

Invasive crab species in the Barents Sea: stakeholder perceptions, incentives, and path dependencies

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1. Introduction

New ecological and economic opportunities and challenges that arise as climate and human behavior shift socio-ecological systems will create new stakeholders in marine species. The perceptions of scientific stakeholders and economically impacted groups are likely to differ depending on many interwoven factors. These include missing or uncertain information on the impacts of change, and opportunity costs of human decision-making at the individual and group levels. This chapter focuses on the ongoing invasions of two different crab species in the Barents Sea: the red king crab (*Paralithodes camtschaticus*) and the snow crab (*Chionoecetes opilio*) in this context. Both species are benthic predatory feeders that are creating new ecosystem dynamics, but in different parts of the Barents. Though the two crabs are highly valued market commodities with internally competing complementary and substitutable demand characteristics, as well as some joint production possibilities in their native Pacific range fisheries, their invasion stories in the Barents are evolving quite differently.

The differences are important not only economically and ecologically, but also in terms of international agreements and other legal and institutional concerns. By addressing the two species together, we are better able to disentangle the causes and effects of various perceptions and path dependencies, as well as examine the incentives of Norwegian and Russian, and third-party international, primary and secondary stakeholders for valuable commercial species whose ecological and economic contexts are shifting with globalization and climate change.

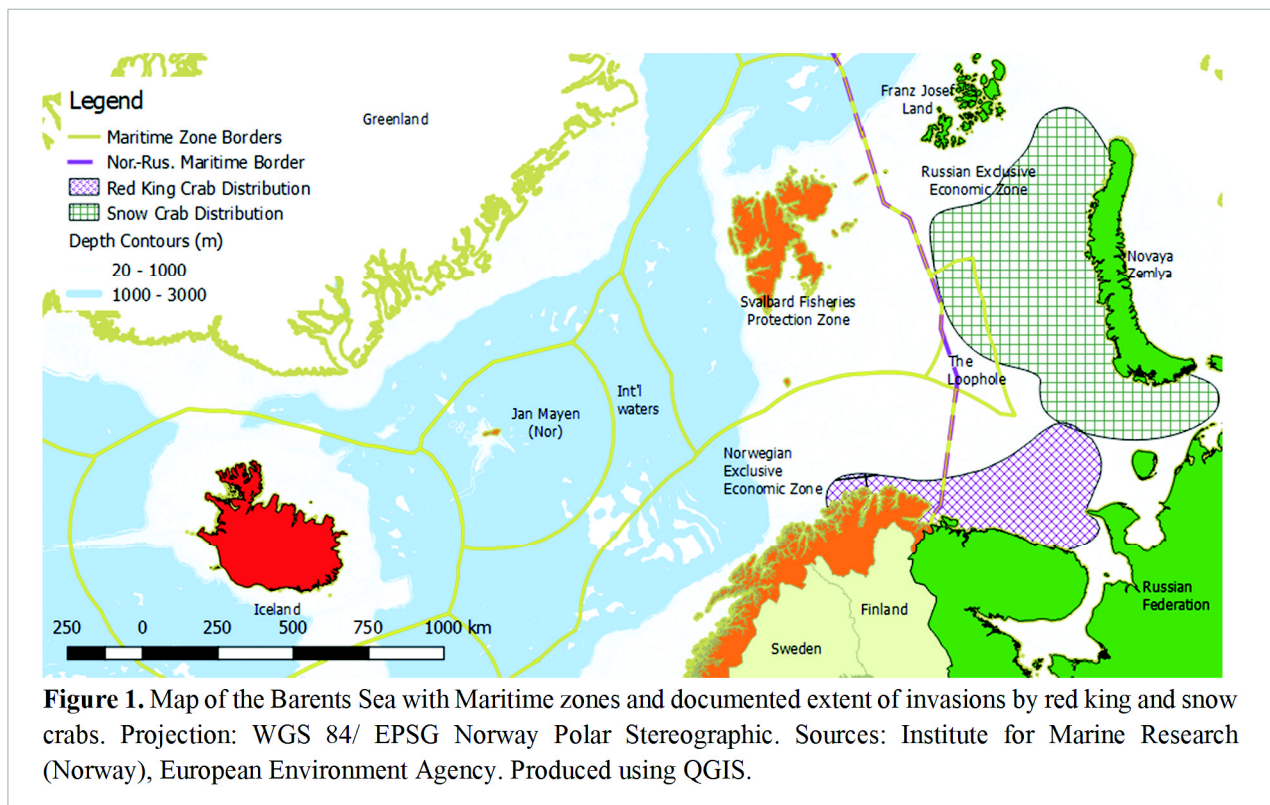
2. Overview of the invasions as fisheries

Both crab species are high value export commodities with little domestic market in the Barents Sea area, but high market value elsewhere. This renders them a rather different problem than the jellyfish and pufferfish invasions considered by Luisetti, Liu and Unal in this volume. The potential for long run profits is significant, but limited by substitutes and high transport costs, with particular challenges regarding quality concerns related to transport distances, particularly for live export. Global conditions for the species are in flux, and in several native habitat areas, population problems including poor recruitment and long term fishing pressures are resulting in management decisions to lower quotas and increase monitoring and enforcement of Illegal Unreported and Unregulated (IUU) fishing.

2.1. The Barents red king crab fisheries in brief

Soviet scientists successfully introduced the red king crab to the Barents in the 1960s. The scientists brought larvae, juveniles, and adults from Russian waters in the Far East to waters close to the Murmansk fjord with the hopes of creating new productive fishing grounds (Orlov and Ivanov, 1978). Russia neither consulted nor informed Norway about the introduction. Over the next decades, the crab spread west into Norwegian coastal waters; whereas in Russia it has mainly expanded in the southern offshore Barents (see Fig. 1). The crab became a nuisance species in Norway, where it interfered with coastal fishing (Sundet, 2014).

Meanwhile, Russian interests continued to want to develop the valuable stock. Norway and Russia have managed transboundary stock fisheries jointly since the 1970s under the joint Russian-Norwegian Fishing Commission, and the reasonable assumption was that the crab would also become jointly managed; this did not evolve as one might have expected. Attempts at cooperation were not able to resolve Norwegian stakeholder conflicts with other coastal fisheries and Russian crab interests simultaneously, particularly in light of the growing awareness of the potential losses from the invasion (WWF Norge, 2002).



Current management in the Barents is divided into four parts: a closed Russian coastal area, a large vessel Russian quota zone with a dominant vessel and quota owner accruing the rents, a small vessel coastal quota zone in Eastern Norway (East of 26°E and South of 71.30°N), and a small vessel open access zone in Western Norway. The Russian zones are purposed for long run stock conservation and profit; these benefits accrue mainly to the very few participants involved in the fishery. The eastern Norwegian quota zone encompasses both demand for profitable local enterprise and accommodation of the Russian fishery's longevity; the western Norwegian open access zone aims to prevent the further spread of the species to the west and south.

The fishing in Norway started with coastal fishers, primary stakeholders in the marine habitat, noticing the crabs as bycatch in their gear. This early warning from the Fisher's Ecological Knowledge (FEK) (Azzurro and Pita, in this volume) alerted the secondary management stakeholders to the ecosystem changes in the 1970s, but it took until the 1990s to persuade the Fisheries Directorate to start an experimental fishery. Part of the delay was due to Russia's persistent calls for allowing the crab stock to continue to grow.

In the first years of the fishery, crab-fishing rents accrued to those who were experiencing losses from the invasion. The crabs became sufficiently numerous, and cod fishing technology adapted sufficiently to reduce bycatch damages to gear so that ongoing bycatch costs no longer justified exclusive compensation measures, and that a second group of stakeholders was granted quota access. Any Norwegian with an eastern Finnmark address and a vessel less than 15 m in length could become part of the crab fishing fleet. This new set of stakeholders has evolved to include over 500 vessels. This policy has now turned contentious and efforts to reduce the ease of entry into the quota fishery are underway. This can be seen as a negotiation amongst Finnmarkians over who should count as a primary stakeholder in the crab. While open discussions are occurring, with official hearings to include stakeholders in quota decisions (Fiskeridirektoratet, 2017a), the fisheries managers have the ultimate responsibility to determine the balance amongst stakeholders. To date, they have chosen a middle path where barriers to entry in the form of other fish landings are required to obtain crab quota shares, but these barriers are not as high as quota holders who make their primary living from fishing might prefer.



Figure 2. A happy tourist with Red King Crab, Finnmark, Norway.

Currently, there is a third group of primary stakeholders evolving in red king crab tourism. Tourists in the north can now choose from a variety of interactions with the crab and industry, which generally include a photo opportunity with a king crab (Fig. 2) and a crab dinner.

These stakeholders also obtain quota for operations in the quota zone under a different set of regulations. Finally, a variety of mobile and fixed infrastructure investments for the export of live red king crab continue to develop.

In the western open access zone, fishers are also calling for expansion of the quota area further to the west to create increased and more long-lived rents from fishing; infrastructure decisions that affect community dynamics will follow any changes in the quota area. Implications are discussed in Section 4. This drive to expand the red king crab habitat is borne of the tremendous profitability of the crab and is progressing faster than the scientific knowledge that can identify whether the monetization of this particular invasive element of the ecosystem is a net gain or loss when ecosystem damages are measured and included. This is perhaps an extreme example of the discussion found in Katsanevakis (this volume).

While formal projections of the potential spread of the red king crab are not readily available, some scientific research suggests the species may tolerate quite cold and warm waters, perhaps in the range of -2 to 18° C, at least for some life stages. This can be interpreted as allowing, for example, a small probability of potential for spread as far south as the Mediterranean, where there has been at least one documented observation of a live crab (Faccia *et al.*, 2009). Though this documentation is published in a reputable journal and is expected to be a true case, there is growing concern that the speed with which information now travels from seaside to the unfiltered internet, as well as to scientists and professional journalists, may result in misrepresentation of threats, poor science, and subsequently damaging policy implementation. This is discussed at greater length in the overview of this volume as well as in the respective chapters of Unal, Azzurro and Hemida in this volume.

Other oceanographic considerations of currents and depths, as well as human movements of vessels and ballast water, will affect exactly where and when the species might arrive in new locations. The species was identified as spreading down the coast of Norway before the open access fishery and before stringent regulations on movement of the crab were put in place (Windsland, 2014; Windsland *et al.*, 2014).

Red king crab from Norway are increasingly being transported and sold live to high-end markets around the world. Russian red king crab are mainly processed and frozen on board the vessels for a broader world market. Actual and potential infrastructure impacts in Norway are considerably more significant than in Russia, and stakeholder entrenchment in the crab's continued fishability in the Barents is stronger. Russia can sell live crabs to Asian markets in better physical condition at lower cost by delivering directly from vessels in the Far East, so a similar set of investments for live crab in the Barents is unlikely.

2.2 *The Barents snow crab fisheries in brief*

The snow crab was first found in Russian Barents waters to the west of Novaya Zemlya in the mid-1990s and it arrived through unconfirmed means. Ballast water is the primary suspected pathway (Kuzmin *et al.*, 1998) though some scientists suggest that the invasion may be a range expansion from the Pacific Arctic (Konstantin Sokolov, 2015). The annual trawl survey conducted jointly by the Institute for Marine Research (IMR) and the N. M. Knipovich Polar Research Institute of Marine Fisheries and Oceanography (PINRO) has tracked the growth and spread of the incipient snow crab population. The agencies have recognized the potential for a profitable new enterprise (Hvingel and Sundet, 2014).

Norway and Russia did not open fisheries until after vessels began to use the International Loophole to fish crab in 2012. Norwegian and EU vessels quickly increased catch from a few tons to over 9 million rounds in the first four years of fishing in the Loophole (see Fig. 3). The bulk of this activity was carried out by fewer than a dozen vessels, and the crab has mainly been processed and frozen on board for export. The snow crab are less hardy, the fishery is further out to sea, and the snow crab have historically commanded lower market prices, than red king crab; to date there has been less investment in live export of crabs, though there is some interest and experimentation (Lorentzen *et al.*, 2018; Nofima, 2015, unk.)

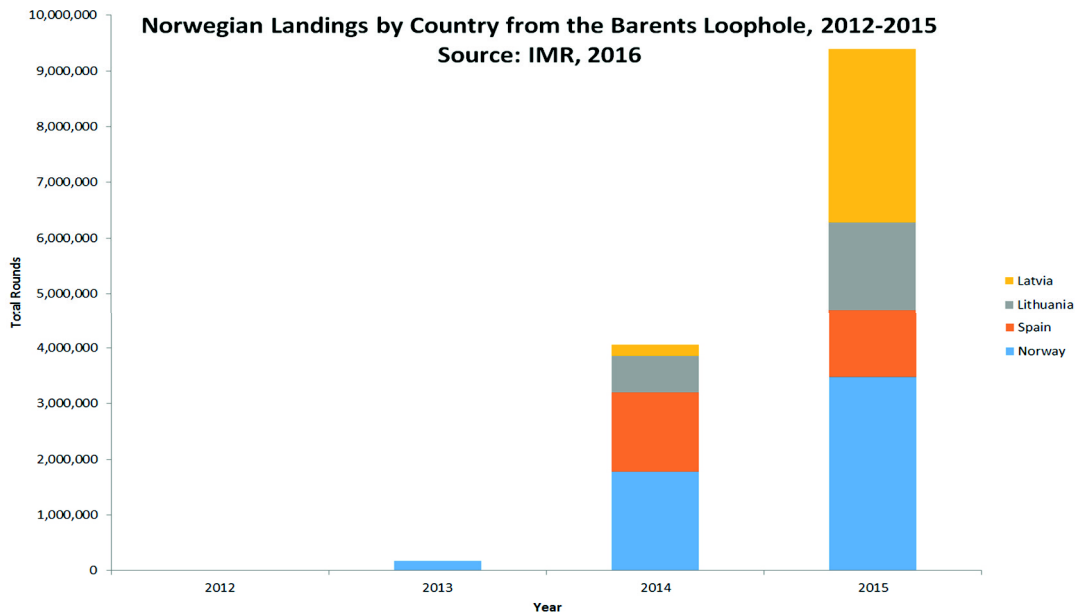


Figure 3. Snow Crab Landings in Norway showing rapid growth in the fishery, 2012-2015.

As with the case of the red king crab, Russians and Norwegians have failed to agree on joint management of the snow crab. They have cooperated, however, where their interests are directly aligned. In 2015, they agreed to a designation of the crab as a sedentary species, effectively transforming the snow crab from a fisheries resource whose international boundaries are determined by 200 nm Exclusive Economic Zone (EEZ) borders to a continental shelf resource (sedentary species) whose international boundaries are determined by the extent of the country's continental shelf. In the Barents, the shelf extends considerably beyond the EEZ boundaries, and the re-definition of the snow crab effectively closed the international waters of the Loophole to foreign vessels. Russia and Norway have subsequently excluded EU vessels from the Loophole (Kaiser *et al.*, 2018).

Adjacent and to the west of the Loophole is the Svalbard Fisheries Protection Zone; the crabs, and the fishers, have spread to this internationally managed commons. The designation of the snow crab as a sedentary species, however, has set up a conflict between Norway, upon whose continental shelf the Zone rests, and the rest of the world. Norway disagrees with the rest of the world (primarily EU vessels), who argue that the 1920s Svalbard treaty, which grants equal rights to commercial opportunities in the archipelago, applies to this part of the Continental Shelf. After the Norwegian arrest of an EU-licensed snow crab-fishing vessel, the conflict is proceeding through the Norwegian and European court systems. Resolution of the conflict has greater stakes than snow crab fishing as valuable rights to hydrocarbon and mineral exploration on the seabed floor surrounding Svalbard will be affected by the ultimate court decisions (Kaiser *et al.*, 2018).

3. Ecosystem Change and Incentives for Conservation

Both crab species are predatory benthic feeders. The baseline scientific understanding of the benthos in the Barents is historically limited; untangling the baseline from the impacts of the crab simultaneously adds extra uncertainty to the already highly uncertain ecosystem processes underway. While change is certainly occurring, there remain questions over a number of basic impacts of the invasion, including the range potential for expansion and the direction of impact on available benthic biomass for consumption by other trophic levels (Hansen, 2015; ICES, 2017; Jørgensen *et al.*, 2017; Jørgensen and Spiridonov, 2013). Magnitudes of impact on e.g. biodiversity loss are decidedly unknown. This renders it impossible to meaningfully apply such valuation methods as described in Luisetti and Katsanevakis, this volume. Ignoring these values because they do not create monetary or monetarizable value for primary stakeholders sets society up to overvalue the fishery compared to other ecosystem changes.

As marine invasions, a precautionary approach that limits the spread of the species would be sensible. Since the species are now established, the earliest opportunities to prevent change by preventing or eradicating the initial introductions have been foregone. Thus implementing the precautionary approach going forward requires active management and expenditures to maintain the status quo in areas that are not yet invaded, while the ‘wait and see’ approach accommodates irreversible change, at low current financial cost but unknown current and future ecological and ecosystem productivity costs. The current profitability of the crabs lends local stakeholder support to the latter policy, under which fisheries have been established.

According to Principle 15 of the Rio Declaration on Environment and Development:

“In order to protect the environment, the precautionary approach shall be widely applied by States according to their capabilities. Where there are threats of serious or irreversible damage, lack of full scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent environmental degradation”.

The 1960s red king crab introduction to the Barents pre-dates the UN Convention on Biological Diversity (1760 UNTS 79; 31 ILM 818 (1992)), to which both Norway and Russia are signatory parties; the unintentional nature of the later snow crab introduction also reduces liability to the countries. The preamble of the CBD reads, *“Where there is a threat of significant reduction or loss of biological diversity, lack of full scientific certainty should not be used as a reason for postponing measures to avoid or minimize such a threat.”*

While the entire treaty’s purpose is to foster national and international actions that increase biological conservation, specific portions address invasive species more directly. Article 8(h) of the treaty requires contracting parties to “Prevent the introduction of, control or eradicate those alien species which threaten ecosystems, habitats or species” – at least, “as far as possible and as appropriate.” Article 14(2) gives the Conference of the Parties (COP) power and responsibility to examine “liability and redress, including restoration and compensation” for damages to biological diversity imposed by one country on another. COP 6 Decision VI/23 (2002) provides non-binding guiding principles for the implementation of Article 8(h).

The compromises needed to secure agreements for multilateral treaties often reduce their scope for implementing forceful compliance mechanisms in return for higher acceptance and compliance, and

the non-binding nature and comprehensive scale of the Convention is no exception. The individual nation states maintain most responsibility for decision-making over invasive species management, and incentives to incur costs when most or all of the benefits will occur outside one's own borders are weak. Invasive species management is a classic weaker-link public good problem (Burnett, 2006), and the additional profit incentives of maintaining these species' populations make it even more unlikely that individual nations will take costly actions to stem the spread beyond their borders. This may also influence scientific inquiry. By maintaining ignorance about the origins of the snow crab invasion, liability cannot be assigned. The influence of direct and indirect regulation on both primary stakeholders, with the secondary stakeholders providing scientific understanding, needs integrated consideration to assess how marine species may affect human activities.

4. Management under uncertainty

There are a multitude of interacting economic, ecological, institutional, and climate uncertainties affecting the evolving crab invasions in the Barents Sea. Management choices, including delayed or no action, will define not only the outcomes for today's stakeholders but also the parameters under which future outcomes can and will come to fruition. Social scientific questions over what Barents Sea ecosystem productivity should consist of, who should gain from that productivity, and what human actions can do, and are doing to affect it explicitly underlie decisions about invasive species management in the region.

4.1 Stakeholder perceptions

Stakeholders involved in Barents Sea ecosystem productivity are many and diverse. Here we separate them into local, regional and global primary and secondary, social and non-social stakeholders, following the discussion in Maccarrone (this volume).

4.1.1 Local primary and secondary social stakeholders: Russia, Norway, and Svalbard

Norway and Russia have long considered the Barents Sea, and its resources, their joint domain. The maritime border between the two countries was only resolved in 2010; the delineation treaty addresses just two issues –how to split the fish and how to split the hydrocarbon resources ("Maritime Delimitation Treaty," 2010). Cooperation has been strong and resilient. The Norwegian and Russian peoples have not waged war against one another for centuries, choosing instead to settle peaceably, from earliest days of Norwegian inhabitation in the north through the treaty of Novgorod in 1326, the question of how they should each tax the Indigenous Sami residents, and how natural resources should be shared between the three groups (Pape, 2004).

In Norway relations between primary fisher stakeholders and secondary stakeholders, including scientists and regulators, exhibit high trust and open communication. The communities are small and heavily fishing-oriented; there is little need to 'get to know' the fishers and their perspectives as there is regular interaction between the stakeholder groups. In Russia, the primary fisher stakeholders are highly concentrated and are well integrated into the decision-making regime of the secondary stakeholders.

Fishery resources have been jointly managed under the Joint Russian-Norwegian Fisheries Commission since the mid-1970s, with less formal cooperation extending further back (Stokke and Hoel, 1991); the Commission has worked together to e.g. set quotas and gear regulations and to conduct stock assessments and research for all transboundary stocks, but now the red king crab is an exception. The appearance of the new species has created tensions that the Commission could not resolve; since

2007, the countries have agreed to manage the red king crabs separately, and the snow crab has similarly failed to come under joint management, in spite of initial expectations in 2012-2013 that it would become so.

The rest of the world has direct footholds through Svalbard's 1920 open access treaty and through the international waters of the Loophole, though the Svalbard archipelago is under Norwegian sovereignty. The treaty may be considered a puzzle piece in the many centuries of nominal peace between the two countries and a unique solution to a complicated case in the long historical progression towards seemingly more permanent borders, rights, and the closing of global commons.

The North-east Atlantic Fisheries Commission, the Regional Fisheries Management Organization (RFMO), works in concert with the countries to prevent overfishing in the Loophole. The snow crab invasion is causing conflict within and beyond the RFMO because mutually beneficial trades such as those that have been negotiated in the past cannot work when the institutional framework of future rights, and the returns to non-social, future generation primary stakeholders, is up for grabs. Trades in fishing quota have traditionally been possible in a static institutional analysis of the returns to fishing the international waters of the RFMO, such as those that resolved the Barents Sea 'cod wars' of the 1990s (Churchill, 1999). These trades are less attractive when historical behavior in the fishery or related fisheries may determine legal outcomes for future rights now contested in court.

As the resources of interest – and the ecosystem services they depend upon – change over time, we are reminded now that institutions too will continue to change as well, and that the forces at work on these incentives may be strongly driven by economic influences that may be multidimensional, crossing species, ecosystems, industrial, sectoral, geographical, and political lines.

4.1.2 Local primary stakeholders: ecosystem consumers

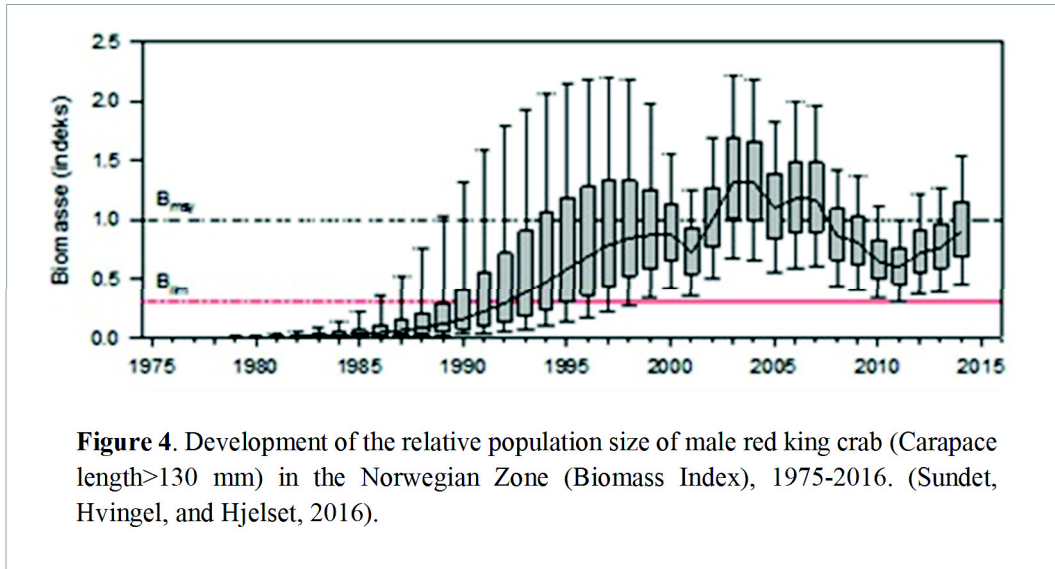
Both ancient peoples and more recent Norwegian immigrants have relied on the productive coastal waters to feed themselves; marketization for Barents Sea fish as early as the 12th Century created fishing wealth for the North (Sjögren, 2009). The Sami, local Indigenous peoples traditionally more focused on reindeer hunting, became more integrated with coastal and fjord fishing over the 19th Century (Sørensen, 2013). These rich and complex fishing communities and ways of life have been threatened in recent decades by shifts in global markets and in technologies for harvest that have moved activities from coastal fleets to offshore activities.

This threat to all coastal communities has raised pressures from individual concerns where the choice is to continue as a fisher or shift to other occupations, to community concerns about continued existence. The red king crab is a new resource, with no historical claims or use in the Barents, presenting a new opportunity for the development of perceptions and claims. Individual residents have the right to harvest small numbers for personal use, and slightly more for is being used under tourism licensing; this is generating some small scale local consumption but still the crab is considered mainly an export commodity.

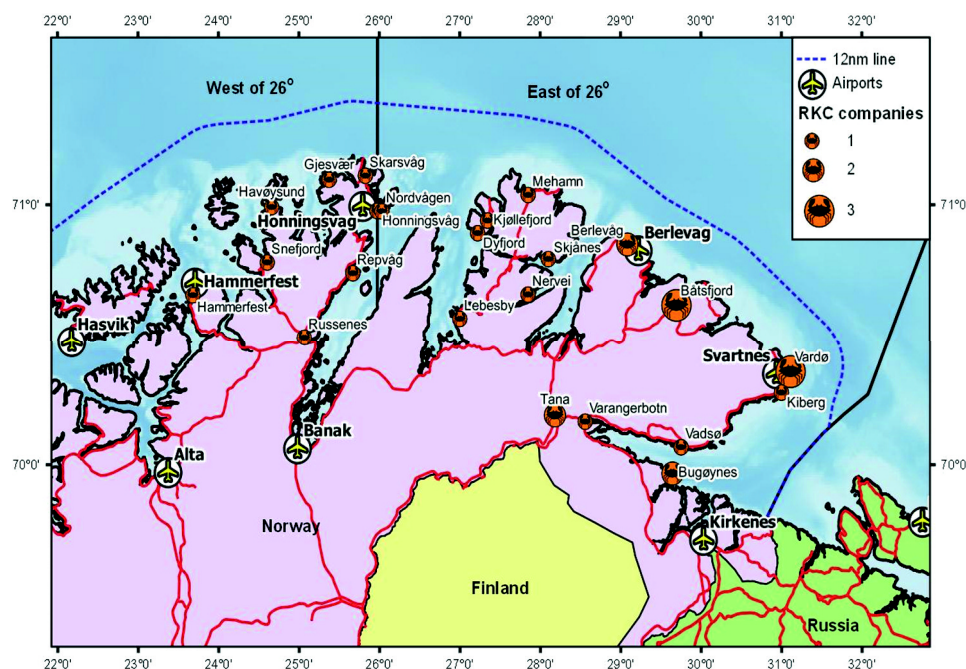
The red king crab fishery's high profitability and low costs (Kourantidou, 2018) have rejuvenated fishing in Finnmark, with increasing numbers of vessels involved in the fishery over time particularly since 2008.

Meanwhile, the population growth of the crab in the quota area is stabilizing after the expansionary phase of the invasion and the introduction of fishing mortality (Fig. 4). The profits to individual fishers

are thus becoming more dependent on the overall number of quota holders amongst whom the total allowable catch is shared, which is in turn increasing calls from within the quota-holding group to restrict entry, and actions by the Fisheries Directorate do so. Starting in 2016, the share of red king crab quota available to a vessel is now tied to the value of other fish harvested (Fiskeridirektoratet, 2017b).



Fishers' calls for stability and long-run production of red king crab are amplified by onshore investments in infrastructure and technology for landing, processing and exporting live crab long distances to market. Live processing requires rapid access to air networks and a different set of infrastructure criteria from that of former fish processing plants now idle throughout Finnmark. The red king crab is spawning new investment in infrastructure in the region, as shown in Figure 5.



The demands of the onshore processing industry have already been instrumental in changing regulations so that red king crab fishing is now year-round, rather than seasonally limited to the fall and winter as it was initially and still is in Alaskan and Russian waters. These limitations, however, are partly ecologically based; the crabs molt in the spring and summer, producing lower quality and volume of meat. Norway's decision to attempt to capture the off-season market speaks to the economic marginality of their enterprises. Costs of air delivery in season are too high to compete with low cost Far Eastern Russian live crab shipboard deliveries. On the other hand, volumes have been too low to compete with frozen production from Pacific sources. See Fig. 5 for representation of this global production, and the closer proximity of the Pacific crabs to their main Asian markets.

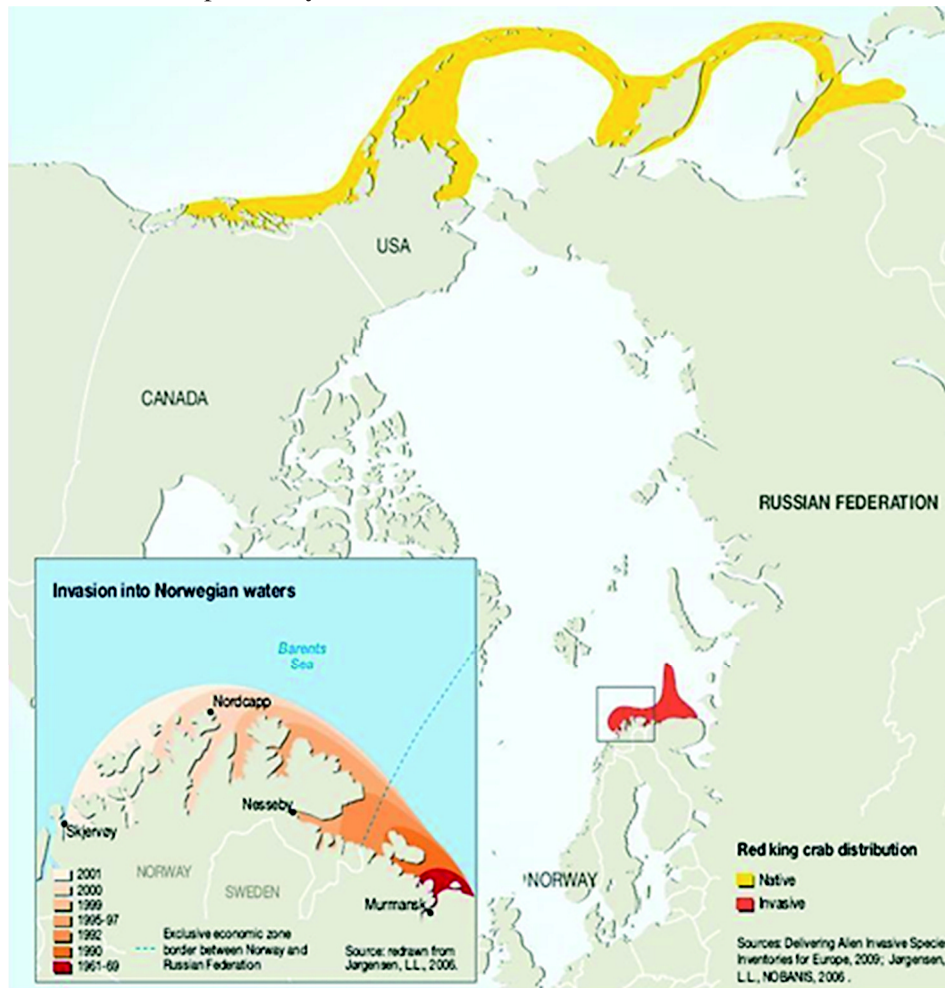


Figure 6. Global distribution of Red King Crab, with inset detail of Barents Sea Invasion. (Jørgensen, 2006).

Live snow crab processing has to date been less successful, but many of the same firms and enterprises that have invested in red king crab processing and supply are turning their efforts to snow crab in an attempt to benefit from economies of scope. If more snow crab comes to land live in Norway, the distribution of returns will improve for local Finnmark interests and further entrench stakeholder interest in maintaining and/or expanding both crab species' commercial viability in the region.

In addition to wishing to restrict access to quota, fishers both within and outside the quota group are asking to expand the quota area to the west in order to better regulate and conserve the crab stock for long run fishing profit (Berg, 2018). Perceptions of the crab as a dangerous biological invasion (Falk-Petersen, 2014) appear to be fading as crab profits expand (Kourantidou and Kaiser, 2017). The election of a conservative government in 2017 is increasing pressure for consolidation of social

resources, a merger of Finnmark and Troms counties, and a focus on profits from natural resources. While it has been agreed that this will not directly affect Finnmark's control of its natural resources, it may challenge how the species is managed as an invader in the western portion. The open access fishery in the west has kept populations low for almost a decade, at low economic cost political and economic pressures are increasing the likelihood of a shift of the quota area further west. A choice to accommodate ecosystem changes in favor of crab habitat over other ecosystem functions is unfolding, and it is being made without full scientific information regarding the consequences.

Once further west, the decision becomes irreversible, and the pressure to expand even further west begins anew. Stakeholders may in fact transform from those who value the current ecosystem productivity to ones who value the transformed ecosystem productivity. The role of scientific research in this transformation is discussed in Section 4.1.3 below.

The effect of the closing of the commons for snow crab fishing in the Loophole and the Svalbard Fishery Protection Zone will be similar. The de-facto open access fishing that worked as a low-cost implementation of precautionary measures to retard the spread of the species has ended and the potential profitability to Russia and Norway is resulting in conservation efforts for the snow crab stock in exchange for unknown ecological costs.

There are fewer local primary stakeholders involved in the snow crab industry, both at sea and onshore. In principle, this could make it easier to regulate with a precautionary approach. This also distances the local stakeholders from witnessing the ecosystem changes, however. With this reduction in transparency and the high stakes both for the profitability levels and the rights to even more potentially valuable assets, there is even less discussion of the snow crab as an invading species than there is of the red king crab; profits are the focus.

The crabs are transforming benthic habitat. While the overall ecosystem impacts are uncertain, there is some evidence of reduced biodiversity, while at the same time available biomass may be increasing or decreasing. There are spatial distinctions in what benthic habitat is currently used for either in ecosystem or human production.

4.1.3 Regional primary and secondary stakeholders: neighbors to invasion

Neighboring jurisdictions to the current invasion areas stand to become recipients of externalities from the further spread of the invasions. Unlike future generations who cannot be present at the bargaining table, these future potential recipients of the current direct stakeholders' decision-making have the potential opportunity to engage socially in the decision-making over the management of the marine environment through negotiations. Their voice, however, may be limited by conflicting interests of the already directly impacted locales, and they may choose to take unilaterally defensive actions rather than work to achieve more generally beneficial cooperative approaches to preventing the spread of the species to their waters. The problem is analogous to that of the internal Norwegian debate over the balance between ecosystem preservation for current ecosystem values or ecosystem transformation for crab production, but at the international scale. The mechanisms for negotiating outcomes that originate in the Convention for Biological Diversity, and their potential weaknesses, have already been described.

While the cases of the crabs are made more complicated by their profitability, other invasive species may bring only external costs to existing fisheries or other ecosystem services. The unknowns are

significant and the global track record for predicting, intercepting, and managing marine invasions is historically poor, with costly consequences (Ruiz *et al.*, 1997). Warming conditions in Arctic waters under climate change are expected to increase vectors and pathways for introductions through increased vessel traffic and greater marine economic activity (Miller and Ruiz, 2014). Snow crab vessels that move among several fishing locations may contribute to this problem by carrying other invaders in their ballast water or on their hulls, increasing the odds of introducing new species in new locations.

4.1.4 Global stakeholders

4.1.4.1 Active ecosystem consumers: crab consumers as primary stakeholders

Both red king and snow crabs have differentiated food product markets that range from high-end live crab to processed and frozen products. A summary of recent data provided in Lorentzen *et al.* (2018) is reproduced here as Table 1. One can see that there are significant differences in willingness to pay for live and frozen crab, and willingness to consume frozen crab by destination; South Korea for example imports live red king crab almost exclusively, while Japan is the opposite.

Table 1. Export markets for Norwegian red king and snow crab, 2016. Reproduced from Lorentzen *et al.* (2018).

| | Japan | | South-Korea | | U.S. | |
|---------------------|----------------|-----------------|----------------|-----------------|----------------|-----------------|
| | Volume, tonnes | Value, 1000 NOK | Volume, tonnes | Value, 1000 NOK | Volume, tonnes | Value, 1000 NOK |
| Red King Crab (RKC) | | | | | | |
| Frozen | 463 | 107,835 | 22 | 5880 | 68 | 11,621 |
| Live | – | – | 776 | 161,370 | 161 | 36,672 |
| Snow Crab (SC) | | | | | | |
| Frozen | 1005 | 92,272 | 108 | 10,552 | 1587 | 118,288 |
| Live | 1 | 106 | 30 | 3695 | 27 | 2763 |

Japan, South Korea and the US all also harvest snow crab, while Japan and the US also harvest red king crab. Additionally, Japan and South Korea have a relative of the snow crab, *S. Japonicus*, that they consume as a substitute for imported snow crab. Other shellfish, fish, and proteins serve as potential substitutes for these products, so that in spite of high and increasing prices, demand elasticities are high, with the exception of short seasonal celebrations that place traditional emphasis on consumption of live crabs.

To our knowledge, the awareness of consumers regarding the ecosystem impacts of their imported crabs has not been directly measured, but informal discussions in live markets and with restaurant patrons and operators in Japan and South Korea suggest at least anecdotally that considerations of whether the crabs are an invasive species or not are inconsequential. Price appears to be the main driver of consumption behavior, and the more crab available, the lower the price can be.

Without information over the sourcing of crabs and their ecosystem impacts, price is not likely to capture the full ecosystem costs of production, even if consumers do hold active and/or passive use values for these ecosystem inputs.

4.1.4.2 Competitive producers

One concern for Barents Sea producers is that their costs are higher than other locales. The distributions of both crabs are illustrated in Figure 6 and 7. As with the red king crab, the snow crab's native habitats are much closer to its principal markets. If other source locations' ecosystem conditions improve, e.g. in the Alaskan or Canadian fisheries, through either natural restorative processes or human-assisted recruitment or other stock enhancement, Barents Sea production will become unprofitable and fishing pressure on the crabs will be reduced, increasing the intensity and breadth of spread.

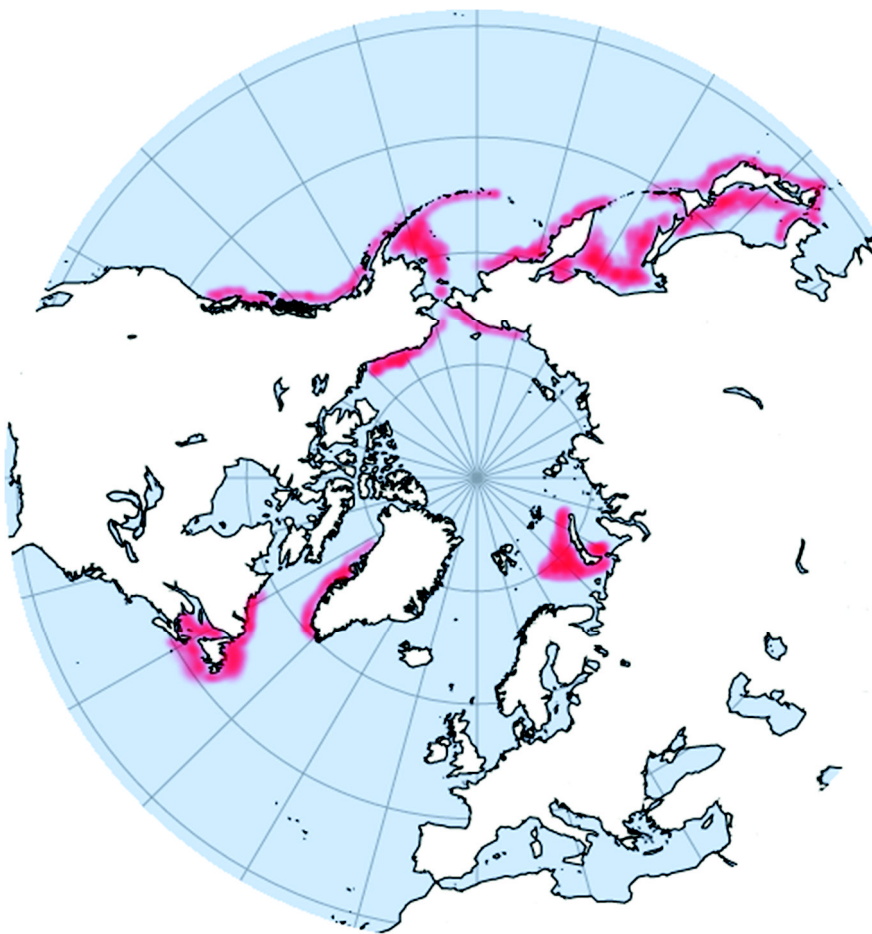


Figure 7. Global Distribution of Snow Crab, *C. Opilio*. (K. Sokolov and Pavlov, 2016)

This potential vulnerability of managing species via market mechanisms also highlights risks that could be associated with any policy proposals to pay fishers directly for harvesting nuisance species, in that incentives to spread the species for gain may ensue.

4.2 Scientific and managerial incentives and biases

The two species are spreading in different directions. The red king crab's tolerance for warmer waters and expansion path to date is likely to promote spread to the west and south, whereas the snow crab's preferred habitats would predict an expansion to the north and north-west. With different stakes, optimal management of limited Barents conservation resources would equate marginal net benefits of activities at the frontiers of each of the invasions; the scale and scope of marine resource management

matter in determining whether better use can be made of limited resources. Simultaneously, research resources would be spatially allocated within species' invading positions, so that the marginal dollar of research is allocated optimally between answering questions about uncertainties in the baseline ecosystem productivity and uncertainties in managing areas that are already invaded (Kourantidou, 2018).

These decisions are, however, subject to incentives held by the research agencies that may affect the agendas in ways that favor one set of findings over another. We find, for example, that in the case of the red king crab, Norwegian and Russian research agendas in the Barents may systematically favor research and results that buffet the continued use of the resource for fishery profit (Kourantidou and Kaiser, 2017). Furthermore, this is likely to be the case whenever profitable fishing opportunities are put up against highly uncertain ecosystem changes, and particularly when there exists vertical integration of research and management in the production of resource commodities. It is essential that valuation efforts such as those described in the chapters by Luisetti, Katsanevakis and Gourguet in this volume directly incorporate these unknowns and uncertainties to provide clear and accurate voice to non-social stakeholders (Maccarone, in this volume).

To the extent that stakes are similar (benthic habitat at risk) and can be transferred from one part of the Barents to another, joint production of e.g. new research knowledge broadly analyzing e.g. baseline conditions of the benthic habitat may have greater benefits than more narrow research into one species or the other. This in turn requires some knowledge or additional research into the question of how similar the habitats at risk actually might be. The research decisions and research needs can benefit from increasing cooperation between agencies and stakeholder interests.

5. The development of path dependencies: lessons in contrast

As profitable invaders, incentives for management of the crab species are mixed. Questions of whether and how to treat the newcomers abound, and answers will put ecosystems and the humans who depend upon them on vastly different economic and ecological paths. Should they be treated as species in need of eradication to prevent ecosystem changes and protect other commercial and non-commercial ecosystem assets that may be affected by their entry into new ecosystems? Or should they be treated as species to protect and conserve - desirable food commodities whose home range habitats in other parts of the Arctic are experiencing climate variabilities and/or other human pressures that make their continued production in those locations uncertain? What are the benefits and costs of these potential paths? How do the answers vary spatially and temporally? Upon what current uncertainties do decisions rest, and what incentives, ranging from funding to stakeholder interests in the questions asked, affect when and how these uncertainties can be resolved?

Perhaps the most valuable lesson from addressing these questions for two species, whose commodity outputs are highly related market goods, invading what might seem at a casual glance to be almost the same place at almost the same time, is that despite many similarities, the details matter extensively. These details need to be evaluated temporally and spatially; the scale and scope matter as well. These findings are not necessarily novel in environmental and resource economics, whether they pertain to the difficulties of using benefits transfer in meaningful ways (Lewis and Landry, 2017); to the spatial scale at which bio-economic parameters are applied in models of spread and damages (Burnett *et al.*, 2007; Kaiser and Burnett, 2007); or to the scope of institutions and commodities impacted (Kaiser *et al.*, 2018). They do remain underutilized in ecological-economic assessments and policy determinations, in part due to their high information costs.

Second, commodification of natural resources such as the crabs fits with a broader global shift, over the past two centuries, to markets and property rights systems that support smooth functioning of these markets. When the commodification captures only part of the ecosystem inputs into production, due to uncertainties or biases in the process, or when rights are spatially or temporally incomplete, then markets cannot function efficiently to allocate resources. Choosing to favor current commodity outputs from ecosystems over broader diversity interests puts those ecosystems on paths that potentially change their overall production capabilities irreversibly. Dependence on market systems to resolve invasive species challenges through such commodification, even in cases where invasive species pressures and/or management expenditures can be significantly reduced under existing framework conditions, may be a costly mismatch between sustainable ecosystem productivity on the one hand and full long run management costs on the other. A more fundamental alignment of valuation and decision-making is required to improve management of marine invasive species.

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