A Case for the Commons: The Snow Crab in the Barents

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Abstract

The open access harvesting of a valuable crustacean species, *C. Opilio* (Snow Crab) in the Barents Sea in international waters is generating a positive externality by slowing the westward spread of the species to sensitive benthic ecosystems. Reclassification of the species to a 'sedentary species'[1] shifts the regulatory environment for the crab in such a way that the crab is no longer in international waters. Rather it becomes part of the extended Russian and Norwegian Continental Shelves in the International Loophole or the Norwegian Continental Shelf in the Svalbard Fisheries Protection Zone, each area facing different management challenges. The economic incentives of the Russians and Norwegians regarding the Snow Crab have thus shifted in ways that exacerbate the invasion aspects of the Snow Crab rather than alleviate them. The asymmetric incentives between the two countries lead to differences for each as a potential source of the crab spreading to new areas. The spread of the crab has both known ecosystem and commercial fishery risks and unknown risks, particularly to uncertain ecosystem values. Therefore, not only will knowable damages accrue more rapidly, there is less time for research and evaluation of ecosystem risks and damages about which we currently have poor understanding. We argue that optimal decision-making regarding profitable invasive species must include analysis that extends beyond standard fisheries economics. Furthermore, this extension must include not only the consideration of ecosystem risks and damages but also the institutional shifts that may occur in response to the economic incentives presented by the invasion.

Keywords: Invasive species; Property rights regimes; Strategic resource use; Snow Crab; fisheries economics

JEL Codes: Q22, Q28

[1] Sedentary species are defined as "organisms which, at the harvestable stage, either are immobile on or under the sea-bed or are unable to move except in constant physical contact with the sea-bed or the subsoil." (UNCLOS, 1982, article 77, part VI)

1. Introduction

The expanding presence of the Snow Crab in the Barents Sea has recently become a topic of growing interest for political analysts and scientific experts. The biological invasion has political, economic and ecological ramifications that extend far beyond the typical case of an introduced species. Political scientists have pointed out some of the existing challenges. These include the applicability of international invasive species agreements to a case with significant potential economic benefits, behavior of different stakeholders in international waters in the Barents, and the complex and disputed property rights surrounding Svalbard, into which waters the invasion is heading (Hansen, 2016; Tiller & Nyman, 2017). They rightly surmise that the stakes for Norway are higher than just the value of the fishery. Norway is acting as though the Snow Crab's classification as a sedentary species creates a test case for cementing property rights to the Continental Shelf in the Svalbard Continental Shelf (SCS).

What the approaches of these papers have missed are the connected shifts in incentives that illustrate the importance of fully integrating biology, climate factors, and economics into policy analyses and decisions. There are two property rights issues at play in the Barents that directly and indirectly affect the overall net benefit of the crabs' presence in the region. Understanding the shift in economic incentives under these rights, and their biologically imposed constraints and externalities, explains what we can expect in terms of overall net gains or losses from the presence of the Snow Crab and the management choices made.

The first property rights issue is the aforementioned contention and uncertainty surrounding the extent of Norway's sovereignty over the SCS. Both the water column and the Continental Shelf of the Svalbard Fisheries Protection Zone (FPZ) have provided controversy over the last century. While Norway is certain the SCS and the Svalbard FPZ are theirs to manage and benefit from (Ministry of Foreign Affairs, 2009), Russia and others contest this view. They argue that the SCS is subject to the 1920 Svalbard Treaty, and that the unique *terra nullius* arrangement on land also extends to the Continental Shelf (Rossi, 2016; Thomassen, 2013). The Treaty recognizes Norwegian sovereignty over the area, but at the same time assures equal access and treatment of the signatory parties for commercial activities and natural resource extraction. The intensity of this controversy is increasing as resource pressures mount around the world.

The second property rights issue stems from changes involving the international waters of the Loophole between Russia and Norway. Fishing activity in the international waters of the Loophole is formally under the jurisdiction of the North-East Atlantic Fisheries Commission (Ebbin, Hoel, & Sydnes, 2005), but the new Snow Crab fishery there began with open-access harvesting in 2012. At that time, both Norway and Russia had been studying the Snow Crab invasion and had yet to open

fisheries in their EEZs. In July, 2015, during the 20th North Atlantic Fisheries Conference (Valletta, Malta, 16-17 July 2015), Norway and Russia agreed on the designation of the crab as a sedentary species. This decision transferred its status from a water column species to a continental shelf resource (Joint Norwegian–Russian Fisheries Commission, 2015). The crab stock in the Loophole then shifted from being in international waters to becoming Russian and Norwegian property on their continental shelves. This is because the continental shelf in the Loophole belongs to their extended continental shelf (outside the 200 nautical miles of both the Russian and the Norwegian Exclusive Economic Zone), putting about 85% of the Loophole on the Russian CS and the rest on the Norwegian CS.

The provisions of the United Nations Convention on the Law of the Sea (UNCLOS) allow the two countries to exercise sovereign rights over their extended continental shelves and therefore to explore and exploit the natural resources lying on the shelf, one of which is now the Snow Crab. Furthermore, the designation of the species as sedentary implies that there is also no requirement by the UN Fish Stocks Agreement for managing the species in cooperation. This is not unquestioned however. The Northeast Atlantic Fisheries Commission (NEAFC) has the responsibility to "ensure the long-term conservation and optimum utilization of the fishery resources in its Convention Area, providing sustainable economic, environmental and social benefits," within the international waters of the NEAFC Convention, which includes the Barents Sea Loophole (NEAFC, 2017).[2] This organization tracks licenses issued by the European Commission to vessels for Snow Crab fishing in the Loophole, which has since caused legal ramifications for the vessels and Norway of significant consequence to the fishery and the ecosystem.

The switch to the sedentary species designation increases the potential Russian stake in the Barents Snow Crab. Still, the extent to which they exercise control over this area will be a function of the incentives to spend on enforcement of their fishery regulations. We investigate Russian and Norwegian incentives and management of the crab before and since the ruling. We argue that, as the Russians have so far maintained a closed and limited experimental fishery for *C. Opilio*, the positive externality generated by the open access harvesting in the Loophole (67,100 km^2 on the invasion's frontier) will disappear if the Russians extend enforcement. We also argue that the relative benefits to Russia of enforcement may be more limited than the benefits of either Russian or Norwegian enforcement to the Norwegians. That is, Norway may have more incentive to close their portion of the commons and to encourage the Russians to do the same. We base this assessment on both economic theory and empirical evidence from after the July 2015 designation at the North Atlantic Fisheries Conference.

[2] NEAFC's authority in the Loophole stems from earlier disagreements over cod fishing that began when climatic changes increased cod in the Loophole (Stokke, 2001).

Should both Russia and Norway successfully close their commons, the question of whether the capture of these resource rents is greater than global losses from the spread of the invasion westward is still an open one. Concerns about uncertain damages remain unalleviated. Potential externalities from a spread of the crab beyond Norwegian and Russian jurisdictions present additional though uncertain costs.

Finally, lessons from dynamics of Snow Crab populations in Canada, Greenland and the Pacific may be pertinent to the management in the Barents. Evolving climatic conditions may have dramatic impacts on the global supply of Snow Crab in ways that promote the rise of Barents Snow Crab (Mullowney, 2015; Mullowney, Dawe, Colbourne, & Rose, 2014). Furthermore, within the Barents, variations in climatic shifts to warmer temperatures (Degen et al., 2016) may push the crab expansion in ways that favor growth more in Russian territory than Norwegian territory. This will influence the asymmetry of incentives for Russia and Norway, and potentially affect the net benefits of the level of cooperation between Russia and Norway in particular, as well as with the rest of the world.

The global fishing commons has shrunk and become increasingly overtaxed in the past ½ century (Jasper, 2010). This general trend has led to increasing recommendations and actions that promote privatization in the world's fisheries. Birkenbach et al., (2017) have recently shown this activity has slowed overfishing and increased the value of the world's ocean productivity, confirming basic economic theory's assertion that closing the commons produces a clear boon. When concerns have been raised in the literature, they have generally focused on shifts in equality and distribution of benefits rather than overall benefit levels (Da-Rocha & Sempere, 2015). Here, we argue that the details of the ecological process may matter significantly in determining the net benefits, further mitigating the realized economic gains. This is particularly true in cases of invasive species and species range expansions, which we expect will continue to increase in frequency and extent under current climate change projections (Perry, Low, Ellis, & Reynolds, 2005). We delineate and examine this complex story here in order to bring awareness to important dimensions of commons management that the literature has yet to address.

We first discuss the dual nature of the Snow Crab as invader and profitable resource. We then investigate the incentives of Russia, Norway and other countries in the Snow Crab industry in the Barents to illustrate how the sedentary species designation impacts the potential net benefits from the crab. We then put the bioeconomic conditions together to analyze more broadly how traditional assumptions about property rights in fisheries need refinements that integrate ecological and economic concerns. We show that the inherent tradeoffs and uncertainties stemming from the bio-

economic conditions place management in a second-best framework. We conclude that the extent of the difference in second-best outcomes from socially optimal management of the Snow Crab may be significant. Open access fishing of crab in the international loophole and the Svalbard FPZ may be second-best optimal to other property rights arrangements.

2. Defining the stakes

2.1. The Snow Crab as a profitable biological invader

2.1.1. Fishery gains

The Snow Crab (*Chionoecetes opilio*) is distributed in the North Pacific (eastern Bering Sea) and the North West Atlantic, including Canada and Greenland (Agnalt, & Jørstad, 2010). *C. Opilio* has recently established in the North East Atlantic and more specifically in the Barents Sea where it is considered invasive.[3] In 1996 the first 5 specimens of Snow Crab were identified in the southeastern part of the Barents Sea, in the net of a trawler fishing for cold water prawn on Gåsbanken (Goose Bank) west of Novaya Zemlya (Sundet, 2015). The crab was mostly likely transferred to the Barents accidentally via ballast water rather than through direct range expansion (Jorstad & Jelmert, 1997).[4]

The species has successfully established in its new environment in the Barents Sea and has expanded its geographical range and abundance (see Figure 1). The Snow Crab's main habitat is currently located in the northern parts of the Russian EEZ as well as in international waters of the Barents Sea (Loophole). The crab is presently expanding into the Svalbard FPZ adjacent to the Loophole. The overall area of distribution covers more than 34% of the Barents Sea (618,000 km^2). Higher densities are found in the eastern part of the Barents Sea, with juveniles mostly in the south east (Pechora Sea) and north east off the coast of Novaya Zemlya, and adults in the central and central-eastern part of the Barents (Novozemelskaya) (Bakanev, 2015).

The fishery has the potential to become quite valuable. In the US, Russia, and Canada, the crab is one of the most valuable harvested species overall.[5] Over the last 4 years, the Snow Crab fishery in the

[3] *Chionecetes Bairdi* is a second species also marketed and sold as Snow Crab, and both species are sometimes labelled Queen Crab (e.g. in FAO statistics). Only *C. Opilio* is present in the Barents.

[4] Recent genetic analysis of samples from the Barents Sea, the Bering Sea, the Canadian east coast (Newfoundland, Gulf of St Lawrence and Labrador coast) and the west coast of Greenland (Disko Bay and Iqaluit) has shown a large genetic distance between the Barents Sea and the Greenlandic crab. The genetic distance is, lower when the Barents Sea samples are compared to the Bering Sea and Atlantic Canadian samples (Dahle, Agnalt, Farestveit, Sevigny, & Parent, 2014). An alternative hypothesis is that the Snow Crab may have entered the Barents Sea via a route north of Siberia from the Chukchi Sea, north of Bering Strait (Sundet & Bakanev, 2014). This hypothesis can be strengthened by Snow Crab findings in both the East Siberian Sea and the Laptev Sea. Limitations of this assumption though include the development pattern of the stock in the Barents Sea as well as the fact that the Snow Crab's presence was only identified in the Kara Sea less than 3 years ago (Sundet, 2014).

[5] The Eastern Bering Sea Fishery has historically been the largest and most commercially valuable crab fishery in the US, where it even has a long-running television series (The Deadliest Catch). The Snow Crab is also among the most valuable

Barents Sea has started taking a growing share of the market. The harvest is growing at a very quick pace: Norwegian landings of Snow Crab have increased over 2000 times in magnitude from a total roundweight of 2,478 kg in 2012 to 5,405,764.2 kg in 2016 (Norges Råfisklag, 2017). According to the Institute of Marine Research in Norway (IMR) the value of the Snow Crab fishery might reach up to 2.5 bil. NOK, which is an estimate based on how landings have evolved to date. Despite existing uncertainties in the stock estimates and the difficulties in biomass simulations (Hansen, Skern-Mauritzen, van der Meeren, Jähkel, & Drinkwater, 2016), there are expectations for sustainable landings of 50,000 tonnes within a 10 year horizon and for 75,000 tonnes within the next 20 years. These estimates are based on population trends of the Canadian stock, taking into account the habitat conditions in the Barents Sea and having used an optimal fishing effort (Fenstad, 2015a; Hvingel, 2015). [6] If these expectations are met, then the Snow Crab fishery will be of much greater commercial value than the mackerel, herring and saithe fishery, and possibly greater than the value of the important cod fishery.

The map in Figure 1 shows the commercial fishery activity of the Norwegian fleet from its beginning in 2012 until 2015 (Source: IMR).[7] The Loophole, center, is shaded to highlight the high levels of activity in the area. The fishery information is overlaid on thermal and bathymetric data to identify how anticipated spread will occur to the North and West.[8,9]

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fisheries in Canada and Greenland, in the northwestern Atlantic (Hardy, Lindgren, Konakanchi, & Huettmann, 2011). Korea also participates in the Snow Crab fishery in the Pacific.

[6] The crab's distribution and spread is being monitored systematically via joint efforts by IMR and the Polar Research Institute of Marine Fisheries and Oceanography (PINRO) in Russia and more specifically through the annual joint Norwegian/Russian Barents Sea Ecosystem Surveys (Anisimova & Jørgensen, 2015; Krivosheya, 2012; Lubin, Jørgensen, & Mashnin, 2013; Pavlov & Sundet, 2014). However, the scientists involved suggest that the research trawlers cannot provide highly accurate estimates of the spatial distribution and the stock (JH Sundet, IMR, personal communication, 2017). Instead, the commercial fleet seems to have a greater potential for tracking the distribution with greater accuracy, despite some problems in reporting attributed to the fact that the fishery is still new (JH Sundet, IMR, personal communication, 2017).

[7] The 2016 commercial fishing activity is not depicted in Figure 1. This is because changes in property rights enforcement present a markedly different picture that does not reflect the abundance or the distribution of the crab in the same manner as the open access fishing behavior.

[8] The Snow Crab is a stenothermic species found in greatest numbers at bottom water temperatures between -1 and 4^{o}C (Chabot, Sainte-Marie, Briand, & Hanson, 2008). In the Barents Sea the Snow Crab is widely distributed in areas with bottom temperatures ranging from -0.7°C to 3.4°C (Alvsvåg, Agnalt, & Jørstad, 2009), with most of the crabs having been found in waters below 2^{o}C (Jørgensen & Spiridonov, 2013). In the central region of the Barents Sea a significant number of crabs have been found in waters from 180 to 350 meters (Alvsvåg et al., 2009). Generally, depth range varies according to season and size.

[9] A number of other parameters besides bottom temperature which seems to be the main driver of the range expansion (Jørgensen & Spiridonov, 2013), such as favorable conditions of salinity, depth and bottom type, coupled with indications from the expansion of the commercial fishery towards the FPZ around Svalbard, indicate a possible northwestern expansion of the species. The trawl catches from the 2015 Ecosystem Survey of the Barents Sea also showed a wider

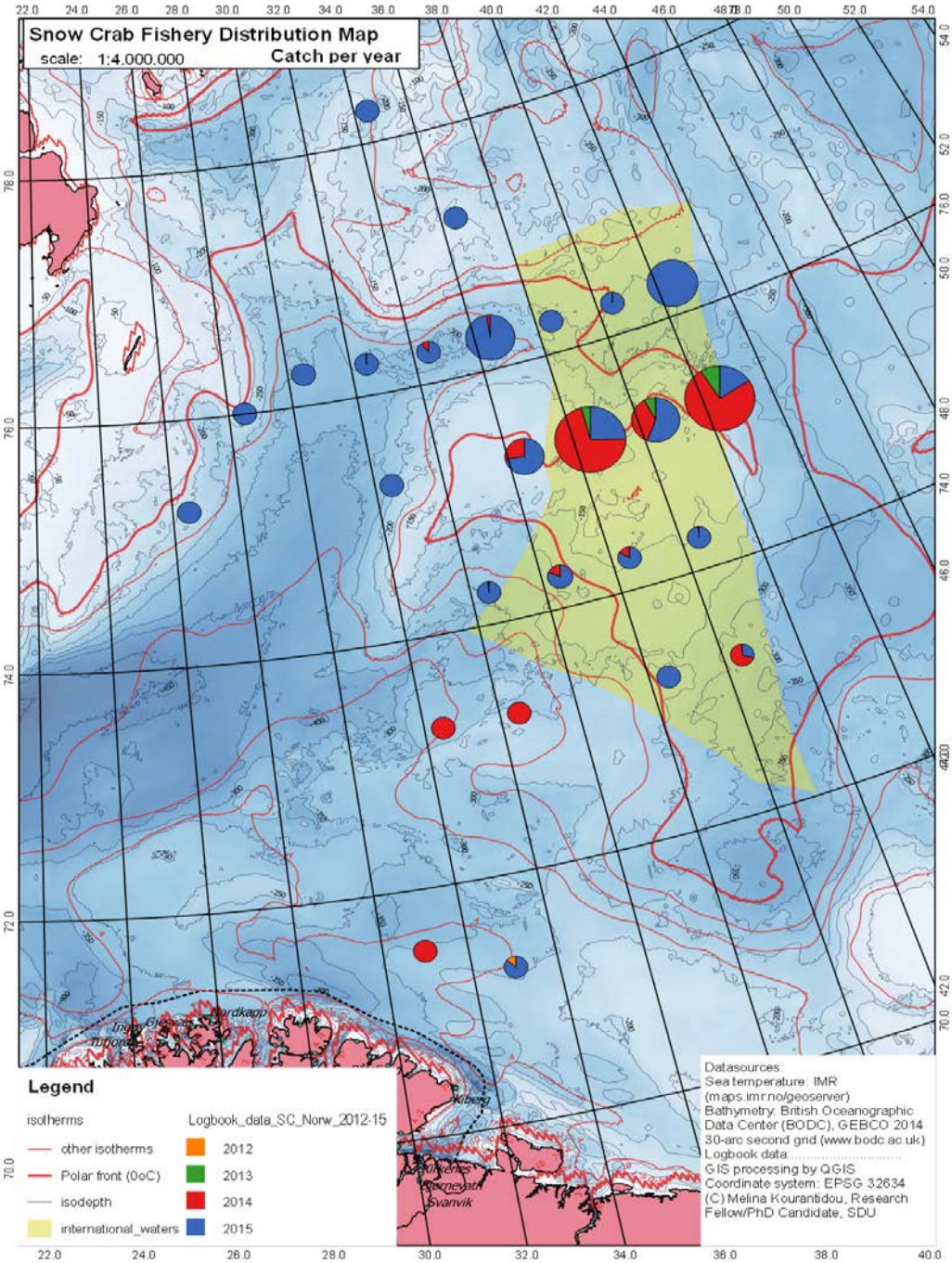

Figure 1 Commercial Fishery Activity (Norwegian Logbook data).
Sources: (Institute of Marine Research, 2017; Natural Environment Research Council, 2017)**.**

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distribution to the west (to 30°11' E) than in previous years (to 36°28' E). Experts consider likely the establishment of the crab in Svalbard and Franz Josef Land, if warming continues (Jørgensen & Spiridonov, 2013).

2.1.2. Ecosystem and climate losses and uncertainties

In its native range, the Snow Crab population is characterized by large inter-annual variation in numbers and landings.[10] In the Barents Sea, this may also become true as the invasion fills in the habitat capacity. Quantitative parameters indicated that in 2015 there was an overall reduction of the Snow Crab population by half compared to previous years, despite the increase in the distribution (Anisimova & Jørgensen, 2015). This adds a significant degree of uncertainty at attempts to predict the future biomass and spread. These biomass shifts may also affect the distribution of crab between Russia and Norway, complicating the management for both nations. Norway's position on the frontier of the invasion makes its investments in enforcement and management less certain, particularly if climate shifts move the continuing invasion more to the north than to the west.

The Snow Crab is a benthic predator that feeds mostly on crustaceans, polychaetes and fish (Jørgensen & Spiridonov, 2013). Its predatory behavior might cause competition with other bottom feeding fish and benthic species (Haug et al., 2017).[11] Impacts of the Snow Crab's presence in the new ecosystem are however particularly hard to identify, especially those occurring through indirect food web links. This also makes them easier for policy makers to ignore in return for immediate and tangible fisheries gains.

A projected expansion towards Svalbard raises additional concerns among scientists given the vulnerability of Arctic food webs that stems from the limited numbers of species at each trophic level (Sundet, 2015). Potential elimination of some species caused by Snow Crab predation is therefore particularly worrisome for Arctic ecosystems, due to potential severe effects upwards and downwards in the food web, as opposed to other more resilient ecosystems where some species' feeding role can be more easily substituted. Direct and indirect threats to other commercial fisheries are also possible.[12]

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[10] A number of reasons such as density-dependent mechanisms as well as changes in water temperatures are likely to result in changes in crab abundance and habitat range (Chabot et al., 2008).

[11] Echinoderms for example, which are known to play an important role in redistribution and remineralization of organic carbon on Arctic shelves (Bluhm, Iken, Hardy, Sirenko, & Holladay, 2009), are among the most common prey items for the Snow Crab (Jørgensen & Spiridonov, 2013). Foraminifera, another dominant category of prey species found in stomach contents of the Snow Crab (Jørgensen & Spiridonov, 2013), represent an important link between lower and higher levels of the food web (Gooday, Levin, Linke, & Heeger, 1992; Hansen, 2015). Changes in the abundance and composition of echinoderms may lead to large structural ecosystem changes and so do potential changes in Foraminifera (Hansen, 2015).

[12] In Newfoundland, the Snow Crab has been observed to be feeding on capelin (Squires & Dawe, 2003) and thus there might be a possibility of the crab representing a threat for post-spawn capelin (Mikkelsen, 2013). Other concerns include the food competition the crab might create with other commercially valuable species, through its predation on the Polychaeta community. The northern shrimp is an example of a commercially exploited species, distributed mostly around Svalbard and in the central part of the Barents Sea, whose distribution is partly overlapping with the Snow Crab distribution. Dvoretsky & Dvoretsky, (2015) find a negative correlation between biomass of Snow Crabs and shrimps,

The distribution of the external costs from the establishment and spread of the invasive crab is likely to vary between Norway and Russia. The natural capital assets imperiled by the invasion vary both across space and time. An adequate understanding of what ecosystem values are at stake is currently lacking for both the Russian and the Norwegian part of the Snow Crab distribution. Joint surveying of the Barents by IMR and PINRO over the past two decades is beginning to quantify the ecological stakes (IMR, 2017). Until entry by commercial vessels in 2012, these surveys were assessing both potential ecosystem changes and the potential for fishery development at a measured pace. While this has increased knowledge about the population, it did little to control the invasion.

Russia has experienced the greatest ecological change so far, as the introduction of fishing vessels in the Loophole and Svalbard FPZ have acted to slow the invasion into Norway. If climate shifts push the invasion more north than west, this imbalance will continue to grow.

2.2 The Initiation and Rapid Growth of the Snow Crab Fishery

Most of the commercial harvesting of the species has taken place in the international waters of the Barents Sea Loophole. This has inadvertently operated as a control measure on the invasion by reducing the stock, particularly on its western frontier. Norwegian and Russian vessels were the first to join the fishery in the Loophole, while Spanish, Latvian and Lithuanian vessels quickly joined in subsequent years (see Table 1 for a recent description of the fishing activity in the Loophole).

Both Norway and Russia have been recently trying to limit participation of EU vessels in the Loophole. The Russian enforcement of property rights was initiated in September 2016, while the Norwegian enforcement was initiated in January 2016 (JCS Arctic Fishing, n.d.). Norwegian enforcement accommodated EU fishing vessels through most of 2016 in the Loophole in pursuit of the crab. Since the end of 2016, however, Norwegian enforcement has targeted EU vessels. In December 2016, Norway prosecuted the Lithuanian vessel “Juros Vilkas” for harvesting Snow Crab on the Norwegian portion of the CS in the Loophole (Øst-Finnmark Tingrett, 2017). In mid-January, 2017, Norwegian authorities arrested the Latvian Vessel “Senator” for laying 2,600 Snow Crab pots in the Svalbard

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which they attribute to prey-predator interactions. The authors consider the Snow Crab’s impact on shrimp though negligible due to the relatively small fraction of shrimps found in stomach analysis of the crab. They do not exclude potential negative ecosystem impacts from the Snow Crab, while they also highlight the fact that the ecosystem may not have adapted yet to the new species whose biomass is still increasing at exponential rates (Dvoretsky & Dvoretsky, 2015). Norwegian shrimp fleets reported numerous incidents to the Coast Guard of costly damages (e.g. broken trawls) caused by Snow Crab gear left behind on the sea bottom. Snow Crab Vessels are fishing with up to 2,500 traps each one of them which are strung together in chains up to several kilometers long (Sundet, 2015). Degradable excluder devices on crab pots, which are mandatory for a Snow Crab license in Alaska while also in Newfoundland and Labrador, are not that common in the Barents Sea. Despite the numerous complaints the Norwegian Coast Guard has received for such incidents in the Loophole, they have not been authorized to intervene in any way (Fenstad, 2015b; Jensen, 2015). This is a reminder that enforcement includes not only property rights to the fishing but also other human management and behavioral incentives.

Fisheries Zone (Mehren & Abelsen, 2017). This has been presented as stemming from fears brought about by the lower Norwegian catch experienced in 2016 due to lack of access to the Loophole (Martinussen, 2017). However our analysis suggests it has more to do with establishing rights to the crab as a sedentary species on the Norwegian continental shelf in the Loophole, and then further to the right to control the Norwegian continental shelf in the Svalbard FPZ.

In the Russian EEZ the commercial fishery started in 2016 for the first time with a relatively small catch (1500 tons), while for 2017 the TAC for the Russian EEZ has been set at 7.87 ktons and the Russian portion Loophole is effectively closed to commercial fishing (S Bakanev, PINRO, personal communication, 2017). Norway has not yet introduced TACs; they have licensed Norwegian Vessels (20 vessels in 2016 and 50 vessels in 2017).

	2015		2016	
	Fishing Activity	No. Vessels	Fishing Activity	No. Vessels
Norway	21.59%	11	47.37%	11
Russia	42.68%	6	13.41%	7
Latvia	19.00%	12	32.31%	10
Lithuania	9.36%	3	5.29%	2
Spain	7.37%	1	1.62%	1

Table 1 Fishing Activity in the Loophole for 2015 and 2016 (until fall 2016) Source: (Ripman, 2016)

2.3 The Snow Crab as a sedentary species

The de facto closing of the commons through the sedentary species designation at the North Atlantic Fisheries Conference in July 2015 removes the fishery from an open access case where theory suggests we will have harvesting at levels that exceed those for highest profitability and could crash the commercial viability of the fishery (Bjørndal & Conrad, 1987; Gordon, 1954; Schaefer, 1957). Instead, Russian and Norwegian authorities have sovereignty over their continental shelves and have recently chosen to close the commons. Continued migration in the Barents between Russian and Norwegian waters, is expected (Degen et al., 2016; Jørgensen et al., 2015). The joint Norwegian-Russian Fisheries Commission has to date handled such transboundary fish stocks, but there are complications in this case. The first is the differing legal status of the Snow Crab, in that it is a sedentary species and does not have to be regulated as a fishery by the Commission. The second is precedent: the only species the Commission has failed to agree on management for is the Red King Crab, with a similar history beginning a few decades earlier (Kourantidou, Kaiser, & Fernandez, 2015).

Thus we might expect that the Norwegians and Russians will develop different harvest control strategies for the species on their own continental shelves. Economic factors for the difference

between the two countries include the diversified supply Russia has for Snow Crab that includes its Far East EEZ. This fishery is closer to market demand and allows for cheaper crab delivery to Asian markets by sea. Norway lacks such diversified supply. Biological factors for the difference between the two countries are linked to the shifting climatic conditions. These may be leading to movement of Snow Crab to deeper, cooler depths such as are provided in Northern Russian waters (Degen et al., 2016) in order to avoid increased water temperatures in shallower Norwegian and Svalbard FPZ waters (Mullowney, 2015; Mullowney et al., 2014).

Failure to handle the spread of the invasion within the Barents would move the strategic interactions between nations to the next consecutive parties – a spatially iterative game that would depend on climatic variations and economic decisions in a pattern similar to the discussion here. The current legal actions underway to extend the continental shelves in the Central Arctic Ocean mean that any northward expansion will also remain a limited entry fishery for the sedentary species rather than one open through international waters. This point is somewhat moot, however, as access to these parts of the shelf remains limited. It is unclear, however, whether the joint resolution by the five Arctic coastal states to refrain from fishing in the Central Arctic Ocean (Shephard et al., 2016) pertains only to the high seas, or whether a sedentary species like the Snow Crab, under individual state jurisdictions, would be seen as exception-worthy.[13] If so, this would reduce the effectiveness of the proposed ban in maintaining healthy and pristine marine benthic habitats.

2.4 The Snow Crab as a test case for Svalbard Treaty rights to the Norwegian Continental Shelf

Sedentary species include other valuable resources such as oil and gas in the Svalbard FPZ. International law under the Svalbard Treaty of 1920 (Molenaar, 2012) clearly indicates Svalbard's land resources are open to all, and precedent has established that the pelagic zone is international waters. The question of the continental shelf, however, remains disputed by Norway. Norway believes they have sovereignty over the continental shelf and a right to govern the Snow Crab, as well as any other 'sedentary species' (Regjeringen, 2017) in the 12-200 mile nautical zone surrounding Svalbard. This has recently become a much bigger concern to both Norway and other stakeholders in the Barents fisheries, as well as the global oil and gas industry. Indeed, the 23rd round of oil licensing, concluded in 2016, gave licenses to Statoil north of the 74˚ line, in the Svalbard Zone (Production licenses 615B and 859, Norwegian Petroleum Directorate, 2017). These have been protested by Russia, and the 24th round promises to instigate similar clashes (Staalesen, 2017).

3. Lessons for Economic Theory and Management

[13] The process of establishing rights in the Central Arctic Ocean is ongoing. A series of meetings is taking place between the five Arctic coastal states, Iceland, China, Korea, Japan, and the European Union to establish a binding agreement limiting fishing in the region (Rayfuse, 2017 in press).

We present this case as a clear example of how dogmatic approaches to property rights regimes that strive to assign unilateral governance to economically profitable species may be more detrimental than beneficial. We argue that optimal decision-making regarding profitable invasive species must include analysis that extends beyond standard fisheries economics. Furthermore, this extension must include not only the consideration of ecosystem risks and damages but also the institutional shifts that may occur in response to the economic incentives presented by the invasion.

3.1 Spatial asymmetries in economic incentives: Russia's Far East Snow Crab Fishery

Figure 2 shows the global distribution of Snow Crab. The Russian Federation has Snow Crab stocks in the Far East as well as in the Barents Sea. Because the main markets for Snow Crab, particularly for live Snow Crab, are located in neighboring Korea and Japan, the Far East Russian fishery has much lower costs in delivering product to market. The stocks of Snow Crab and market linkages are also more established in the Far East; the Russians have been providing live crab for decades (Nofima, 2017). With these lower costs and developed markets, Russian incentives to invest in Snow Crab production in the Barents are lower than those of the Norwegians. As global prices have risen for Snow Crab, however, the benefits to conserving and utilizing the Barents' stock in addition to the Far East stock are increasing. The diversified portfolio of the Russians creates greater incentives to conserve the stock in the Barents, particularly as a reserve stock. This enables continued capitalization of the higher prices with little risk to overall supply by harvesting in the Far East. That is, the higher price induces greater interest in conservation of the Barents stock by transferring the use of the stock from open access EU fishing to exclusive Russian fishing. This conservation fosters the continued expansion of the invasion and reduces incentives to research and identify the costs of ecosystem damages.

Figure 2 Global Distribution of *C. Opilio.*
Source: (Sokolov & Pavlov, 2016)

3.2 International Environmental Agreements have Loopholes

The Norwegian authorities have arrested and fined two vessels for Snow Crab fishing on the Norwegian Continental Shelf in the past year. The captain and owners of the *Juras Vilkas* were prosecuted for illegal harvesting of Snow Crab on the Norwegian Continental Shelf within the Loophole. The defendants were acquitted on Jan. 24, 2017. A week earlier, a second, Latvian flagged vessel, the *Senator*, was arrested for Snow Crab fishing on the Norwegian continental shelf in the Svalbard FPZ (Jeffries, 2017). This case is also working its way through the European courts.

The first case rests mainly on whether the sedentary species classification in the Loophole gives Norway the right to exclude other countries from fishing the resource, as suggested by UNCLOS, or whether the NEAFC Convention (1980) supersedes this exclusivity and gives the regional authority the ability to regulate sedentary species like Snow Crab in the Loophole (PECH secretariat, 2016; Regjeringen, 2017). The second case adds to the complexity because of the additional requirements of the Svalbard treaty for equal treatment.

Russia and Norway became parties of the UN Convention on Biological Diversity long before the appearance of the Snow Crab in the Barents Sea, which can require them to take remedial actions when an invasive species becomes established. However in this case the CBD COP6 Decision VI/23 on ''Alien species that threaten ecosystems, habitats or species'' has been ignored by both countries and

fails to drive ongoing policy on the management of the invasive crab because the introduction of the crab has not been classified as intentional.[14]

3.3 Price shifts change incentives for institutions as well as enforcement levels

The crabs may even be considered by some to increase biodiversity in the Barents Sea (Sundet & Hoel, 2016). As profitability of an introduction increases, incentives to capture the profits increase as well.[15] With low levels of regulation and enforcement, these higher prices might stem growth and spread of the invasion through open access overharvesting. Stakeholders with the ability to adjust institutional mechanisms that can limit this overharvesting will pursue these adjustments, as we are seeing with the pending court cases initiated by Norway's arrests of fishing vessels in both the Loophole and the Svalbard FPZ. Successful implementation of harvest limits increases the profitability of the resource to the owners of the resource. In exchange, stakeholder's claims that are more tenuous, such as under the Svalbard Treaty in this case, are reduced. The consolidation of control to the Russian and Norwegian authorities further increases the ability to limit harvest and to stifle concerns about changes to global benefits from e.g. preserving benthic biodiversity.

The expected northwesterly spread of the crab is raising hopes for the opening a new economic activity in Svalbard (Abelsen & Eftestøl, 2017) that would be open to all parties to the treaty. This increased profitability also holds for Norwegian interests in the area. The payoffs to Norway of excluding others from the Svalbard FPZ are increasing in the increasing prices. This has driven Norwegian efforts to protect the new resource from other international players through the arrests of vessels in both the Loophole and the Svalbard FPZ as described above.

4. Conclusions

The conventional wisdom that private property rights solve the externalities fails to hold in the case where the ''commons'' problem is coupled with a spatial externality. The former open-access regime (Barents Sea Loophole) coincided to a great extent with the invasion frontier and worked to ameliorate damages from the Snow Crab invasion by reducing the externality. The welfare for the two countries, now that efforts to exclude international players from the fishery are underway, may increase due to higher fishing rents. This will be at the expense of benthic productivity for Norway and Russia and ecological values to the rest of the world if it turns out that the newly introduced crab is of

[14] This is not the first time the two countries take a dissenting stance towards a commercially valuable invasion. The Red King Crab further south in the Barents Sea, for which scientific observations on ecosystem losses are better documented, is an additional case of violation of the CBD (Miljøvernforbund, 2010; WWF-Norge, 2002).

[15] Minimum prices for Canadian Snow Crab jumped 46% in the last year (Navigator, 2017); overall, North American wholesale prices have hit $8 per pound, a rise of 25-50% over most years (McDowell Group, 2016). These trends are expected to continue as Alaskan and Canadian quotas decline.

significant ecological concern. Standard economic theory allows for assessment of the optimal balance of rents and damages avoided in such a case if the damages are known; in this case they are not.

The cooperation of Russia and Norway is limited at the research front (Korneev et al., 2015). Despite the fact that the crab invasion might warrant more focused control efforts at certain points located at the frontier of areas with sensitive benthic habitat in line with the NEAFC's mandate for management of both fisheries and habitat in international waters would support the need for joint management. Currently, there is no plan for joint management on behalf of either side.

The Snow Crab is not the first commercial crustacean invasion shared between Norway and Russia. In the case of the earlier Red King Crab invasion in the southern Barents Sea (Kourantidou et al., 2015), the two countries' cooperation is also limited. This is in spite of the long-standing and well-functioning Joint Russian-Norwegian Fisheries Commission. Initial discussions about management of both species in the Commission led rather to an agreement to act individually; this is clearly a response to economic incentives competing with each other and ecological uncertainties.

The spatial dimension of the externality problem has both ecological and economic complications. The impending range shifts of the Snow Crab indicate that should Norway change its perspective to favor control of the invasion over fishery profits, any possible future efforts to prevent the spread further northwest towards Arctic waters need to be mindful of the management applied in the neighboring Russian jurisdictions. This is a standard concern of invasions that further reduces incentives to identify and include ecological damages in decision making. Again, joint action is needed, not only between Norway and Russia, but also including any other stakeholders. This could be operationalized through NEAFC.

Although both Norway and Russia have recently started enforcing property rights, the question of whether the enforcement benefits are higher than the enforcement costs remains open. If the ecosystem values at stake from the invasion are high enough, enforcement decreases social welfare. We further propose that those enforcement benefits and costs are most likely associated with the Continental Shelf rights: The rights to the Snow Crab which is now a continental shelf resource are paving the way for future rights to other valuable resources lying on top or underneath the continental shelf such as oil, gas, minerals etc. On the invasion frontier, one's decisions matter not just for balancing the commercial and ecological benefits of any crab harvest in their own waters but also for the spread of the invasion, for example in this case into other waters west and north.

The Snow Crab presents a useful case of multiple ongoing and competing proceedings that are identifying conflicts in maritime law that will be enhanced by climate change impacts on species presence and diversity. The ability to identify clearly the economic incentives and asymmetries in this

single species invasion, turned fishery, presents an opportunity to explore how climate changes' uncertainties will play out at the international scale. Further, in highlighting these conflicts, pathways for reducing social losses from new invasions are shown. These include greater cooperation at all stages, from research through harvest, but also greater dialogue about standard economic recommendations for fisheries management and habitat protection. In this case, we show how an open access fishery may be the most pragmatic option to weigh uncertain outcomes for both economic and environmental gains.

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