Results report 2020

ARCtic Marine Resources under Climate Change: Environmental, Socio-Economic Perspectives and Governance

In the Arctic, higher temperatures and retreating sea ice will redefine boundaries of biological life, ecological structure, and commercial and social opportunities. Complex interactions exist, from the physical impacts in terms of temperature, ocean currents, and sea ice, via biological and ecological adaptations in terms of changing habitats, growth, and species interactions, via social and business enterprises in terms of new fishing areas and trade routes, to governance implications in terms of pressure on existing agreements, surveillance, and commercial activity. ARC-Change will study some of these interlinkages while bringing together expertise from an array of disciplines and institutions.

ARC-Change has been successful and compared to ambitions set out in the project dissemination plan, outcomes on all levels are more than fulfilled. During the full project period, ARC-Change has contributed 11 scientific publications, including journal articles, book chapters, reports, doctoral thesis chapters, and a master's thesis. ARC-Change researchers have also written several popular articles and op-eds, and contributed presentations and poster presentations to scientific conferences, workshops, and meetings. Further, several papers are in progress, including a synthesis that draws on all parts of the project and frames it in a larger context of research on climate change in the Arctic region. A complete overview of project output, which we will keep updating for a while after the project period, is available at our homepage (goo.gl/rxMhHP).

The project consisted of four work packages. The first was concerned with environmental and ecological changes to the Arctic marine habitat. A main focus has been on the effect of warmer and fresher water on ideal spawning conditions for the Northeast Arctic cod stock. This stock, providing for the most valuable whitefish fishery in the world, has spawned along the Norwegian coast for more than a thousand years. The historical importance of cod along the Norwegian coast cannot be underestimated. But the future of the stock is uncertain. Recently published research (Sandø *et al.* 2020) establish likely scenarios where environmental conditions for spawning at traditional sites such as around the Lofoten archipelago are not present. These scenarios are based on downscaling of broadly accepted climate projections together with ecological knowledge of spawning and fish behavior.

Another focus in work package 1 was an analysis of sea ice variability and maritime activity around Svalbard. Sea ice represents danger for ship traffic and fishing, but is also a tourist attraction in itself. The analysis was carried out by Alexandra N. Stocker, master student at the University Centre of the Westfjords, Ísafjörður, Iceland, and presented in her master thesis (Stocker 2019). The work was supervised by ARC-Change researcher Angelika Renner. Alexandra considered data on sea ice concentrations and Automatic Identification System (AIS) data for ships for the period 2012 – 2018. Maritime activity has increased significantly over the years, both in terms of the number of vessels and of longer seasons of operation. Through interviews with boat captains, decision-makers, sea ice researchers, and industry representatives, additional insights into how sea ice variability affects maritime operations. An article based on Stocker's master thesis is currently in preparation.

The second work package has focused on various economic perspectives, in particular with regard to fisheries in Arctic and sub-arctic seas. A focus has been on productivity and efficiency in the Norwegian purse seine fishery in the Norwegian Sea. Several papers are written and are in various stages of preparation or review. A core finding is that productivity has at times been falling in the fishery, which is in contrast to expectations and predictions from economic theory. Reasons are many and varied, and the various papers delve into these in great detail. The work on the Norwegian purse sein fishery has been carried out in collaboration with the MESSAGE project (RCN project no. 255530).

Another focus has been on international agreements over pelagic fisheries in the North-East Atlantic. These fisheries are pursued by fleets from many nations, and agreements have been unstable and difficult to establish. The case is interesting because there are both ecological and economic interlinkages between different fish

stocks and fishing fleets. An analysis of the game theoretic properties of the situation indicate that while great economic gains could be realized if nations cooperated and coordinated their fleets, these gains would be very unevenly distributed. Further analysis suggests that with well-designed quota transfers between nations, Pareto improvements are possible for all participants, and with these, greatly improved overall economic performance. The analysis is presented in a manuscript that currently is in review. As with the work on the Norwegian purse seine fishery, this work was done in collaboration with the MESSAGE project.

A third focus in the second work package has been on theoretical modeling of seasonal features in the canonical fisheries model. Arctic fisheries are subject to significant and extreme seasonal variations, and the topic is of great importance for the project. This research has its roots in an earlier project (the EINSAM project, RCN project no. 234238) and has come to its provisional conclusion in the ARC-Change project. Three articles from this research are published, while three more are currently in preparation or review. The major innovation is a simple and intuitive modeling framework for periodic or seasonal features in the type of models that typically are used in fisheries economics to advice on management. The framework is presented in a recently published paper (Kvamsdal *et al.* 2020a), and the other papers demonstrate applications of this framework (Kvamsdal *et al.* 2017, Ni and Sandal 2019). The papers that are yet to be published further generalize the modeling approach and demonstrate applications beyond the original setting of fisheries management.

Finally, the second work package includes an analysis of ecosystem wealth in the Barents Sea (Kvamsdal *et al.* 2020b). The analysis is innovative in broadening the established method for this type of analysis to include both environmental uncertainty and natural capital stocks not directly utilized. The wealth represented by the main Barents Sea fisheries is estimated to NOK 50.6 billion (2016). The current management regime is predicted to maintain wealth near the present day level, while and alternative ecosystem-based management regime can increase wealth significantly (20-25%). Further, the analysis illustrate that evaluations based on market prices may undervalue natural capital. The line of research has inspired further work and will be carried on in the newly funded research project Production in the Barents Sea Fisheries: Across species and fisheries (RCN project no. 302197).

The third work package has been concerned with issues of governance and international law in and around the Arctic. Research has delved into the agreements and processes regarding fisheries in the central Arctic Ocean (Hoel 2017), a comparative study of status and management of Arctic and sub-arctic fisheries (Hoel 2018), and how Arctic fisheries management evolves (Hoel 2020). Also, ARC-Change researchers participated in the interdisciplinary workshop and contributed to the subsequent report *Ocean sustainability under global change*. The workshop and report was facilitated by Future Earth and the Institute of Marine Research in Bergen. Further, the main public outreach from ARC-Change, through op-eds and popular articles, originates from the third work package. Finally, presence of project partners in international, policy-oriented forums (FAO, Arctic Council meetings, Arctic Frontiers, and others) has been of great value to the project.

The fourth work package was devoted to project management and coordination, and to synthesize project results and emerging perspectives into one meaningful whole. A synthesis manuscript is in progress, with plans for submission to a peer-review scientific journal in the relative near future. The synthesis concludes with emerging perspectives on needs for more interdisciplinary research and governance development.

The project has organized and contributed to a string of meetings and conferences. The project organized, in collaboration with the REGIMES project (RCN project no. 257628), a special session on Arctic fisheries and climate change during the NAAFE (North American Association of Fisheries Economist) Forum 2017 in La Paz, Mexico. In collaboration with REGIMES, RAC-Arctic (funded by the Belmont Forum), and STOCKFISH (RCN project no. 257614), ARC-Change organized a stakeholder meeting in Tromsø in March 2019. The meeting was attended by industry representatives, policy makers, and researchers from the different projects, something that facilitated two-way communication about challenges and knowledge of Arctic marine resources and climate change. Meeting participants discussed questions regarding expectations on biological production, fish stock distributional changes, and research priorities. One moment that emerged from the

discussion was that while industry acknowledges climate change and observes various environmental changes, these are considered more as adaptation issues and less as fundamental problems or threats to their business.

ARC-Change initiated and organized the Bergen Fisheries Economics Workshop in 2017 and 2018, both held at the Norwegian School of Economics. These were informal meetings geared towards productive discussions of on-going research. While many of the participants were directly involved in ARC-Change, also other researchers attended the workshops that had – in agreement with the ARC-Change research agenda – an interdisciplinary profile. Topics included density-dependent growth and cannibalism in Northeast Arctic cod, different evaluation approaches for fishery policy, deregulation of gear selectivity in catch-share fisheries, Japanese fisheries policy, the Arctic fisheries agreement, and catch shares allocation.

The fourth work package also published six newsletters that reported on progress and activities in the project. These are all available from the project webpage (goo.gl/rxMhHP). Finally, below is the (current) list of ARC-Change publications. As already said, several manuscripts are yet in review or remain in various stages of preparation but will eventually contribute to the legacy of ARC-Change.

Publications

Bjørndal, M.T., Bjørndal, T. and Ekerhovd, N.-A. (2017). Økonomisk analyse av klippfisknæringa. *Økonomisk fiskeriforskning: Ledelse, marked, økonomi*, 1-13.

Ekerhovd, N.-A., and S.F. Kvamsdal (2017). Up the Ante on Bioeconomic Submodels of Marine Food Webs: A Data Assimilation-based Approach. *Ecological Economics* 131, 250-261 (doi: 10.1016/j.ecolecon.2016.09.005).

Hoel, A.H. (2017). The 5+5 process in Arctic fisheries. In: R.W. Corell, Jong Deog Kim, Yoon Hyung Kim, Oran R. Young (eds.), *The Arctic in World Affairs: A North Pacific Dialogue on Arctic Futures*, pp. 127-138.

Hoel, A.H. (2018). Northern Fisheries. In: Mark Nuttall, Torben R. Christensen, Martin Siegert (eds.), *The Routledge Handbook of the Polar Regions*.

Hoel, A.H. (2020). The evolving management of fisheries in the Arctic. In Scott, K. and D. VanderZwaag (eds.), *The Edward Elgar Research Handbook of Polar Law*. London: Edward Elgar.

Kvamsdal, S.F. (2019). Indexing of Technical Change in Aggregated Data. *Computational Economics* 53(3), 901-920 (doi: 10.1007/s10614-017-9771-8).

Kvamsdal, S.F., J.M. Maroto, M. Morán, L.K. Sandal (2017). A bridge between continuous and discrete-time bioeconomic models: Seasonality in fisheries. *Ecological Modelling* 364, 124-131 (doi: 10.1016/j.ecolmodel.2017.09.020).

Kvamsdal, S.F., J.M. Maroto, M. Moran, L.K. Sandal (2020a). Bioeconomic modeling of seasonal fisheries. *European Journal of Operational Research* 281(2), 332-340.

Kvamsdal, S.F., L.K. Sandal, D. Poudel (2020b). Ecosystem Wealth in the Barents Sea. *Ecological Economics*, forthcoming.

Ni, Y. and Sandal, L.K. (2019). Seasonality matters: A multi-season, multi-state dynamic optimization in fisheries. *European Journal of Operational Research* Vol. 275, no. 2, pp. 648-658.

Sandø, A.B., Johansen, G.O., Aglen, A., Stiansen, J.E. and Renner, A.H. (2020). Climate change and new potential spawning sites for Northeast Arctic cod. *Frontiers in Marine Science*, forthcoming.

Stocker, A.N. (2019). *Sea ice variability: implications for the development of maritime activities around Svalbard.* Master thesis, University of Akureyri, University Centre of the Westfjords, Iceland.

Main project partners: