NordForsk

Arctic Climate Predictions: Pathways to Resilient, Sustainable Societies (ARCPATH)

Responsible Development of the Arctic: Opportunities and Challenges - Pathways to Action

Annual Reporting of Nordic Centres of Excellence

General information

Name of the Nordic Centre of Excellence:			Arctic Climate Predictions: Pathways to Resilient, Sustainable Societies (ARCPATH)
Name of the responsible leader of the NCoE:			Yongqi Gao and Astrid Ogilvie
Reporting period			2019-01-01 – 2019-12-31

1. PROGRESS AND RESEARCH RESULTS

(i) ***Unique research achievements***

Introduction

ARCPATH is an ambitious project designed specifically to integrate results derived from a variety of traditionally very different and separate academic disciplines. In this spirit, the project seeks to address the complex and interlinked issues of climate and socio-economic change occurring in the Arctic by focusing on near-term changes, with the overarching goal of fostering responsible and sustainable development. This requires the reconciliation of environmental, social, and economic demands. ARCPATH methods involve cutting-edge cross-disciplinary collaboration. The disciplines and knowledge systems include: climatology (global modelling; dynamic downscaling; historical climatology); environmental science; economics; oceanography and cryosphere research; marine and fisheries biology; fisheries management; anthropology; governance systems; human eco-dynamics; and local and indigenous knowledge. In the context of both global and Arctic climate change as well as social-ecological and socio-economic change ARCPATH focuses on developments in local communities in Iceland, Greenland and, to a lesser degree, northern Norway. During the past year, significant progress has been made in all these areas.

Changes in Arctic and Global Climate

This forms a very large component of ARCPATH and includes two work packages: WP2 *Improved Global Climate Prediction by Initialisation of Arctic Sea Ice and Sea-Surface Temperatures;* and WP3 *Arctic Climate Predictions and Regional Downscaling.* The major achievement of ARCPATH has been to improve the prediction of climate of the next few years at high latitudes, through the application of state-of-the-art climate models, new initialisation methods, and high-resolution regional climate models. This is to meet the demands of the societies and stakeholders in the ARCPATH focus regions for a more nuanced picture of how rapidly their climate will change up to 2030. Such information cannot be accurately provided by

currently available long-term climate projections. A detailed description of this work may be found in one of the ARCPATH overview publication by Yang *et al*. (2020).

To predict climate over the next few years models must account for both the effects of long-term climate change and shorter-term fluctuations of climate. While most studies focus on the former, we have focused on the latter and have based our predictions on contemporaneous realistic ocean and sea-ice conditions. In particular, the ocean and sea ice in the models are synchronized with the observed evolution of climate using data assimilation. This method, known as *initialisation*, is used to adjust the model to be close to the observed oceanic, sea-ice, and atmospheric conditions. In this way, we can use the model to predict the evolution of the ocean, sea ice, and climatic conditions over the next months and years. In ARCPATH we have developed, implemented and tested advanced initialisation methods with a focus on sea ice, which is of particular importance for Arctic regions. In the following discussion, a definition of the term "skill" may be helpful. In simple terms, in the fields of weather forecasting and climate prediction "skill" refers to a measure of the accuracy of a forecast or prediction. The baseline skill for ARCPATH is provided by earlier model versions and already existing predictions from the fifth phase of the Coupled Model Intercomparison Project (CMIP5) data archive. Analysis of these previous systems shows that the additional use of concurrent observations improves predictions beyond 4 years only in the North Atlantic subpolar gyre region (Christiansen *et al.,* 2020, in prep.). This agrees with previous findings, that, in particular, show little skill in predicting ocean conditions in the Nordic seas beyond several years (Langehaug *et al*. 2017).

ARCPATH uses two different global climate models known as EC-Earth3 and NorCPM. Both use sea-ice modules that have five different ice categories, instead of a single ice category as used in former model versions. This leads to a more realistic simulation of sea ice, but the increased complexity makes it technically more challenging to assimilate observed data. To solve these challenges in EC-Earth3 we have developed a more advanced (non-linear) method to link the observed and modelled sea-ice conditions, while NorCPM uses an advanced method known as the Ensemble Kalman filter (EnKF). We have implemented strongly-coupled data assimilations of ocean and sea ice in a fully-coupled system. This is a method that enables data in one model component (the ocean) to correct another component of the model (sea ice). We have been the first to show that this method provides more skilful climate predictions. *This is a significant research highlight and a crucial step towards more reliable future climate predictions in Arctic and sub-Arctic regions.* We have used these methods to assimilate observed sea-ice concentration, ocean water temperature, and ocean salinity.

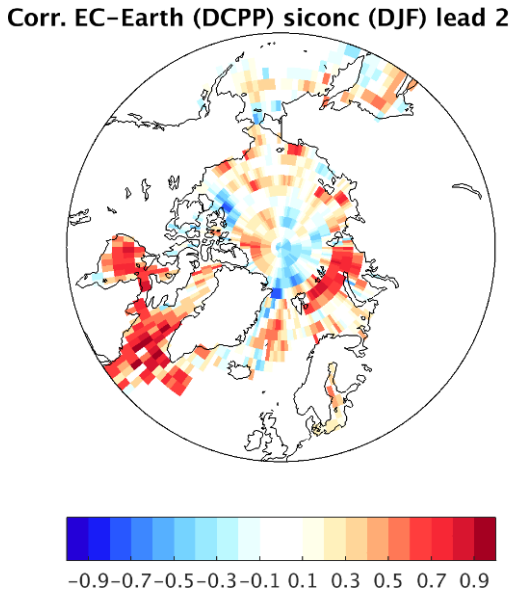

Figure 1. *Correlation between predictions for the multi-annual average winter (DJF) sea-ice concentration (mean of 2nd to 5th predicted winter) with the observed equivalents (taken from ORA-S5 ocean reanalysis.*

The following are further key achievements obtained in 2019. We have also completed decadal prediction experiments with our updated prediction systems. These are an ARCPATH-contribution to CMIP6, which provides the scientific basis for the upcoming IPCC-report. The focus of the analysis of the prediction skill has been on the ARCPATH region (Nordic Seas including coastal areas of Greenland, Iceland and Norway). In Fig. 1 it can be seen that the predictive skill of the sea-ice concentration is high along the ice edges in the North Atlantic sector of the Arctic, particularly in the Barents Sea and the Labrador Sea, but also the Greenland Sea shows some skill for sea-ice predictions on the 2-5 year time scale.

The standard model resolution of the NorCPM and EC-Earth prediction systems described above is around 100 km and may be considered to be coarse for climate-change adaptation purposes. Thus, in order to deliver appropriate climate information at the local scale to Work Packages 4 and 5 two strategies are being followed. The first is to perform high-resolution global climate predictions (25km resolution) and the second is to perform regional model simulations (around 10 km resolution) where predictions with ARCPATH global prediction models standard resolution are used as forcing data at the boundaries of a regional model. High resolution in climate models means that climate processes can be better resolved and variables can be provided at smaller spatial scales. This is especially important in regions where e.g., temperature or precipitation varies over small distances as in mountainous regions or along coastlines. The geographical locations that ARCPATH focuses on, specific coastal communities of Iceland, Greenland and Norway, are exactly such regions, requiring a high spatial resolution. During 2019, we dynamically downscaled simulations of the two global climate models EC-Earth and NorCPM with a high-resolution ocean model and a high-resolution atmosphere model over the target region of ARCPATH. The dynamical downscaling approach generally yields improved transports of ocean heat and volume across the Nordic Seas, compared to observational estimates. These improvements of the large-scale flows are important for the local climate in the Nordic Seas and along the coasts of Iceland, Greenland and Norway. Changes in the large-scale flows impact both mean and seasonal variability of surface parameters at a local scale (e.g., at selected ARCPATH locations). The regional ocean predictions of sea-surface temperature and sea-ice concentration resolve more local details (Fig. 2).

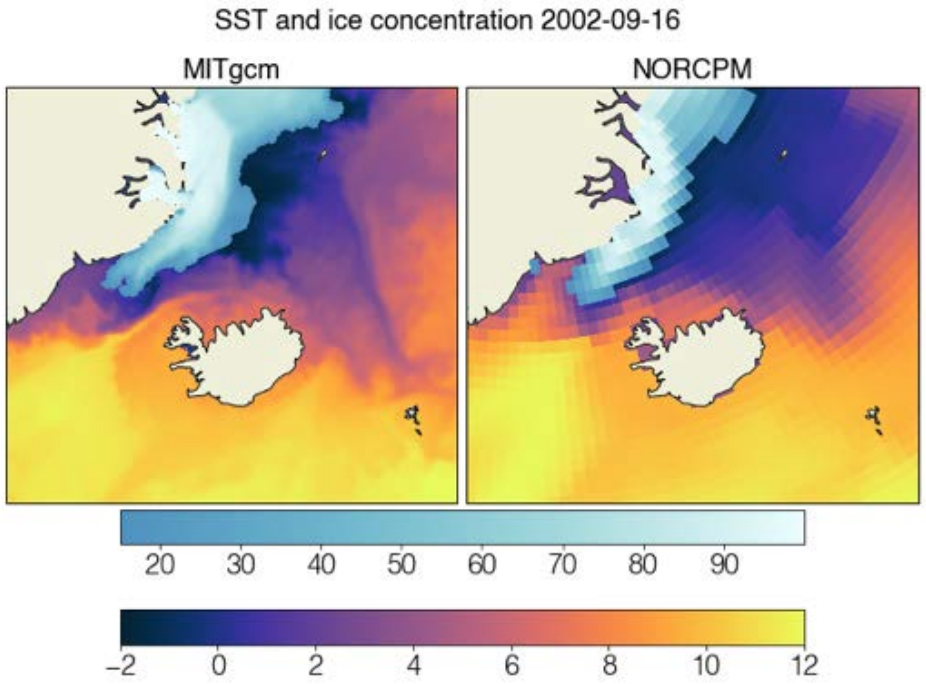

Figure 2. *Sea surface temperature in the high resolution model,* MITgcm *(left) and the coarse model,* NORCPM *(right)*

The regional atmosphere predictions indicate promising results for air temperature at specific locations in Iceland (Fig. 3). For Keflavík both the observed annual temperature and the year-to-year variations are well reproduced by the regional predictions for the period 2002-2011. For Húsavík, the year-to-year variations are well reproduced but the temperature in the regional model predictions is substantially too cold. Here, a so-called bias correction can help where the mean temperature difference between model and observations will be subtracted from the model and only the anomalies are compared to each other.

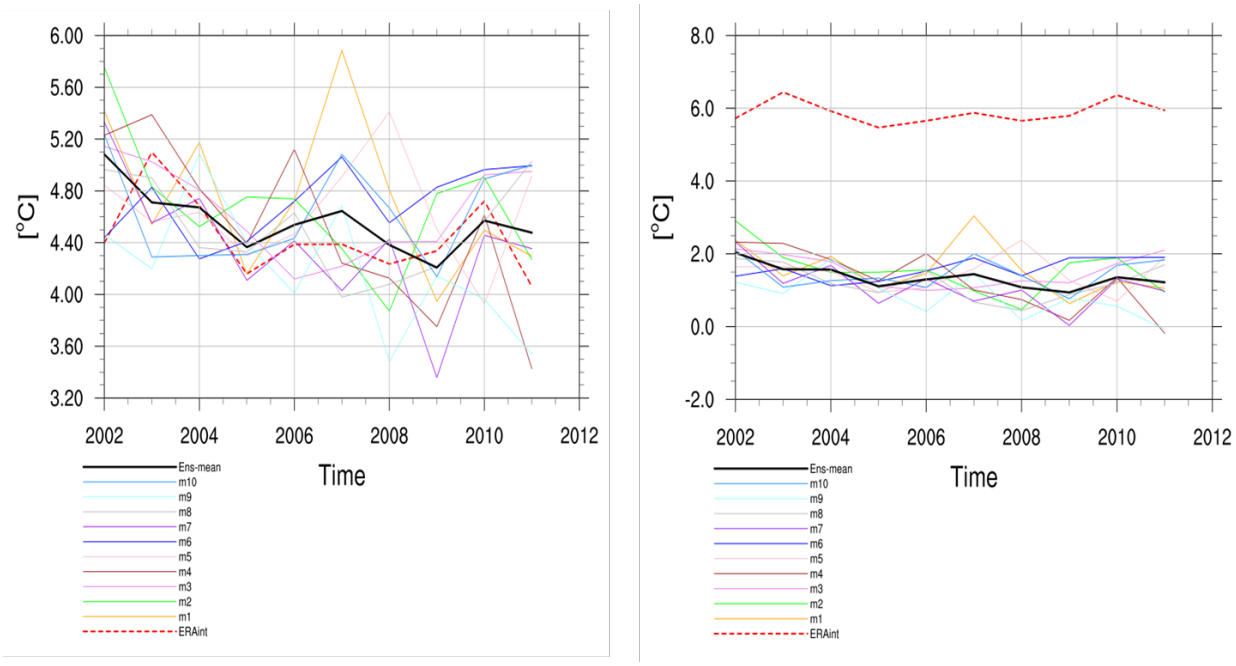

Figure 3. *Regional predictions of atmospheric temperature for Keflavik (left) and Húsavik (right).*

Forming a bridge between the past and the present, WP1 on *Climate, Environmental Change, and Human Eco-Dynamics* considers changes in climate, sea ice and social-ecological changes during the period ca. 1700 to 1900 with a particular focus on Iceland. Results regarding information on climatic variations have been discussed in earlier reports, as well as significant integration between the documentary climate records and systematic instrumental data. In particular, DMI and SAI have worked together to analyse Astrid Ogilvie's sea-ice index, a historical reconstruction of the amount of ice sighted from Iceland, measuring the amount of ice in the Greenland Sea. This integrative collaboration has been highlighted in previous reports and is given as an example of synthesis in King and Ogilvie (2020). This collaboration is ongoing and is described in Section 6. Also ongoing are analyses of historical storms and marine-mammal use.

Changes in Climate, Social-Ecological Systems, Marine Governance, Cetaceans and Tourism

The other two major work packages in ARCPATH consider several inter-related topics associated primarily with marine issues in the context of both climatic and social-ecological/socio-economic change. These are the closely interlinked: WP4 *Climate, Social-Ecological Systems, Cetaceans and Tourism* and WP5 *Marine Governance, Security and Rapid Social and Environmental Change.*

The main focus of WP4 is to analyse to what extent climate change, tourism, and industrial development puts cetaceans (and human societies dependent on their use) under increasing and even unsustainable pressure. Thus, there is an integrative focus on marine changes in the Arctic, with particular regard to linkages between environmental changes and variations in cetacean populations, and the growth of whale-watching tourism. Over the life of the project, social, economic and marine biological research and fieldwork has taken place in Iceland, Greenland, and the seas around Svalbard and northern Norway. In the case of Norway, the focus has been on the shifting relationships between migrating whales, fisheries, and tourism

in Andøya and Skervøya and how research can contribute to new knowledge and dialogue to develop responsible whale-watching practices.

For Iceland, research has included anthropological fieldwork in Húsavík and Norðurthing municipality documenting present and historical marine resource use. This has involved a focus on past and present marine-use activities, including whale hunting and the contemporary emphasis on whale-watching activities. An important focus, and relating directly to the ARCPATH attention to issues of sustainable development in its research communities, is collaboration with local authorities and stakeholders in terms of developing a Marine Protected Area. The aim is to better manage the multiple and growing use of the Skjálfandi Bay area adjacent to Húsavík which is where whale-watching currently takes place. A continuing emphasis has been on the blue whales that have increasingly been moving north and currently come into Skjálfandi Bay every summer in June. As noted in the 2018 ARCPATH report, we now have a photo-identification catalogue of 148 different individuals and it has been possible to make matches of the same blue whales sighted off Svalbard and from Húsavík. This possible shift may be linked to warming Arctic waters as noted in our earlier studies. Analyses based on this exciting work were published in 2019 (Madsen *et al*., 2019). Although the "staple" of the whale-watching industry is now the humpback whale, the novelty of the presence of blue whales is of great interest and the loss of these great creatures could negatively impact the Húsavík tourism industry. In addition to this, it may be noted that PhD student Olli Luisa has finished data collection and is currently analyzing the acoustic data for harbour porpoises and white-beaked dolphins and using these data for habitat modelling of these small cetaceans. Potential effects of climate change will be noted, thus strengthening links between WPs.

Another key focus in WP4 is on social-ecological systems, ecosystem services (ES) and cetaceans in the Arctic. The research objective is to reveal the multi-faceted social importance of cetaceans through the ecosystem services they provide and to analyse trade-offs between different ecosystem services derived from multiple uses of cetaceans. To address this task, as early ARCPATH reports indicated, the following five research questions have been posed: (i) What is available in terms of previous research on the topic?; (ii) How do people benefit from and value the ecosystem services provided by marine mammals in the Arctic?; (iii) What are the different social groups that co-produce and use the ES associated with marine mammals? How are the benefits distributed between social groups within communities?; (iv) How have marine mammals in the Arctic been managed to date and what are the trajectories for their future management?; What are the actors and institutions involved?; (v) How can the valuation of whale ecosystem services be used to inform decision-making processes and the governance of marine protected areas? Recent work has addressed all five research questions with fieldwork being conducted in our research locations, in particular in Húsavík but also in Andøya in Norway and western Greenland in Ilulissat, Aasiaat and Disko Island/Qeqertarsuaq. The work is conducted by an interdisciplinary team of biologists, economists and anthropologists, applying both quantitative and qualitative research methods. In 2019, six journal articles were produced with more to come in 2020 and 2021. Based on this work, a preliminary conclusion is that sophisticated pluralistic ecosystem services assessments, taking into consideration different local cultural contexts, can be useful for evaluating multiple uses of cetaceans and providing informed policy advice, including recommended actions to adapt to climate change. The specific contributions to the literature in 2019 and the major insights derived from this work are described below. First, a systematic literature review was conducted to evaluate the literature on Arctic ES, the first in the academic literature. Applying the Search, Appraisal, Synthesis and Analysis (SALSA) and snowballing methods and three selection criteria, 33 publications were sourced, including peer-reviewed articles, policy papers and scientific reports, and their content synthesized using the thematic analysis method. The results identify five key themes in the literature: (i) general discussions of Arctic ES; (ii) concepts of social-ecological systems; (iii) ES valuations; (iv) ES synergies and/or trade-offs; (v) integrating the ES perspective into management. The meta-synthesis of literature reveals that the ES conceptual tool is increasingly being applied in the Arctic context in all five themes; however, there remain large knowledge gaps concerning mapping, assessment, economic valuation, analysis of synergies, trade-offs and mechanisms behind them, and social effects of ES changes (Malinauskaite*, et al*., 2019).

Following these analyses, the next inquiry focussed specifically on the ecosystem services of cetaceans. This analysis delivered the first comprehensive evaluation of cetacean (whale) ecosystem services in the academic literature. The research provided a classification of whale ecosystem services using the established Common International Classification Ecosystem Services (CICES) framework. It illustrated what the appropriate methods (monetary and non-monetary) are for their valuation and showed the importance of value pluralism when considering the contributing role of ecosystem service valuations in decision-making, not the least in the context of indigenous communities (Cook *et al*., 2020). Embarking on assessing the value of whale ecosystem services, the first step completed in 2019 was a study on the willingness of Icelanders to pay for expansion of the whale sanctuary in Faxaflói Bay, Iceland (Malinauskaite, *et al*., 2020). The results suggest a significant recreational and conservation value of whales in Faxaflói bay. As one of the goals of assessing whale ecosystem services is to inform decision-making, further work in 2019 involved the first evaluation in the academic literature on the extent to which whale sanctuaries contribute to ecosystem-based management (EBM). A fifteen-criteria framework for evaluation was derived for marine EBM and applied with reference to six whale sanctuary case studies, including two Arctic whale sanctuaries in Faxaflói Bay, Iceland and Ninginganiq, Canada, and the International Whaling Commission's two designations in the Indian Ocean and Southern Ocean. The results reveal the generally very limited contribution of whale sanctuaries to marine EBM, unless planners are explicit in stating conservation goals and embedding these within management plans (Cook *et al*., 2019).

During ARCPATH fieldwork in Húsavík in August 2019, two Masters´ students and a PhD student were involved in data collection where data were collected on the socio-cultural value of whales. The students were able to use these data in their forthcoming theses in 2020 and 2021. ARCPATH was also linked to the EU-funded *Trans-Atlantic Marine Mammal* network in the learning process of developing marine-mammal protected areas. The network has asked for advice and input to its work with a synthesis report on climate change, marine resources and MPAs in the Arctic. To begin linking the importance of tourism and recreation (including whale watching) to the United Nations Sustainable Development Goals (SDG), using the case study of Iceland, Cook *et al.* (2019) advanced conceptual understanding of the synergies and trade-offs between a nation's tourism sector and performance across the 169 targets of the SDG. Empirical results were derived from four theme-based focus groups, consisting of expert participants, who were tasked with completing scoresheets concerning their perception of the extent of synergies and trade-offs for each target. A total of 32 synergies and 11 trade-offs were identified (Cook *et al*., 2019). Contributing to goals in WP4 and WP5 researchers explored the concept of systemic risk of cruise ship accidents in general and in the context of the Arctic and whether the insurance sector has a role to play in addressing cruise ship accidents. The findings suggest that if the worst-case scenario(s) materializes the likely consequences might be worse in the Arctic than in many other places around the globe. Arctic cruise ship challenges relate to weather conditions and ice, navigation and communication conditions, and lack of critical infrastructure (Jóhannsdóttir and Cook 2019).

A specific focus of WP5 has been a study of the Ittoqqortoormiit/Scoresbysund area of eastern Greenland. Fieldwork was concluded in January 2019, during which seasonal hunting areas and routes had been explored for 12 months. This research has meant working closely with local hunters who were supplied with handheld GPS equipment to collaborate in the documentation of exact hunting places and mapping of hunting expeditions. This was followed by archival work and statistical research. ARCPATH results of this fieldwork show that, compared to what was already known concerning the Ittoqqortoormiit hunting area over time, the hunting area today has drastically decreased over the past 15 years. So too has the number of occupational hunters, increasing the need both for new economic opportunities on the one hand, and for strengthening the position of the hunters in Ittoqqortoormiit. Many inhabitants are concerned about the lack of viable opportunities, and thus migrate to Denmark or western Greenland. Meanwhile, international oil companies are purchasing prospecting licenses. While such interest would spark concern in many indigenous communities in the Arctic, their activities are welcomed in Ittoqqortoormiit, since it is hoped the companies will create local employment opportunities, and so save the future viability of Ittoqqortoormiit.

Research has continued on the evaluation of the use of marine mammals (including polar bears) in this region of eastern Greenland. The ringed seal is by far the most stable resource in Ittoqqortoormiit; however, the polar bear and narwhal are the most contested. The narwhal, and what is known, and especially, not known, about the narwhal is a primary point of contention between hunters in Ittoqqortoormiit (and Tasiilaq) and biologists, government departments, and NAMMCO (the North Atlantic Marine Mammal Commission - see https://nammco.no/). We have explored these disparate knowledge forms (including the vast gaps in knowledge) and noted how the narwhal in eastern Greenland emerges from this contention as an animal that seems defined much more by economy and politics than what is scientifically known about it.

Furthermore, we have continued to work on a "youth and newcomers to fisheries" project related to governance issues. This research in Iceland with youth and newcomers to fishing included a focus on development with lumpfish fisheries and small boat-owners associations. This was a new project development in that these people could be the individuals who will be most impacted by the climate change predictions researched by WPs2-3, so a clearer link between work packages on climate and WP5 on governance has emerged. This work is nearing completion, with manuscript preparation underway. We have also conducted historical archival research on coastal communities in Iceland, specifically related to gender, fisheries and social justice.

PROJECT HIGHLIGHTS

Examples of project highlights include the publication of several significant papers and presentations. These are given in detail in tabular form. However, notable examples are: i) the papers by Wang *et al*. (2019), Kimmritz *et al*. (2019) and Shah *et al*. (2020) that show for the first time how initialisation of sea-surface temperatures, sea-ice concentration and thickness can improve the seasonal prediction of Arctic sea-ice extent. This is of particular value to the ARCPATH social-ecological studies in coastal communities, particularly in Greenland, where sea-ice changes are of extreme importance; ii) a paper by Ogilvie, commissioned by Nordregio (https://www.nordregio.org/) compares regional development and discusses both opportunities and challenges in the context of both climatic and social-ecological developments in ARCPATH study areas with a specific focus on issues of interest to ARCPATH such as whale-watching tourism and marine-mammal distribution (Ogilvie, 2019). In addition to these, it should be noted that ARCPATH has contributed 5 chapters to the volume to be edited by Douglas Nord entitled *Nordic Perspectives on the Responsible Development of the Arctic: Pathways to Action* on topics related to arctic and global climate change, field work in local communities, the value of ecosystem services and research synthesis. These chapters will form a significant contribution to highlighting quintessential ARCPATH research and the legacy of the project. As in previous years, ARCPATH has continued with involvement in a large number of prestigious presentations to conferences and meetings, as well as at outreach venues. These are listed in tabular form. Those specifically organised by ARCPATH are described in Section 4. Of the many invited and keynote conference presentations given by ARCPATH members just four are highlighted here: i) In February, Níels Einarsson gave a public lecture at the Department of Anthropology at the Autonomous University of Barcelona on fishing rights and financial capitalism in Iceland; ii) In May, Astrid Ogilvie presented the ARCPATH project at a panel showcasing Elizabeth Ogilvie´s film *Out of Ice* at a panel at the Università Ca' Foscari Venezia, (Venice, Italy) in association with the Venice Biennale; iii) Also in May, Yongqi Gao gave a presentation on Arctic warming, impacts, uncertainties, implications and prospects at the Arctic Circle China Forum held in Shanghai, China; iv) In September, Margaret Willson gave a keynote presentation for the International Maritime Organization on gender and maritime policy in a panel introduced by Guðni Th. Jóhannesson, the President of Iceland.

Research collaboration outside ARCPATH has been excellent. Only a few examples are mentioned as this continuing collaboration involves a large number of colleagues. The ongoing collaboration by the University of Iceland team with marine biologist Professor Joseph Roman, one of the world's leading conservation biologists, has been extremely successful, and has included augmenting their Ecosystem Services assessments and resulted in a further co-authored publication *Reflections on the ecosystem services of*

whales and valuing their contribution to human well-being by this team (Cook *et al*., 2020). In March 2019, in an effort to continue ARCPATH research beyond the life of the project, Astrid Ogilvie submitted a proposal to the US National Science Foundation entitled *Observations and Responses: Convergent Challenges in the Arctic and Subarctic (ORCCAS)* in collaboration with Roman. Other PIs included Níels Einarsson, Leslie King and Marianne Rasmussen from ARCPATH. The proposal was not funded but will form the basis for further proposals to continue ARCPATH-related work. The same may be said of the Belmont Forum application which included ARCPATH colleagues and which was led by Torben Koenigk entitled *Impacts of Climate Change on Ocean Systems and Society: Mitigation Pathways and Adaptation Options for Sustainability (OSMOSIS).*

Significant collaboration has also continued with the cultural anthropologist and author Dr Margaret Willson who provided crucial input to Chambers *et al.* (2020). See also Section 7. A number of other activities were undertaken to connect activities and experiences with stakeholders and institutes, including the CER-ARCTIC Centre for Arctic studies at the Autonomous University of Barcelona, in particular with colleagues Professor Françoise Breton and Dr Eduard Ariza. ***Internal collaboration within ARCPATH is excellent, and for those involved, is perhaps the most significant highlight of the project.***

A further highlight for this past year has also been successful fieldwork in all our planned research locations. After secondary data analysis of scholarly and popular publications, archival documents etc. and a focused ethnographic study of past subsistence strategies in Skjálfandi Bay, fieldwork was expanded to encompass three other coastal sites, vulnerable fishing villages, in northeast Iceland. Fieldwork also explored contemporary issues of coastal community adaptation to environmental change, governance systems and other socio-economic change. Research activities in 2019 included observations, surveys and multiple in-depth, semi-structured interviews. A new focus on western Greenland has brought novel insights into how convergent climate and social-ecological changes are impacting communities there. This work forms a major focus of Chambers *et al*. (2020).

(ii) ***Nordic added value the project brings 1) scientifically, 2) for the consortium 3) for stakeholders; ([To be duplicated in the on-line form***

As noted in the original ARCPATH application, the rapid and far-reaching changes in the Arctic will cause global effects and will certainly also impact Arctic Nordic regions, both directly and indirectly. It is thus essential that Nordic researchers combine their expertise in order to elucidate and understand these changes. ARCPATH has built a Nordic Centre of Excellence that capitalises on the long experience of established researchers, leading experts in their fields, as well as many young scientists who bring fresh insights and who will help to achieve long-term Nordic added value. The interdisciplinary and collaborative group that constitutes ARCPATH is generating knowledge of high importance for development in the Arctic region, actively creating a critical mass for success and expertise. Within ARCPATH, we facilitate close collaboration between disciplines such as physical sciences focusing on climate predictions, natural sciences focusing on ecology and behaviour of cetaceans and social sciences such as anthropology, economics, history and sociology focusing on the societal importance of cetaceans and the implications of climate change. The project therefore not only acknowledges that multiple disciplines are needed to identify responsible development paths for the Arctic region but is integrating them in the research. Combining the expertise of each institution is facilitating important synergies in knowledge creation, and it is clear that the research conducted could not be done by each partner institution on its own. ARCPATH is already drawing international talent to the Nordic region through recruitment of senior scholars, post-doctoral researchers, Masters and PhD students. DMI and SMHI developed a common new prediction system, which would not have been possible without the project. The transdisciplinary approach of ARCPATH, which by definition relies on active collaboration with stakeholders, is expected to deliver significant added value for stakeholders. Stakeholders participate in the research through design of research questions, qualitative (interviews) and quantitative (surveys) research methods and are expected to be able to rely on the results for better-informed decision-making. As an example, the project aims to deliver tangible knowledge for decision-makers contemplating the establishment of an MPA in Skjálfandi Bay in northern Iceland.

(iii) ***Description of the development of gender perspectives and an analysis of the importance of this development.***

ARCPATH places much emphasis on gender perspectives, and **the project has both a female and a male lead**. ARCPATH complies with the general objectives of NordForsk to increase recruitment of women and improve gender balance in projects. Climate science has traditionally been dominated by males; however, this project has an excellent gender balance and includes leading female scientists for both climate and social science spheres. ARCPATH involves a good gender balance among the team leaders (7 female and 7 male). Of the 7 project work packages, 4 are led or co-led by women (WP1 and WP6 are led by Dr Astrid Ogilvie, WP4 is led by Dr Marianne Rasmussen and WP 2 is co-led by Dr Shuting Yang. Dr Ogilvie is also the co-leader of WP5.

Issues of gender tend to be under-represented in the Arctic discourse, requiring greater emphasis on gendered dynamics in projects, research, community well-being and policy making, to mention but a few. In terms of current developments, through partnership between the Stefansson Arctic Institute (SAI) and the Arctic Council project Gender Equality in the Arctic (GEA) ARCPATH continues to address this imbalance and prejudices against women. A particularly noteworthy ARCPATH development is the dissemination and outreach initiative entitled *Seawomen of Iceland/The Arctic* described in the dissemination section.

(iv) ***Any difficulties encountered - e.g., in staffing, data analysis, etc. and how these are addressed***

ARCPATH has faced changes in key staff: one PI is on maternity leave, one researcher had a six-month's sick leave in 2019, and another left the ARCPATH partnership in January 2020. There are also delays beyond the control of the Consortium. A critical one for the climate predictions made by ARCPATH partners was the significantly delayed release of external forcing data for Coupled Model Intercomparison Project 6 (CMIP6). It was important to wait for these data because we wished to utilize the most accurate available external forcing and to contribute simulations to CMIP6 in support of the Intergovernmental Panel on Climate Change (IPCC) Assessment Report 6. The release of the forcing data required to perform experiments over the historical period was delayed by more than a year (from mid-2016 until October 2017). The forcing data required for performing future climate experiments for the period beyond 2014 was also delayed by more than a year (August 2017 to March 2019). These caused delays to the entire global modelling community efforts. Time was also required to implement the CMIP6 forcings into the ARCPATH climate models and to tune the ARCPATH climate models thereafter. The tuning process is particularly time intensive for the higher resolution climate model setups. The financial issues connected to the falling value of the Norwegian currency (NOK) since the ARCPATH budget was completed in February 2015, have continued. The Icelandic partners have repeatedly pointed out the fact that a more than 20 percent lowering in value of NOK has meant that, in effect, funding for a whole year is missing. The financing of this loss has fallen on the project partners who have bravely shouldered the deficit in an attempt to keep to project goals. To add to these difficulties, we are now facing the harsh reality of the COVID-19 economic crisis which will undoubtedly result in cuts of institute budgets. Financial issues have already hampered ARCPATH in developing collaboration with other NCoEs. In 2019 we did reach out to another NCoE but discovered that we would have to pay a collaborator for their time. We had no funds for this. (However, see the plans for a collaborative paper with REXSAC colleagues in Section 6 below.)

(v) ***Changes introduced or envisaged in the research objectives or design***

There are no changes in the research objectives.

(vi) ***Specific efforts undertaken to encourage synergistic collaboration across academic fields and disciplines both in the research and outreach efforts of your project?***

Plans have been made for two integrative multi-authored and interdisciplinary articles that will consist of input from all work packages as they are now sufficiently advanced to facilitate and demonstrate project integration. The first will be on developments on the Icelandic Arctic island of Grímsey, a place which has

significant cultural meaning for Iceland as an Arctic nation. This will be an interdisciplinary analysis of climate change and marine policy and how fisheries governance systems shape the fate of the depopulating island community and how young people and women are leaving the island. The paper will include recommendations for pathways for local development. A preliminary title for the paper is *Climate, Quotas and Community Resilience in an Arctic Island Community.* One important aspect of this study is the potential for impacts of dwindling sea ice and more unpredictable and precarious sea conditions on small-scale fishing which is a highly weather-sensitive activity.

The second paper will focus on developments in the whale-watching community of Húsavík, northern Iceland. For WP4 and 5 there has been significant data gathering, in particular on ecosystem services as well as historical (WP1) and contemporary marine resource use in the region. There will be a description of the historical, social and economic change during the past ca. 30 years, in particular regarding the introduction of whale watching in a fishing community, but also analysing the relationship of this change coupled with climatic and marine ecological change. The paper will also discuss the move towards a Marine Protected Area in the Bay of Skjálfandi, and the local and national discourse involved in the creation of such an arrangement. Moreover, we plan to include predictions for the next 10 years of climatic, oceanic and cetacean, ecosystem services and socioeconomic implications for the marine environment and community involved. A preliminary title for this second paper is *Climate Change and Coastal Adaptations in a Northern Icelandic Coastal Community: Marine Tourism and Sustainability in Transition.*

Although both papers have specific localities as points of departure they will also speak to wider and more general processes that are common to other northern societies that share features of marine adaptations, climate sensitivity and social and economic vulnerability in a globalized environment. We are planning to have finished both papers at least by the first half of 2021. This work will be led by Drs Einarsson, Ogilvie, Davíðsdóttir and Rasmussen in collaboration with other ARCPATH social and natural scientists including younger ARCPATH researchers. The authors of these papers will also include two seasoned arctic researchers who work closely with ARCPATH members. These are Professors Oran R. Young, international relations specialist, and Lawrence Hamilton, sociologist, who is also on ARCPATH's Scientific Advisory Board.

In past years DMI and SAI have worked together to analyze Astrid Ogilvie's sea-ice index, an historical reconstruction of the amount of ice sighted from Iceland, measuring the amount of ice in the Greenland Sea. We have featured this collaboration as a highly successful example of integration among natural and social science data (in past reports and in King and Ogilvie, 2020). The index covers the period 1600-2000 and is an important and independent source for information of past climate in Europe and the North Atlantic region. We have mainly focused on a comparison between this index and observations and other climate proxies. We found that, in the instrumental era, the Iceland sea-ice index correlates negatively with Northern Hemisphere mean-summer temperature and the summer North Atlantic Oscillation (NAO) index. It correlates positively with the reconstruction of the Fram Strait transport. For the full 400 years period there are only weak, or vanishing, correlations to NAO reconstructions, temperature sensitive proxies, and solar forcing. The low-frequency variability is mainly connected to changes in the frequency of ice-free years. This integrative work between WPs 1,2, and 3 will continue over the coming year with emphasis on the significance and robustness of the correlations with the intention of the results being described in a scientific paper.

A further multidisciplinary collaboration and paper is planned as the result of cooperation between the two NCoEs, ARCPATH and REXSAC. This will focus on comparative aspects of economic development in Nanortalik, southern Greenland, and Húsavík, northern Iceland. The two communities share economic characteristics and local aspirations towards multisectorial developments, with reconciliation of fisheries, tourism and industrial activities. These include a goldmine in Nanortalik and a new silicon metal smelter factory in Húsavík. In this joint project between two NCoEs we will be looking at the role of social capital and human development factors in shaping alternative and existing pathways for the communities involved, sharing research results, and empirical findings.

2. RESEARCHER MOBILITY

Gender, job title, organisation	Site of work	Purpose of visit	Duration of visit	Comments, output of the visit
Female, MS student, Huiling Zou, from Nansen-Zhu International Research Centre, China	Nansen Environmental and Remote Sensing Center, Norway	Collaboration	01.04-31.05.2019	Joint manuscript
Female, Professor, Brynhildur Daviðsdóttir, from University of Iceland	CER-Arctic at the Autonomous University Barcelona, Spain	Collaboration	26.04-24.05. 2019	Journal publication
Female, PhD student, Laura Malinauskaite University of Iceland	CER-Arctic Autonomous University Barcelona, Spain	Collaboration	Spring 2019	Journal publication
Female, Co-Leader, Astrid Ogilvie Stefansson Arctic Institute	INSTAAR University of Colorado	Collaboration	01.01.-31.03.and 20.10-31.12.2019.	Research proposals to NSF and NordForsk
Female, Marianne Rasmussen, University Iceland Research Centre Húsavík	University Southern Denmark	Collaboration	01.01-01.02.2019.1	manuscript preparation

	Female	Male
Number of visiting months by gender	13.6	0
Number of visiting researchers by gender	4	0

3. RESEARCHER TRAINING AND EDUCATION

Please list the number of PhD and Post Docs, both national and international is asked for.

How many PhDs and Post Docs are recruited from the Nordic countries and how many are recruited from the other countries?

	Female	Male
Number of Nordic PhD students recruited	0	1
Number of non-Nordic PhD students recruited	1	0
Number of Nordic Post Docs recruited	0	0
Number of non-Nordic Post Docs recruited	0	0

Specify the number of PhD degrees achieved at the Centre in the reporting period.

	Female	Male
Number of PhD degree achieved	0	0

Tom Barry (IS, M) began PhD work in 2019 at the University of Iceland. He is an ARCPATH project participant and employed as Executive Secretary, International Secretariat of the Conservation of Arctic Flora and Fauna (**CAFF**). Supervisors are prof. Brynhildur Davíðsdóttir, prof. Oran Young and Dr Níels Einarsson. PhD expected 2021.

Jade Nicole Zoghbi (Spain). PhD work starts in 2020 at the CER-ARCTIC Research Centre Autonomous Univ. of Barcelona. Supervisors prof. Eduard Ariza and Dr Níels Einarsson.

Master students:

Chloe Senglat (F). 2019. Decadal study of spatio-temporal seasonality of phytoplankton and Megaptera novaeangliae occurrence: a multi-tool-based approach. Master thesis.

Sofia Albrecht (F). 2019. Habitat Use of Minke Whales (*Balaenoptera Acutorostrata*) in Skjálfandi Bay Master thesis.

Marina Ortega Calvo (F). 2019. Harbor porpoise (Phocoena phocoena) spatiotemporal distribution in Skjálfandi bay (Iceland) using whale watching platforms (2009 – 2018). Master thesis.

Justin Brown (M). 2019. Abundance and distribution shifts of humpback whales (Megaptera novaeangliae) in Ísafjarðardjúp. Master thesis.

Kelly Morin (F). 2019. Investigating the Migratory Movement of Humpback Whales (Megaptera novaeangliae) between Husavik, Iceland and Greenland using Photo-identification. Master thesis.

Marc-Alexander Gose (M). 2019. Population genetic analyses of north-east Atlantic humpback whales (Megaptera novaeangliae) on the coast of Iceland. Master thesis.

Marianna Leoni (F). 2019. From Colonialism to Tourism: An Analysis of Cruise Ship Tourism in Ittoqqortoormiit, East Greenland. Master thesis. University of Iceland.

4. MEETINGS AND NETWORKING

In all years of the ARCPATH project Marianne Rasmussen has led a masters-level field course at the University of Iceland´s Research Centre in Húsavík on *Studying Marine Mammals in the Wild* on the fundamentals of a suite of field methodologies used in the study of free-ranging cetaceans. Students receive background lectures on the diverse assemblage of dolphins and whales off Húsavik, as well as learning the theory and practice of the use of each of the different cetacean research methodologies.

A session on "Climate Variability and Prediction in High Latitudes" was organised by Yongqi Gao and Torben Koenigk at the General Assembly of the European Geoscience Union (EGU) in April in Vienna. It included 31 contributions and had an audience of 150 persons. The session aimed for a better understanding and representation of the mechanisms that control high latitude climate variability and predictability in both hemispheres at sub-seasonal to multi-decadal time-scales in past, recent and future climates. Results from ARCPATH and other relevant EU H2020 projects were presented and synergies among ARCPATH and EU H2020 projects (e.g., Blue-Action and APPLICATE) were discussed. ARCPATH participants also included Pasha Karami from SMHI, Tian Tian, Shuting Yang from DMI, Madlen Kimmritz from NERSC and Fumiaki Ogawa from UiB. Abstracts for oral presentations and posters at the ARCPATH session may be found at: CL4.12/AS4.12/CR1.14/OS1.29 Climate Variability and Prediction in High Latitudes.

In collaboration with the Dartmouth College Institute of Arctic Studies the SAI organized the annual Vilhjálmur Stefansson Memorial Lecture as an ARCPATH-sponsored event at a special high-profile session at the Arctic Circle Assembly conference in Reykjavík. The Arctic Circle Assembly is a significant dissemination event with more than 2000 delegates iincluding scientists, government representatives and stakeholders from Arctic communities. The 2019 lecture, titled *An Arctic without End: Visions for our Planet in an Age of the Anthropocene* was presented by Dr Michael Bravo, of the University of Cambridge and Head of Circumpolar History and Public Policy Research at the Scott Polar Research Institute, as well as a member of the ARCPATH Scientific Advisory Board. Introductory speeches were also made by Dr Ólafur Ragnar Grímsson, chairman of the Arctic Circle and former President of Iceland, and Dr Níels Einarsson, Director of the Stefansson Arctic Institute. Also participating were ARCPATH PIs and previous presenters in the lecture series: Professors Leslie King, Brynhildur Davíðsdóttir, Astrid Ogilvie, and Oran R. Young. As well as being an ARCPATH event the lecture was a contribution to the Icelandic Chairmanship of the Arctic Council (AC) 2019-2021, with the AC Chair of Senior Arctic Officials attending. Other contributions to the Arctic Circle Assembly were a session organized by David Cook on *Marine Sustainability Challenges*. Presenters in this session were Catherine Chambers, Lára Jóhannsdóttir and Laura Malinauskaite.

The ARCPATH annual meeting was held 14-15 October at the Nordic House in Reykjavík, Iceland and organized by Astrid Ogilvie and Níels Einarsson of SAI. The chosen date was timed to dovetail with the Arctic Circle Assembly Conference. During the first day there were three invited keynote lectures: Professor Lawrence Hamilton (from ARCPATH´s advisory board) spoke on *Detecting Social Impacts from Environmental Change in the North* and ARCPATH collaborator Professor Margaret Willson spoke on *Gender Inequality at Sea in Iceland: Thoughts Toward Affecting Balance*. This was followed by a discussion on *ARCPATH, Environmental Change and Gender Equality.* The third guest lecture was by Professor Eduard Ariza on *ARCPATH and the CER-ARCTIC Institute.* Presentations by ARCPATH team members included updates on climate predictions as well as on social-ecological aspects such as the establishment of Marine

Protected Areas. The second day was devoted to discussing the Nordforsk NCoE SAB comments on the ARCPATH annual report and drafting a response. There were 24 delegates at the meeting.

5. INFRASTRUCTURE AND DATA POLICY

ARCPATH partners use their institutional or national infrastructures to compile climate and marine data for integrated analysis, assimilation into models and intercomparison with model projections. The same infrastructures are used to store the new datasets resulting from these analyses and modelling activities, in accordance with the data policies of their organisations. National infrastructures can be shared by the institutions of that country, e.g., Norwegian ARCPATH partners all have access to advanced HPC facilities in the National Infrastructure for Research Data (NIRD), and can store data in among others, NIRD and the Norwegian Marine Data Centre (NMDC). ARCPATH has, as part of its Open Science pilot, established a data catalogue that will offer open access to datasets generated in the project. The data catalogue is implemented using an open source data management system CKAN (Comprehensive Knowledge Archive Network), with metadata describing, among others, parameters, units, accuracy, data licenses and links for data access. Using CKAN core functionality we have set up the data catalogue and extended its metadata schema with the same elements as adopted for the H2020 INTAROS data catalogue. The CKAN core includes some plugins for visualisation of the datasets and its associated resources. In addition, we have installed a community plugin for presenting resources such as conference presentations, fact sheets, reports and journal papers in PDF format. This allows partners to accompany their datasets with additional resources that explain the context of the data or illustrate how the data have been used in e.g. scientific studies or assessments for authorities or local communities.

6. GOVERNANCE

ARCPATH is led by the Project Leader (Yongqi Gao) and Co-Leader (Astrid Ogilvie). Dr Kjetil Lygre acts as the project manager to facilitate daily management. Further to this, the wider management team of ARCPATH consists of the Project Leader, Co-Leader and four other work-package leaders. Members are drawn from three different Nordic countries (Norway, Sweden and Iceland) and the gender balance is also addressed. The management team is responsible for promoting and facilitating cooperation between the partners in the Centre. Where necessary, decisions regarding the Centre are taken according to a majority vote. An Advisory Board (AB) consisting of highly-qualified colleagues from both natural and social science disciplines has been set up for the Centre. The role of the AB is to provide advice and support to better achieve project goals. The AB consists of: Professor Cecilia Bitz, University of Washington, USA; Dr Burkhardt Rockel, the Helmholtz-Zentrum Geesthacht Institute for Coastal Research; Professor Lawrence C. Hamilton, Professor of Sociology at the University of New Hampshire, USA; and Professor Michael Bravo, Head of Circumpolar History and Public Policy Research at the Scott Polar Research Institute, and Fellow of Downing College, University of Cambridge.

7. OUTPUT AND DISSEMINATION OF RESEARCH

The ARCPATH project has disseminated its findings in the usual manner in scientific publications, in workshops, at conferences, and during fieldwork with stakeholders. An example of the latter is the presentation given by Laura Malinauskaite and David Cook on social and ecological change and ecosystem services of whales in the Arctic to the "World of Greenland" group in Ilulissat in August 2019. ARCPATH considers dissemination to the general public to be of great importance and one example of this is a presentation by Astrid Ogilvie in November 2019 to some 100 members of the Boulder chapter of the Rotary association on Arctic climate change and the ARCPATH project. Examples of invited keynote lectures are given in Section 1 on project highlights.

However, in order to spread information about ARCPATH's work to an even wider community, other, novel means of dissemination have been used. In particular, we have collaborated with artists and photographers who closely collaborate with local informants in their work. These include Kerry Koepping and Andrea Sparrow from the Arctic Arts Project that is dedicated to visually communicating the science of climate change (https://www.arcticartsproject.com/). It was fortuitous that Koepping and Sparrow were in Ilulissat and Qeqertarsuaq at the same time as Astrid Ogilvie in May 2019. Among other things, their work during this visit resulted in a telling summing up of the situation in Greenland in video form by Sparrow (see https://vimeo.com/347149339) in which the unusually warm temperatures we all were experiencing were highlighted. It is now established that the average annual land surface air temperature north of 60° N for October 2018-August 2019 was the second warmest since 1900 and it was the warmest year on record for Greenland (Arctic Report Card, 2019 https://arctic.noaa.gov/Report-Card).

Many of the discussions between ARCPATH researchers and local informants have focused on the melting of sea ice and glaciers. Collaboration between ARCPATH and the environmental artist, Elizabeth Ogilvie, has been ongoing since 2016 and has resulted in dissemination of ARCPATH findings through her film, *Out of Ice*, (available online at http://outofice.org.uk/book/the-film/) and her book of the same name (Ogilvie, E. 2017) where Astrid Ogilvie has a popular article on sea ice. Other, non-traditional methods of communication have also been used by ARCPATH, for example, Astrid Ogilvie has posted an account of local effects of sea-ice loss in Iceland and Labrador drawn partly from local knowledge (https://bifrostonline.org/sea-ice-stories-from-iceland-and-labrador/) on the online platform Bifröst (see https://bifrostonline.org/about/). This is an environmental humanities intervention on climate change led by educators and researchers from the Nordic Network for Interdisciplinary Environmental Studies (NIES) working in close collaboration with numerous partners from civil society. Such collaboration will continue in 2020 and, to this end, together with a graduate student, Astrid Ogilvie will submit a proposal to the University of Colorado to present a photographic exhibition on sea-ice loss.

Further to these, in 2019 we initiated a dissemination and outreach initiative entitled *Seawomen of Iceland/The Arctic*. This project, based on Dr Margaret Willson's work, will be led by the Stefansson Arctic Institute and the Institute of Arctic Studies at Dartmouth College. This international travelling media-based exhibit, which also includes a dedicated webpage, will present a graphic and engaging glimpse into the lives of strong and resilient women who for centuries have braved the Arctic waters in search of fish. The exhibit will be designed to offer a gender empowering and inspiring visual narrative of experiences of extraordinary women, bringing them to life through ethnographic and historical insights. The material will address gender impacts of marine management policies on participation and recruitment of women to fishing, a profession which has increasingly become a male-dominated activity in spite of obvious potential for gender equality measures. Gender equality in all aspects and sectors of society is a key policy issue in Nordic cooperation, including the Nordic Arctic but fishing has until now not been part of the central discourse. With this ARCPATH outreach activity we hope to redress this omission.

Peer-reviewed Publications / of which Open Access	21 / 18
Non-peer-reviewed Publications / of which Open Access	5 / 5
Reports	0
Invited conference presentations	9
Conference presentations, oral / poster	39 (30 / 9)
Number of appearances in media	5
Outreach and dissemination to the public	12

8. PROGRESS PLAN FOR THE COMING YEAR

During 2020, climate predictions with the high-resolution version of the global model EC-Earth will be performed. These high-resolution predictions will be compared to the low-resolution predictions from WP2 (which were finalized in 2019) and the regional downscaling of the low-resolution predictions (which have been provided by WP3 in 2019). The focus of the comparison will be on the temperature and salinity in the ocean around Iceland, Greenland and in the Nordic Seas, sea-ice conditions in the Arctic, and specifically along the east coast of Greenland, air temperature, precipitation and winds and the probability for occurrence of extremes. This comparison aims to answer two scientific questions: a) what is the advantage of high resolution for prediction skill?; and b) are low-resolution global predictions (followed by high-resolution regional downscalings) or high-resolution global predictions providing higher skill for the ARCPATH target regions? Solving these questions is of vital importance in order to develop the most reliable future prediction systems. These are essential for any further usage of prediction for socio-economic or ecosystem-related impact studies. The global prediction results will be uploaded to a global data storage facility and will thus be freely available for impact and adaptation studies world-wide. ARCPATH is thus making an essential contribution to European and world-wide climate services.

The results from the predictions will be specifically used to contribute to common analyses across all ARCPATH WPs targeting the main ARCPATH regions in Iceland and Greenland. 1. Based on observed linkages between changes in ocean temperature and position of whales, climate projections and predictions will help to project near future and potential far-future movements of whales. The consequences of potential whereabouts of whales for the local communities will be discussed (see also WP4 below). 2. Cooperation will continue among WP1, 3, 4 and 5 on an evaluation of changes in wind speeds, wind direction, wave behaviour, swell and storminess on the northern coast of Iceland and how such key parameters affect the opportunity for fishing operations and whale watching in these areas (relevant to the number of days where small fishing boats or tourist boats have to stay in the harbour due to risk, safety and weather conditions.

During 2020 analysis will take place of all data gathered through fieldwork activities in 2018 and 2019 in Iceland, Norway and Greenland. This includes transcription and coding of over 50 interviews from the three study sites and a statistical assessment of a preference valuation study in Húsavík, involving nearly 600 participants on which the first sociocultural valuation study of whale ecosystem services in the academic literature will be based, with either *Ecological Economics* or *Ecosystem Services* a likely publication outlet. This activity (in combination with other activities previously described) is expected to result in 5 journal publications published in either 2020 or 2021, a Masters thesis in 2020 and a PhD thesis in 2021. The articles

are as follows: (i) An assessment of consumer surplus of recreational whale watching in Reykjavík. This study reports on the results of a contingent valuation study conducted on the harbour in Reykjavik, which asked whale watching tourists, after returning from their trip, how much they would have been willing to pay in addition to their ticket price. This will contribute to the assessment of recreational value of whales; (ii) Sociocultural valuation of ecosystem services of whales in Skjálfandi Bay, Iceland. The socio-cultural valuation study examines the multiple ecosystem services (ES) provided by whales in the community context of Skjálfandi Bay, North Iceland, using a multi-method approach consisting of stakeholder mapping, semi-structured interviews, observations, and socio-cultural preference surveys to elicit stakeholders' attitudes to and perceptions of the contribution of ES provided by whales to human wellbeing. The study begins to address the research gap in non-monetary values associated with marine ecosystem services; (iii) Management of whales in the Arctic: lessons from Iceland, Greenland and Norway. The paper will explore the existing management strategies of whale resources in Iceland, Greenland, and Norway through case study comparison of the three ARCPATH locations. Stakeholder maps, semi-structured interviews, and qualitative data analysis are employed to elicit the current trends, challenges and opportunities in the governance of whale resources in these three countries and, more broadly, the rapidly changing Arctic marine ecosystems. A Masters thesis on *Socio-Cultural Valuation of Whales and Climate Change Adaptation in Húsavík, Iceland* will be produced by Sarah Seabrook Kendall.

Dr Janne Flora will work on Scoresbysund material for completion and submission of two journal articles relating to WP5 by July 2020 to two of the following journals: *Acta Borealia, Arctic Anthropology, Arctic, Ecological Anthropology, Etudes/Inuit/Studies*. Dr Willson will write up the results of archival research conducted in 2019, resulting in a book. She will also work on developing, finalizing and presenting Seawomen exhibit projects. Dr Chambers will complete two book chapters with co-authors from WP4 and WP5, and complete one manuscript on youth in coastal communities related to WP5. The year will also be spent on confirmation of earlier results from interviews by conducting new interviews with new informants (triangulation) and follow-up interviews with lumpfish fishers on governance issues. (Contingent on COVID-19 precautions and limitations.) Gunnarsson will write up the main findings from all previous stages of research. Topics for papers (2) are: Coastal Seascapes in 'Skjálfandi' Bay': Historical Mapping of Marine Resource Use, and Conflicting Perceptions, and Communities, Change, and the Challenges of Co-Management – Anthropological Perspective from Northeast Iceland. Simultaneously, before taking the last steps of the writing process, a knowledge transfer strategy will be developed, and the sites revisited to consult with local stakeholders. A third paper has also been outlined (based on an unpublished MPhil thesis presented at Cambridge University and supervised by Dr Michael Bravo) on the topic of the legacy of colonial encounters in East Greenland.

From 2020 eight ARCPATH and REXAC researchers will collaborate in a new major international research project with a Nordic lead, with the University of Uppsala as coordinator, working with researchers from 14 other Nordic and international institutes. This is a 3.5 year and 6.2 million Euros grant entitled JUSTNORTH – *Toward Just, Ethical and Sustainable Arctic Economies, Environments and Societies* (grant from Horizon 2020 call LC-CLA-07-2019: *The Changing Cryosphere: Uncertainties, Risks and Opportunities*). Here we will explore issues of Arctic development and the impacts of social, economic and environmental inequality. In addition, we will consider how current Arctic development is occurring alongside the adverse effects of climate change within an integrated global system deficient in mechanisms for incentivising just transitions toward sustainable development. The project will merge justice theories with sustainable development goals to enable EU policy coherence toward just transitions. This will be integrated with an investigation of the empirical realities of existing Arctic economic activities in 16 case studies using innovative research methodology, through conceptual, comparative, descriptive, correlation, policy, legal and interview-based analysis techniques. Though this, JUSTNORTH will offer policy, legal and regulatory pathway recommendations, by developing a framework from the reconciliation of the various ethics and value systems present in the Arctic, which can serve as a cornerstone for determining the viability of economic activities in the Arctic in line with the goals of sustainable development. Adhering to co-production of knowledge with stakeholders throughout, JUSTNORTH will bring insights from indigenous, local, business,

State and NGO perspectives of the social, economic and environmental complexities of the Arctic into the realm of policymaking for just sustainable development.

Further to this, Astrid Ogilvie is a PI on a newly-awarded project through the Belmont Forum entitled *Understanding Resilience and Long-Term Ecosystem Change in the High Arctic: Narrative-Based Analyses from Svalbard (SVALUR)*. This will continue the kind of work that ARCPATH has been engaged in, in a new High Arctic location. Several ARCPATH PIs, led by Astrid Ogilvie, have responded to the 2019 Nordforsk call on "Interdisciplinarity" with a pre-proposal for a project entitled: *Interdisciplinary Approaches to Convergent Challenges in the Arctic (INTERARC)*. If funded, this would be a significant contribution to continuing the work of ARCPATH and ensuring the legacy of the project.

9. SUCCESS STORIES AND UNEXPECTED RESULTS

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As regards our work in eastern Greenland, ARCPATH has found that as opposed to the findings of biologists who have specialized in narwhal in Greenland for decades, who argue that only one stock of narwhal frequent the Ittoqqortoormiit fjord, hunters in Ittoqqortoormiit argue that the fjord is frequented by at least two. Following the advice of the hunters, funds have finally been allocated by the Greenland government to study whether the narwhal that arrive in spring are indeed different from the summer stock, which is the one usually studied. If indeed there are different stocks, there will be grounds to re-count the entire East Greenland narwhal population, and remap their migration patterns. This may lead to significant and more locally adaptive hunting management.

WP5 research with youth and newcomers has led to unexpected project development with lumpfish fisheries and the small-boat owners association. Youth and small scale-fisheries could be the most impacted by the climate change predictions researched by WPs2-3, so a clearer link between work packages on climate and WP5 on governance has emerged.

The collaboration with photographers and artists with regard to dissemination has been an unexpected success story and is ongoing. A further success story is the new highly successful fieldwork conducted in western Greenland with the potential for further elucidating integration across work packages. ***Other success stories are found throughout this report, in particular in section 1.***

10. STAKEHOLDER INVOLVEMENT

Interdisciplinary research with a co-production of knowledge approach always involves stakeholders in one way or another and ARCPATH team members are experienced in this type of research. The project's resulting breadth and variety of community-based experience has provided a platform from which to analyse our own field practices with the goal of developing a potential guiding template to assist other researchers contending with methodological and ethical concerns of field and community-based research. Such analyses could prove vital in an era of changing expectations of scientific funding agencies that often call for increased community engagement in social-ecological systems research. Working closely with local informants, the project thus aims to produce findings that aid in the responsible and sustainable development of the Arctic. Stemming from its experience of a primarily community focus, this ARCPATH analysis can aid in developing local and international climate change adaptation measures and new pathways to sustainability throughout the Arctic and beyond. Increasingly, knowledge co-production and, in particular, the inclusion of local and traditional knowledge holders, is now an important determinant of

the success of co-management regimes that are being adopted as governance mechanisms in the Arctic. ARCPATH takes such issues extremely seriously. The project strives for interdisciplinarity, an approach that takes multidisciplinarity (research that simply draws on different disciplines) one step further to interdisciplinary research involving true integration. ARCPATH research and stakeholder involvement is described extensively in Chambers *et al*. (2020).

11. RELEVANCE FOR SOCIETY

Research into notions and practices of sustainability require a holistic and integrative perspective, not least taking into account the everyday lives and realities of humans and the societies in which they live. Our research brings such understanding and awareness to a field which has otherwise been dominated by the natural sciences and environmentalist groups. Also, employing integrated research methods of anthropology, history, gender studies and fisheries, ARCPATH research is breaking new ground in the roles of women in fisheries and sea work in rural communities of Iceland. Through outreach and synthesis, this project is expanding its impact to integrate other Northern and Arctic communities in addressing gender equality in maritime policy and practice.

The socio-economic effects that occurred in relation to the introduction of the individual transferable quota system have continued to play out at regional scales and are now coupled with the impacts of increasing privatization, globalization, automation and climate change. The participants in this study all expressed a desire for local histories to supplement the larger national narratives and many, also, expressed their concern that policy making today does not persistently protect and enhance the well-being of fishing communities in Iceland. It is important for the project to continue to work with the local stakeholders so that their voices are properly represented in the research.

2020 will witness the culmination of research activities in the ecosystem services part of WP4. This will be particularly evident in the forthcoming management publication and the conceptual insights gleaned from the development of the first ecosystem services cascade model in the context of whale resources. In addition, the sociocultural valuation of whale ecosystem services study will represent useful information to marine spatial planning in Iceland, e.g., the design of a Marine Protected Area in Skjálfandi Bay as well as provide insights into potential adaptive measures to changes in the provisioning of ecosystem services due to climate change.

12. LONG-TERM EFFECTS ON POLICY

A primary objective of ARCPATH is to ensure that our findings are communicated to all relevant researchers and communities and to inform the public. As ARCPATH has a major focus on climate prediction an important objective is to provide new insights and a better understanding of possible near-term future climate change. In conjunction with this, ARCPATH focuses on socio-economic changes and it is equally important to inform communities of our findings regarding these. In an ideal world, we may also influence policy, and even if this can be a difficult and delicate matter, we have considerable opportunities to introduce policy relevant findings to such important Arctic governance stakeholders as the Arctic Council (AC), not least now that Iceland has taken over the chairmanship for two years, commencing in May 2019. An example of policy outreach is that the University of Iceland´s Institute for

Economic Research reviewed the results of the ARCPATH contingent valuation study for their report written for the Icelandic government on the profitability of whaling in Iceland. Astrid Ogilvie was invited to present ARCPATH research findings to an open seminar organised by the Icelandic Ministry of Transport and Local Government (*Byggðastofnun*) in the presence of the Nordic Committee of Senior Officials for Regional Policy and Nordregio's Board of Directors at the University of Akureyri in September 2019.

13. PROGRAMME EVALUATION

The opportunity to undertake interdisciplinary and cross-disciplinary synthetic research encompassing a wide variety of individual disciplines in the service of sustainable development in the Arctic is a pleasure and a privilege. Liaison with the NordForsk secretariat has been satisfactory. Although very time consuming, it is felt that compiling the annual report is a valuable exercise in many ways; it is useful for team members to reflect on progress that has been made both within the different disciplines involved and regarding synthesis, and to take stock of the different outputs produced by the team in terms of publications, presentations and outreach. The SAB has commented that descriptions of the climate sections of ARCPATH have been difficult to follow. Every effort has been made to clarify these so that they can be followed by laypersons (without reducing these descriptions to the point of making little sense). The SAB has also commented that project integration and syntheses are not clear. We note the comment regarding synthesis for the 2018 report "the one concern here is that the report gives the appearance that the team is going to synthesize results when the study is near completion …". We do not understand how this impression has been given as, on the contrary, we constantly emphasize the importance of incorporating synthesis from the start of the project. As there was considerable discussion on synthesis in the 2018 annual report, it seems unnecessary to repeat this. However, every effort has been made to clarify project integration. The comment has also been made by the SAB that the report should be compiled and edited by one person. This in fact has always been the case (albeit with input from all team members). However, the difficult situation this year due to the complete disruption of normal academic life has called for a somewhat different approach with the ARCPATH team working hard to minimise the burden of writing and editing on just one person. It should be strongly emphasised that ARCPATH team members work extremely well together with very frequent communications. The production of this report has been no exception, with online meetings and numerous email/Skype/ and phone communication on a daily basis.

References given in the text may be found in list of project publications with the exception of these: Langehaug, H.R., Matei, D., Eldevik, T. *et al.* 2017. On model differences and skill in predicting sea surface temperature in the Nordic and Barents Seas. *Clim Dyn* **48,** 913–933 https://doi.org/10.1007/s00382-016-3118-3; Ogilvie, E. 2017. Out of Ice, Black Dog Publishing, London; Xie J, Counillon F, Bertino L. Impact of assimilating a merged sea-ice thickness from CryoSat-2 and SMOS in the Arctic reanalysis. *The Cryosphere*. 2018;12(11).

Annual Reporting of Nordic Centres of Excellence
Appendix 1.

14. STANDARD REPORT FORMAT OF ACADEMIC OUTPUT

Title:	Author(s)	Journal/Conference/Publisher	Publication type	Open Access
Future projections of cyclone activity in the Arctic for the 21st century from regional climate models (Arctic-CORDEX).	Akperov, M., O. Gutjahr, N. Koldunov, F. Boberg, M. Adakudlu, T. Koenigk et al.	Global and Planetary Change 182, https://doi.org/10.1016/j.gloplacha.2019.103005	Journal Article: Peer Reviewed	Yes
Arctic Ocean freshwater dynamics: Transient response to increasing river runoff and precipitation.	Brown, N. J., Nilsson, J., & Pemberton, P.	Journal of Geophysical Research: Oceans, 124, 5205–5219. https://doi.org/10.1029/2018JC014923	Journal Article: Peer Reviewed	Yes
Reflections on the ecosystem services of whales and valuing their contribution to human well-being.	Cook, D., Malinauskaite, L., Davíðsdóttir, B., Ögmundardóttir, H., Roman, J.	*Ocean and Coastal Management*, 105100. (2020).	Journal article (reviewed)	Yes https://www.journals.elsevier.com/ocean-and-coastal-management
Whale sanctuaries – an analysis of their contribution to marine ecosystem-based management.	Cook, D., Malinauskaite, L., Roman, J., Davíðsdóttir, B., Ögmundardóttir, H	*Ocean and Coastal Management*, 104987. (2019)	Journal article (reviewed)	Yes
Synergies and trade-offs in the Sustainable Development Goals – the case of the Icelandic tourism sector.	Cook, D., Saviolidis, N., Davíðsdóttir, B., Jóhannsdóttir, L., Ólafsson, S.	*Sustainability*, *11*(15), 4223. (2019)	Journal article (reviewed)	Yes
Analysis of Ensemble Mean Forecasts: The Blessings of High Dimensionality	Christiansen, B.	Monthly Weather Review, https://doi.org/10.1175/MWR-D-18-0211.1	Journal Article: Peer Reviewed	Yes
Tending to Destinations. Conceptualising tourism's transformative capacities.	Huijbens, E.H. and Jóhannesson, G.T.	*Tourist Studies*, 19,: 3, 279-294 (2019) https://doi.org/10.1177/1468797619832307	Journal article (Peer reviewed)	Yes
Systemic risk of maritime-related oil spills viewed from an Arctic and insurance perspective.	Jóhannsdóttir, L., Cook, D.	*Ocean and Coastal Management*, 104853. (2019).	Journal article (reviewed)	Yes

Impact of Ocean and Sea Ice Initialisation On Seasonal Prediction Skill in the Arctic	Kimmritz, M., F. Counillon, L. H. Smedsrud, I. Bethke, N. Keenlyside, F. Ogawa, and Y. Wang	Journal of Advances in Modeling Earth Systems, 2019, http://dx.doi.org/10.1029/2019MS001825	Journal Article Peer Reviewed	Yes
Towards normal Siberian winter temperature	Koenigk, T., R. Fuentes-Franco	International Journal of Climatology 2019, 1-8, doi:10.10002/joc.6099	Journal Article: Peer Reviewed	Yes
Willingness to pay for expansion of the whale sanctuary in Faxaflói Bay, Iceland: a contingent valuation study.	Malinauskaite, L., Cook, D., Davíðsdóttir, B., Ögmundardóttir, H., Roman, J.	*Ocean and Coastal Management*, 105026. (2020)	Journal article (reviewed)	Yes
Arctic ecosystem services: a literature review.	Malinauskaite, L., Cook, D., Davíðsdóttir, B., Ögmundardóttir, H, Roman, J.	*Ecosystem Services, 36*, 100898. (2019)	Journal article (reviewed)	Yes https://www.journals.elsevier.com/ecosystem-services
Barents-Kara sea ice and European winters in EC-Earth	Ringgaard, I. M., S. Yang, E. Kaas, J. Hesselbjerg Christensen	Climate Dynamics, http://link.springer.com/article/10.1007/s00382-020-05174-w	Journal Article: Peer Reviewed	Yes
The vulnerability of destinations to climate change: A comparative analysis of contextual socio-political factors.	Santos-Lacueva, R. Ariza, E. Romagosa, F. and Saladié, O.	Journal of Sustainable Tourism, DOI: 10.1080/09669582.2019.1607865	Journal article, Peer reviewed	Yes
Assimilation of semi-qualitative sea ice thickness data with the EnKF-SQ	Shah A., L. Bertino, F. Counillon, M. Gharamti, J. Xie	Tellus A: Dynamic Meteorology and Oceanography, 72:1, 1-15, DOI: 10.1080/16000870.2019.1697166	Journal Article: Peer Reviewed	Yes
A wider view of assessments of ecosystem service in coastal areas: the perspective of social-ecological complexity.	Solé, L. and Ariza, E.	Ecology and Society 24 (2):24.	Journal Article: Peer Reviewed	Yes
Seasonal predictions initialised by assimilating sea surface temperature observations with the EnKF	Wang Y, F Counillon, N Keenlyside, L Svendsen, S Gleixner, M Kimmritz, P Dai, Y Gao	Climate Dynamics, 2019, https://doi.org/10.1007/s00382-019-04897-9	Journal Article: Peer Reviewed	Yes
Opportunities and Challenges for Nordic Arctic and Subarctic Regions: A Case Study Approach	Ogilvie, A.E.J.	In: Nilsson, K., Karlsdóttir, A. and Refsgaard, K. (eds.) *Nordic Working Papers Opportunities and Challenges for Future Regional Development* - notes from an open seminar, with EK-R (Nordic Committee of Senior Officials for Regional Policy) and Nordregio's Board of Directors at University of Akureyri, Organised by Ministry of Transport and Local Government, Byggðastofnun and Nordregio, 12 September 2019, Nordisk ministerråd, Copenhagen. http://urn.kb.se/resolve?urn=urn:nbn:se:norden:org:diva-5802	Book chapter for Nordregio and Nordic Committee Handbook (peer reviewed).	Yes (Available online)

Tourism geography in and of the Anthropocene.	Gren, M. and Huijbens, E.H.	In D.K. Müller (Ed.) *A Research Agenda for Tourism Geographies*. Edward Elgar Publishers: Cheltenham, pp. 117-127. (2019)	Book article (Peer reviewed)	
Afterwords. Involving Earth – Tourism matters of concern.	Huijbens, E. H.	In M. Mostafanezhad and R. Norum (eds.). *Anthropocene Ecologies: Entanglements of Tourism, Nature and Imagination*. London: Routledge, pp. 187-189. (2019)	Book article (Peer reviewed)	
Recognized Seaworthy: Resistance and Transformation among Icelandic Fisher Women	Willson, M. and Tryggvadóttir, H.	In T. King et al. (Eds.), *At Home on the Waves*. Berghahn Books: New York (2019)	Book article (Peer reviewed)	
A comparison of marine ecosystem-based management concerning two Arctic whale sanctuaries: Faxaflói Bay and Ninginganiq.	Cook, D.	Proceedings of the Arctic Circle Assembly, Reykjavík, Iceland. (2019)	Conference proceedings	Yes
Whale sanctuaries – an analysis of their contribution to marine ecosystem-based management.	Cook, D., Malinauskaite, L.	Proceedings of the European Society of Ecological Economics Conference, Turku, Finland. (2019)	Conference proceedings	Yes
Sociocultural valuation of ecosystem services of whales in Skjálfandi Bay, Iceland.	Malinauskaite, L.	Proceedings of the Arctic Circle Assembly, Reykjavík, Iceland (2019).	Conference proceedings	Yes
Sociocultural valuation of ecosystem services of whales in Skjálfandi Bay, Iceland.	Malinauskaite, L., Cook, D.	Proceedings of the European Society of Ecological Economics Conference, Turku, Finland (2019).	Conference proceedings	Yes
Transformation of socio-ecological systems in the Artic: marine ecosystem change and management in coastal communities.	Malinauskaite, L., Cook, D.	Proceedings of the 2019 Mexico Conference on Earth System Governance, Oaxaca, Mexico (2019).	Conference proceedings	Yes
The Arctic Research Center of the Universitat Autònoma de Barcelona: First steps	Ariza, E. and Einarsson, N.	Invited presentation at the Lisbon International Arctic Conference and Workshop. Instituto Superior de Ciencias Sociais e Politicas. Universidade de Lisboa. 13th Dec.	Conference presentation - Invited	
Fishing rights and financial capitalism in Iceland: Fram common property to panaceas of private ownership	Einarsson, N.	Public lecture at the Dept. of Anthropology, Autonomous Univ. of Barcelona, 21. February 2019	Conference presentation - Invited	
Sustainable Arctic Tourism	Huijbens, E. H.	Panel at the Embassy of Iceland in London, Knightsbridge, England, 26th June 2019, organised by Polar Research and Policy Initiative.	Conference presentation - Invited	
Arctic Climate Predictions - Pathways to Resilient, Sustainable Societies (ARCPATH) and Historical Sea-Ice Records from Iceland	Ogilvie, A.E.J.	Panel on *Out of Ice* by Elizabeth Ogilvie and Rob Page, Ca'Dolfin: Università Ca' Foscari Venezia, Venice, Italy, 7 May 2019.	Conference presentation - Invited	
Arctic Climate Predictions - Pathways to Resilient, Sustainable Societies (ARCPATH)	Ogilvie, A.E.J.	DIS Travel Abroad Expedition to Ilulissat and Qeqertarsuaq, Ilulissat, Greenland, 27 May 2019.	Conference presentation - Invited	
Opportunities and Challenges for the Nordic Arctic Region	Ogilvie, A.E.J.	Opportunities and challenges for future regional development, Open seminar with EK-R (Nordic Committee of Senior Officials for	Conference presentation - Invited	

		Regional Policy) and Nordregio's Board of Directorsi, Organised by Ministry of Transport and Local Government, Byggdastofnun and Nordregio, University of Akureyri, 12 September 2019. Oral version of published paper.		
Arctic Climate Predictions: Pathways to Resilient, Sustainable Societies (ARCPATH): Some "fishy" aspects.	Ogilvie, A.E.J.	Re-visiting Fisheries History - Re-visiting Iceland, NAFHA Conference, University of Iceland, Reykjavík, Iceland, 17-18 October 2019.	Conference presentation - Invited	
Whale research in Iceland	Rasmussen, MH	Scandinavian Physiological Society, Harpa, Reykjavik, Iceland	Conference presentation - Invited	
All Aboard: Icelandic Women, Equality and Opportunity at Sea.	Willson, M.	International Maritime Organization conference in Reykjavík in September 26, 2019	Conference presentation – Invited	
Multiple goals in fisheries management: a case study of the Icelandic lumpfish fishery.	Chambers, C.	Arctic Frost Early Career researcher meeting and conference. October 16-18. Cedar Falls, Iowa (2019)	Conference presentation - oral	
Good Marine Governance: Social Aspects of Fisheries and Aquaculture.	Chambers, C.	Arctic Circle Assembly. October 10-12. Reykjavík. (2019).	Conference presentation - oral	
Equitable development of aquaculture in Iceland.	Chambers, C.	Regional Studies Association Research Network Sustainability in the Coastal Zone annual meeting, April 12-13. Limerick. Ireland.	Conference presentation - oral	
Ecosystem services of whales and their valuation in the Arctic.	Cook, D.	Unversity Centre of the Westfjords, Ísafjörður, Iceland. (2019)	Conference presentation (Oral)	Yes
Observations needed for enhancing the accuracy of reanalysis in polar regions.	Counillon, F	CLIVAR Global Synthesis and Observations Panel (10th session), Woodshole, February 5-6, 2019	Conference presentation - oral	
Enhancing the skill of dynamical climate prediction: Avenue explored with the NorCPM	Counillon, F., N. Keenlyside, S. Barthelemy, M. Kimmritz, Y. Wang, I. Bethke	Workshop: Big data, data assimilation, and uncertainty quantification, IHP, Paris, France, November 12-15, 2019	Conference presentation - oral	
Status of climate prediction and future challenges: a perspective from Norway	Counillon, F., N. Keenlyside, S. Barthelemy, M. Kimmritz, Y. Wang, I. Bethke	International Computing in the Atmospheric Sciences (iCAS) symposium, Stresa, Italia, September 8-9, 2019	Conference presentation - oral	
Analysis of decadal forecasts and other progress from DMI	Christiansen, B	ARCPATH annual meeting, Reykjavik, October 14-15, 2019	Conference presentation - oral	
Arctic Warming Impacts: Uncertainties, Implications and Prospects	Gao, Y	Workshop Presentation: Arctic Circle China Forum, May 10-11, 2019, Shanghai, China	Conference presentation - oral	
Arctic Climate Predictions: Pathways to Resilient, Sustainable Societies	Gao, Y	Workshop Presentation: Arctic Circle China Forum, May 10-11, 2019, Shanghai, China	Conference presentation - oral	

Arctic Climate Predictions: Pathways to Resilient, Sustainable Societies	Gao Y and Astrid E. Ogilvie	EGU General Assembly April 7-12, 2019, Vienna, Austria (Poster)	Conference presentation - Poster	Yes
Feasting on friends. Whales, puffins and tourism in Iceland.	Huijbens, E.H.	The 11th International Critical Management Studies Conference: Precarious Presents, Open Futures. The Open University, Milton Keynes, UK. 27th - 29th June 2019.	Conference presentation - oral	
Local Impacts of the 1783-84 Lagagígar Eruption in Iceland	Júlíusson, Á.D, Ogilvie, A.E.J., Demarée, G.R.	INQUA 2019, 25-31 July 2019, Dublin, Ireland.	Conference presentation - Oral	
Variability and global impact of Arctic sea ice and subpolar Gyre.	Karami M P, T Koenigk and Q Zhang	IUGG General Assembly 2019	Conference presentation - oral	
Recent developments of the Norwegian Climate Prediction Model for seasonal to decadal predictions	Kimmritz, M., F. Counillon, Y. Wang, I. Bethke, N. Keenlyside	Alfred-Wegener Institute seminar, Bremerhaven, Germany, June 20, 2019	Conference presentation - oral	
Assessing the contribution of ocean and sea ice initialization for seasonal prediction in the Arctic	Kimmritz, M., F. Counillon, Y. Wang, I. Bethke, N. Keenlyside	EGU General Assembly April 7-12, 2019, Vienna, Austria,	Conference presentation - oral	
Siberian cooling trends and the linkage to Arctic sea ice loss	Koenigk, T., R. Fuentes-Franco	EGU, Vienna 2019	Conference presentation - oral	
Decadal prediction efforts at SMHI – Ongoing work and future plans.	Kruschke, T. et al.	EC-Earth Meeting, ECMWF, Reading (UK), 21-23 May 2019	Conference presentation - oral	
The migratory movements of blue whales (Balaenoptera musculus) inhabiting Arctic and Sub-Arctic areas of the Northeast Atlantic.	Madsen, R, Rasmussen, MH, Olsen, MT, Lydersen, C, Vikingson, GA, Kovacs, KM, Palner, MKH Bertelsen, JL, Jacobsen, JS, Jørgensen, MS, Whittaker, M, Jacobsen, T, Scott, J and Iversen, MR	Dansk Havpattedyr Symposium, Odense, Denmark	Conference presentation - Oral	
Social-ecological change and ecosystem services of whales in the Arctic.	Malinauskaite, L	UAB CER ARCTIC, Barcelona (2019)	Conference presentation (Oral)	Yes
Ecosystem services of whales in the Arctic.	Malinauskaite, L, Cook, D.	World of Greenland, Ilulissat, Greenland. (2019).	Conference presentation (Oral)	Yes
Recent whale research at the University of Iceland's research center in Húsavík	Rasmussen, MH	Whale congress, Húsavík, Iceland	Conference presentation - Oral	
Contribution to the Transatlantic twinning of MPA managers to Iceland's future MPA management plan.	Rasmussen, MH	The 5th International Conference on Marine Mammal Protected Areas, Greece	Conference presentation - Oral	

Pacific contribution to decadal surface temperature trends during the 20th century	Svendsen, L.	EGU General Assembly April 7-12, 2019, Vienna, Austria	Conference presentation - oral	
Impact of anomaly initialization to the Arctic Ocean on decadal prediction using the EC-Earth3 model	Tian T, S Yang	EC-Earth Meeting, ECMWF, Reading (UK), 21-23 May 2019	Conference presentation - oral	
Sensitivity study on decadal prediction skill to Arctic sea ice initialization in an Earth system model with a multi-category sea ice module	Tian T, P Karami, S Yang, T Koenigk, W Klaus, F Massonnet, M Caian	EGU, Vienna 2019	Conference presentation - oral	
Empirical anisotropic multivariate localisation in the ensemble Kalman filter for Earth System models	Wang, Y, F. Counillon, S. Barthelemy	International EnKF workshop, Voss, Norway , June 3-5, 2019	Conference presentation - oral	
Norwegian Climate Prediction Model (NorCPM)	Wang, Y., F. Counillon, N. Keenlyside, M. Kimmritz, I. Bethke, H, Langehaug, F. Li, Y. Gao	China-Norway Third-pole-Arctic workshop, October 7-9, 2019, Bergen, Norway	Conference presentation - oral	
On the climate variability and the recent abrupt cooling over Subpolar North Atlantic	Yang, S, B Christiansen, S S.Drijfhout, J Mecking	Workshop on climate prediction in the Atlantic-Arctic sector, Bergen, June 5-7, 2019	Conference presentation - oral	
The recent abrupt cooling over Subpolar North Atlantic: Exploring the variability of the North Atlantic.	Yang, S, S S Drijfhout, J Mecking, B Christiansen	EGU, Vienna 2019	Conference presentation - oral	
On the decadal variability in the Subpolar North Atlantic and its recent abrupt cooling trend	Yang, S, B Christiansen, S S.Drijfhout, J Mecking	European Meteorological Society GA2019, 9 -13 September 2019, Copenhagen, Denmark	Conference presentation - oral	
Coupled climate modeling with focus on the Arctic	Yang, S	Danish Meteorological Society seminar, Nov. 6, 2019, Copenhagen, Denmark	Conference presentation - oral	
The recent abrupt cooling over North Atlantic: A forced signal or natural variability?	Yang, S, S S.Drijfhout, J Mecking, Bo Christiansen	CMIP6 Analysis Workshop, Barcelona, March 24-28, 2019	Conference presentation - Poster	
Factors influencing the atmospheric responses to Arctic sea ice reduction	Yang, S, I M Ringgaard, J Hesselbjerg Christensen, E Kaas	PAMIP workshop, Totnes, UK, June 24-27, 2019	Conference presentation - oral	
Habitat use of minke whales in Skjálfandi Bay, North Iceland	Albrecht, S and Rasmussen, MH	Worlds Marine Mammal conference, Barcelona, Spain.	Conference presentation - Poster	
Harbor porpoise (Phocoena phocoena) annual and seasonal distribution in Skjálfandi Bay, Iceland. Using opportunistic data over the past 10 years H(2009-2018) collected from whale watching platforms.	Calvo, MO and Rasmusen, MH	Worlds Marine Mammal conference, Barcelona, Spain.	Conference presentation - Poster.	
The actual and potential skill of dynamical decadal forecasts	Christiansen, B, Yang, S	EGU, Vienna 2019	Conference presentation - Poster	Yes

The skill of dynamical decadal forecasts with focus on the North Atlantic	Christiansen, B, S Yang	Workshop on climate prediction in the Atlantic-Arctic sector, Bergen, June 5-7, 2019	Conference presentation - Poster	
The role of Arctic sea ice initialisation in decadal climate prediction: linking the Arctic sea ice loss and the mid-latitude climates	Tian T, P Karami, S Yang, F Massonnet	Workshop on climate prediction in the Atlantic-Arctic sector, Bergen, June 5-7, 2019	Conference presentation - Poster	
Refinement methods of Arctic sea-ice initialization for improving the decadal prediction skill in the Arctic	Tian, T, P Karami, S Yang, T Koenigk, F Massonnet	European Meteorological Society GA2019, 9 -13 September 2019, Copenhagen, Denmark	Conference presentation - Poster	
Constraining ice thickness to improve Arctic sea ice prediction with the EC-Earth3 Climate Prediction model	Tian T, P Karami, S Yang, T Koenigk, F Massonnet	Polar CORDEX Meeting 2019, Copenhagen, Oct. 7-13, 2019	Conference presentation - Poster	
Geopolítica del deshielo en el Ártico: intereses globales e impactos locales	Breton, F.	Invited lecture at the Faculty of Economics and Business, Autonomous Univ. of Barcelona (UAB). 23rd of May.	Outreach to the public - Invited talk	
Árctic s'escalfa.	Breton, F.	Memorial Xavier Batalla. Invitation to the round table on the Artic. April 25th, at Col·legi de Periodistes de Catalunya, Barcelona. https://www.periodistes.cat/actualitat/noticies/lartic-sescalfa-la-geoestrategia-del-canvi-climatic	Outreach to the public - Roundtable with journalists	
Arctic landscapes transformations facing uncertainties of climate change and human management impacts. The emergence of new visions and values	Breton, F.	Lecture at a UAB Master course on "Intervenció i Gestió del Paisatge". May 22, MUHBA, Museu d'Historia de Barcelona.	Outreach to the public - Invited talk	
Árctic s'escalfa.	Breton, F.	Memorial Xavier Batalla. Invitation to the round table on the Artic. April 25th, at Col·legi de Periodistes de Catalunya, Barcelona. https://www.periodistes.cat/actualitat/noticies/lartic-sescalfa-la-geoestrategia-del-canvi-climatic	Outreach to the pubic- Roundtable with journalists	
Equitable governance in Icelandic fisheries and aquulture.	Chambers, C.	Dalhousie University Marine Affairs Lecture Series, Invited talk. November 19. (2019)	Outreach to the public - Invited	
Good Ocean Governance in Fisheries and Aquaculture: Examples from Iceland."	Chambers, C..	Lecture at the FFI/FAO summer school, Þingeyri, Iceland, Sep 9. (2019)	Outreach to the public - Invited	
Oceanography and Environmental Applications	Counillon, F	Data assimilation summer school, Timissoara, Romania, July 22nd-August 2nd, 2019	outreach to the public (course)	
Comments regarding a government bill with a clause on constitutional status of Icelandic natural resources (In Icelandic).	Einarsson, N.	30. June 2019 Available on government webpage https://samradsgatt.island.is/oll-mal/$Cases/Details/?id=1387	Outreach to the public (public service)	Yes
Tourism in Iceland. From boom to ?	Huijbens, E. H.	Invited speaker at the Umeå University, department of geography. Umeå, Sweden, 26th April 2019.	Outreach to the public (Invited)	

Arctic Climate Predictions - Pathways to Resilient, Sustainable Societies (ARCPATH)	Ogilvie, A.E.J.	Outreach presentation to Boulder Valley Rotary Club. 19 November 2019.	Outreach to the public (Invited)	
The "Frozen North": Key Arctic Explorers and the Search for the Northwest Passage	Ogilvie, A.E.J.	Outreach presentation to Sons of Norway, Boulder, Colorado, 22 November 2019.	Outreach to the public (Invited)	
Icelandic fisheries, society and gender through the life of a female fishing captain.	Willson, M.	Talk at Árni Magnússon Institute for Icelandic Studies in Reykjavík on November 1, 2019.	Outreach to the public - Invited	
The changing coastal Arctic	Breton, F.	Invited appearance on the programme on Catalunya Radio, "La nit dels ignorants" with Xavier Solà, May 5th. https://www.ccma.cat/catradio/alacarta/la-nit-dels-ignorants-3-0/francoise-breton-geografa-i-ambientalistacal-que-la-gent-es-comprometi-en-la-defensa-del-litoral/audio/1039263/?fbclid=IwAR2GFMnLmklfHz7pHJcEp0DCMD3emuT5jko0qz9wktZltCZ2PR6mbjVMvlk#.XNkC3FpM_y4.facebook	Media	
Extremväder i Europa måste tas på allvar	Koenigk, T.	ETC-nyheter: Klimat: https://www.etc.se/klimat/extremvader-i-europa-maste-tas-pa-allvar 27 June 2019	Media appearance	
Sörmland varmt som Paris år 2100	Koenigk, T.	30 July 2019: Eskilstuna Kuriren:	Media appearance	
Nya klimatscenarier med SMHI's globala klimatmodell	Koenigk., T. Döscher., R.	27 October, Swedish National TV. TV4	Media appearance	
Klimatförändringar i Svalbard	Koenigk, T.	January 2020, Swedish Radio - P1	Media appearance	

Photograph above shows calving icebergs from the Sermeq Kujalleq (Jakobshavn) glacier adjacent to the town of Ilulissat, western Greenland. Taken from the ferry on the return to Ilulissat from Qeqertarsuaq/Disko Island after fieldwork. Photograph: Astrid Ogilvie, May 2019.

Photograph on the cover page: ARCPATH team members on the occasion of the Nordforsk annual meeting held in Reykjavík, Iceland in May 2019. From left to right: Marianne Rasmussen, Leslie King, Astrid Ogilvie, Yongqi Gao and Kjetil Lygre. Photograph: Unknown ARCPATH colleague

NORDIC CENTRE OF EXCELLENCE: ARCPATH

https://ncoe-arcpath.org/

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