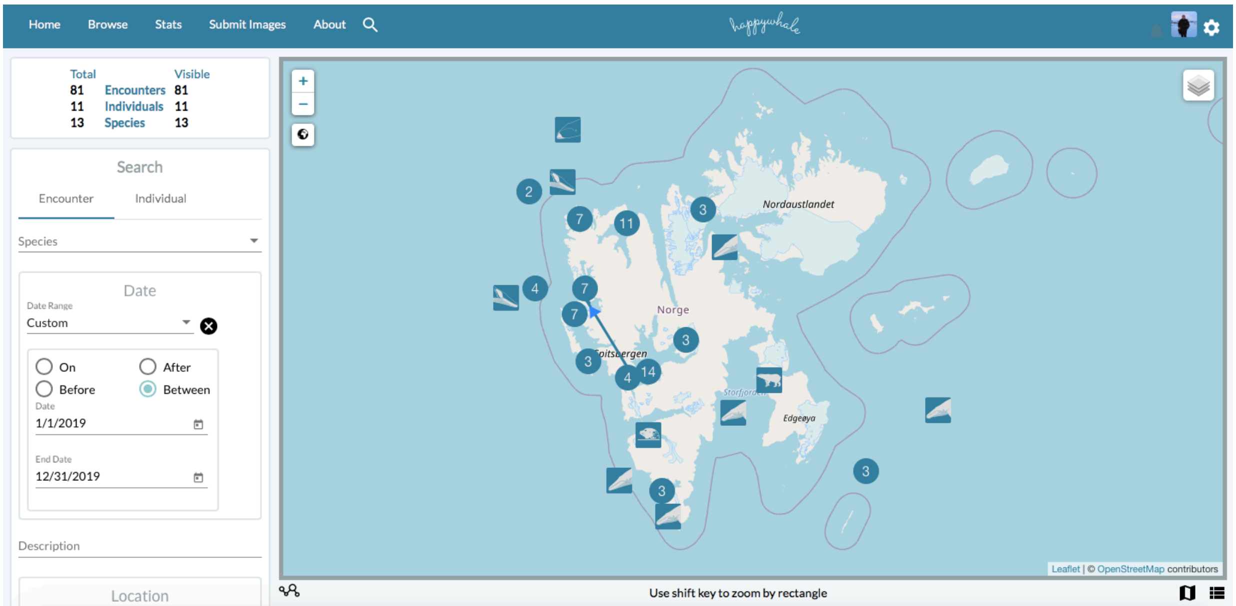


Figure 16. Happywhale records of marine mammals from Svalbard in 2019 (81 encounters of 13 species). The digits indicate numbers of encounters too close together to be shown on the map. They will show up when zooming in on the map. The arrow indicates two locations where the same individual has been encountered.

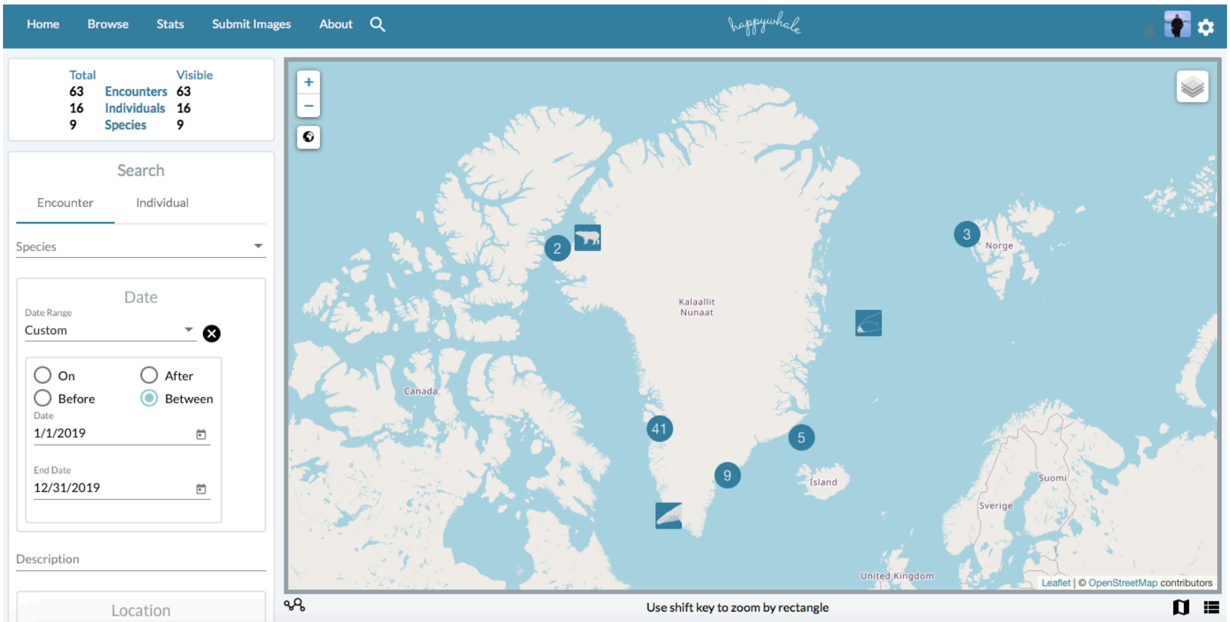


Figure 17. Happywhale records of marine mammals from Greenland in 2019 (60 encounters of 7 species are actually from Greenland while 3 Svalbard records has been mislabeled as Greenland). The digits indicate numbers of encounters too close together to be shown on the map. They will show up when zooming in on the map.

Table 2. Systematic list of marine mammals, the number of encounters in Svalbard and Greenland in 2019 verified by photos in the Happywhale database, and the conservation status of each species (extracted April-May 2020).

English name	Scientific name	Svalbard	Greenland	IUCN category	Svalbard Red List	Greenland Red List
Polar Bear	*Ursus maritimus*	9	2	VU	VU	VU
Walrus	*Odobenus rosmarus*	4	0	VU	VU	NT
Hooded Seal	*Cystophora cristata*	0	1	VU	EN	LC
Bearded Seal	*Erignathus barbatus*	6	0	LC	LC	DD
Harbor Seal	*Phoca vitulina*	3	0	LC	VU	CR
Ringed Seal	*Pusa hispida*	2	0	LC	VU	LC
Bowhead Whale	*Balaena mysticetus*	3	1	LC	CR	NT
Fin Whale	*Balaenoptera physalus*	7	1	VU	LC	LC
Sei Whale	*Balaenoptera borealis*	1	0	EN	NA	DD
Blue Whale	*Balaenoptera musculus*	16	0	EN	VU	DD
Minke Whale	*Balaenoptera acutorostrata*	4	0	LC	LC	LC
Humpback Whale	*Megaptera novaeangliae*	22	51	LC	LC	LC
White-beaked Dolphin	*Lagenorhynchus albirostris*	1	0	LC	LC	NA
Beluga	*Delphinapterus leucas*	3	0	LC	DD	CR
Sperm Whale	*Physeter macrocephalus*	0	1	VU	NA	NA
Northern Bottlenose Whale	*Hyperoodon ampullatus*	0	3	DD	LC	NA

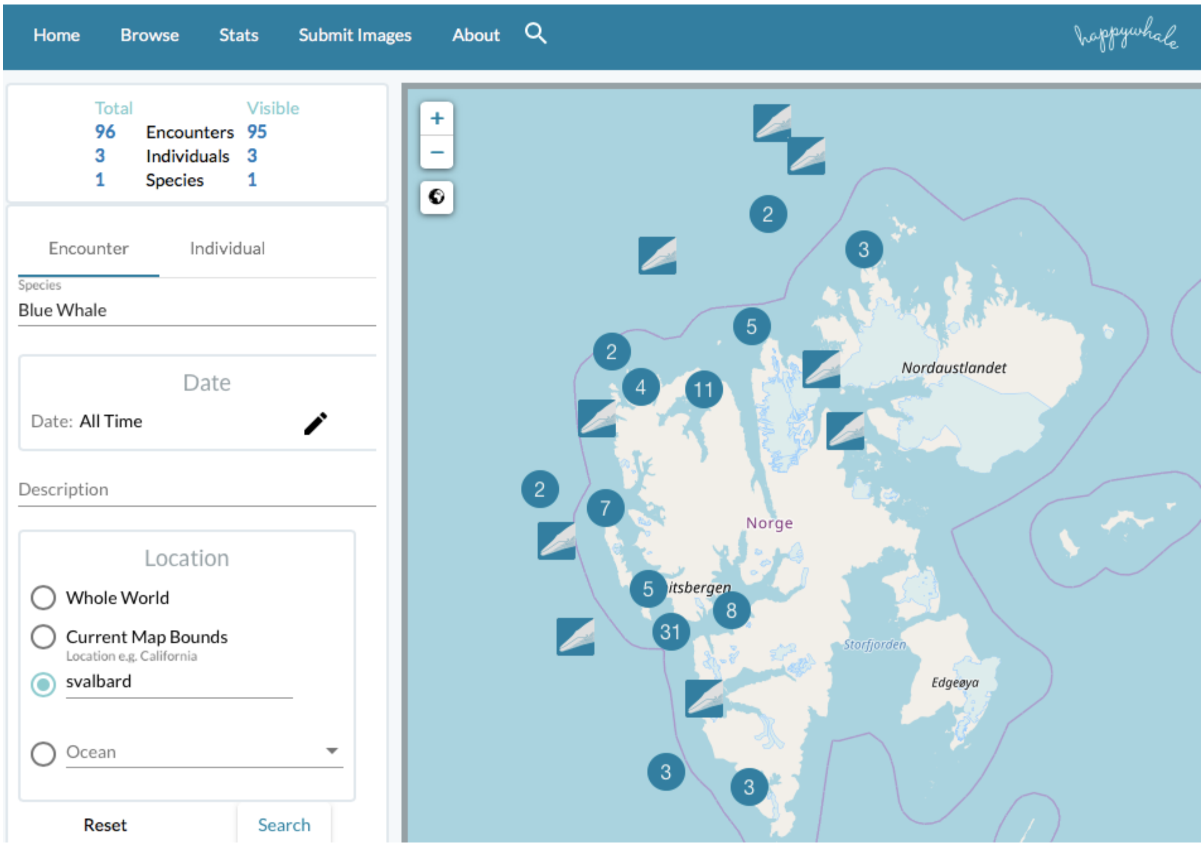


Figure 18. Records of Blue whale *Balaenoptera musculus* from Svalbard during 2014-2019 by Happywhale, verified by photos available at the Happywhale website (n = 95 encounters). The digits refer to number of encounters and these will show up when zooming in.

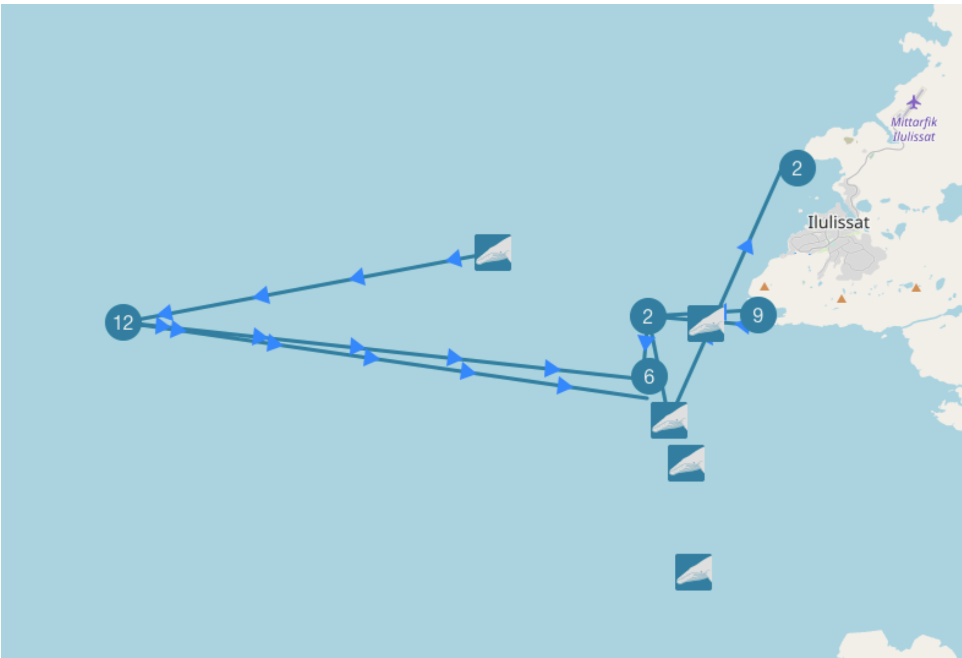


Figure 19. Some of the Humpbacked Whales *Megaptera novaeangliae* in Disko Bay, Greenland, in 2019 were repeatedly photographed at locations close to the town of Ilulissat. The digits refer to number of encounters and these will show up when zooming in.

Citizen Science Program 3: Secchi Disk Study

We have only been able to extract limited information from the Secchi Disk online database (May 2020) at the website https://www.playingwithdata.com/secchi-disk-project/. Apparently only one (unnamed) vessel contributed data from Greenland during 2019 and none from Svalbard.

The map showing entries and Secchi depths worldwide suggests that the seas around Svalbard and Greenland are very sparsely covered, see Figure 20. Overall, since 2013, the Secchi Disk Study has received 3 measurements of Secchi depths from Svalbard and 8 from Greenland. The records have been submitted by 4 vessels.

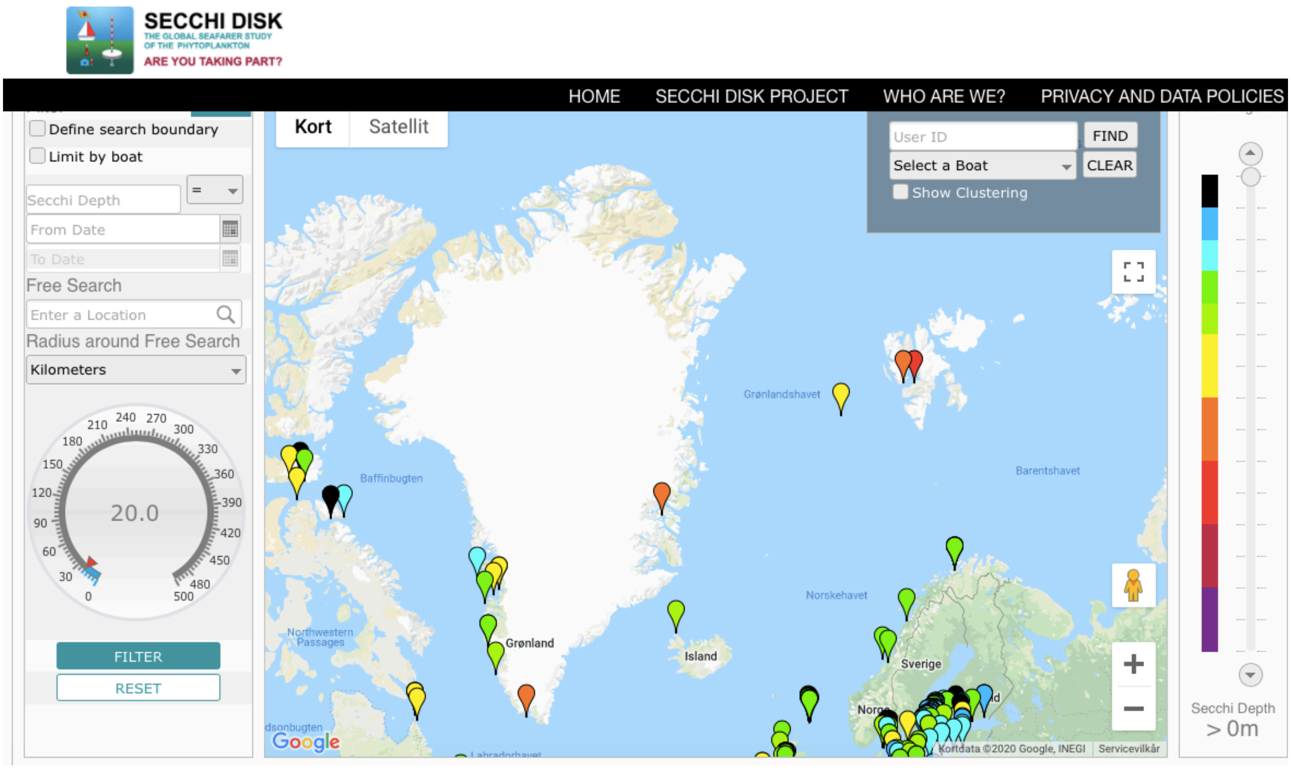


Figure 20. Location for entries of Secchi depths. Each marker represents a vessel (or reading). Some markers may not have a vessel name associated with them if the owner did not provide that information. Clicking on a marker will show you the information for that marker, any associated media, and a graphical representation of the data as a bar chart for either the boat associated with the marker, or all the markers within the boundary (on a boundary search), or all the markers returned by the filter. Screenshot from the Secchi Disk online database (extracted May 2020).

Citizen Science Program 4: Cloud Observations

We extracted information from the Cloud Observations online database (April 2020). The findings are described below.

Eleven records of cloud cover with photos were submitted from 2019, five from Svalbard and four from Greenland. From the database we cannot locate the precise dates or coordinates. We can however see that the Svalbard records were observed from three vessels, one American, one Canadian and one Swedish, whereas the records from Greenland were from one American, one Canadian and one Norwegian vessel.

Who can use Cloud Observations online database? The cloud cover records are accessible to everyone at the online database as follows, taking as an example the Svalbard records: (1) Protocol Layers: Select "Atmosphere", Select Clouds, Select Cloud cover; (2) Filters: Find a Site, Choose a Site, enter Longyearbyen – Svalbard; (3) Data Counts 2019-01-01 to 2019-12-31; (4) Result 5 locations shown on map. Examples of the photos from Svalbard are shown in Figure 21.

Overall, the Cloud Observations program has been active since 1995. From 1995 to 2019, the Cloud Observations program has received tens of records of cloud cover from Svalbard and from Greenland, see Figure 22.

Figure 21. Example photos of cloud cover in Svalbard from the Citizen Science program Cloud Observations.

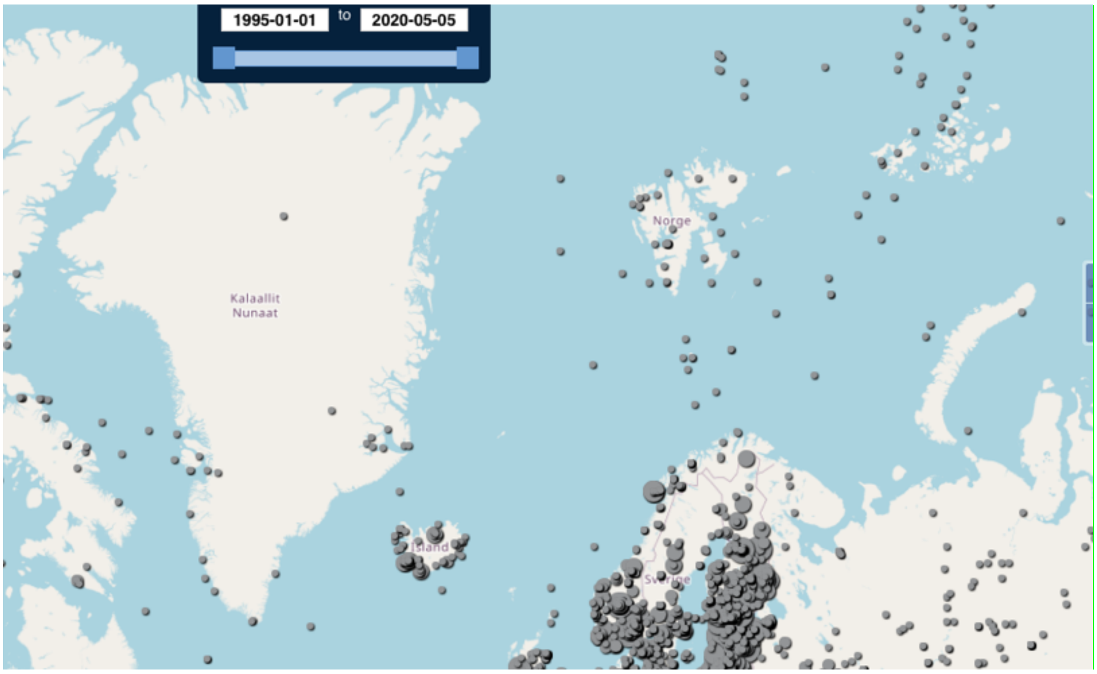


Figure 22. Extract of global map of positions from where cloud cover records have been obtained by the Cloud Observations program 1995-2019. Screenshot from the Cloud Observations online database (Source: vis.globe.gov; accessed April 2020).

Citizen Science Program 5: Tidal glaciers as Hot Spots for Top Predators

We obtained information from Prof. Jan M. Weslawski of IO PAN.

No records were obtained during 2019. Previously, however, records were obtained from 31 tidewater glacier bays in Svalbard, all located on the island of Spitsbergen (Figure 23). Cruise captains obtained photos and made notes of wildlife, and they collected surface water samples and Secchi depth measurements in August 2011, 2015, 2016 and 2017 (Simoniello et al. 2019; Dragańska-Deja et al. 2020).

Figure 23. Map of tidewater glaciers in Spitsbergen, Svalbard where photos, wildlife records, and water samples were obtained by cruise captains during 2011-2017. Source: Dragańska-Deja et al. 2020.

Citizen Science Program 6: Plastic Debris on Arctic Shores (IO PAN)

We obtained information from Prof. Jan M. Weslawski of IO PAN.

No records involving photos of plastic washed ashore and the fauna attached to it were obtained by IO PAN's citizen science program Plastic Debris on Arctic Shores in 2019. In both Svalbard and Greenland, there were several initiatives aimed at collecting and documenting plastic debris in 2019, including one led by the Governor's Office in Svalbard.

Prior to 2019, IO PAN obtained records of plastic and the fauna attached to it from cruise guests and cruise guides and other volunteers along the beaches of Spitsbergen, Svalbard. The findings will be available shortly, see Figure 24 (Weslawski, J.M. et al. in review, *Frontiers in Marine Science*, May 2020).

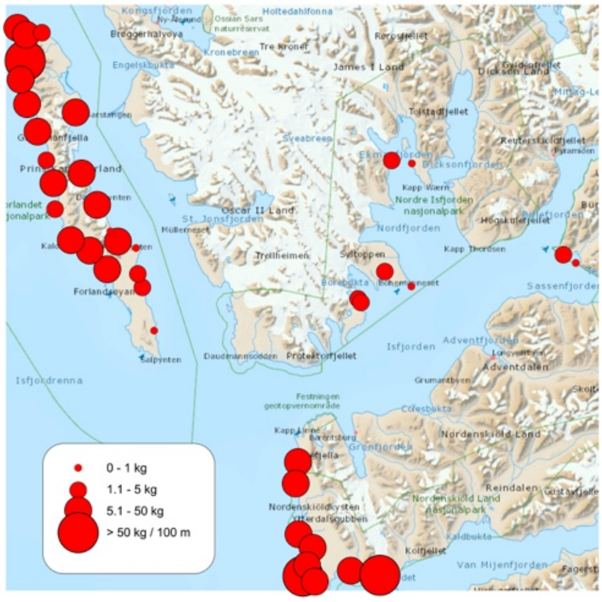


Figure 24. Macro plastic concentrations found during coastal surveys by cruise guests, cruise guides and other volunteers in Svalbard, prior to 2019 (Weslawski, J.M. et al. in review, *Frontiers in Marine Science*, May 2020).

4.3 Focus group discussions with resource users

We extracted 2016-2019 information from the PISUNA-net online database (5 May 2020). The information was kindly reviewed by Paviarak Jakobsen, Qeqertalik Municipality. The findings are described below.

The focus group discussions engaged 30 fishermen, hunters and environmentally-interested people from the Natural Resource Committees in the settlements of Akunnaaq, Attu, Kangarsuatsiaq and Kitsissuarsuit, and the town of Qaanaaq. The communities are distributed across 1,200 kilometers of the coast of Greenland, from 67.56 to 77.28 N. They reported observations from 4,287 field trips. The field trips were undertaken in all months of the year, most in July-September (438-505 field trips per month) and fewest in April (180 field trips per month), see Figure 25.

Which attributes were recorded? The community members summarized observations and knowledge of trends in abundance for 33 attributes, including sea-ice, climate/weather, 10 fish, 3 land mammal, 8 marine mammal and 10 bird taxa as shown in Figure 26.

As an example of the information that can be obtained from focus group discussions with resource users, the community members reported their perceptions of ecological dynamics and relationships related to 22 taxa of fish, mammals and birds. Their reports included 7 distinct types of dynamics and relationships: (1) Relationship between the abundance of wildlife species and sea-ice, sea-temperature, ocean currents, snow melt, wind and/or humidity; (2) Competition for food or feeding/nesting areas; (3) Range extensions; (4) Threats to wildlife species; (5) Nuisance to human activities; (6) Food choice of wildlife species; and (7) Perceived effects of wildlife management decisions, see Table 3.

The ultimate objective of the focus group discussions with resource users is to guide and improve decision-making on natural resource management. A wide range of management actions have been proposed, differing according to the species and location. A total of 197 recommendations were made for 21 resources. In Table 4 we summarize and provide examples of the management recommendations made for the most frequently reported species. The proposals relate to: changes in hunting and fishing seasons (85 proposals) and quotas (32); establishment of bylaws or changes in license regulation (24), research (21), trade (21), area closures (11), and fishing gear (3). Some have been implemented while others were declined or are still awaiting approval.

The activities and findings of the resource users engaged in the PISUNA program are met with great interest among other residents in Greenland. The number of members of the Facebook group PISUNA.org has been rapidly increasing since the group was established in 2012 (Figure 27). Today, almost 1% of Greenland's 37,000 active Facebook users are members of this Facebook group.

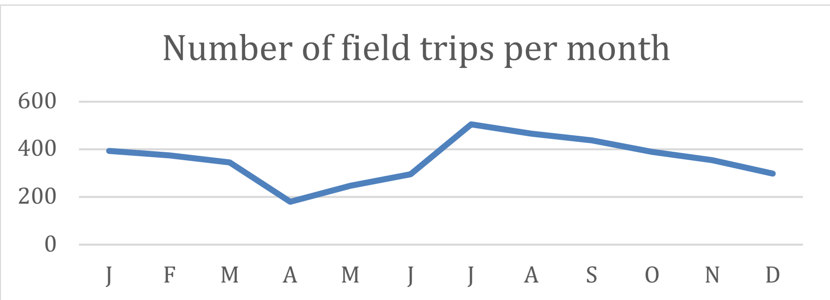


Figure 25. The number of field trips per month of the year, reported from Akunnaaq, Attu, Kangarsuatsiaq, Kitsissuarsuit, and Qaanaaq Natural Resource Councils in Greenland, 2016-2019 (*n* = 4,287 field trips). Source: PISUNA-net (5 May 2020).

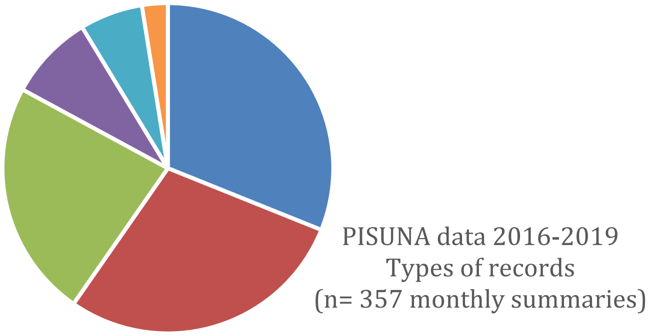


Figure 26. The proportion of records of the status of marine mammals (blue), fish (red), birds (green), land mammals (lilac), climate and weather (light blue), and sea-ice (orange) from Akunnaaq, Attu, Kangarsuatsiaq, Kitsissuarsuit, and Qaanaaq Natural Resource Committees in Greenland, 2016-2019 (*n* = 357 monthly reports). Source: PISUNA-net (5 May 2020).

Table 3. The community members' perceptions of ecological dynamics and relationships in North West Greenland 2016-2019. Source: PISUNA-net (5 May 2020).

	Snow melt relationship	Sea-ice relationship	Ocean current relationship	Competition for food or area [1]	Perceived range extension	Threats to wildlife	Nuisance to narwhale hunting [2]	Perceived effects of management [3]	Food choice info. provided	Body condition info. provided
Fish										
Capelin			+							
Arctic char	+									
Atlantic cod			+	+	+				+	
Polar cod				+	+					
Wolffish *spp.*			+		+					
Redfish					+					
Grenadier *spp.*					+					
Greenland halibut								+		
Marine mammals										
Walrus				+	+		+	+		
Ringed seal		+								
Harp seal									+	
Bearded seal		+								
Harbour porpoise										+
Beluga								+		
Humpback whale				+						
Land mammals										
Arctic fox						+				
Caribou				+						+
Musk ox				+						
Birds										
Snow goose					+					
Common eider		+		+						
Kittiwake				+						
Brünnich's guillemot		+		+				+		
Other										
Wildfire						+				
Trawlers						+				

Note: [1] Competition for food (walrus/common eider; humpback whale/jellyfish), feeding areas (caribou/musk ox; Atlantic cod/polar cod), and nesting sites (kittiwake/Brünnich's guillemot); [2] Dangerous individual walruses, Qaanaaq Fiord, in summer; [3] Perceived positive impacts of management interventions.

Table 4. Trends in the abundance of selected fish, mammal and bird taxa (increase/decline/no major change), and the number and type of management actions proposed by Akunnaaq, Attu, Kangarsuatsiaq, Kitsissuarsuit, and Qaanaaq community members in North West Greenland 2016-2019 (# = total number of monthly reports about each taxa). The abundance of Atlantic cod increased 2016-2017 and declined 2018-2020. Source: PISUNA-net (5 May 2020).

	#	Trend	Bylaw or license	Trade	Research	Quota	Season	Area closure	Gear	No action needed	Example
Atlantic cod	49	↑↓	0	9	15	14	0	3	0	3	Thorough studies, fishing area closure, regulate seals; <2018: increase quota
Wolffish sp.	10	↑	0	6	3	0	0	0	0	0	Establish trade (Akunnaaq, Kangarsuatsiaq); census stock (Kangarsuatsiaq)
Greenl. halibut	15	~	0	0	0	0	0	0	0	4	None; 'current management is fine' (Attu, Qaanaaq)
Caribou	12	~	3	0	0	0	11	0	0	0	Change hunting season; later for part-time hunters; tighten waste regulations
Muskox	12	~	0	0	3	3	0	3	0	0	Area closure Naternaq; census stock Nassuttoq; increase quota Kangarsuatsiaq
Walrus	15	↑	3	0	0	3	15	0	0	0	Change season, 2 licenses/trip (Attu); increase quota (Kangarsuatsiaq); cull aggres. males (Qaanaaq)
Seal	51	~	6	6	0	0	0	0	0	24	Establish fur trade (Akunnaaq, Attu); reduce the stock to minimize competition with fisheries
Beluga	12	↑	3	0	0	3	0	0	0	3	Proposes >1 license to hunters, update quotas (Attu); ' management is fine' (Kangarsuatsiaq)
Humpback wh.	12	~	0	0	0	3	0	0	0	6	Increase quota (Attu, 2016)
Common eider	24	↑	0	0	0	0	18	0	0	0	Allow egg collecting first half of June, extend the hunting season
Thick-b. murre	23	↑	3	0	0	0	5	2	0	2	Hunting season 1 Dec-15 Jan (Attu); protect breeding cliffs, hunt at sea year round (Qaanaaq)

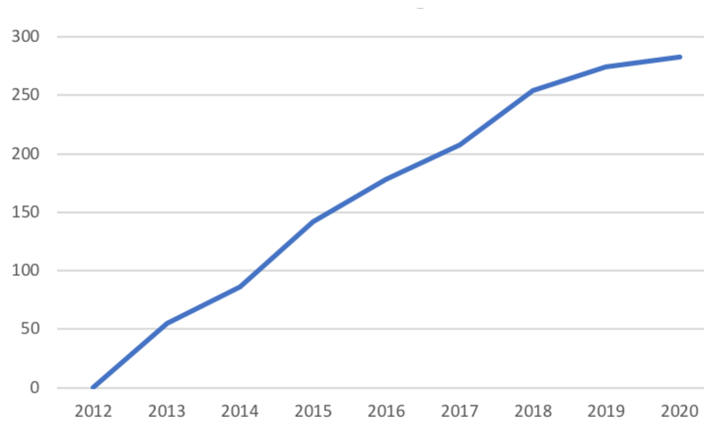


Figure 27. The development in the number of members of the Facebook group PISUNA.org from 2012-2020.

4.4 Qualitative interviews and workshop dialogues

Below we describe the outcome of the two dialogue workshops held in Svalbard.

<u>Dialogue workshop in Longyearbyen in Dec. 2018</u>. Local actors reported a number of important challenges and possibilities related to climate, nature and the environment within their sector, and critical knowledge gaps. Safe housing is a high priority for area and community planning in Longyearbyen, i.e. finding safe areas for new homes, and securing existing homes.

With regard to climate change, key priorities of the local actors were reported to be:

- Area planners cannot themselves undertake research on the impacts of climate change, they depend on scientists to provide data, models, maps etc.
- Area planning has to be based on existing reports/theses
- Often there are uncertainties regarding the rate and timing of environmental impacts
- Is it important for area planners to know all about the cause of environmental changes if their effects and impacts are known?

- There is a need to know not only how climate change impacts on infrastructure but also how it affects us as individuals and as a society
- There is also a need for more technical information, updated reports and research

Dialogue workshop in Longyearbyen in March 2019. At this workshop, the participants discussed how they can contribute to sustainable management and development in Svalbard and in the region. Through group work and discussions in plenum, the participants looked at opportunities and needs across sectors and actors.

The leader of the Planning and Development Department in the Local Council presented key issues addressed by the Local Council: local democracy, work and business in Longyearbyen, nature and environment, and the changing climate. Sustainable planning and urban development in the Arctic and providing a safe and attractive place for the community are challenging tasks. Public services, infrastructure and logistics – inc. energy production, the field of culture and leisure, access to nature, a rich cultural life and sports, are all important parts of the efforts to provide good living conditions for the inhabitants.

Longyearbyen Local Council as an organization was also represented. The main issue for the Local Council in 2017-2019 was planning for new safe homes and plans to secure or demolish and construct new homes, as well as the development of a better school service, and development for tourism and business in general.

The local business association in Svalbard could not recall any previous collaboration between researchers and local businesses. Five years ago, Longyearbyen was a thriving town based on mining, with minor tourist activities and a stable Norwegian community, according to the business association. The community became more unstable in 2015, and a decision was taken to develop the tourist sector. This has resulted in an increasing number of non-Norwegians in Svalbard. The number of non-Norwegians in schools and kindergartens has increased to 50%, and the participant turnover is considered high. Research is needed to monitor and understand the changing local society.

The participants also discussed how the environment in the Arctic region is changing fast. Better environmental monitoring and management are urgently needed. The changes in the environment are due to increasing temperatures. Sea-ice is decreasing, human activities are increasing and wildlife is affected. These changes have a severe impact on people's living conditions in Longyearbyen and Svalbard as a whole. To ensure sustainable development in the Arctic, more knowledge is needed on climate and environment.

The leader of UNIS Safety Center talked about the objective of the Arctic Safety Center, which was established to contribute to a safe and sustainable human presence in the high Arctic. The ambition is that the center should share knowledge and build competence though education and research, tailor-made courses and guidance to academia, industry and Arctic settlements. They undertake research and sell safety training to the industry, as well as to the cruise operators. Collaboration between different stakeholders is established through the *Svalbard Portal*, which is intended as an e-learning platform that provides up-to-date knowledge on the natural environment in Svalbard, and information on how we can have a safe presence in the natural environment. It is funded by the Svalbard Environmental Protection Fund. The partners behind the portal are Longyearbyen Local Council, the Governor, Visit Svalbard and the Norwegian Polar Institute. Another example of collaboration is the *Driva Project,* where snow sensors are deployed in the terrain to obtain snow cover data.

BaseCamp Explorer Foundation, representing a part of the tourism activities, is operating through a "sustainable tourism" approach. It supports stronger collaboration and knowledge-sharing for sustainable tourism.

A number of specific proposals were made by the workshop participants:

1) The field staff from the Governor's Office should gather further information, share data, ask for more detailed data, photos, etc.
2) The establishment of tighter criteria on what constitutes a research cruise should be considered.
3) Stronger cooperation with all local industries/businesses and local authorities involved should be emphasized, as well as support for the cruise industry in terms of providing better information to tourists and local communities on environmental, social and cultural matters.
4) Better infrastructure should be provided in the local communities, such as walking paths and pavements for resident safety, both for the locals and visiting tourists. Further knowledge to provide updated local information on environmental protection, suggested routes, safety "suggestions" for 2, 3, 5 and 10-hour stay, must be presented.
5) Ideas were also raised about more local power to impose restrictions on the tour operators, through the requirement of compulsory AECO membership or maximum numbers of tourists.
6) For monitoring, there may be a need for further vessel tracking, and the monitoring of visitor numbers.
7) There is also a need for more knowledge-based arguments for business development, and
8) More research on the limitations and possibilities for development and business, and likewise on the value of tourists coming to Svalbard. Many come to experience the emptiness and pristine untouched nature but overcrowding will damage the environment and have a negative impact on the local community (see also Olsen et al. 2020).

Through group and plenum discussions, the participants looked in more detail at opportunities and needs across sectors and actors, today and in the future. The organization of a social science side-event at the Svalbard Science Conference was suggested, to present what was discussed at this workshop. The workshop report is available at https://www.dropbox.com/s/d2c4lws507up74j/2019%20Cruise%20Expedition%20Monitoring%20Workshop%20in%20Svalbard%20Report.pdf?dl=0

4.5 Linking climate change data-collecting and research with the local needs

The Svalbard Social Science Initiative (SSSI) was invited to present the network for Longyearbyen Lokalstyre on Sep. 16, 2019. This was followed by a dialogue with the politicians and administration. The network initiative was appreciated, and the politicians expressed a wish to collaborate over time with the researchers. The network and the meeting with the Local Council were described in the local newspaper *Svalbardposten* (https://svalbardposten.no/mange-forsker-pa-byen-var/19.11483). Subsequently, the network hosted a side-event and presented a poster at the Svalbard Science Conference in Oslo on Nov. 4, 2019, where each session was led by the different members of the SSSI.

Most SSSI members are undertaking research connected to Longyearbyen; some also have agreements with UNIS and one researcher is conducting research in Barentsburg. Hornsund and Ny-Ålesund are also part of some of the research projects. While social science research on Svalbard has intensified over recent years, there was previously little coordination and communication between individual projects that could be deemed equal to the coordinated research efforts in Svalbard-related research in some of the natural sciences.

Improvement of international cooperation. At this side-event to the 2019 Svalbard Science Conference, SSSI brought together people from the local communities in Svalbard with social science and humanities researchers focused on Svalbard. Together we looked at the past, present and future of living on Svalbard and discussed current research on the human dimensions of the changes underway in Svalbard. Members of SSSI and invited speakers represented different scientific disciplines of relevance to Svalbard science. Members of the SSSI come from multiple institutions in Norway and Europe, mostly early career scientists. This improves the international collaboration for research and enhances the outcomes for the local community at Svalbard. Several of the members of the SSSI have been invited to take part in, and co-host, workshops held by INTAROS. We will coordinate future efforts and collaborate on new applications in order to reduce both costs, travel and work effort. Through workshops and group discussions, we aim to strengthen the ways in which social science and humanities research, from different countries, can work with and for the local community, as well as consolidate the research network and plan future activities.

Through the discussions at the side-event, we addressed and identified important topics for the Svalbard community today, inc.:

- Resource extraction
- Recycling
- Post-mining imaginaries
- Children and living conditions
- Level of services, migration and mobility
- Capacity building
- Space anthropology (anthropological understanding of space and place)
- Hybrid identities/statelessness, including economic migrants
- Recreation, including outdoor space quality
- Citizen science opportunities
- Community services

These are emerging topics to be investigated if Longyearbyen's challenges to be a sustainable community are to be met in the future. Research can only be fruitful if there is a strong representation of local actors in Longyearbyen.

Identified research gaps. From the discussions at the side-event, it has become evident that there are a number of research gaps in Svalbard. These include:

- Health (clean water, food supply preparedness, rabies, risk management/safety for people)
- Gender
- Energy policy

- Tools for analyzing rapid social changes, as the conventional planning tools are unable to respond to the rapid changes in the Svalbard society
- Urban futures, which involve closer collaboration also with Oslo School of Architecture and Design
- Changing world orders and power relations make it important to address this issue, which is highly relevant for Svalbard
- Urban spaces including outdoor space quality and conflicts with environmental protection. It is important to find a balance between use and protection of the outdoor space
- Research on topics relating to manual workers

Priorities and recommendations for future work**.** Based on the discussions at the side-event, it has become clear that a number of social tools are not currently being used but may have important potential in Svalbard. These tools include:

- Community environmental monitoring (qualitative and quantitative)
- Mapping how people use and experience the spaces
- Experimental approaches combined with existing methods
- Meta mapping of ongoing research projects. This work started at the first workshop and should be continued
- Longitudinal studies and datasets

These methods are considered to add value and move Svalbard social science research forward. Researchers currently working in Svalbard are encouraged to diversify and adapt them to the situation in Svalbard.

The workshop revealed the need for our initiative to coordinate our efforts and develop new projects for and in the Svalbard community, and increase the efficiency of the research efforts in Svalbard. There is also a need to develop a system of result sharing between projects, beyond what is offered by the "Research in Svalbard" (RiS) database, and we will start to produce publications and other outreach activities from the SSSI research. We believe it is essential to develop a system for coordinating results and findings, make it more visible and encourage people to develop projects that continue (as opposed to re-doing) work already completed through collaborative projects, publications, potential conference panels and other relevant outcomes.

There is a huge opportunity to prepare and plan for more collaborative international research in Svalbard e.g. on how community services can respond to Longyearbyen's rapidly changing needs.

There are important benefits of having multidisciplinary researchers with different theoretical perspectives and methodological approaches working together in the same locality, touching upon the same topics, bringing added value to the various research projects, and to society as a whole. The sharing and collaborative interpretation of already collected data, including the verification/falsification of developed hypotheses and findings, will hence constitute an important part of this work.

The initiatives contributed to important community dialogues during the Covid-19 crisis in Svalbard.

5. Perspectives: What have we learned?

This chapter examines the community-based and citizen science observing activities we have piloted and what we have learnt about their usefulness in Disko Bay, Greenland, and Svalbard. For each community-based and citizen science observing activity that involved field-based data-gathering, the following six characteristics are assessed:

- Cost to local and other stakeholders
- Requirement for local and external expertise
- Sampling accuracy and precision
- Ability to support decision-making processes
- Potential for enhancing local stakeholder capacity
- Capacity to inform international monitoring

5.1 Garage-type geophone device to observe earthquake hazards

We deployed four geophone sensors, two in Disko Bay and two in Svalbard. The instruments were connected to power and the Internet. Seismic data were transmitted in near real-time to the Raspberry Shake organization where they were displayed on a publicly available website.

Cost to local and other stakeholders

In Disko Bay, the geophone sensors were deployed with families of full- or part-time fishermen and hunters in the basements of their houses. Each family was compensated for the cost of Internet and power with DKK 300 (€40) per month. The recurrent, annual cost per sensor (without depreciation) was DKK 3,600 (€480). In Longyearbyen, the sensors were deployed by the staff of Svalbard Museum and Radisson Blu Polar Hotel. Both locations have flat rate Internet, and the power consumption of the instruments was considered negligible, so the instruments were hosted free of charge. The four sensors were purchased at a cost of approx. US$ 1,600. There were only minimal expenses for transporting the sensors to the installation sites in Greenland and Svalbard because they were brought there when INTAROS staff visited the areas for other purposes.

Requirement for local and external expertise

The community members did not need specific expertise e.g. in seismology, since aside from plugging the geophone sensors to Internet and power, there was no community member involvement in the geophone data collection. The external expertise involved both physical science (seismology) and participatory social-anthropological and facilitation skills. In Disko Bay, the installment of the geophones in the bedrock under houses was possible because of the relationship and trust that already existed between the community members, the government and scientists through many years of collaboration within the PISUNA program.

Sampling accuracy and precision

We compared the signal-to-noise ratio by garage-type geophone sensors with those of permanent seismic stations. We found that, in Disko Bay, the geophones' signal-to-noise ratio was comparable to the permanent sensors within the frequency range well covered by the geophones. In contrast, in Longyearbyen, the buildings are constructed on poles, and no suitable location with minimal or no noise could be found for the geophones.

Ability to support decision-making processes

The geophone sensors in Disko Bay complement permanent seismic stations by improving detection, location and data support for understanding cryo-generated and tectonic seismic events. Staff of Qeqertalik Municipality have already been directly involved in the piloting of the geophones: on a quarterly (three-monthly) basis, they and the village-based municipal offices assisted in communicating between the community members and the scientists. Workshops and meetings with the authorities and the communities are planned to present the lessons learnt from the piloting of the geophones. It is envisaged that this will contribute to further awareness among decision-makers on the safety issues in Disko Bay. In Longyearbyen, the piloting of the geophones is unlikely to contribute to decision processes.

Potential for enhancing local stakeholder capacity

In Disko Bay, there is potential for enhancing the awareness of the communities and the local government authority (Qeqertalik Municipality) regarding safety issues related to seismic events in the region. However, fulfilling this potential requires dialogue with the municipal staff and the community members, and staff time and funding for targeted outreach. In Longyearbyen, the awareness-raising potential is minimal because the buildings are constructed on poles and the data from the sensors were of limited value and thus not suitable for public display.

Capacity to inform international monitoring

The data from the sensors is transmitted in near real-time to the Raspberry Shake organization servers. From there, they are extracted by national and regional agencies, processed and analyzed for seismic event detection and location before the data is entered into international data repositories, specifically at the International Seismological Center. The original data is stored at the Raspberry Shake servers for one year; the University of Bergen and GEUS host permanent copies of the data to be made available in the integrated Arctic Observing System.

5.2 Expedition cruise operator-based environmental observing of multiple variables

We cooperated with expedition cruise operators and organizers of citizen science programs and encouraged the use of six environmental observing tools among cruise guests and cruise guides in Disko Bay and Svalbard.

Cost to local and other stakeholders

The citizens making observations of the environment were cruise guests and cruise guides. The data collection, organization, analysis and interpretation was undertaken by scientists employed at research institutions and non-governmental organizations; each group of scientists is responsible for their own citizen science program. The cruise guests and cruise guides were not compensated for their time and effort; they engaged in the activity because it was meaningful for them and it may make the cruises an even richer experience for them. We have been unable to quantify the cost in time and effort and other resources used by the scientists in running the citizen science programs.

Requirement for local and external expertise

For the six citizen science observing tools piloted, the requirements for expertise among the data collectors, i.e. the cruise guests and cruise guides, are limited. Some species identification skills are an advantage. Moreover, the cruise guests and cruise guides must keep records and follow a prescribed method with procedural rigor. The expertise required by the scientists depends on the individual program but includes, beyond knowledge of the monitored attribute, socioeconomic literacy and technological skills, such as in the use of digital platforms for visual communication and for data storage.

Sampling accuracy and precision

With the exception of the Secchi Disk Study, all six piloted programs use photos for documentation purposes. In three programs, the photos are stored with their metadata online (with the name of the attribute photographed, location, time, and observer), making it possible to validate and countercheck the observation in perpetuity. One of the citizen science programs (eBird) also use statistical analysis of the data in order to search for anomalies that are beyond the normal or expected range: scientists based in the region are alerted to validate the records. Finally, the citizen science programs allocate individual observers with ranks based on their knowledge, allowing data to be disaggregated according to this ranking.

Ability to support decision-making processes

The use of the cruise guests' and cruise guides' observations to support decision processes requires: (1) that the attribute observed is a topic of relevance to decision processes (i.e. that the observations contribute to one or more of the "key benefit areas" defined by the Sustaining Arctic Observing Network; *sensu* Starkweather et al. 2020; Eicken et al. in review), and (2) that the findings emanating from the observations are accessible (or actively made available) in a format appropriate for the decision-makers to act upon. With regard to (1), we found that some of the observed attributes are indeed relevant to decision processes in Disko Bay and Svalbard in the short-term. Examples include observations of geese, cetaceans and polar bear. In contrast, observations of attributes such as plankton density and clouds may only be relevant to decision processes in the long term. With regard to (2), to our knowledge, none of the datasets (or findings emanating from the datasets) are actively communicated to the decision-makers in Disko Bay or Svalbard or available online in a format that is appropriate for the decision-makers to act upon.

Potential for enhancing local stakeholder capacity

It is unlikely that the engagement in citizen science observations of cruise guests and cruise guides, who are mostly visitors to the Arctic, will substantially enhance the capacity of resident Arctic communities.

Capacity to inform international monitoring

The data from the citizen science programs undertaken by cruise guests and cruise guides is transmitted to the scientists and institutions who lead the programs. From there, the data is entered into international data repositories.

5.3 Focus group discussions with resource users

With the municipal authorities and fishermen and hunters in Disko Bay, Greenland, we tested focus group discussions for monitoring and managing living resources as part of the PISUNA program.

Cost to local and other stakeholders

Within the PISUNA program, the fishermen, hunters and environmentally-interested people that are members of the Natural Resource Committees in each community meet regularly (e.g. every three months). At each meeting, they discuss the status of living resources and possible management interventions. Each participant in this meeting (up to 6 in each community) are paid an honorarium of DKK 600 (€ 81) by Qeqertalik Municipality (Attu, Kitsissuarsuit and

Akunnaaq) or INTAROS (Kangarsuatsiaq and Qaarnaq). The community members make observations of living resources and resource use during fishing and hunting activities, so there are minimal other costs for them in terms of time, effort or money. The cost to other stakeholders includes the staff time of an advisor with Qeqertalik Municipality. The advisor uses some hours every week to assist the community members and forward their management proposals to decision-making bodies in the government. His salary and travel costs are paid by Qeqertalik Municipality. Translation of data from Greenlandic to English and Danish, entry of data into PISUNA and PISUNA-net websites, and the regular maintenance of the webpages are undertaken by staff of NORDECO and ELOKA (Exchange of Local Observations and Knowledge for the Arctic).

Requirement for local and external expertise

The local expertise in each participating community comprises 5-12 community members who are interested in helping to manage the living resources. They typically come from those families in the community who are significant users of the resources, often including the most experienced fishermen and hunters (Danielsen et al. 2014). The participants are often also involved in voluntary work in the local branches of fisher and hunter organizations. In each community, one or more of the community members usually also has local social and community-relations expertise. The external expertise required is mainly participatory social-anthropological and facilitation skills.

Sampling accuracy and precision

Simone Hansen compared the community members' perceptions with Greenland Fisheries License Control's records of landings of Greenland halibut (*Reinhardtius hippoglossoides*) and Atlantic cod (*Gadus morhua*). Greenland Fisheries License Control's landings data are the main dataset used for scientists' fish abundance assessment in the region. She made comparisons both on a monthly and a three-monthly timescale. She found correspondence between the community members' perceptions of trends in abundance and the fisheries landings of cod on both time scales. For Greenland halibut, however, she found correspondence only on a quarterly scale and not on a monthly scale (Hansen 2018). Previously, another study compared community members' perceptions with scientists' reports of trends in the abundance of 24 attributes (Danielsen et al. 2014). The community members and the professional scientists produced corresponding results for 12 attributes. Only for two populations, nearshore Greenland halibut and breeding Arctic tern *Sterna paradisaea*, was there disagreement between local and scientists' reports of trends in abundance. For ten attributes, it was not possible to locate any scientist-produced data to allow for a comparison with the community members' findings.

Ability to support decision-making processes

From the perspective of the Greenland Ministry of Fisheries and Hunting, the PISUNA program has been established precisely for the purpose of providing opportunities for resource users to inform decisions on managing the living resources in Greenland. The PISUNA program has great potential to inform decision processes. There are many examples of findings and proposals from PISUNA community members that have led, or contributed, to government action. In 2017, e.g., PISUNA proposals contributed to the government's decision to establish a moratorium on muskox (*Ovibos moschatus*) hunting in one of the largest hunting areas, Naternaq (Lersletten), until scientists had surveyed the status of the population. Nevertheless, it is a widespread concern among the PISUNA community members that the government is not listening sufficiently to the observations and management proposals they submit.

Potential for enhancing local stakeholder capacity

Participating in PISUNA provides an opportunity for the community members' insights and knowledge to be used and their voices heard. From 2016 to 2019, the community members submitted 197 management proposals supported by observations in the field to the authorities. Management proposals from PISUNA have contributed to changes in the hunting regulations for several species of birds and mammals.

Capacity to inform international monitoring

The organizers of the PISUNA program are working towards sharing the PISUNA dataset with international repositories and getting the metadata on the PISUNA dataset published in data discovery catalogues such as EUDAT-B2FIND. An important first step was the establishment of the searchable, web-based PISUNA-net (https://eloka-arctic.org/pisuna-net/).

In Table 5, we summarize our assessment of eight key characteristics of the community-based and citizen science observing activities that we piloted in Disko Bay and Svalbard.

Table 5. The variation in eight key characteristics across the three approaches to people-based observing of the Arctic environment: citizen seismology, expedition cruise guests' observing, and focus groups with resource users.

	Cost to local stakeholders	Cost to external stakeholders	Requirement for local expertise	Requirement for external expertise	Sampling accuracy and precision	Ability to support decision-making processes	Potential for enhancing local stakeholder capacity	Capacity to inform international monitoring
Citizen seismology	+	++	+	+++	+++	+	+	+++
Expedition cruise guests' observing	+	++	+	++	+/+++	+	+	+++
Focus groups w/resource users	+++	++	++/+++	++	+/+++	++/+++	+++	+/+++

+ = low, ++ = intermediate, +++ = high

6. Prospects for positive developments for Arctic observing

In the previous chapters, we have presented the lessons learned from piloting the community-based and citizen science observing activities in Disko Bay, Greenland, and Svalbard. In this chapter, we will discuss how the lessons can contribute to positive developments for environmental observing.

We have piloted five community-based and citizen science observing and networking activities in Disko Bay, Greenland, and Svalbard. Three of the activities involve data-gathering in the field and two comprise communication processes to encourage dialogue between scientists, citizens and local decision-makers on climate change efforts.

The three activities that involved field-based data-gathering represent very different types of approach: (1) The geophones case is an example of automated data collection with residents of the Arctic. The role of the participants is, however, extremely limited; they only help with installation, provide electricity and Internet. If the data is to inform decision-making, it will need to be interpreted and analyzed by seismologists and the findings made available to decision-makers and community members in an appropriate format on which to base decisions.

(2) The expedition cruise operator-based environmental observing is an example of human production of data by visitors to the Arctic. The participants are cruise guests and guides, and their role is limited to making observations and taking measurements and photos. They also forward the data to international citizen science programs. As in the first example, if the data is to inform decision-making, it will need to be interpreted and analyzed by scientists and the findings made available to the appropriate decision-making bodies.

(3) The third activity, the focus group discussions with resource users, is an example of human production of data by resident communities. In this case, the participants' role is not limited to making observations and submitting records to scientists. The citizens also interpret and discuss their records, and they propose management interventions to the local authorities. Moreover, the citizens themselves decide what attributes they observe. In this example, communicating findings and proposing decisions based on these observations are in-built components of the monitoring process. The authorities may still not use the findings to make decisions, because of other shortcomings, but the data and proposed decisions are available to the decision-makers to decide upon.

Garage-type geophone device to observe natural hazards

Our experience with deploying four garage-type geophones with citizens in Disko Bay and Svalbard suggests that local factors drive the level of success (Voss et al. 2019; Jeddi et al. 2020). In Disko Bay, stable locations providing high signal-to-noise ratios were obtained at each site. The families in Disko Bay were keen to install the sensors in the bedrock under their houses, probably because of the trust and respect and collaboration that already existed between the fishermen, hunters and the authorities within the PISUNA monitoring and management system. The sensors in Disko Bay were therefore able to provide high-quality data for the observation of seismic signals in the region (Jeddi et al. 2020). In Svalbard, in contrast, given the limited availability of appropriate locations (i.e. buildings not on poles), combined with the high cost of indoor space, finding suitable locations for the instruments turned out to be impossible. This was probably exacerbated by the already strong presence of research environments in Svalbard, making people less likely to engage in "yet another research project".

Our piloting of garage-type geophones with citizens demonstrated the logistical challenges facing citizen seismology efforts in the polar regions. It showed the importance of local factors in driving the level of success in each deployment. By analyzing citizen-generated data together with existing scientist-executed seismic sensors, we have however demonstrated the potential usefulness of citizen seismology in the Arctic. In the Disko Bay case, citizen seismology significantly improved both event detection and event location and contributed to enhancing our understanding of seismic events. A denser network of scientific and community seismometers combined may be a feasible approach to better understanding and addressing safety issues from landslides and related tsunamis.

Aside from providing data, citizen seismology also has potential for raising community awareness of natural hazards (Jeddi et al. 2020). Our future efforts in Disko Bay area will therefore include meetings and workshops with the communities in the Disko Bay settlements of Akunnaaq, Attu and Aasiaat, as well as with Qeqertalik Municipality and the central authorities.

Expedition cruise operator-based environmental observing of multiple variables

Our experience with testing the use of six CS programs with cruise guests and cruise guides on expedition cruises in Svalbard and Greenland suggests that cruise guests and cruise guides can potentially generate large quantities of high-quality data on the environment for use in both decision-making and research but that the success depends on at least five factors:

First, successful observing depends on the existence of CS programs. Cultural and historical sites are increasingly under threat in the Arctic. Community members, scientists and decision-makers in Svalbard identified a need for photo-documentation of these sites, yet it was impossible to find a suitable CS program for this purpose. This is in sharp contrast to the multitude of programs dealing with biodiversity and natural science. Photo-documentation of cultural and historical sites over an extended timeframe has great potential for answering questions related to the management of these sites.

Second, prompt feedback to the cruise guests in an appealing way is critical. Four of the tested CS programs are global programs with an Arctic window, whereas the remaining were developed specifically for the Arctic. Two of the global CS programs have good working digital platforms (eBird, Happywhale). These platforms enable observers to immediately obtain feedback on how their records correspond or otherwise with other observers' records of the same attributes in the same area. Other CS programs relied on observers submitting their observations by email to the CS program coordinator and obtaining feedback after a while.

The CS programs with advanced digital platforms are, however, very costly to maintain. eBird, for instance, has an annual budget of several million euro. It is unlikely that it will ever be possible to establish and sustain advanced digital platforms that are developed specifically for observing the Arctic. There are large benefits from building on existing global programs rather than developing new Arctic-specific ones.

Third, some attributes are more appealing to cruise guests and cruise guides than others. Taking Secchi depths or photographing clouds are unlikely to generate the same enthusiasm among visitors to the Arctic as observing and photographing birds and marine mammals.

Fourth, observations are only likely to get used by decision-makers at the local and national level in the Arctic if the records are analyzed and interpreted with a view to informing decision processes and if the findings are communicated to the decision-makers in appropriate formats. Observations in their raw form (or in the form used to establish excitement and create awareness among the observers) are rarely useful to decision-makers.

Fifth, if the observations by cruise guests and cruise guides are to contribute to decision-making - and thus improved natural resource management in the Arctic - there is a need for an intermediate organization that can facilitate the dialogue between the operators, the CS programs and the decision-makers. Such an organization could be AECO or the Polar Citizen Science Collective. A conceptual model of such a "one-stop" approach is shown in Figure 28. Funds will need to be set aside for this facilitation role.

To sum up, some citizen science is already being undertaken by expedition cruise operators in the Arctic but our findings suggest there remains huge unexplored potential. CS programs with cruise guests and cruise guides on expedition cruises are able to generate large numbers of observations from those areas of the Arctic that are visited by expedition cruises. These areas are mainly Svalbard, Greenland and South East Alaska. Cruise guests and cruise guides are able to generate observations during the cruise season in the region, which at the moment runs from April to September. There are already operational CS programs, and they could potentially be applied among more cruise expedition operators. It is suggested that every expedition cruise ship be equipped with one or more iPads or tablets that can enable easy uploading of observations to the individual CS programs. Moreover, CS programs could be extended to cover further geophysical, biological, environmental and cultural topics. It will be important to build on the existing CS programs in further work. Careful design and proper evaluations are important. This could contribute to new ways of working together. Local decision-makers, scientists and operators should together decide on what is needed. Further effort is needed on the part of CS programs so as to not only provide feedback to the cruise guests and cruise guides but also to make the datasets useful for decision-makers.

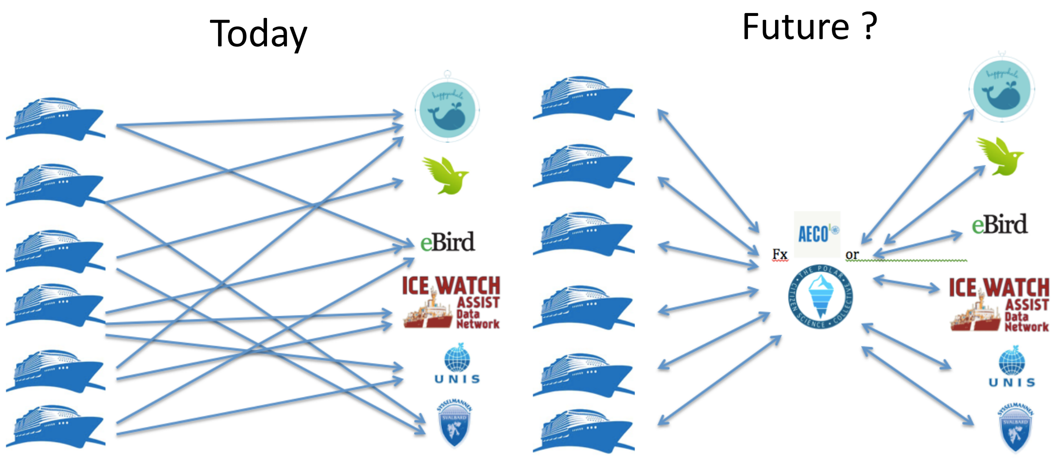


Figure 28. Conceptual model of a "one-stop" approach for facilitating dialogue between expedition cruise operators, citizen science programs, and decision-makers in the Arctic.

Focus group discussions with fishermen

The focus group discussions of the PISUNA monitoring and management system enabled fishermen, hunters and other environmentally-interested people in the villages in Disko Bay to document their observations and knowledge of the environment and to use this information for making proposals to the authorities on how the management of the natural resources should be improved. Natural resource management measures based on local observations and local knowledge were proposed and some of the proposals have been implemented. The result is that the time between observed environmental change and action has been shortened, while fishermen, hunters and other environmentally-interested people in the villages have begun to have a greater influence on natural resource management. The capacity of public resource managers to use this approach was enhanced through an in-service course under the auspices of UArctic. Storing and communicating findings was facilitated by strengthening PISUNA-net, the digital platform with the community members' observations and management proposals.

In our assessment, the functioning of the PISUNA monitoring and management system has been significantly improved over the past few years with regard to five areas, which were earlier identified as weaknesses (DFFL & NORDECO 2013). First, among the two municipalities covering Disko Bay, one of them, Qeqertalik, has since 2018 set aside staff time and honoraria for the volunteer members of the Natural Resource Committees. This ensures that a municipal advisor has time to support the work of the Natural Resource Committees in this municipality and that the participants are (symbolically) compensated for the time in meetings. Importantly, the attention to PISUNA by the municipal leadership sends a clear message to the public that the efforts by the fishermen and hunters are appreciated. Secondly, "dual" communication lines have been established from the communities to the Ministry of Fisheries, Hunting and Agriculture and to the municipalities. The vulnerability to possible loss of summary forms and data has thereby been reduced. Unfortunately, because of recent staff changes within KNAPK, this "dual" communication line may not be continuing. Thirdly, there has been increased awareness among the participants in the Natural Resource Committees about the importance of diligently filling in the monthly summary forms on observations and management proposals, including providing contextual data such as quantifying the number of field trips. Fourthly, the storage and communication of findings has been improved particularly with the establishment of the PISUNA-net database but also through improvements in the website with the reports in their original language (www.pisuna.org). Finally, the PISUNA forms have been revised so that accurate Greenlandic terms are being used.

Despite these important improvements, several challenges remain: (1) Many management proposals still do not seem to be considered by the decision-makers (Mustonen et al. 2017). (2) There is varying effort across the communities in documenting their observations. Moreover, village meetings to validate findings and agree on management proposals with the broader community, envisaged to take place every year, are lagging behind. (3) Effective communication of findings and management proposals are being hindered by PISUNA-net requiring foreign language skills; few community members, public resource managers and decision-makers in Disko Bay are familiar with English. It is also uncertain whether "dual" communication lines will proceed after the recent staff changes in KNAPK. (4) Because of the largely "*ad hoc*" development of PISUNA in the past, the institutional roles and responsibilities with regard to implementing PISUNA among the municipal and central authorities and KNAPK are not fully clear, and this sometimes creates confusion. (5)

Sustainability of PISUNA over time remains a challenge, although Qeqertalik Municipality has started supporting staff time and honoraria.

To mitigate the challenges listed above, we propose a number of recommendations. First, we propose that a dispensation scheme be established so that selected Natural Resource Committees and municipalities are, on an experimental basis, given increased responsibility for making decisions on natural resource management. Other Arctic countries manage a number of natural resources locally that are currently largely managed by the central authorities in Greenland (e.g. egg-collecting in Arctic tern breeding colonies in Iceland; hunting of eider ducks and geese in Canada). Responsibility for making decisions on the management of natural resources locally would increase the incentive among the community members to document the status of the resources and contribute to their sustainable use. Second, we propose that a national policy on local documentation and management be developed, ensuring that the necessary human professional and financial resources are allocated in both the Ministry, municipalities and communities and clarifying the roles and responsibilities of all actors. Third, the digital platform PISUNA-net should be improved, enabling non-English speakers to use it for data management, storage and communication (see Johnson et al. in review). Finally, we recommend strengthening of the exchange of experience and networking with other initiatives on community-based monitoring in Scandinavia (e.g. Porsanger Fjord, Brattland et al. 2019), Yakutia (Enghoff et al. 2019), Canada (Johnson et al. 2016; 2018), and Alaska (Fidel et al. 2017).

7. Literature cited

Amante, C., & Eakins, B. W. (2009). ETOPO1 arc-minute global relief model: procedures, data sources and analysis. *NOAA Technical Memorandum NESDIS NGDC-24.* Boulder, CO: National Geophysical Data Center, doi: 10.7289/V5C8276M

Anthony, R. E., Ringler, A. T., Wilson, D. C., and Wolin, E. (2018). Do low-cost seismographs perform well enough for your network? An overview of laboratory tests and field observations of the OSOP Raspberry Shake 4D. *Seismol. Res. Lett.* 90, 219–228. doi: 10.1785/0220180251

ASM. (2018). *Joint statement of the Ministers om the occasion of the second Arctic science ministerial*. https://www.iarpccollaborations.org/uploads/cms/documents/asm-2-joint-statement.pdf. 16 p.

Brattland, C., Eythórsson, E., Weines, J. *et al.* 2019. Social–ecological timelines to explore human adaptation to coastal change. *Ambio* **48,** 1516–1529. https://doi.org/10.1007/s13280-018-1129-5

Clinton, J., Larsen, T., Dahl-Jensen, T., Voss, P., and Nettles, M. (2017). Special event: Nuugaatsiaq Greenland landslide and tsunami. Incorporated Research Institutions for Seismology Washington DC. https://ds.iris.edu/ds/nodes/dmc/specialevents/2017/06/22/nuugaatsiaq-greenland-landslide-and-tsunami/.

Clinton, J.F., Nettles, M., Walter, F., Anderson, K., Dahl-Jensen, T., Giardini, D., Govoni, A., Hanka, W., Lasocki, S., Lee, W.S., McCormack, D., Mykkelveit, S., Stutzmann E., and Tsuboi, S. (2014). Real-time geophysical data enhance Earth system monitoring in Greenland, Eos Trans. AGU, 95(2):13-14. doi:10.1002/2014EO020001.

Cuyler, C., Daniel, C. J., Enghoff, M., Levermann, N., Møller-Lund, N., Hansen, P. N., ... & Danielsen, F. (2020). Using local ecological knowledge as evidence to guide management: A community-led harvest calculator for muskoxen in Greenland. *Conservation Science and Practice*, *2*(3), e159.

Dahl-Jensen, T, et al. (2004). Landslide and Tsunami 21 November 2000 in Paatuut, West Greenland, Natural Hazards, 31: 277-287, 2004.

Danielsen, Finn, Elmer Topp-Jørgensen, Nette Levermann, Piitaaraq Løvstrøm, Martin Schiøtz, Martin Enghoff, and Paviarak Jakobsen. 2014. "Counting what counts: using local knowledge to improve Arctic resource management." *Polar Geography* 37: 69-91.

Danielsen, Finn, Martin Enghoff, Eyðfinn Magnussen, Tero Mustonen, Anna Degteva, Kia K. Hansen, Nette Levermann, Svein D. Mathiesen, and Øystein Slettemark. 2017. "Citizen science tools for engaging local stakeholders and promoting local and traditional knowledge in landscape stewardship". In *The Science and Practice of Landscape Stewardship,* edited by Claudia Bieling and Tobias Plieninger, 80-. UK: Cambridge University Press.

Darbyshire, F.A., Dahl-Jensen, T., Larsen, T.B., Voss, P.H., and Joyal, G. (2017). Crust and uppermost-mantle structure of Greenland and the Northwest Atlantic from Rayleigh wave group velocity tomography. Geophysical Journal International. 212(3), 1546–1569. doi:10.1093/gji/ggx479.

DFFL og NORDECO. 2013. Evaluering, 'Opening Doors to Native Knowledge', Piniakkanik Sumiiffinni Nalunaarsuineq, Projekt numre #A09173; #A10173; #A11173. Nuuk, Greenland. 19pp. Available at: http://www.pisuna.org/documents/Evaluering%20PISUNA%206Dec,%20revNov14.docx

Dragańska-Deja, K., Błaszczyk, M., Deja, K., Węsławski, J. M., & Rodak, J. (2020). Tidewater glaciers as feeding spots for the Black-legged Kittiwake (Rissa tridactyla): A citizen science approach. *Polish Polar Research*, 69-93.

Enghoff, Martin, Nikita Vronski, Vyacheslav Shadrin, Rodion Sulyandziga and Finn Danielsen. (2019). *INTAROS Community-Based Monitoring Capacity Development Process in Yakutia and Komi Republic, Arctic Russia.* CSIPN, RIPOSR, NORDECO and INTAROS.

Fidel, Maryann, Noor Johnson, Finn Danielsen, Hajo Eicken, Lisbeth Iversen, Olivia Lee and Colleen Strawhacker. 2017. *INTAROS Community-based Monitoring Experience Exchange Workshop Report*. Fairbanks: Yukon River Inter-Tribal Watershed Council (YRITWC), University of Alaska Fairbanks, ELOKA, and INTAROS.

Flora, J., Johansen, K. L., Kyhn, L. A., & Mobech, A. (2019). Piniariarneq – Fangsten i Østgrønland kortlagt af fangere. Aarhus Universitet, DCE – Nationalt Center for Miljø og Energi, 232 s. http://dce2.au.dk/pub/FangstKortlagtAfFangere_DK.pdf

Gilchrist, G., Mallory, M. and Merkel, F. 2005. Can local ecological knowledge contribute to wildlife management? Case studies of migratory birds. *Ecology and Society* 10(1): 20.

Greenland Government, 1999, Landstingslov nr. 12 af 29. oktober 1999 om fangst og jagt, §2 stk. 3. Available at: http://dk.nanoq.gl (Accessed 20 May 2020).

Gregersen, S. (1982). Earthquakes in Greenland. Bull. Geol. Soc. Denmark. 31, 11-27. doi: 10.1007/978-94-009-2311-9_20.

Hansen, S.G. (2018). An assessment of community based monitoring in the Arctic. MSc Thesis. Natural History Museum of Denmark, Faculty of Science, University of Copenhagen in cooperation with Snowchange and NORDECO. 90pp.

Hestnes, E., Bakkehøi, S. and Jaedike, C. (2016). Longyearbyen, Svalbard – vulnerability and risk management of an Arctic settlement under changing climate – a challenge to authorities and experts. In Proc. Of the International Snow Science Workshop 2016, Beckenridge.

Hicks, S. P., Verdon, J., Baptie, B., Luckett, R., Mildon, Z. K., and Gernon, T. (2019). A shallow earthquake swarm close to hydrocarbon activities: discriminating between natural and induced causes for the 2018–2019 Surrey, United Kingdom, Earthquake Sequence. *Seismol. Res. Lett.* 90, 2095–2110. doi: 10.1785/0220190125

Jeddi, Z, Voss, P.H., Sørensen, M.B., Danielsen, F., Dahl-Jensen, T., Larsen, T.B., Nielsen, G., Hansen, A., Jakobsen, P. & Frederiksen, P.O. (2020). Citizen Seismology in the Arctic. *Front. Earth Sci.* 8:139, DOI: http://doi.org/10.3389/feart.2020.00139

Johnson, Noor, Carolina Behe, Finn Danielsen, Eva M. Krümmel, Scot Nickels and Peter L. Pulsifer. 2016. *"Community-based monitoring and Indigenous knowledge in a changing Arctic: a review for the Sustaining Arctic Observing Networks."* Sustaining Arctic Observing Networks. Ottawa, ON: Inuit Circumpolar Council.

Johnson, Noor, Maryann Fidel, Finn Danielsen, Lisbeth Iversen, Michael K. Poulsen, Donna Hauser and Peter Pulsifer. 2018. *INTAROS Community-based Monitoring Experience Exchange Workshop Report Québec City, Québec.* ELOKA, Yukon River Inter-Tribal Watershed Council (YRITWC), University of Alaska Fairbanks, and INTAROS, Québec City, Québec.

Johnson, Noor. *et al.* n.d. Digital platforms for community-based monitoring. BioScience (in press)

Kaltenborn, B. P., Østreng, W., & Hovelsrud, G. K. (2020). Change will be the constant–future environmental policy and governance challenges in Svalbard. *Polar Geography*, *43*(1), 25-45, DOI: 10.1080/1088937X.2019.1679269

Lennert, A. E. (2017). A Millennium of Changing Environments in the Godthåbsfjord, bridging cultures of knowledge. PhD thesis. Ilisimatusarfik, Greenland Institute of Natural Resources and Climate Research Centre, 223 pp.

Manconi, A., Coviello, V., Galletti, M., and Seifert, R. (2018). Short communication: monitoring rock falls with the Raspberry Shake. *Earth Surf. Dyn.* 6, 1219–1227. doi: 10.5194/esurf-6-1219-2018

Meltofte, H. (ed.) (2013). Arctic Biodiversity Assessment. Status and trends in Arctic biodiversity. Akureyri, Iceland: CAFF.

Merkel, F.R. 2010. Evidence of recent population recovery in common eiders breeding in Western Greenland. *Journal of Wildlife Management* 74: 1869–1874.

Misund, O. A. (2017). Academia in Svalbard: an increasingly important role for research and education as tools for Norwegian policy. Polar Research, 36. doi: 10.1080/17518369.2017.1308131.

Mustonen, Tero, Vladimir Feodoroff, Pauliina Feodoroff, Aqqalu Olsen, Per Ole Fredriksen, Kaisu Mustonen, Finn Danielsen, Nette Levermann, Augusta Jeremiassen, Helle T. Christensen, *et al.* 2018. "Deepening Voices - eXchanging Knowledge of Monitoring Practices between Finland and Greenland". *SnowChange Cooperative, NORDECO, KNAPK, Greenland Institute of Natural Resources, and Greenland Ministry of Fisheries and Hunting.* Accessed December, 14 2019. http://www.snowchange.org/pages/wp-content/uploads/2018/01/gronlanti.pdf

Naalakkersuisut (2017). Presentation by Naalakkersuisut. UN Gen Ass. 16th Session of the Permanent Forum on Indig Issues, New York, April 2017; Video præs pisuna, 2.udg. 2018 https://vimeo.com/370860020

Nettles, M., and Ekström, G. (2010). Glacial earthquakes in Greenland and Antarctica. Annu. Rev. Earth Planet. Sci. 38, 467–491. doi:10.1146/annurev-earth-040809-152414.

Nielsen, J., Rosing-Asvid, A., Meire, L., & Nygaard, R. (2020). Widespread occurrence of pink salmon (Oncorhynchus gorbuscha) throughout Greenland coastal waters. *Journal of Fish Biology*. In press.

Nuttall, M. 2009. Living in a World of Movement: Human Resilience to Environmental Instability in Greenland. Pp. 292-326 in (S.A. Crate and M. Nuttall, Eds.) *Anthropology and Climate Change: From Encounters to Actions*. Left Coast Press, Walnut Creek, California.

Olsen, J., Hovelsrud, G. K., & Kaltenborn, B. P. (2020). Increasing shipping in the Arctic and local communities' engagement: A case from Longyearbyen on Svalbard. In *Arctic Marine Sustainability* (pp. 305-331). Springer, Cham.

Ottemöller, L., Voss, P. and Havskov, J. (2018). Seisan earthquake analysis software, User's manual Version 11, University of Bergen, p. 576.

Peterson, J. (1993). Observation and modeling of seismic background noise. US Geol. Surv. Tech. Rept. 93-322: 1–95.

Podolskiy, E.A., and Walter, F. (2016). Cryoseismology. Rev. Geophys. 54, 708–758, doi:10.1002/2016RG000526.

Post, E., Forchhammer, M.C., Bret-Harte, M.S., Callaghan, T.V., Christensen, T.R., Elberling, B., Fox, A.D. et al. 2009, Ecological dynamics across the Arctic associated with recent climate change. *Science* 325: 1355–1358.

Poulsen, Michael K., Lisbeth Iversen, Naja E. Mikkelsen and Finn Danielsen. 2019. *Cruise Expedition Monitoring Workshop and Dialogue-Seminar: On improving and expanding the environmental monitoring efforts of cruise ships in the Arctic*. Bergen: NORDECO, NERSC and INTAROS.

Riedlinger, D., and Berkes, F., 2001, Contributions of traditional knowledge to understanding climate change in the Canadian Arctic. Polar Record, 37, 315–328.

Sandven, S. et al. (2016). Integrated Arctic Observing System Project (INTAROS), Project Document. NERSC, Bergen.

Seafarers, S. D., Lavender, S., Beaugrand, G., Outram, N., Barlow, N., Crotty, D., ... & Kirby, R. (2017). Seafarer citizen scientist ocean transparency data as a resource for phytoplankton and climate research. *PloS one*, *12*(12).

Sejersen, F. 2003. Greenlands Nature Management (in Danish). *Grønlands Naturforvaltning*. Akademisk Forlag, Copenhagen, Denmark.

Simoniello, C., Jencks, J., Lauro, F. M., Loftis, J. D., Weslawski, J. M., Deja, K., ... & Kobara, S. (2019). Citizen-Science for the Future: Advisory Case Studies From Around the Globe. *Frontiers in Marine Science*, *6*, 225.

Svalbardposten. (2019). (https://svalbardposten.no/mange-forsker-pa-byen-var/19.11483). Svalbard Science Conference, to present what was discussed at this workshop. The workshop report is available at https://www.dropbox.com/s/d2c4lws507up74j/2019%20Cruise%20Expedition%20Monitoring%20Workshop%20in%20Svalbard%20Report.pdf?dl=0

Van Bets, L. K., Lamers, M. A., & van Tatenhove, J. P. (2017). Collective self-governance in a marine community: Expedition cruise tourism at Svalbard. *Journal of Sustainable Tourism*, *25*(11), 1583-1599.

Voss, P., Nielsen, G., Hansen, A., Jakobsen, P., Frederiksen, P.O., Danielsen, F., Sørensen, M., Jeddi, Z., Dahl-Jensen, T. & Larsen, T.B. (2019). Cryoseismological recordings in West-Greenland, from permanent and community based seismic stations. *American Geophysical Union*, Fall Meeting 2019, abstract #S23D-0663.

Weslawski, J.M. et al. manuscript in review, *Frontiers in Marine Science*, May 2020.

Annexes

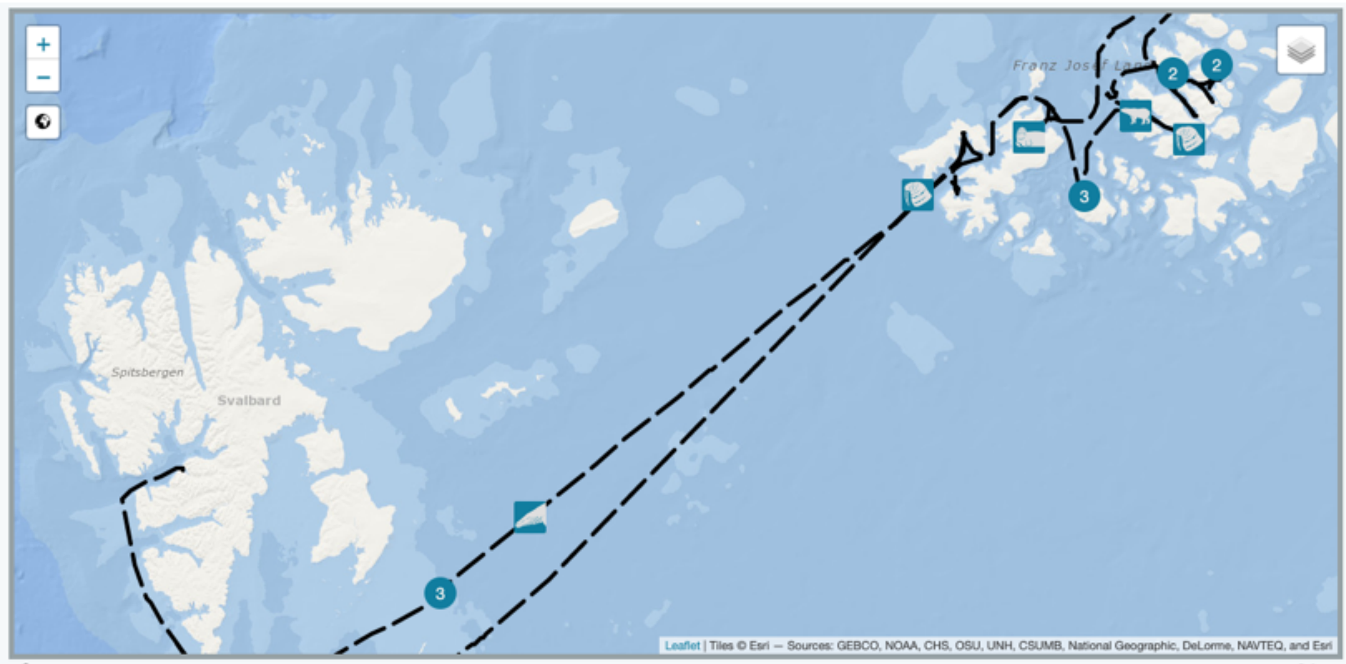
Annex 1. Systematic list of bird species, the number of checklists they appear on, and the largest record, from Svalbard (2002-2019) and Greenland (2005-2019), in the eBird database (extracted April-May 2020).

English name	Scientific name	No. of checklists Svalbard	No. of checklists Greenland	Largest record Svalbard	Largest record Greenland
Tundra Swan	*Cygnus columbianus*	2	0	1	0
Whooper Swan	*Cygnus*	2	0	1	0
Brant	*Branta bernicla*	141	7	130	28
Barnacle Goose	*Branta leucopsis*	978	57	1000	835
Canada Goose	*Branta canadensis*	3	52	4	100
Snow Goose	*Anser caerulescens*	1	5	1	30
Pink-footed Goose	*Anser brachyrhynchus*	589	57	1000	700
Graylag Goose	*Anser anser*	2	0	2	0
Greater White-fronted Goose	*Anser albifrons*	0	10	0	42
Long-tailed Duck	*Clangula hyemalis*	308	53	70	80
King Eider	*Somateria spectabilis*	256	40	250	700
Common Eider	*Somateria mollissima*	1430	153	796	200
Steller's Eider	*Polysticta stelleri*	1	0	1	0
Velvet Scoter	*Melanitta fusca*	2	0	4	0
Common Scoter	*Melanitta nigra*	4	0	3	0
Common Goldeneye	*Bucephala clangula*	1	0	2	0
Red-breasted Merganser	*Mergus serrator*	0	26	0	12
Ruddy Shelduck	*Tadorna ferruginea*	5	0	5	0
Tufted Duck	*Aythya fuligula*	13	0	4	0
Greater Scaup	*Aythya marila*	1	0	1	0
Northern Shoveler	*Anas clypeata*	1	0	2	0
Eurasian Wigeon	*Mareca penelope*	6	0	2	0
Mallard	*Anas platyrhynchos*	11	127	1	122
Northern Pintail	*Anas acuta*	19	2	2	3
Green-winged Teal	*Anas crecca*	43	0	14	0
Harlequin Duck	*Histrionicus histrionicus*	0	11	0	32
Horned Grebe	*Podiceps auritus*	1	0	1	0
Rock Ptarmigan	*Lagopus muta*	187	40	13	19
Common Swift	*Apus apus*	1	0	3	0
Sora	*Porzana carolina*	0	1	0	x
Red-throated Loon	*Gavia stellata*	475	87	11	8
Common Loon	*Gavia immer*	5	49	2	10
Arctic Loon	*Gavia arctica*	1	0	1	0
Yellow-billed Loon	*Gavia adamsii*	2	0	1	0
Northern Fulmar	*Fulmarus glacialis*	1741	444	20000	100000
Great Shearwater	*Ardenna gravis*	0	49	0	2500
Sooty Shearwater	*Ardenna grisea*	1	6	1	15
Northern Gannet	*Morus bassanus*	9	5	40	3
Great Cormorant	*Phalacrocorax carbo*	0	68	0	30
Eurasian Oystercatcher	*Haematopus ostralegus*	2	0	2	0
Black-bellied Plover	*Pluvialis squatarola*	2	2	2	1
European Golden-Plover	*Pluvialis apricaria*	11	2	3	6
Pacific Golden-Plover	*Pluvialis fulva*	1	0	1	0
Common Ringed Plover	*Charadrius hiaticula*	300	58	10	18

Whimbrel	*Numenius phaeopus*	4	0	1	0
Black-tailed Godwit	*Limosa limosa*	4	0	1	0
White-rumped Sandpiper	*Calidris fuscicollis*	0	2	0	1
Ruddy Turnstone	*Arenaria interpres*	82	45	20	22
Red Knot	*Calidris canutus*	9	18	50	30
Ruff	*Philomachus pugnax*	1	0	2	0
Purple Sandpiper	*Arenaria interpres*	944	52	260	20
Sanderling	*Calidris alba*	53	42	30	300
Dunlin	*Calidris alpina*	149	26	80	30
Baird's Sandpiper	*Calidris bairdii*	0	4	0	9
Little Stint	*Calidris minuta*	1	0	5	0
Buff-breasted Sandpiper	*Calidris subruficollis*	1	0	1	0
Pectoral Sandpiper	*Calidris melanotos*	3	0	1	0
Common Redshank	*Tringa totanus*	5	0	1	0
Red-necked Phalarope	*Phalaropus lobatus*	31	33	7	15
Red Phalarope	*Phalaropus fulicarius*	227	11	24	15
Atlantic Puffin	*Fratercula arctica*	631	30	400	100
Black Guillemot	*Cepphus grylle*	1618	184	250	12000
Razorbill	*Alca torda*	8	16	100	500
Dovekie	*Alle alle*	52	113	25000	12000
Common Murre	*Uria aalge*	34	13	25000	250
Thick-billed Murre	*Uria lomvia*	1216	87	60000	500
Long-tailed Jaeger	*Stercorarius longicaudus*	137	73	15	12
Parasitic Jaeger	*Stercorarius parasiticus*	1156	57	11	50
Pomarine Jaeger	*Stercorarius pomarinus*	149	64	60	20
Great Skua	*Stercorarius skua*	433	18	12	4
Black-legged Kittiwake	*Rissa tridactyla*	1880	327	25000	13673
Ivory Gull	*Pagophila eburnea*	332	39	60	50
Sabine's Gull	*Xema sabini*	44	8	7	5
Black-headed Gull	*Chroicocephalus ridibundus*	8	19	3	6
Ross's Gull	*Rhodostethia rosea*	0	4	0	6
Mew Gull	*Larus canus*	4	1	2	1
Lesser Black-backed Gull	*Larus fuscus*	17	100	14	15
Herring Gull	*Larus argentatus*	7	29	1	6
Iceland Gull	*Larus glaucoides*	30	296	2	1000
Glaucous Gull	*Larus hyperboreus*	1736	603	200	2000
Great Black-backed Gull	*Larus marinus*	88	230	10	200
Black-headed Gull	*Chroicocephalus ridibundus*	0	19	0	6
Arctic Tern	*Sterna paradisaea*	1372	80	600	1000
White-tailed Eagle	*Haliaeetus albicilla*	0	68	0	4
Short-eared Owl	*Asio flammeus*	1	0	1	0
Snowy Owl	*Bubo scandiacus*	0	6	0	1
Merlin	*Falco columbarius*	1	0	1	0
Gyrfalcon	*Falco rusticolus*	1	42	1	4
Peregrine Falcon	*Falco peregrinus*	0	44	0	20
Rook	*Corvus frugilegus*	0	1	0	1
Common Raven	*Corvus corax*	0	525	0	100
Hooded Crow	*Corvus cornix*	2	0	1	0
Horned Lark	*Eremophila alpestris*	0	3	0	1
Greater Whitethroat	*Sylvia communis*	1	0	1	0
Barn Swallow	*Hirundo rustica*	3	0	1	0
European Robin	*Erithacus rubecula*	1	0	1	0
Bluethroat	*Luscinia svecica*	1	0	1	0
Fieldfare	*Turdus pilaris*	0	1	0	6
Northern Wheatear	*Oenanthe oenanthe*	8	322	2	32
Redwing	*Turdus iliacus*	2	16	1	7
Meadow Pipit	*Anthus pratensis*	3	13	5	3

American Pipit	*Anthus rubescens*	0	5	0	3
White Wagtail	*Motacilla alba*	7	7	2	5
Brambling	*Fringilla montifringilla*	1	0	1	0
Common Redpoll	*Acanthis flammea*	1	197	2	80
Hoary Redpoll	*Acanthis hornemanni*	0	31	0	100
Lapland Longspur	*Calcarius lapponicus*	1	224	1	150
Snow Bunting	*Plectrophenax nivalis*	1135	441	50	100

Annex 2. An example of the marine mammal sightings made on one voyage from Svalbard to Franz Josef Land — GPS and sightings recorded with tablets funded by INTAROS. While the focus used to be on humpbacked whale, different marine mammals are now being recorded. The digits refer to number of encounters and these will show up when zooming in.



----------- END of DOCUMENT-----------

INTAROS

This report is made under the project
Integrated Arctic Observation System (INTAROS)
funded by the European Commission Horizon 2020 program
Grant Agreement no. 727890.

Project partners: