INTERNATIONAL CENTER FOR SETTLEMENT OF INVESTMENT DISPUTES
ICSID CASE NO. ARB/20/11

PETERIS PILDEGOVICS AND SIA NORTH STAR
Claimants

v.

KINGDOM OF NORWAY
Respondent

EXPERT REPORT OF DR. BROOKS KAISER

Introduction

My name is Brooks Kaiser, I am Professor and Head of the Management and Economics of Resources and the Environment Group at the University of Southern Denmark (Esbjerg, DK). I hold a PhD in economics from Northwestern University (Evanston, IL). I am also head of the University of the Arctic Thematic Network on Global Ecological and Economic Connections in Arctic and sub-Arctic Crab Markets, and Fellow and Unit Lead on Fisheries at the Polar Research and Policy Initiative. I have recent papers on resource economic questions pertaining to Barents Sea crab fisheries published in the leading international journals and outlets for lay readers, including Marine Policy, Fisheries Research, Journal of Environmental Economics and Policy, the Journal of Environmental Management, The Conversation, and the Mediterranean Science Commission. My CV is attached as Annex 1. I have been instructed by the law firm Savoie Laporte, acting on behalf of the Claimants, Mr. Peteris Pildegovics and SIA North Star, in ICSID Case ARB/20/11, an arbitration brought against Norway under the Latvia-Norway 1992 treaty for the promotion and protection of investments. I understand my duty is to assist the Tribunal in an independent and impartial way.

List of Acronyms

BESS	Benthic EcoSystem Survey
Bmsy	Population of stock associated with Maximum Sustainable Yield (MSY)
CBD	Convention on Biological Diversity
CPUE	Catch Per Unit of Effort
CS	Continental Shelf
EEZ	Exclusive Economic Zone
Fmsy	Fishing mortality associated with Maximum Sustainable Yield (MSY)
GIS	Geographical Information Systems
ICES	International Council for the Exploration of the Sea
IMR	Institute of Marine Research
MSC	Marine Stewardship Council
MEY	Maximum Economic Yield
MSY	Maximum Sustainable Yield
NEAFC	North East Atlantic Fisheries Commission
PINRO	Polar branch of the Russian Federal Research Institute of Fisheries and Oceanography
RKC	Red King Crab
SC	Snow Crab
SFPZ	Svalbard Fisheries Protection Zone
VNIRO	Russian Federal Research Institute of Fisheries and Oceanography

Abbreviations for units of Measure

EUR	Euros
km	kilometers
ktons	kilotons (1000 tonnes)
m	meters
nm	nautical miles
NOK	Norwegian Kroner
RUB	Russian Rubles
USD	United States Dollars

Counsel for the claimants have instructed me to address and answer the following questions in this report:

1. Present the relevant available economic data since the beginning of the fishery (by year and by country):
    a. Total industry catches
    b. Total industry revenues (if available)
2. Discuss the state of the Norwegian snow crab industry from an economic standpoint (rudimentary, developed, profitable, unprofitable, etc.).
3. Which factors inform the establishment of fishing quotas?
4. With regards to the establishment of a quota for snow crab fishing in the Barents Sea:
    a. What are the relevant environmental factors?
    b. What are the relevant economic factors?
5. Based on available scientific data for the period 2017-2021, and applying the relevant factors, what would be an appropriate quota for the snow crab fishery in areas of the Barents Sea under Norwegian control (including Svalbard and the Norwegian side of the Loop Hole)?
6. Discuss North Star's integrated business model as compared with competitors (in particular Norwegian competitors):
    a. Was North Star the only company in a joint venture with an onshore snow crab transformation company (Seagourmet)?
    b. What are the advantages (and disadvantages if any) of such a business model vs the rest of the industry?
7. Can this model explain North Star's lead in terms of productivity and expected profitability?
8. In your opinion, are the Norwegian quotas for snow crabs justified based on either environmental or economic factors?
9. In light of historical industry catches, is it reasonable to think that Norway would have adopted the same quotas if it had considered the interests of all industry participants on an equal footing?

Please find my answers below:

1. Present the relevant available economic data since the beginning of the fishery (by year and by country):

a. Total industry catches

1. The total industry landings from catches in the Barents Sea from the beginning of the industry through the most recently available data in 2020 are shown in Table 1 below. These are landings in tonnes of snow crab from the Barents Sea by vessel country, and thus cover landings in Norway and the Russian Federation from the relevant stock of snow crab. The data comes from the stock assessment conducted by the Norwegian Institute of Marine Research (**IMR**) for 2021 **(BK-0001, p. 8)**.

Table 1: Barents Sea Snow Crab Catches. Source (BK-0001, p. 8).

Barents Sea Snow Crab Catches				
Year	Landings (tonnes)			Total Landings
	Norway	Russia	EU countries	
2012	2	0	0	2
2013	189	62	0	251
2014	1800	4104	2300	8204
2015	3482	8895	5763	18140
2016	5290	7520	3690	16500
2017	3153	7780	2	10847
2018	2804	9728	-	12532
2019	4038	9840	-	13878
2020	3405*	10500**	-	13905*

* through 11. November 2020

** through 29. October 2020

b. Total industry revenues (if available)

2. Total industry values are published annually by the Norwegian Fishermen's Sales Organization (Norges Råfisklag) **(BK-0002)**. Their results are presented in Table 2 for 2010-2019; data for 2020 is not yet available.

Table 2: Norwegian Snow Crab 1st Hand Values

Snow Crab Catch and Value		
Year	Catch (roundweight tonnes, converted)	1st Hand Value, 1000 NOK
2010	0	
2011	0	

2012	2	2
2013	189	3 241
2014	1 881	56 354
2015	3 105	121 745
2016	5 406	191 178
2017	3 101	155 790
2018	2 812	166 234
2019	4 049	265 444

Source: Norges Råfisklag
(Norwegian Fishermen's Sales Organization)

2. Discuss the state of the Norwegian snow crab industry from an economic standpoint (rudimentary, developed, profitable, unprofitable, etc.).

3. Norwegian snow crab industry is nascent and unprofitable in its current form **(BK-0003, BK-0004)**. The Norwegian survey of vessels actively participating in the industry shows a continuous loss over time (Table 3 and Table 10).

Table 3: Brief Financial Overview for the Norwegian Snow Crab Fleet (Values in 1000 NOK)

Financial Overview for the Norwegian Snow Crab Fleet					
Average Vessel Profitability Survey Results, Norwegian Snow Crab Vessels					
	2015	2016	2017	2018	2019
Earnings*	20820	42620	26887	27258	40476
Total operating costs*	28240	49667	36357	36439	51248
Operating profit*	-7420	-7047	-11471	-9182	-10772
Ordinary profit before tax*	**-9564**	**-7977**	**-15562**	**-10396**	**-12599**
Active Vessels	*6*	*7*	*9*	*7*	*7*

Data from Norwegian Fisheries Directorate Vessel Profitability Surveys, 2015-2019 (BK-0005, Vessel Group 14 (G22)).

4. In this section, we discuss first the production and then the value of the industry. The production discussion includes what has been produced and growing capacity for production. The value discussion includes revenues and profitability in the Norwegian industry as well as broader understanding of the profitability now and growth into the future.

a. Snow Crab production in Norway

5. Snow crab (*Chionoecetes Opilio*, also sometimes referred to as Queen Crab, or reported together with closely related *C. bairdi*, or Tanner Crab) have been a global fishing resource for over a century. The species is new to the Barents Sea, however, and the entry of Norway into the industry has only recently begun. The timeline is unique in fisheries development, and has been explained at length in a recent snow crab issue of a journal on Norwegian fisheries economics research (BK-0006) and summarized in Figure 1. The potential for a future fishery, and/or for attempting to minimize losses from an invasive species, starts in 1996 with the initial finding of the species off Goose Bank (Novaya Zemlya) in 1996 (BK-0007).

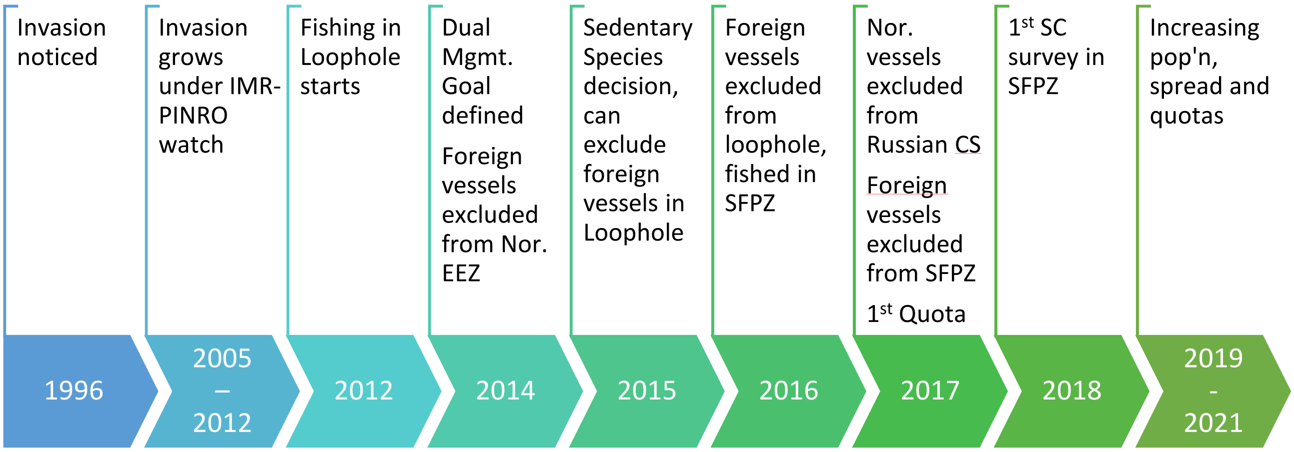

Figure 1: Timeline of Norwegian Snow Crab Resource Development

6. As indicated in Figure 1, institutional changes over time have affected the outlook of the industry in complex ways that make assessing the fishery's potential additionally challenging. This report thus focuses first on the bio-economic potential of the Barents Snow Crab production regardless of the ownership or capabilities of the vessels engaged in the fishery, and then addresses some questions regarding the specifics of the North Star business model.

7. The Snow Crab is the second invasive crab species to become a commodity resource in the Barents in recent years. The Red King Crab was introduced to the Barents Sea in the 1960s and has since become a valuable commercial species in northern Norway (BK-0008, BK-0009). Snow Crab biomass estimates in the Barents Sea are significantly higher than those for the Red King Crab, as are accompanying expectations for profits. While there are meaningful differences between the two species, in particular with respect to where the species' habitats are, the experience of the Red King Crab illuminates management choices and actions that Norway has taken recently with respect to the development of an invasive crab species that are helpful in understanding the evolution of the Norwegian Snow Crab fishery.

8. Since the discovery of the presence of the species in the Barents Sea and its subsequent use as a fishery resource commencing in 2012, expectations for Barents Sea production have been high. These expectations were fueled by the rapid rate of expansion of the species, particularly in comparison to the Red King Crab expansion that had begun decades earlier but already has been outpaced by the snow crab (Figure 2).

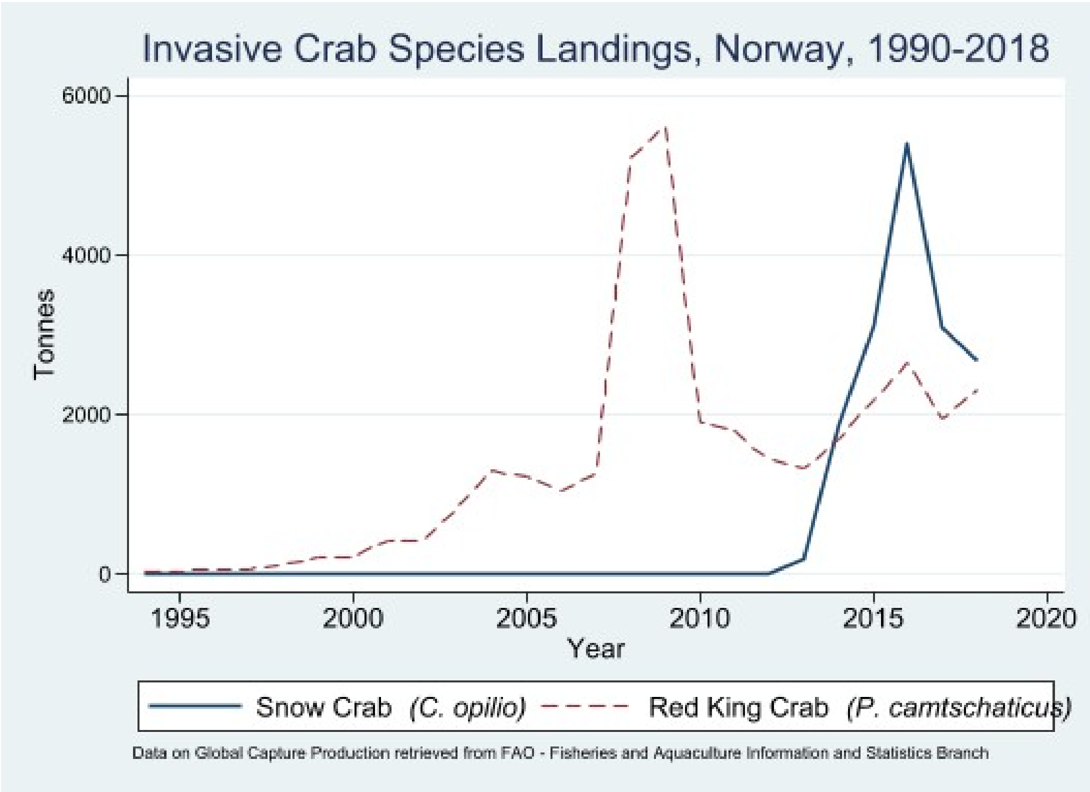

Figure 2. Landings in Norway of the invasive Red King Crab have been eclipsed by snow crab harvests in a few short years. Data from FAO-Fisheries and Aquaculture Information and Statistics Branch (BK-0010)

9. The optimism has been fed by presentations such as those made at IMR in 2014 and other optimistic reports as documented in the news and other scientific presentations **(BK-004, BK-00011, BK-0012, BK-0013)**.

10. While the rhetoric suggesting significant growth potential may have died down in recent years, the story told by the data does not, in fact, appear to have changed from this early optimism. For example, Russian crab vessel association “Far Eastern Crab Catchers Association” purchased considerable Russian quota in the Barents Sea for 2020, requiring investment in new vessels as part of the quota sale, and causing relocation of vessels from the Sea of Okhotsk to the Barents Sea in 2020 in anticipation of profitable harvests. This came in response to Russia's decision in 2019 to reform crab quota allocation so that one half of the crab quota would be auctioned, with rights for 15 years, along with an agreement to invest in new crab fishing vessels. While I do not have a complete breakdown by buyer or between Red King Crab and Snow Crab, SeafoodSource reported after the 2020 auctions that the portion of Barents Sea Red King Crab and Snow Crab quotas sold for RUB 42.8 billion (USD 669.64 million, EUR 600.44 million) for 10,800 tonnes of red king crab and 13,200 tonnes of snow crab **(BK-0014)**. Furthermore, these harvests are expected to be sustainable and even growing in the long run, as the association has paid to initiate the Marine Stewardship Council (MSC) certification process for the fishery **(BK-0015)**, while another crab association has already obtained MSC certification for Snow Crab in the Barents **(BK-0016)**.

Pertinent Barents Sea Conditions for the Snow Crab Fishery

11. The Barents Sea is a highly productive Arcto-boreal marine ecosystem whose waters are bordered by Norway and Russia, and contain the internationally shared Svalbard Archipelago (**BK-0017**, p. 1). The temperature and depth conditions are such that the Snow Crab may be expected to extend its spread throughout much of the approximately 1.6 million km^2, particularly to the north and west. Fisheries in the Barents are generally advised by the International Council for Exploration of the Sea (**ICES**), though this is not the case for the two invasive crab species, where management is done by Russia and Norway independently (**BK-0017**, p. 12).

12. The sea is underlain entirely by Continental Shelf (**CS**) that is within the 350 nm limits for Norway, Russia, and the Svalbard Archipelago, but the Exclusive Economic Zone (**EEZ**) 200 nm limits mean that there are international waters known as The Loophole, generally overseen with governance through the North East Atlantic Fisheries Commission (**NEAFC**). Furthermore the Svalbard Treaty (1920) and subsequent developments for the 200 nm zone mean that, while Norway has sovereignty over the archipelago and an EEZ around the islands, management and enforcement of fishing regulations has presented a number of challenges over time (**BK-0018, BK-0019, BK-0020, BK-0021**).

13. The Institute for Marine Research (**IMR**) and the Polar branch of the Russian Federal Research Institute of Fisheries and Oceanography (**PINRO**) are the two scientific bodies in the Barents Sea charged with overseeing resources and scientifically advising their management. They have jointly conducted Benthic Ecosystem Surveys (**BESS**) annually for decades, in which they gather data from trawl surveys at a set of stations (**BK-0022**).

14. Spatially explicit Norwegian fisheries accounting divides the Barents Sea into "statistical areas" illustrated in Figure 3. These statistical areas are used here to further determine potential densities and Snow Crab populations in the different management zones.

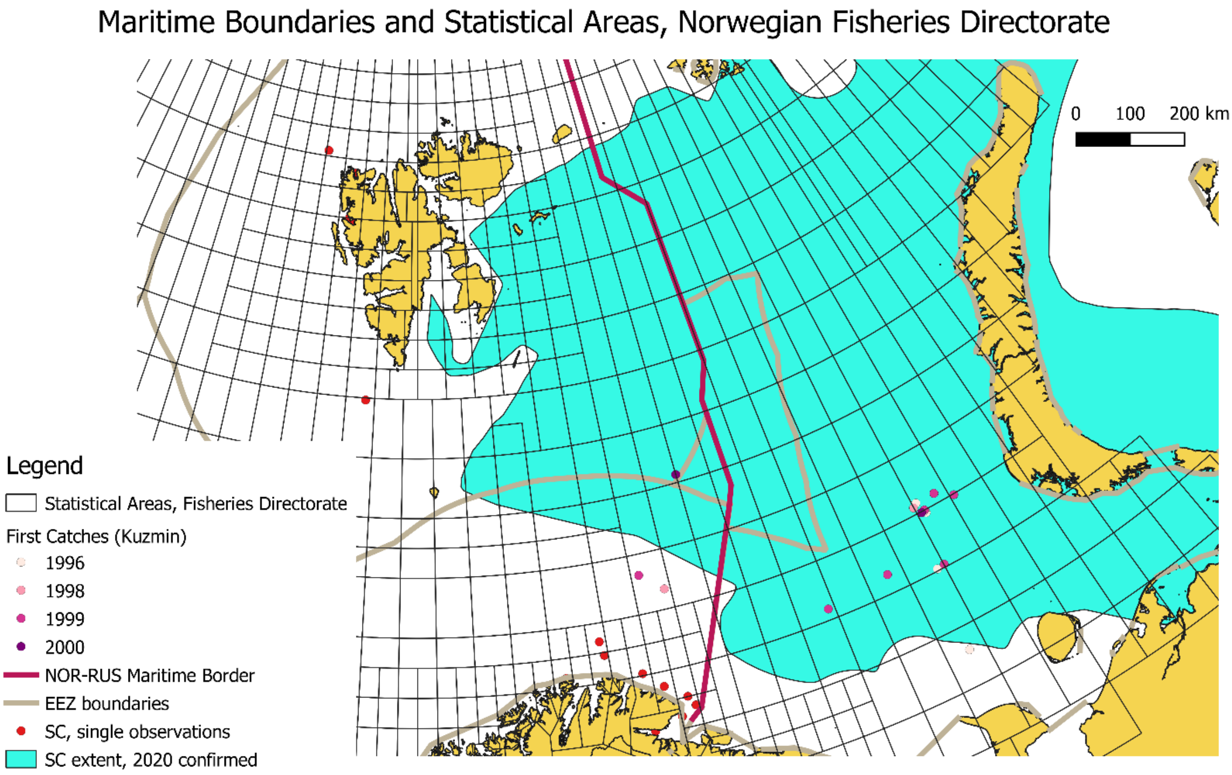

*Figure 3: Maritime borders and Fisheries Statistical Areas in the Barents Sea. Figure generated by Brooks Kaiser using QGIS software and data from The Norwegian Fisheries Directorate geoserver (Statistical Areas), the Institute for Marine Research geoserver (Snow Crab (SC) observations and extent, and NOR-RUS maritime border), Kuzmin (**BK-0007**) (First catches), and marineregions.org (EEZ boundaries).*

Initial invasion

15. The initial arrival of the invasive Snow Crab is believed to have been accidental. Conflicting opinions on the 'how' which are likely to remain unanswered and vary between ballast water introduction and natural range expansion from the Bering Sea population. There is agreement that the population in the Barents Sea consists of a single stock and is not being continuously fed by introductions from other populations (**BK-0015**, p. 81).

16. The Norwegian Biodiversity Information Center, a national information clearing house, classifies the Snow Crab as a "Potentially High Risk invasion" (**BK-0023**) due to its high invasion potential throughout the Barents Sea combined with its many unknown ecosystem impacts.

17. Answers regarding how Snow Crab was introduced in the Barents Sea would clarify some management obligations for ecological conservation of existing benthic habitat. However, with no reason to believe purposeful or continuing introduction, the distinctions regarding the introduction pathway may not be so meaningful. In short, if the Snow Crab had been intentionally introduced after the Convention on Biological Diversity (**CBD**) agreements on invasive species in the 1990s, then Norway would bear some international obligations to prevent the Snow Crab from spreading outside its waters. Without evidence of purposeful introduction or ability to assign liability for accidental introduction, these obligations are lessened (**BK-0024**).

Spread in the Barents

18. From 2005, Snow Crab have been reported in the BESS conducted jointly by IMR and PINRO and provide the longest time series of information on the density and spread of the Snow Crab in the Barents. These BESS data have been supplemented in recent years by logbook and pot survey data from Russian and Norwegian fishing effort in the Loophole, the Russian EEZ (Russia) and the Svalbard Fisheries Protection Zone (***SFPZ;*** *Norway*).

19. The IMR-PINRO reports generated from the BESS data have been used to generate estimates shown in Figure 4 of the existing (2016) and future extents of the spread of the Snow Crab, under different expectations of future sea bottom temperature conditions. The future extent describes the full expansion expected under different ocean conditions rather than temporal expansion, and no explicit time frame is given (**BK-0025**, p. 95). This follows from the fact that the existing time-series of data do not clearly reveal the pattern and tempo of spatial spread in the Barents (**BK-0025**, p. 97). While depth conditions are suitable throughout virtually all of the Barents, the full extent of the spread is expected to be limited by temperature conditions. The species' preferred bottom temperature range is -1°C to +3°C. Average bottom temperatures in most of the Barents currently satisfy these conditions. In all four cases, there is a positive probability of Snow Crab presence throughout the Barents Sea. The lowest probabilities are for the Norwegian Exclusive Economic Zone (EEZ), situated in the warmer waters to the south of the invasion path. While colder sea bottom temperatures (-1 deg. C. over current) increase the probability of Snow Crab presence, the spread is expected throughout the Barents even with warmer temperatures (+1 deg. C. over current).

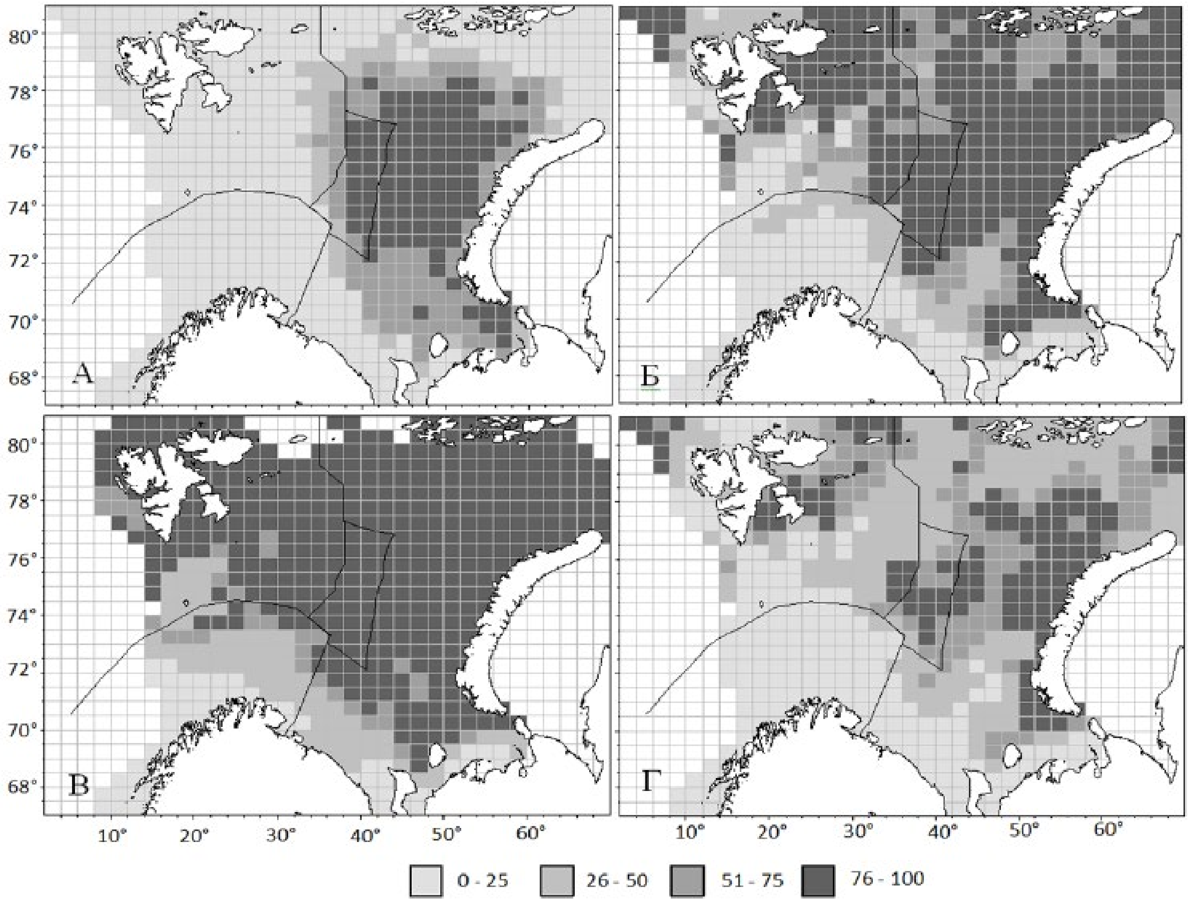

Figure 4: Forecast distribution of snow crab in the Barents Sea as presented in the Marine Stewardship Council fisheries assessment report [Fig. 6] ***(BK-0015****, p. 89). The probability (%) of occurrence as observed with 2010-2016 IMR-PINRO data (Upper left panel), the forecast distributions at the current annual average temperature (Upper right panel), if temperature averages 1°C lower than the current average (Bottom left panel) and if temperature averages 1°C higher than average temperatures (Bottom right panel).*

20. The data used to generate the maps in Figure 4, already 5 years old, may significantly underestimate both the current and future presence of the crab in the northwest portion of the Barents. In 2018, IMR supplemented the IMR-PINRO surveys with a pot-based survey concentrated on the SFPZ. (See Annex 2 for additional visualization). This survey method matches the catch technology used in the fishery and provides better understanding of the spread of the species to date, and thus can more accurately reflect the extent of Snow Crab in the Barents Sea, as opposed to the BESS IMR-PINRO surveys which are trawl surveys.

21. The results (orange circles) of IMR's 2018 pot-based survey in 2018, illustrated in Figure 5, show that the progress of spread in the northwestern Barents is much further underway than the 2017 IMR-PINRO surveying, which includes the area sampled with the pot-based survey, suggests (green circles).

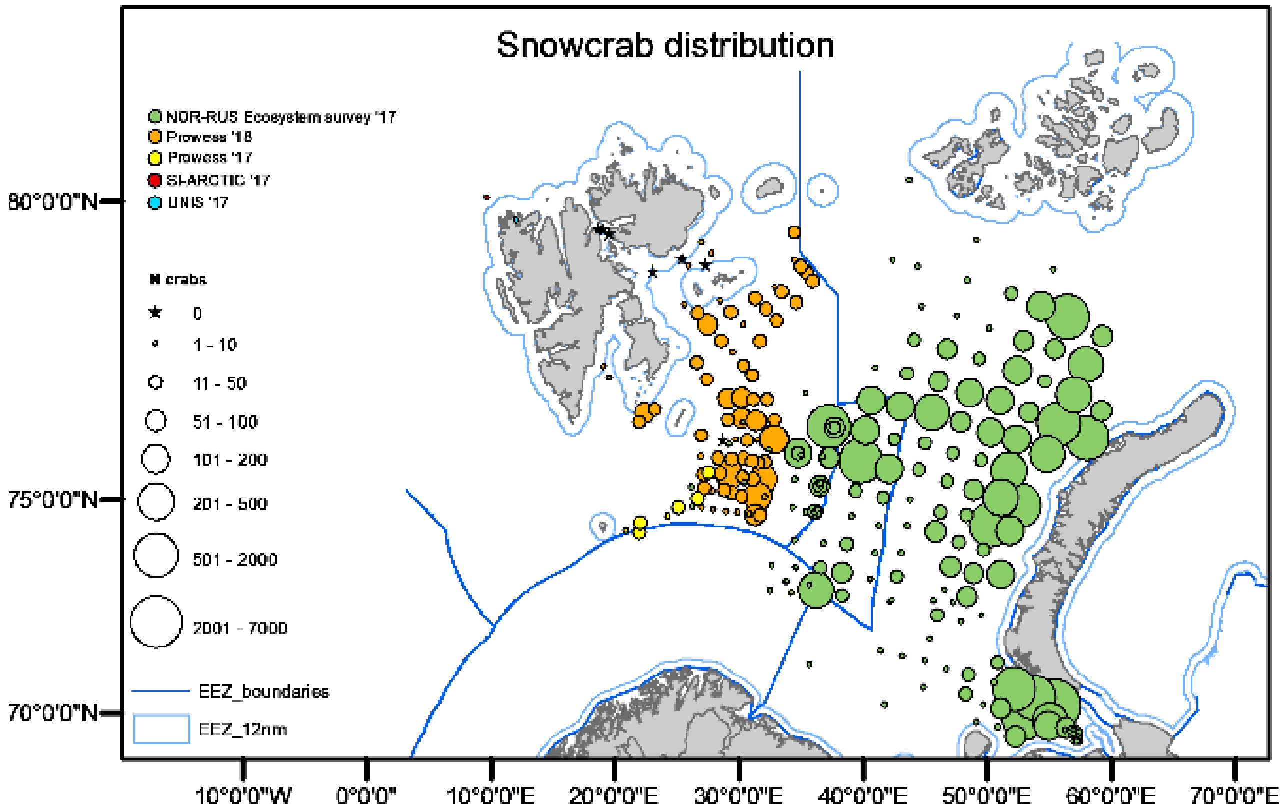

Figure 5: Snow Crab distribution compiled from IMR-PINRO surveys and supplemented by the 2018 Norwegian pot survey.

22. The head of research for benthic resources at IMR, Carsten Hvingel, presented in 2018 that the spread should reach its furthest extent by 2030 (**BK-0026**). This, in conjunction with the 2018 pot-based survey results, sets the outer bound for the timeline until the spread is at its maximum coverage.

Fishing Statistical Areas by Estimated Presence of SC

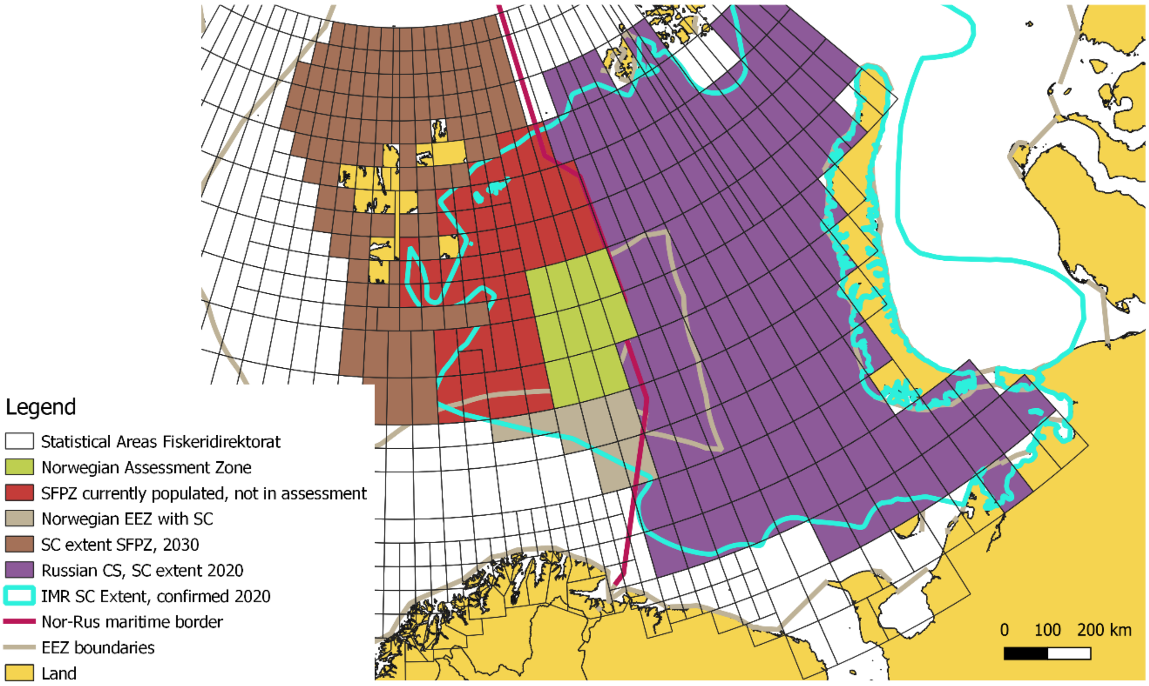

Figure 6: Norwegian fisheries statistical areas identified by zones for crab assessments and regulation.

23. The current spatial areas covered by stock assessments of both countries are considerably smaller than the full expected extents in their waters. The Russian Federation has not allowed fishing in its CS portion of Loophole (85% of the Loophole area) since 2017, even by their own vessels, while the Norwegians have only calculated biomass estimates for a limited portion of the SFPZ, shown in green in Figure 6. The snow crab quotas are thus based on advice given for only a limited portion of the Barents Sea. Without long run data, they have also used parameters for the models based on snow crab populations elsewhere, with particular reference to Atlantic Canada and the Russian fisheries in the Bering Sea **(BK-0001**, p. 10). IMR has surveyed a much greater area, with the first survey in 2018, using techniques suited specifically to snow crab instead of the more general benthic survey tools used in the IMR-PINRO joint surveys of the same area (**BK-0027**, p. 4). While population density on the Russian continental shelf currently appears higher than that of the Norwegian shelf, the species is still expanding its range, while presumably increasing its density in locations that are not already at capacity.

24. Thus the sum of crab population estimates in the assessment areas is an inappropriate measure of capacity for the potential fishing regions, underestimating the productive capacity significantly. To determine appropriate estimates of potential catch and associated quotas, the impacts of spread and increasing densities on populations must be accounted for.

b. Areal densities of Snow Crab in the Barents

25. We define the Maximum Sustainable Yield (**MSY**) of the Norwegian Snow Crab fishery as the highest yield that can be repeatedly harvested over time. The *Biomass* associated with this yield level, in other words, the population that supports MSY, is defined as **Bmsy**. Without fishing pressures, any given area is assumed to be able to support a certain number of crabs at a *carrying capacity* for the area. This carrying capacity reflects the ecosystem's ability to sustain the population at a constant level over time. With an invading species, new areas of invasion are initially below their carrying capacity and the Bmsy as the species settles and colonizes the area with just a few initial specimens. The relationship between the carrying capacity and the Bmsy is not known with certainty, but has been modeled in both the Russian and Norwegian stock assessments as following a logistic growth function as shown in Figure 7 (**BK-0028**, p. 9). In the IMR stock assessments, the stock biomass is measured by an index rather than by weight, so that the Bmsy is calibrated to a value of 1, and the carrying capacity is double that, or 2[1].

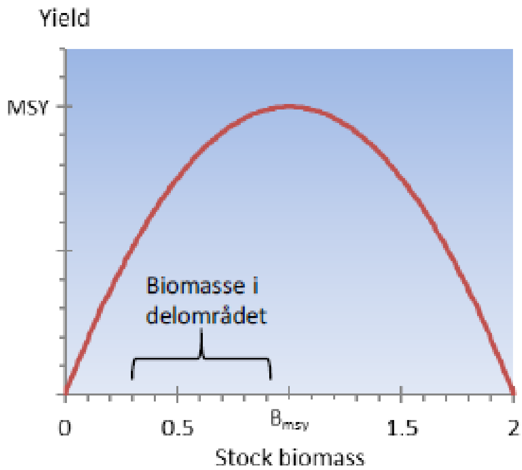

Figure 7: Logistic Production Function with Biomass Index, Bmsy =1. From IMR Snow Crab Stock Assessment Reports. The parenthesis shows the portion of the curve in which IMR estimates the population for the area under investigation was in 2019.

[1] This is a function of the mathematical form of the logistic curve. Its use in fisheries economics is the norm presented in all textbooks. Meaningful deviations from this assumption would generally only be needed if there were an assumption that a high initial population is required to set off the invasive growth.

26. To estimate the MSY for a fully invaded Barents Sea, both the extent of the spread (as shown for example in Figure 4) and the density of the biomass is needed. Similarly, the MSY for any smaller area can be realized only when densities in that area have reached Bmsy or higher. That is, as the density of the crabs is increasing toward carrying capacity, MSY is achievable for a given area once the population has risen to Bmsy in that area. The curve in Figure 7 illustrates the relationship between growth and population posited by IMR for Snow Crab in the area surveyed, without harvest. At any given population, the curve shows the growth rate to the next period. Note that only at the carrying capacity (2) and extinction (0) are the populations naturally stable. The parenthesis shows where IMR estimated the stock biomass range to be for the area in 2019 – below Bmsy. Though they have not included the figure itself in the 2021 stock assessment, the current estimate is that the stock biomass for the area has now grown to be at or above Bmsy.

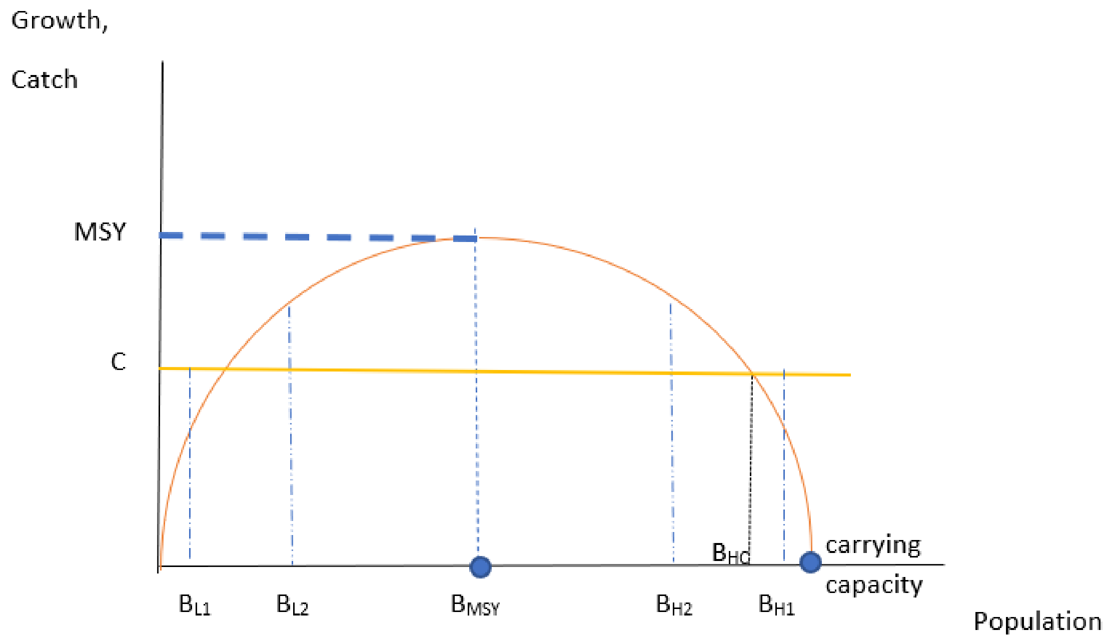

Figure 8: The relationship between population, catch, and MSY with a logistic growth function.

27. Figure 8 provides additional information for interpreting the meaning of the IMR estimates like the one shown in Figure 7 that are used in the stock assessment reports for 2017-2020. Assume that the population can grow along the path shown by the red curve, just as with Figure 7. Then a harvest level of *C* will have different impacts on the ability to reach MSY depending on the population. If population is very low for the area, at B_{L1} for example, then catch at *C* is higher than the growth level (red line), and population will fall toward zero. If population is higher, so that the growth rate is above *C*, such as at B_{L2}, then growth will outpace catch and the population will be increasing. This has been the case since 2017 in the area for which IMR has generated stock assessments.

28. If population is actually above Bmsy for the area, as IMR estimates that it may now be, then harvest at *C* will either be below growth (as it is at B_{H2}) and the population will continue to grow, or harvest will be above growth (as it is at B_{H1}) and population will fall. In both cases, however, the population will be moving toward B_{HC}, which is inefficient in that more crabs could be caught sustainably over time, with a lower population level. Since Snow Crabs are an invasive species and thus higher population levels are also expected to bring unknown ecosystem costs, there is extra advantage to avoid being overly conservative in setting the path to Bmsy.

29. There are a variety of estimates of densities available in the form of Catch Per Unit of Effort (CPUE) from (1) the Loophole (2014-2016), (2) the Russian EEZ fishing (2017-2020), and the Norwegian fishing in the SFPZ (2017-2020). CPUE is the measure of productivity of fishing effort applied to the population. High CPUEs indicate that the resource level is high for the given level of effort and vice-versa. CPUE calculations over time allow fishermen and managers to understand how effort levels are changing the available resource levels. With this information, improved forecasts of populations and their growth can be made. Unfortunately, the estimates for Barents Sea Snow Crab suffer greatly from lack of comparability due to differences in the definitions of catch and effort. That is, for some, catch is defined in tonnes (live weight or round weight), in others, in number of crabs. Effort is sometimes defined by number of pots, by soak time, or by the area of spatial coverage, and intercomparisons are not feasible. They also suffer from high uncertainty due to short time horizons associated with the fisheries in each location (3-4 years each), the limited biological assessment information available for the invasive species in its new habitat, and the limited number of vessels engaged in the fisheries. Uncertainty notwithstanding, estimates are being produced by both Norwegian and Russian scientists in efforts to inform the fishery. Their joint and independent efforts inform our estimated populations and subsequent MSY calculations.

30. Overall expected growth in the catch potential from a growing total population of Snow Crab in the Barents Sea was estimated to follow the trajectory in Figure 9, rising to a mean estimate of ~65 ktons in 2030, with a 95% confidence interval range from ~35 to ~100 ktons. This estimate and figure are reproduced in the 2017-2020 advisory reports produced by IMR for the Fisheries Directorate, with no changes to the overall estimation. It originates from 2016 calculations presented by IMR at various workshops and conferences (**BK-0029**). The model behind this estimate is a Bayesian Surplus Production Model, which works as described in Figure 8 but directly includes uncertainty in the calculations (see Annex 3 for additional information) and is the base tool used by both the Russian and Norwegian scientists in calculating biomass and catch potential estimates. The differences are in the data used to inform the model, which are a function of the areas under evaluation.

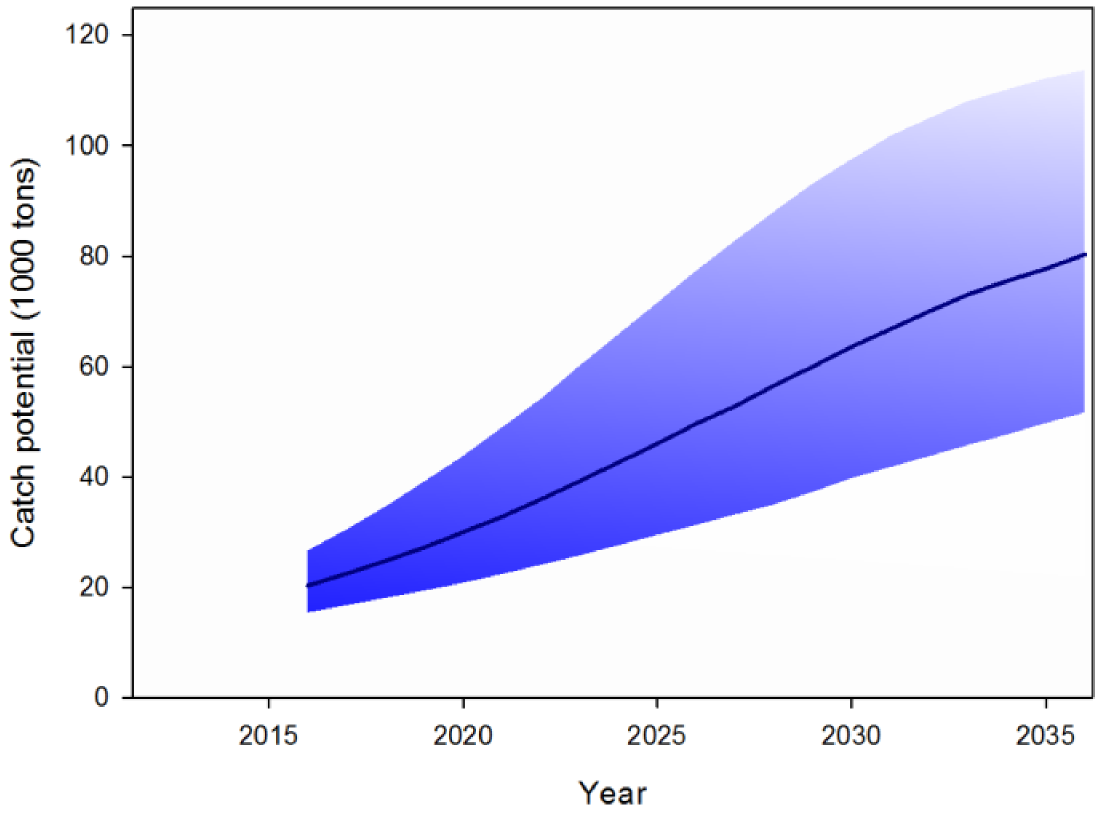

*Figure 9: Modelled trajectory of Barents Sea Snow Crab biomass using a Bayesian Surplus Production Model (**BK-0028**, p. 10)*

Norwegian Density Estimates

31. Norway began to provide stock assessment advice to the Ministry in 2017, and IMR has concentrated that effort on a limited and defined area in the SFPZ, shown in Figure 6 (approximately the green statistical areas). In Figure 6, we also show the additional statistical areas that cover the current extent and expected spread of the crab to 2030 on the Norwegian CS. The map allows us to use the current assessment zone (green) evaluation of the stock to predict (1) information relevant to the current population in the SFPZ (burgundy) and (2) information relevant to the expected additional population spread in 2030 (brown). Note that the Loophole is considered fully invaded and the area estimated does not change over time.

32. The IMR stock assessments include quota advice for the region in which a table is presented with various probabilities associated with potential quota (and harvest) levels. The 2021 table is reproduced here (Table 4) for ease of discussion.

*Table 4: IMR Stock Assessment Summary as Quota Advice, 2021 (reproduced from (**BK-0001**, p. 1)).*

	Catch Alternatives for 2021 (tonnes)					
	4500	5000	5500	6000	6500	7000
Probability that population <Blim	<1%	<1%	<1%	<1%	<1%	<1%
Probability that population <Bmsy	17%	19%	20%	21%	23%	25%
Probability that fishing mortality > Fmsy	7%	12%	18%	25%	34%	43%
Probability that fishing mortality > Flim	1%	2%	2%	4%	6%	9%
Change in population 2020 to 2021	-2%	-4%	-5%	-9%	-11%	-15%
Change in fishing mortality 2020 to 2021	0%	+6%	+15%	+22%	+30%	+38%

*Table on p. 1 of the IMR Snow Crab assessment and quota advice for 2021. [Translated from the Norwegian]

33. Since 2017, the range of these analyses has shifted from 3600-4500 tonnes in 2017 (**BK-0030**, p. 1) to the 4500-7000 tonnes per year shown here in 2021 (**BK-0001**, p. 1). This confirms the understanding that the species density is growing in the assessment zone at the current fishing levels.

34. From 2017-2020, IMR estimated that the population was below Bmsy with 100% certainty (**BK-0027**, p. 1, **BK-0028**, p. 1, **BK-0030**). In the stock assessment for 2021, however, this certainty was significantly reduced. The second row, "Probability that the population < Bmsy", is the probability that the population will be below Bmsy at the quota levels in the column headings, if they are adopted and fished. One can see that even a quota of 7000 tonnes is expected to leave a population greater than Bmsy with 75% probability. For 2021, there is a stated expectation that the population is at or near Bmsy.

35. This is illustrated in the biomass index and fishing mortality estimates in the stock assessment, reproduced in Figure 10. The biomass index is above 1, signalling population above Bmsy, while the fishing mortality index is estimated below one, with the 95% confidence interval just reaching 1, so that fishing mortality, translated to catch of ~4000 tonnes/year, is considerably lower than Fmsy.

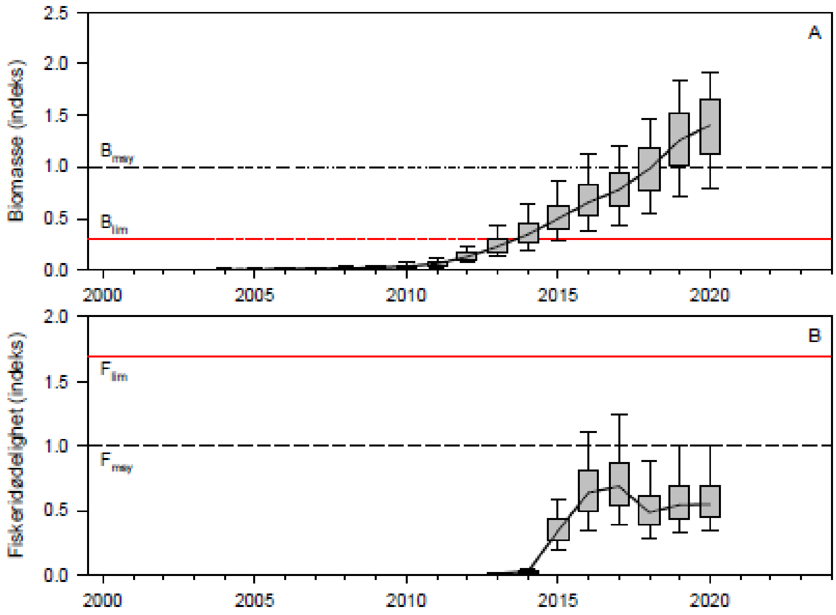

*Figure 10. Estimated biomass index (Biomasse indeks) and fishing mortality index (Fiskeridødelighet index) for Snow Crab in the Norwegian fishing zone of the Barents Sea. Reproduction of Figure 11 in (**BK-0001**, p. 12).*

36. Thus, 7000 tonnes is a reasonable, probably conservative estimate of Fmsy for the stock assessment zone, associated with a population estimate of Bmsy = 46.6 ktons.

37. The 2018 pot-based survey in the SFPZ increased expectations about the rate and intensity of the Snow Crab spread (recall Figure 5). These survey data and the IMR-PINRO survey data are combined, and also supplemented by an index based on the stomach contents of the snow crab predator, cod (torsk). Finally, the data from logbooks for the 4 years of fishing in the assessment zone allow for the creation of a catch rate (CPUE-based) index. IMR has now calibrated the three data sets against the reference growth anticipated in the initial Bayesian surplus production model whose results are illustrated in Figure 9 (from **BK-0001**, Figure 10, p. 11).

38. The calibrations show how well the original model, which predicts Barents Sea catch potentials of up to 100 000 tonnes, fits with the newer data from the three available datasets. 80% confidence intervals for the original model are shown in gray in each of the three panels in Figure 11, with the realized values over time shown as the solid black line. The 80% confidence interval for the very short catch rate index contains the observed rates (top panel), as does the cod index (middle panel), indicating reasonable fit of the model foe these parameters. On the other hand, the combined IMR-PINRO BESS and pot-survey results (bottom panel) indicate that the model is now underestimating population growth. The survey estimates place the population considerably above the expected values for 2019 and 2020. The increasing CPUE-based index in the top panel, which suggests that the same effort catches more crabs now than it did in previous years, further confirms densities are increasing.

39. The indices are used rather than specific biomass estimates to reduce some of the compounding effects of uncertainty, as discussed in Annex 3 and **(BK-0031)**.

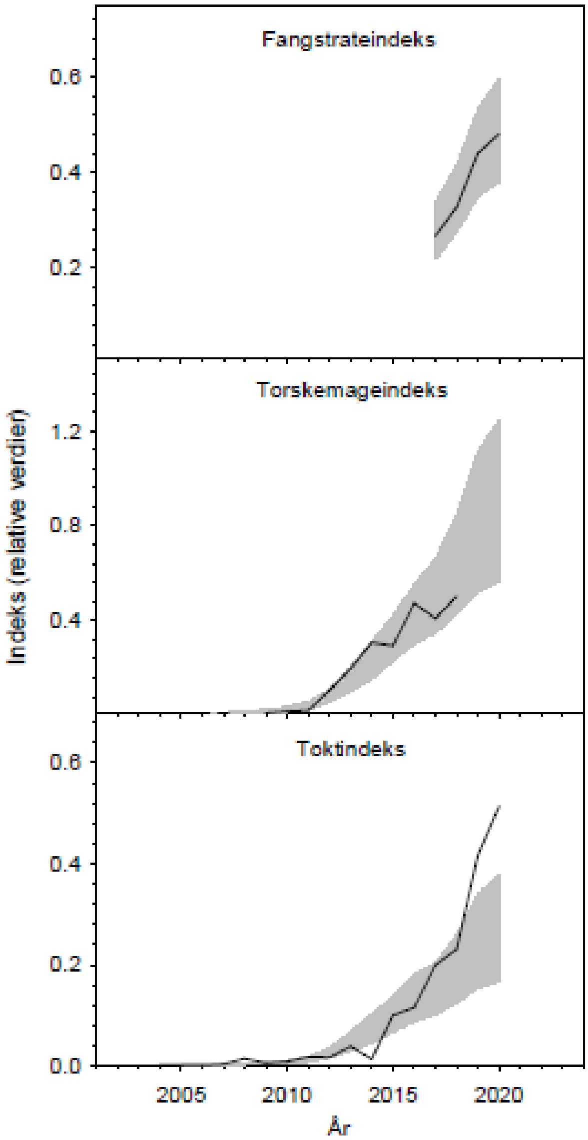

*Figure 11. Model estimates from the IMR fisheries management advice for Snow Crab for 2021. Translation: Top panel: Catch Rate Index; Middle panel: Cod Stomach Index; Bottom Panel: Survey Index. Y-axes are Indices of relative value. X-axis is year. (Reproduction of Figure 10 in (**BK-0001**)).*

Russian Density Estimates

40. As the invasion's starting point and early spread has been primarily in the Russian EEZ and emanating west and north from there, and there was no fishing pressure until 2014, Russian productivity in the Russian EEZ is expected to reflect high densities of Snow Crab and a more developed population. As mentioned, two crab fishing associations are involved in the MSC certification process for Snow Crab in the Russian Barents. The certification process requires review and publication of the stock assessment information used to determine the bioeconomic sustainability of the fishery.

41. Figure 12 shows that until 2020, the population estimates for the Russian EEZ have continued to increase for the zone despite increasing harvests from 2013 (solid line). In 2020 the median biomass estimate has fallen slightly, but it is still above the target (MSY) biomass of 365,000 tonnes.

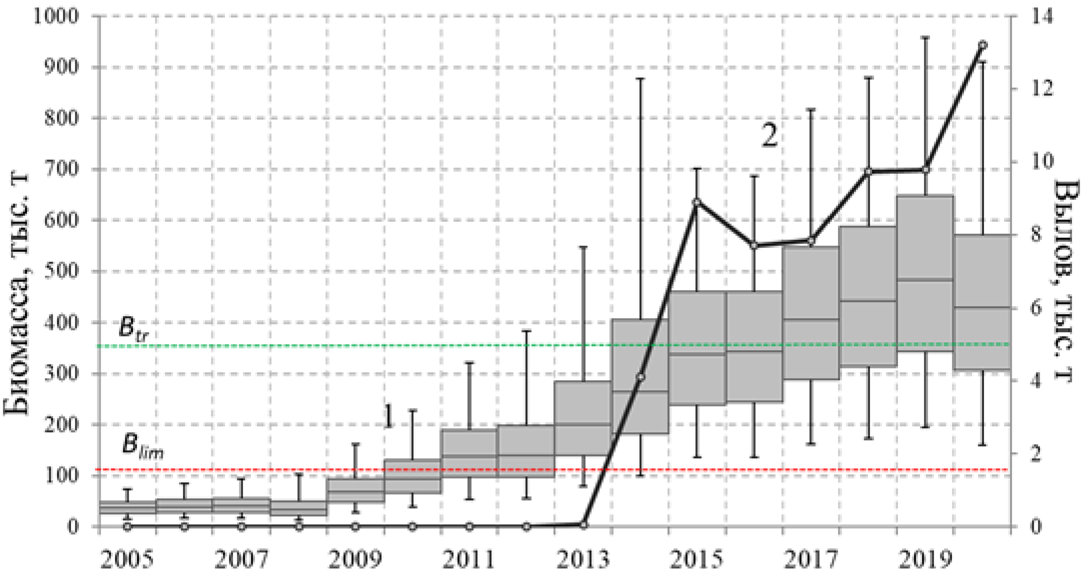

*Figure 12: Snow Crab fishable stock biomass (ktons) estimated by Bayesian surplus production model (left hand axis), with 95% confidence interval around the median, and Yield, ktons (right hand axis), 2005-2020. Green line is the target biomass (~Bmsy), while Blim [=0.30 Btr) is the threshold population of concern. Pers. Comm. S. Bakanev, updating fig. 26 in (**BK-0015**, p. 95).*

42. A summary of the parameters of the model for the Russian EEZ is reproduced from (**BK-0015**, p. 96) in Figure 13. The mean MSY for the Russian EEZ is estimated at 54.15 tonnes, with the Bmsy = 365.6. For the purposes of understanding the Norwegian portion of the stock, this information is useful for extrapolation. This is possible because the Russian assessments include spatially explicit estimates of density derived from CPUE data on the Loophole catches (2014-2016) and the Russian EEZ catches thereafter.

Results of the fit of the Bayesian stock production model to the Russian Snow crab catch data an estimates of stock biomass. MSY = Maximum Sustainable Yield, B = Stock Biomass, F = Fishing mortality K = carrying capacity, q = catchability. (Source: PINRO)

	Mean	SD	25 %	Median	75 %
MSY	54.15	28.03	34.98	52.34	71.47
B_{msy}	365.6	81.35	307.4	355.7	412.1
K	731.1	162.7	614.8	711.4	824.2
q	1.006	0.09738	0.941	1.008	1.071
F_{msy}	0.151	0.07651	0.09945	0.1477	0.1967
B_{lim}	109.7	24.4	92.23	106.7	123.6
B_{pa}	182.8	40.67	153.7	177.9	206

Figure 13: Parameters for Bayesian surplus production model used for estimates of Russian EEZ stock assessment

43. The Russian data provide estimates for the fishable stock that can be applied not only in the Russian EEZ, but also the Loophole and part of the Svalbard Fisheries Protection Zone (**BK-0015**, p. 37, **BK-0016**, p. 93).

44. The figures below are from 2016 data. The density of the stock in the Loophole is estimated to have fallen from the fishing in the previous years, from an original density of 774 tonnes per thousand km^2 as estimated in the Russian EEZ. As no one has fished the Loophole since 2017, and the growth and spread illustrated in the Norwegian stock assessment data suggest that there is rapid growth from potentially low initial populations, this estimate of 426 tonnes/thousand km^2 is assumed to be out of date and a response to open access fishing pressures in the Loophole. They may also have simply exceeded sustainable harvest levels for the population density at the time, which may not yet have been at capacity levels. Given all the many uncertainties in combination with the rapid spread west and the lack of fishing pressure in the Loophole for the past four years, it is reasonable to assume that the Loophole densities are now once again in line with the 774 tonnes per thousand km^2 estimated for the remainder of fully invaded areas.

*Table 5: Densities and fishable stock in 2016 for portions of the Barents Sea (reproduced from (**BK-0016**, p. 37)*

Area	Study area size, thou.square km	Density of legal stock, t/ thou.square km	Fishable stock, thou. t		
			Median	95% confidence interval limit	
				Lower limit	Upper limit
Russian EEZ	471	774	405	201	608
International waters of the Barents Sea	73	426	31	15	47
Svalbard	14	774	11	5	16
Total	558	-	447	221	671

45. This is possible given that in 2015, the published extent of the Snow Crab invasion (IMR) extended just to the edge of the Loophole, while it is clear from fishing effort that crabs were available at commercial levels farther to the east (see Figure 14). Barents Sea snow crab fishing in 2014 and 2015 was conducted almost entirely in the Loophole, with some limited fishing in the SFPZ. Annual catches were ~8 ktons in 2014 and ~18 ktons in 2015. A third year of Loophole fishing with some SFPZ fishing in 2016 (~25% of the total) accounts for an additional ~16.5 ktons in or near the international waters (see also Table 10 below).

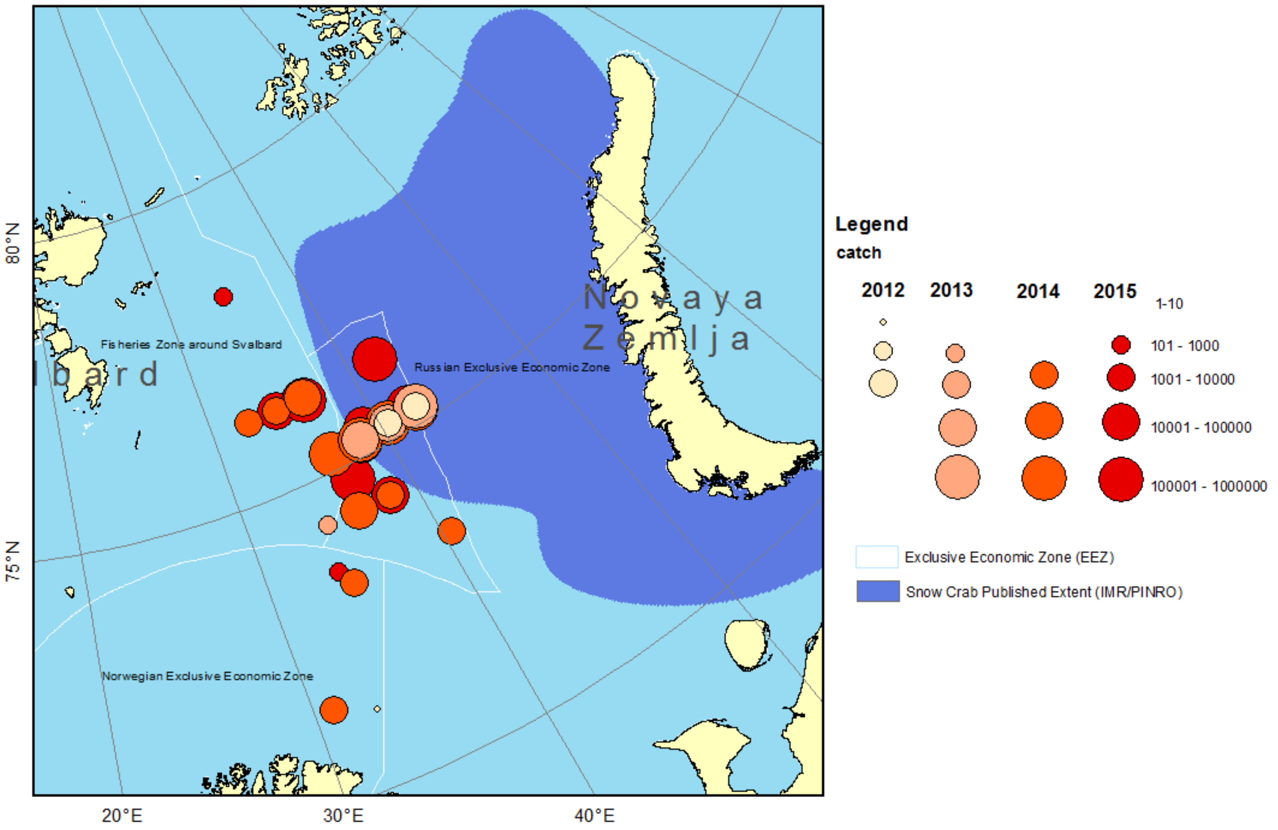

Figure 14: Map of locations and sizes of Norwegian vessel catch in the Barents Sea, 2015. Vessel and Catch Data from electronic logbooks, Snow Crab extent data from IMR. Map produced by Brooks Kaiser.

46. There are insufficient data and too much variability to estimate a current density for much of the Svalbard zone, but we should expect it can climb to this same level, as the PINRO assessments do for the estimated density for 14,000 km^2 of the area included in the 2016 estimates. The figures indicate that the fishable stock for the Loophole, if fully recovered, may be 56.5 thousand tonnes, up from 31 thousand tonnes in 2016. At that stock, following the standard (conservative) harvest control rule used by the Russian Federation of 15%, a Loophole catch of up to 8.475 tonnes could equate to MSY.

47. Like the Norwegian quotas, Russian TAC recommendations have been extremely conservative. First, the Loophole has been closed entirely. Additionally, PINRO made Russian TAC recommendations of 45 ktons in 2019 using a 'highly precautionary' (**BK-0016**, p. 40) estimate for the conditions in the Russian Barents Sea fishing zone, based on the model and understanding of native populations' recruitment patterns in both eastern Russia and Atlantic Canada. Nonetheless, the management authorities deemed the time series of observations too short and the assessment uncertainties too high for this figure, and the TAC for 2019 was set at 9840 tonnes, or only 21.9% of the scientifically recommended TAC (**BK-0016**, p. 40). In 2020 this was raised, but only to 13,250 tonnes (**BK-0001**, p. 8). The 2021 quota is set at 13,000 tonnes (**BK-0032**).

c. Extending the MSY estimates to the full SFPZ and to 2030.

48. Overall, then, the conservative assessment approaches and quota setting to date in both the Russian and Norwegian portions of the Barents mean that the existing quota structure underestimates the available biomass for sustainable harvest in the Barents both today and into the future.

49. Though (**BK-0015**, p. 86) shows that the majority of the snow crab population is currently expected to be in the Russian zone, higher densities than are currently present are expected in the Norwegian Barents even under less favorable temperature conditions. Furthermore, particularly if the Russian population continues to be harvested so conservatively, growth to the west will be consistently fed by spatial spread as well as local reproduction. The Russian closure of snow crab fishing in the Loophole also reinforces the likelihood of a resilient population reservoir for both the Russian zone and the Norwegian zone. The logistic model used in the scientific reports does not directly include spatial recruitment, with which it is hard to obtain closed form solutions estimating populations **(BK-0033**, p. 570). In the Russian estimates, this may be of little importance because as **(BK-0015**, p. 89) shows, the spread is already present with high probability throughout the zone.

Combining the spread and density results for estimates of sustainably harvestable biomass in the Loophole and SFPZ.

50. To determine estimates for MSY levels in the Barents Sea Loophole and SFPZ that amalgamate the many sources of information, three sets of primary estimates are derived and shown in Table 6.

51. First, using QGIS (Geographical Information Systems) software the areas for the relevant portions are estimated. The areas for the Statistical Areas shown in Figure 6 are estimated and shown in the first column of Table 6. By 2030, the area of spread is estimated to more than double over current levels in the SFPZ. Then, because the density in 2030 for the entire additional SFPZ may not have achieved Bmsy, I estimate a full-density equivalent area. To do this, I assume that the mean of a random variable with a χ^2 distribution with less than a 5% chance that the entire region is at capacity provides a reasonable estimate of the expected full-density equivalent area (see Annex 4). The full-density area equivalent is then calculated to equal 240 thous. Km^2.

52. With the spread factors estimated, three sets of MSY figures are estimated for 2021 and 2030. Using the information from the Norwegian stock assessments, in which the scientists find that 7 ktons is an appropriate estimate of MSY for the assessed area given the current state of knowledge, the estimated 2021 MSY is 42.760 ktons for the entire area, which increases to 67.387 ktons in 2030.

53. Using the Russian density estimates calculated from catch rates (CPUE, Columns 4 and 5), the 2021 estimate is 45.356 ktons and the 2030 estimate is 73.220 ktons. In this model, the density estimate of 0.774 ktons per 1000 km^2 (shown in Table 5) is used to calculate an estimated population, from which 0.15 is assumed to be sustainably harvestable following the Russian evidence.

54. Finally, using the Russian production model estimates, the 2021 estimate is 25.760 ktons and the 2030 estimate rises to 43.090 ktons. In this model, the current Barents Sea production estimate of 83 ktons is shared out evenly by area amongst the zones (including the REZ and NEZ), and then the implicit density is used to calculate the expanded range to 2030.

Table 6: MSY Estimates for Barents Sea Loophole and SFPZ, Current and 2030

		Ktons MSY (mean)					
	Area (1000 km2)	Norwegian Data (production model)		Russian Data (density estimates)		Russian Data (production model)	
Year		2021	2030	2021	2030	2021	2030
Loophole	99.06	10.164	10.164	8.475	8.475	7.320	7.320
SFPZ:							
Currently Assessed	68.22	7.000	7.000	7.920	7.920	5.040	5.040
Currently Populated	249.45	25.596	25.596	28.961	28.961	13.400	13.400
Assumed Spread by 2030	279.10	0.000	24.627	0.000	27.864	0.000	17.330
Total:	695.83	42.760	67.387	45.356	73.220	25.760	43.090

55. There is no way to know the probability distributions within these estimates or across these estimation methods. Thus, rather than attempt to force calculation of a single point estimate, these values are presented as the mean ranges for 2021 (from 25.760 – 45.356 ktons) and 2030 (from 43.090 – 73.220 ktons) in Figure 15.

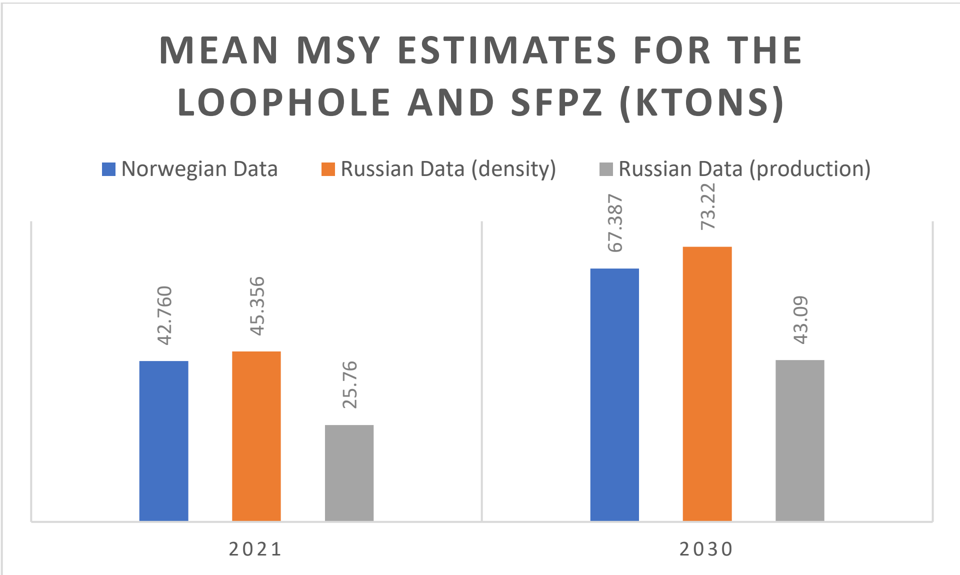

Figure 15: Mean estimates of Current and Potential MSY for the Loophole and the SFPZ

Norwegian production in the global context

56. Snow Crab fisheries around the world have existed for decades, with production shifting first from Japanese vessels to American and Russian production through enclosures of the seas in the formation of EEZs through the 1970s and 1980s, and then to Canadian production in the 1990s as Canada's cod stocks failed and their Snow Crab fisheries grew. At the present time, Norwegian production makes only a small contribution to the industry's production and sales. The market for *C. opilio* remains dominated by Atlantic Canada, Alaska (USA), and Russia with other small harvests from Greenland, Korea and Japan. This is expected to change significantly as conditions in Atlantic Canada and Alaska have deteriorated in recent years (**BK-0034**).

57. As shown above, Barents Sea production is expected to grow as the species continues to spread and increase in density. At the same time, Alaskan and Canadian production levels are struggling to maintain current catch levels and are expected to continue to fall in coming years, with Canadian production down by almost half in the past decade (**BK-0035, p. 4, BK-0036, BK-0037, BK-0038**). Russian production in both the east (Bering) and the west (Barents) is becoming increasingly better regulated, including a series of treaties targeting Illegal, Unreported or Unregulated (IUU) fishing. Russian quota restructuring has resulted in increased cartelization of crab fishing. All these forces should be expected to put downward pressure on production that is reflected in higher and possibly more stable prices.

58. In short, future income from Snow Crab in the Barents is expected to increase both through increased production and rising prices, discussed next.

d. Snow crab value and profitability

A Global commodity with global pricing

59. The Sea Around Us Project (**BK-0039)** has estimated landed values for the full catches of species globally using reports of ex-vessel prices and landed values. Data are converted from local currencies to US dollars, and then normalized to 2005 USD for comparability over time and place. The results are illustrated in Figure 16. While most catches of *C. Opilio* have occurred in national waters (within EEZs), some have occurred in international waters. This is the case for the catches from the International Loophole in the Barents Sea in recent years. The importance of this catch in overall value, shown with the scattered dots in Figure 16 has been low, in line with the small share of global catch to date from the region.

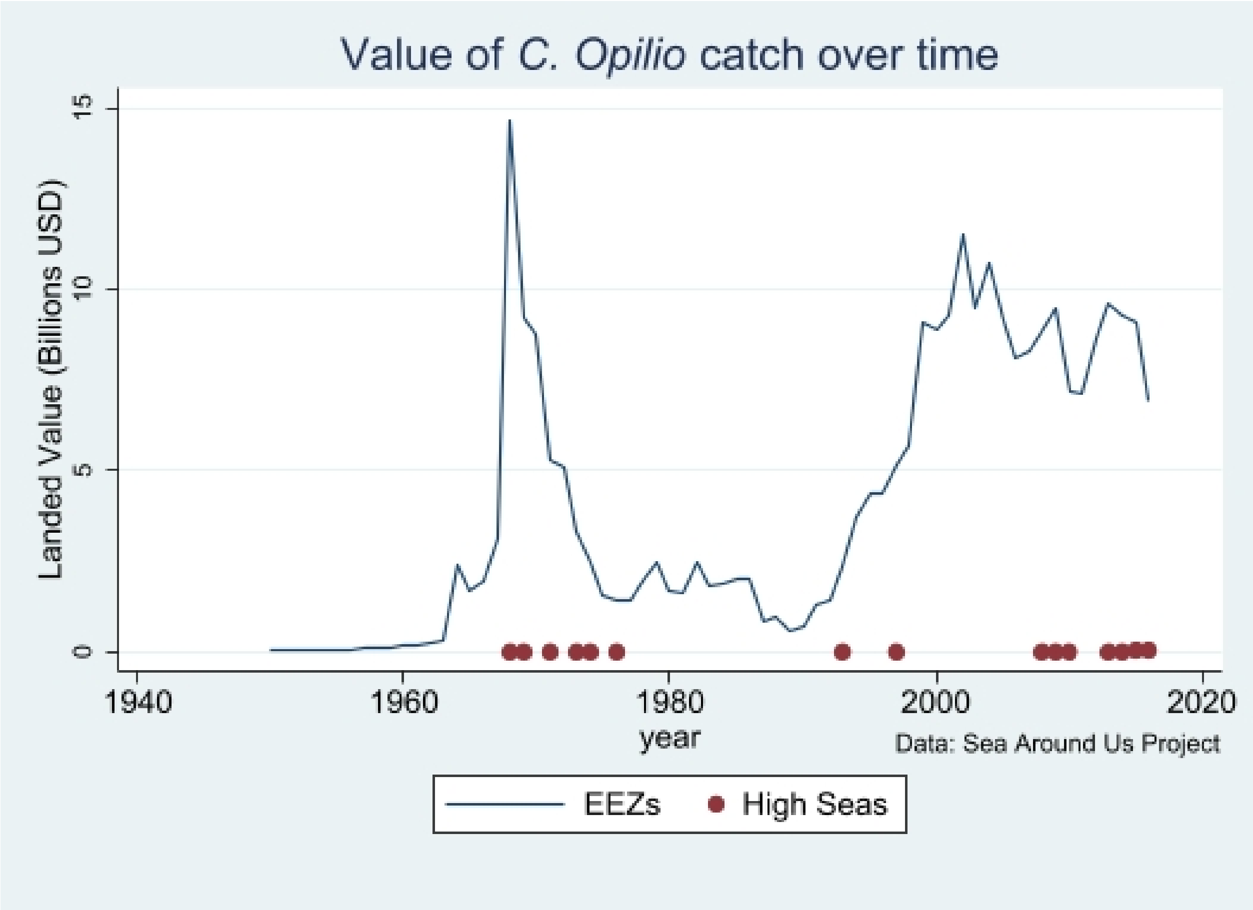

*Figure 16: Value of total C. Opilio catch over time, 2005 USD (Billions). Data from estimations by the Sea Around Us Project (www.seaaroundus.org, (**BK-0039**))*

60. The increase in value beginning in the 1990s occurs at the same time as the large increase in catch from Canadian waters. The growth in value is not only from the additional catch. As illustrated in Figure 17, the per unit value also grew through the 1990s and has been relatively constant since that time.

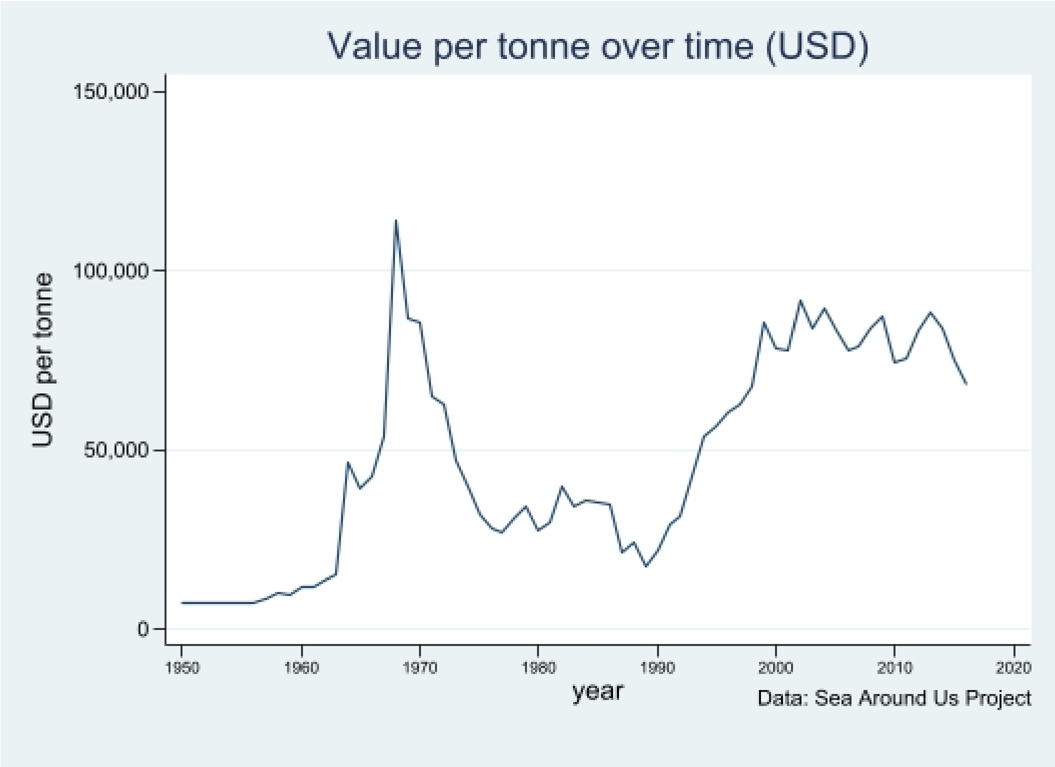

*Figure 17: Value per tonne, 2005 USD. Data from Sea Around Us Project (www.seaaroundus.org, (**BK-0039**))*

61. The Sea Around Us project data only runs through 2016. In recent years, prices have been increasing. The Norwegian evidence discussed in the following section reflects the broader industry trends described above.

Prices for Norwegian Crab

62. As Norwegian landings have progressed, rising during the initial open access harvesting of the Loophole and then falling some as activities moved in to the SFPZ, value has followed the same overall pattern (see Figure 18). It has however increased at a faster pace than catch from 2017, reflecting rising prices.

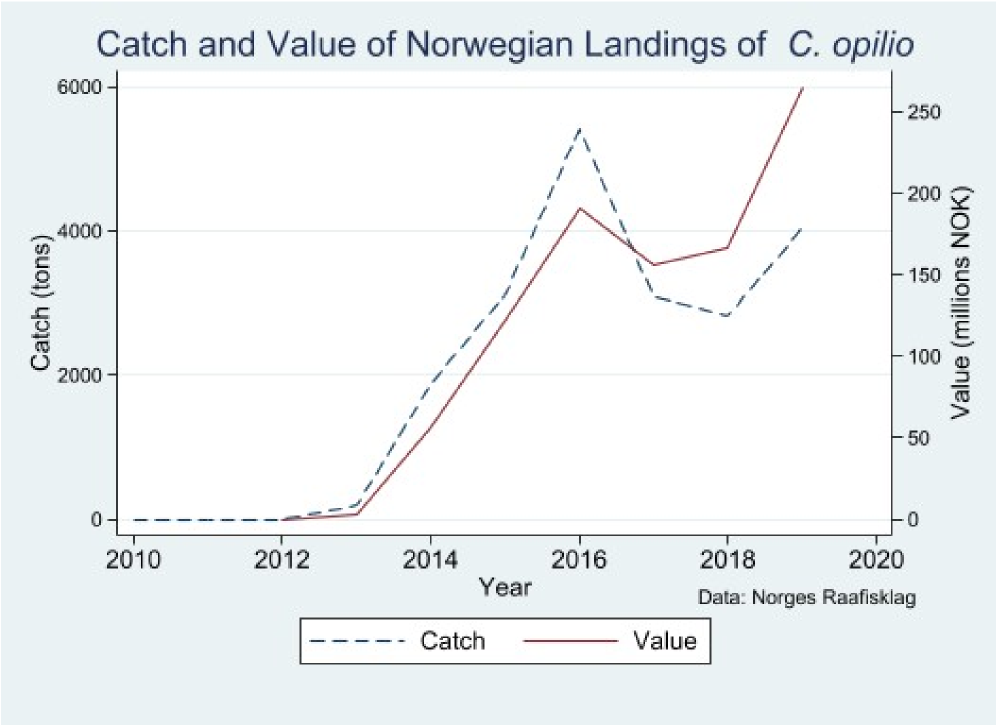

Figure 18: Catch and Value of Norwegian Landings of C. opilio, 2012-2019.

63. This relative growth in value is illustrated in Figure 19. While 2020 prices have been affected by corona complications in markets and logistics, these effects are expected to be temporary, and prices are expected to continue to rise in the long run.

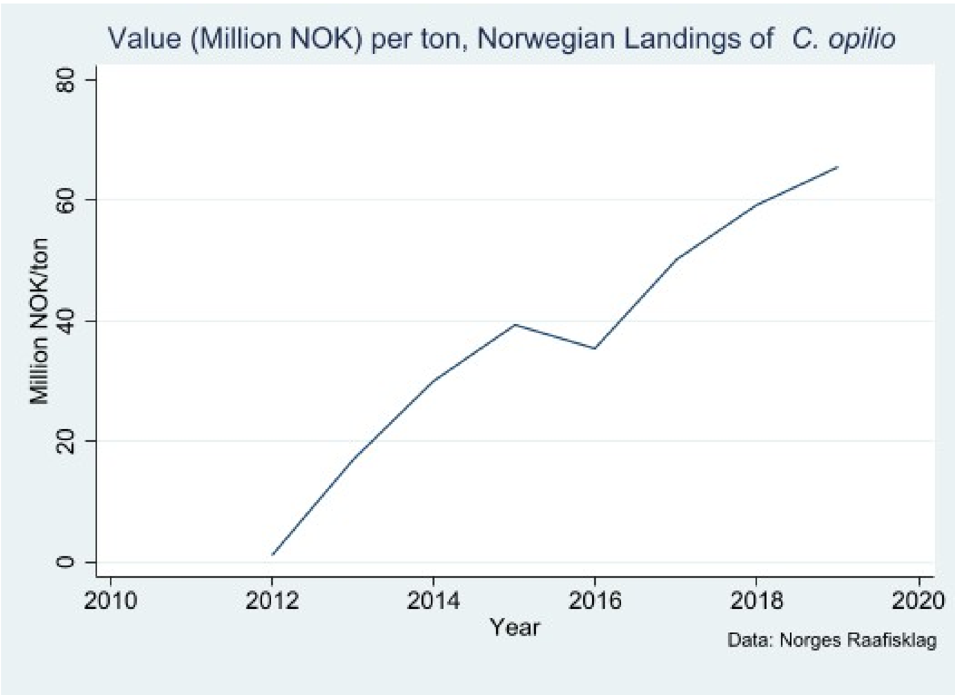

Figure 19: Value per ton in Norwegian landings of C. opilio, 2012-2019. Data from Norges Raafisklag.

64. Norwegian fisheries have legislated minimum prices for landings at Norwegian ports. These price supports function to assure a minimum return on a given catch. When a fishery's prices are considered sufficiently high, the minimum support prices will not be increased further. The data in Table 7 show how minimum prices in the Norwegian Snow Crab fishery have changed since 2015; prices for both live and frozen crabs rose in the first two years, while prices for frozen crab rose throughout the period from 2015-2018. Prices have been fixed since 2018, signaling they are no longer binding. On the other hand, in October 2020 the rules for weighing clusters changed in an effort to more uniformly account for water and ice additions to weights from processing.

Table 7: Minimum Prices at the dock for Norwegian Snow Crab

Date	Live Crab (kr/kg)			onboard frozen clusters
	at least 800 g	500-800 g	350-500 g	(kr/kg)
26-Oct-20				Change in rules for weighing
24-Jan-18	30	25	15	80
9-Jan-17	30	25	15	60
1-Feb-16	25	20	10	50
22-Jun-15	23	17	8	47

Minimum prices not set for crabs less than 300 grams or Injured crabs.

65. Confirmation that minimum price supports are no longer requested comes from investigating export price data for Norwegian snow crab, shown in Figure 20. The price data suggests robust, diversified, and growing markets in Asia and Europe in addition to the United States.

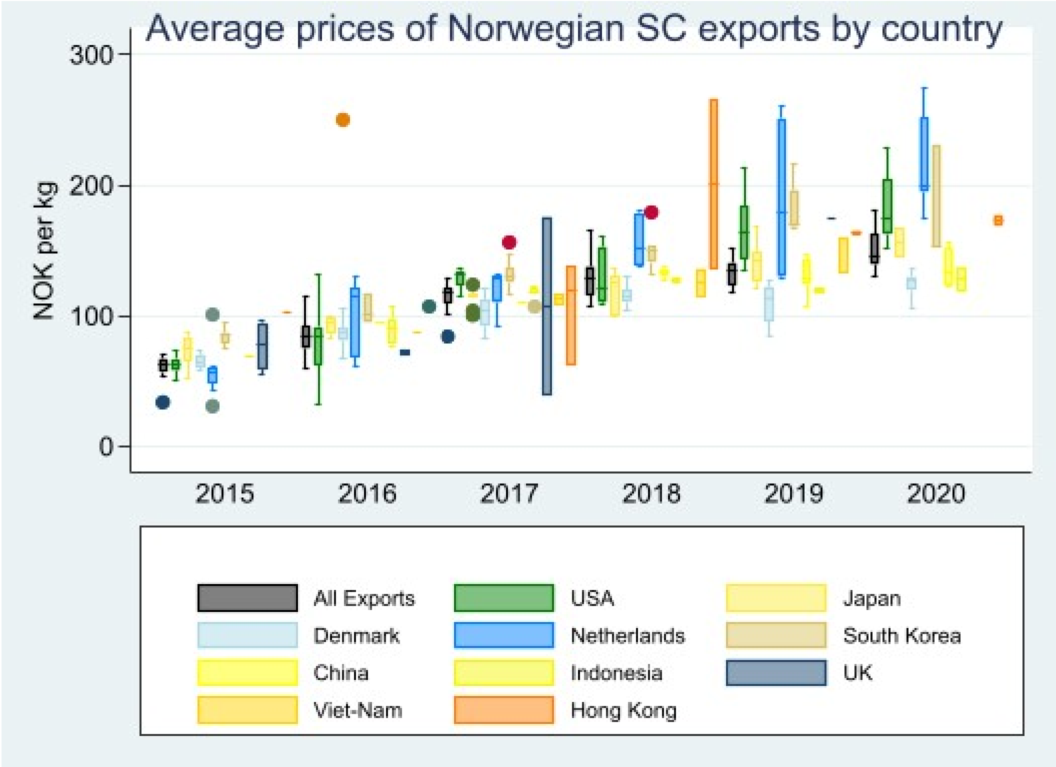

Figure 20: Average export prices (NOK per kg) by country. Box plots generated from monthly data averaged over the calendar year. Data source: Urner Barry.

66. The visible upward trend is clarified by looking at the characteristics of all Norwegian export prices over time (averaged by year) shown in Table 8. There has been a mean increase in prices of about 18 NOK per kg per year, equating to about an 18% average annual growth in prices. The sustainability of such growth in the long run is unclear, but the 5-year trend is convincing.

Table 8: Characteristics of the Norwegian Export Price over time (Data: Ulmer Barry)

Year	Mean	Std. dev.	Min.	Max.
2015	60.66	9.88	34.01	70.10
2016	85.09	15.54	59.78	115.67
2017	114.59	12.06	84.32	128.57
2018	128.17	16.57	106.76	165.78
2019	133.84	9.78	117.66	151.28
2020	151.13	18.25	131.02	181.23

67. Several other factors, particularly at the global level, some mentioned elsewhere, reinforce the assessment of strong continued growth in prices and value for the fishery:

- Strong global demand and continued price increases over the past decade

- Poor recruitment in leading fisheries in Alaska and Canada pushing global supplies down
- Increased investment in generating value from non-traditional crab products in Norway
- Increasingly effective governance at national and international levels

Current Norwegian profitability

68. In spite of these attractive prices and promising outlook, the Norwegian snow crab industry is nascent and unprofitable in its current form (**BK-0003, BK-0004**). The Norwegian survey of vessels actively participating in the industry shows a continuous loss over time (Table 9).

69. There is an understanding that the losses are being absorbed in anticipation of an increasingly regulated fishery (**BK-0004**). This understanding rests on unilateral and bi-lateral Russian and Norwegian actions already taken to exclude participants in the fishery. These actions have, in turn, imposed some of the current losses on the Norwegian fleet and could not have been anticipated in 2012 through 2017.

70. These are summarized in Figure 1 and include:

- July 2015, Russia and Norway jointly determine that the Snow Crab is a sedentary species and thus subject to UNCLOS regulations as a continental shelf resource rather than a fishing resource. This extends the rights to exclusive harvest of a species from the 200 nm EEZ designation to a 350 nm continental shelf designation. This closes the International Loophole to Snow Crab fishing.
- Russia and Norway initially agree to joint management and harvest as they have with all other joint stocks in the Barents Sea, with the exception of the Red King Crab, under the Joint Fisheries Commission since the mid-1970s. Foreign vessels move from fishing in the Loophole to fishing in the SFPZ.
- Russia rescinds shared access to its CS in 2016, so that from 2017 on Norway is also excluded from the Russian CS and vice versa. This severs any continued efforts at joint management, and though the crabs are considered a single stock, they are assessed and managed separately.
- Norway closes access to the SFPZ for foreign vessels, counter to many previous efforts to share SFPZ resources amongst other interested parties **(BK-0018, BK-0019, BK-0020, BK-0021**).

Table 9: Financial Overview for the Norwegian Snow Crab Fleet

Financial Overview for the Norwegian Snow Crab Fleet					
Average Profitability Survey Results, Norwegian Snow Crab Vessels					
	2015	2016	2017	2018	2019
Earnings*	20820	42620	26887	27258	40476
Total operating costs*	28240	49667	36357	36439	51248
Operating profit*	-7420	-7047	-11471	-9182	-10772
Fishing Vessel Value*	38831	38554	46188	52170	56881
Total assets*	60281	64993	61021	70193	73783
Equity*	-7035	3740	-21970	-14359	-27218
Long-term debt*	46459	36584	64850	70193	91950
Short-term debt*	20857	24670	18142	12543	9050
Total equity and debt*	60281	64994	61022	70193	73783
Ordinary profit before tax*	**-9564**	**-7977**	**-15562**	**-10396**	**-12599**
Average vessel age (years)	43.5	39.57	42.22	43.14	44.14
Days at sea	282	244	231	165	189
Total operating cost per day at sea*	100.14	203.55	157.38	220.84	271.15
Length (m)	52.03	52.53	52.73	54.69	54.69
Vessels in Survey	*3*	*5*	*5*	*5*	*6*
Active Vessels	*6*	*7*	*9*	*7*	*7*
Fleet totals:					
Crab firsthand value*	121287	190890	133964	158558	243524
Crab tonnes (round weight)	3073	5400	2679	2654	3731
Average price per unit	39.47	35.35	50.01	59.74	65.27

* Value in 1000 NOK

Data from Norwegian Fisheries Directorate Vessel Profitability Surveys, 2015-2019 (**BK-0005**)

3. Which factors inform the establishment of fishing quotas?

Institutional and geo-political factors informing the establishment of fishing quotas for Snow Crab in the Norwegian portion of the Barents Sea

71. In general, fishing quotas are set to meet goals determined by the state or states that govern the seas in which the species live. While goals may vary, the general aim of fishing quotas is to reduce open access incentives to overharvest a species and to maximize long term productivity and value of the fishery **(BK-0040)**. Thus, the general goal is to maximize harvest or profit levels over time (Maximum Sustainable Yield (MSY), or Maximum Economic Yield (MEY), depending on information available and the balance between ecological and economic input to the decisions). Note that MSY is strictly a volume-based measure, the highest continuously replicable harvest level in e.g. ktons. MEY adds a value component by including the revenues and costs from the harvest of the crabs in the calculations, so that the sustained maximum over time is the value rather than the quantity of the harvest. MEY is generally more complex to determine due to information gathering costs not only about the quantity and growth characteristics of the species but also of the prices and costs faced in the market.

72. Variations from MSY/MEY goals generally stem from social (equity) concerns, in which productivity is traded off for distributional outcomes, or environmental/ecological concerns, in which the fisheries productivity is traded off for gains from other ecosystem services and values (e.g. another fishery, or endangered or otherwise vulnerable habitat).

73. In theory, scientists working through a variety of organizations produce scientific stock assessments that objectively project the species populations and changes in populations expected to come from harvesting at various levels. In practice, there can be a great deal of scientific uncertainty involved in this process. Often, and particularly with high valued species like Arctic and sub-Arctic crab species, the result is that the stock assessment deliberations themselves may involve political considerations of various rights-holders (**BK-0041, BK-0042, BK-0043**). The analyses of any such stock assessments must be evaluated in this context.

74. In practice, the process of establishing quotas in Norwegian fisheries is well summed up by the following statement:

> “A common witticism in fisheries circles goes as follows: “Rumours say that only two persons, the Fisheries Director (in Bergen) and God (in Heaven), know all the details about the quota system but that God is now giving up!” The reason that the quota system is so complex is because it was not established with defined goals and procedures at a specific point of time, but rather developed gradually and incrementally, often in response to crisis, and legitimized as a much needed and rational reform. (**BK-0044**, p. 132)”

75. This evolutionary process, in Norway at least, has centered for off-shore fisheries on granting (Norwegian) vessels who have previously made a substantial portion of their living from harvesting the resource, and allocations of quota have generally initiated as individual vessel quotas with quota factors determined from vessel length. Rules surrounding the vessel quotas have, over time, been increasingly liberal in their transferability amongst vessels and owners (**BK-0044**).

76. The Snow Crab is a shared stock with Russia, and under standard conditions quotas would be jointly determined with Russia at annual meetings of the Joint Fishery Commission established in 1974. These quotas would be informed by research gathered through international scientific organizations including the International Council for the Exploration of the Sea (ICES) and national and regional marine research institutes (Norwegian Institute for Marine Research (IMR) and PINRO, the polar branch of the Russian Federal Research Institute of Fisheries and Oceanography (VNIRO)). This is how quotas are determined for all other joint stocks in Barents' waters, with the exception of the Red King Crab[2]. Additionally, if species are present in international waters then quota setting also incorporates agreements under regional management plans that manage such international waters. The Northeast Atlantic Fisheries Commission (NEAFC) is of particular importance for the Barents Sea stocks.

77. IMR-PINRO cooperation includes annual surveys and reports on the status of Barents Sea ecosystem and stock conditions. The surveys have been tracking snow crab since 2005. The data are consistent through 2013, and several reports on the growth and projections for spread and growth were made in the period 2014-2016 using these data, such as those shown in Figure 4. The changes in activity in the Loophole, including the commencement of international fishing activities and the closing of the Loophole to external parties, changed the quality and availability of the data following this point (**BK-0045**). For 2014-2016, for example, the annual IMR-PINRO survey did not include the Loophole, so that data from those years come from the international fisheries landings (as shown in Table 10).

78. Since the snow crab has been declared a sedentary species and Russia and Norway have agreed that the only jointly determined activities will be to conduct and share research

[2] The Red King Crab (Red King Crab) is also a valuable yet invasive species in the Barents Sea. Introduced purposefully near Murmansk by Soviet scientists in the 1960s, the Red King Crab population grew and spread west into Norwegian waters. When the crabs began causing significant damages to Norwegian coastal cod fishermen, Norway initiated a fishery in the early 1990s, soon followed by Russia. The species is not present in international waters. As Norway also sees the Red King Crab as an invasive species that it would like to prevent from spreading further west while Russia does not, in 2007 they established a split management scheme whereby the eastern population is quota-regulated and the western population is open access. The open access fishery is intended to use market forces to commercially extirpate the species in the west. The efficiency of this strategy hinges on the extent to which the prices can cover increasing marginal costs of extirpation; because the prices do not include other social benefits the amount of effort at reducing the population may be below the optimal level. It is made particularly difficult by the conflicting goals that stem from the species' status as both a pest with uncertain impacts and a valuable commodity.

information with each other and to inform each other of their quota decisions (**BK-0046**, p. 7, **BK-0047**, p. 5), and since it has been so far upheld by Norwegian courts that the Continental Shelf in the Svalbard Fisheries Protection Zone (SFPZ) is Norway's domain rather than open to international enterprise under the Svalbard Treaty of 1920 (which is contested by other States party to the Svalbard Treaty), the final decision regarding quota for the Norwegian Continental Shelf is entirely at the discretion of the Fishery Directorate. At the same time, Russian law pertaining to national resources prohibits Norwegian vessels from fishing on the Russian Continental Shelf, so that this discretion is limited to the Norwegian continental shelf only (**BK-0046**, p. 7).

4. With regards to the establishment of a quota for Snow Crab fishing in the Barents Sea:

a. What are the relevant environmental factors?

b. What are the relevant economic factors?

79. The environmental and economic factors are primarily taken together due to the stated mandate that both be explicitly considered. The stated criteria for determining these quotas have been explicitly delineated by the Norwegian Fisheries Directorate as twofold since 2014, and articulated in each IMR stock assessment report since 2017 (**BK-0030**, p. 1). They are:

1. Maximize the long term harvested yield, and
2. Minimize the risk of unwanted ecosystem effects

80. These two goals are in many ways incompatible. Maximizing the long term harvested yield requires allowing the spread of the species to its full extent and then harvesting at MSY for the indefinite future. Minimizing the risk of unwanted ecosystem effects from the invasion requires putting effort into damping down both the population and spread of the crab, through intensive harvest. To attempt a balance, as the Norwegian government proposes, one may re-phrase the goals into a single objective: to maximize the net benefit of the crab's presence.

Quota setting

81. Norway has set annual snow crab quotas since 2017, as shown in Table 10. The table here, translated reproduced from (**BK-0001**, p. 8), also shows quotas for the Russian fleet as well as landings from the Barents by Norwegian, Russian and EU vessels. These data, with some updating for quota information on 2021, are plotted in Figure 14.

*Table 10: Overview of Snow Crab catches, quota advice and quota decisions in the Barents Sea, 2012-2020 (Autumn). Source: **(BK-0001**, p. 8).*

Recommended Catch Alternatives for Norwegian Quota, Fixed Quota and Catches of Snow Crab (tonnes) in the Barents Sea in the period 2012-2020 distributed by countries							
Year	Catch Alternatives (tonnes)	Fixed Quota (tonnes)		Landings (tonnes)			Total Landings
	(IMR, Norway)	Norway	Russia	Norway	Russia	EU countries	
2012				2	0	0	2
2013				189	62	0	251
2014				1 800	4 104	2 300	8 204
2015			1 100	3 482	8 895	5 763	18 140
2016			1 600	5 290	7 520	3 690	16 500
2017	3 600 - 4 500	4 000	7 840	3 153	7 780	2	10 847
2018	4 000 - 5 500	4 000	9 840	2 804	9 728	-	12 532
2019	3 500 - 5 000	4 000	9 840	4 038	9 840	-	13 878
2020	<5 500	4 500	13 250	3 405*	10 500**	-	13 905*

* through 11.November 2020

** through 29.0ctober 2020

82. Figure 21 and Table 10 illustrate that Russian quotas and catches have been rising more rapidly than in Norway, and that Norway has, until 2021, been setting quotas at the low end of the advised range from IMR (Table 10: Column 1).

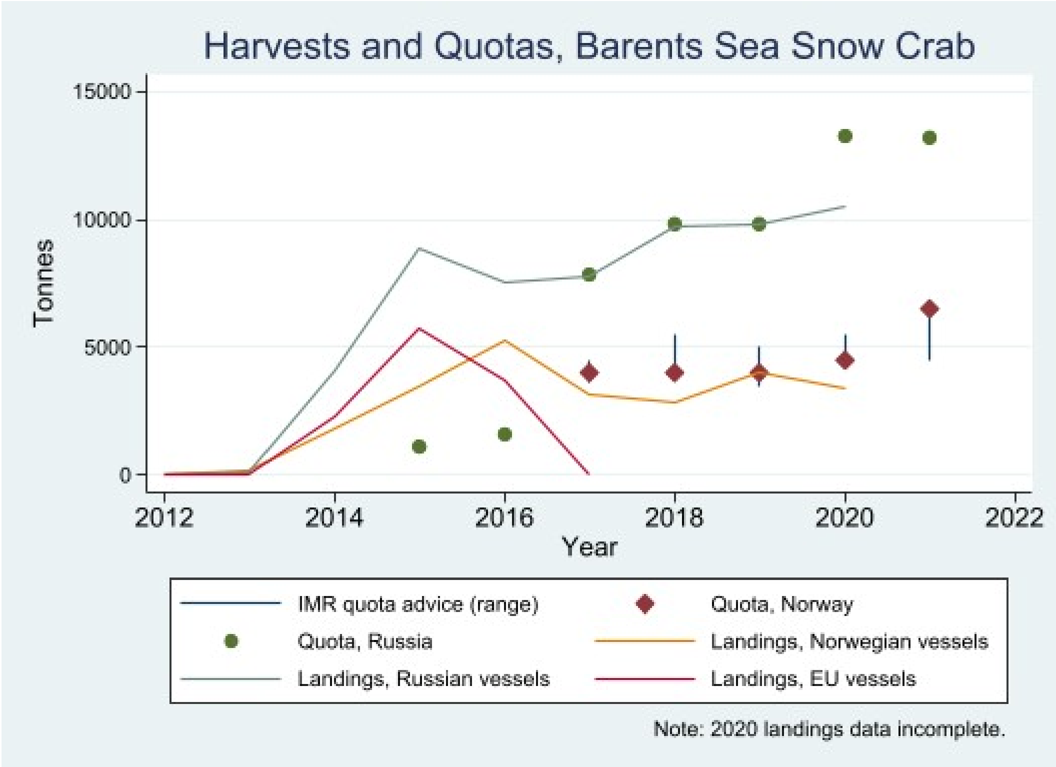

*Figure 21: Harvests and Quotas for Snow Crab in the Barents Sea. Data from (**BK-0001**, p. 1,8) and (**BK-0032**). 2020 landings data through Nov 11 (Norway) and Oct 29 (Russia) only.*

83. Table 11 shows the gap between the highest IMR-advised harvest level and the quota limit. Until 2021, the quota has consistently been set below the highest IMR-advice level, while the advice range has been increasing to reflect the higher estimated populations. This policy is at odds with that adopted in the case of the invasive Red King Crab, where quotas have consistently exceeded the IMR advice (see Annex 5).

Table 11: Norwegian Snow Crab Quota as a Percentage of Recommended IMR Advice, 2017-2021

Norwegian Quota and Advice for the Snow Crab Management Area*			
Year	IMR Advice	Quota Limit	% of highest advice level
2017	3600- 4500 t	4000 t	89%
2018	4000-5500 t	4000 t	73%
2019	3500-5000 t	4000 t	80%
2020	up to 5500 t	4500 t	82%
2021	up to 6500 t	6500 t	100%

*The Management Area is illustrated as extending:
East to West from 30° E to the Maritime Border with the Russian Federation, and
North to South from 77° N to 74°30' N.

Bio-economic factors that should drive the establishment of effective Snow Crab quotas

Negative impacts from the invasive species reduce net benefits

84. As the crab is expected to cause some ecological and/or economic consequences that reduce the benefits of the long run presence of the crab, in a perfect world, one should choose a higher harvest level than the uncorrected population models recommend. The exact amount by which the harvest should be increased depends on the additional per unit costs of the crab relative to the net benefit of their harvest. Unfortunately, these additional costs are rarely known and virtually impossible to estimate, as they stem from e.g. unknowable changes to poorly understood benthic ecosystem processes. In light of such complexities, Norway has chosen spatially differentiated management for the Red King Crab, for example (**BK-0048, BK-0049**). This spatially differentiated management, established in 2007, tries to keep higher fishing pressure on areas to the west of a quota-regulated zone to limit the spread of the invasion to the west.

85. If the same model were applied in the case of the Snow Crab, one would expect to see open access fishing throughout much of the SFPZ; certainly for the part of it where the densities of crab are currently lower and therefore fishing effort is less profitable, such as the areas in brown and burgundy in the map in Figure 6.[3]

Spread as an ongoing process

86. A further cause of underestimation of the species population is that the models used so far in the Barents are not spatially explicit. In other words, they pertain only to a defined area with an assumed carrying capacity, growth is driven from reproduction within the area and removals are driven by natural mortality and fishing pressures in the area. While Snow Crab can and do cover significant territory in their adult stages, the recruitment and spread process is dominated by the currents that transport larvae in patterns that facilitate settling and growth. Bio-geo-physical models to understand this spread are only just being developed (**BK-0035**), but we can say that, without incorporating this aspect of recruitment in the assessments, population estimates may be artificially low.

5. Based on available scientific data for the period 2017-2021, and applying the relevant factors, what would be an appropriate quota for the Snow Crab fishery in areas of the Barents Sea under Norwegian control (including Svalbard and the Norwegian side of the Loophole).

87. To approach the jointly stated environmental and economic goals of the Norwegian Snow Crab fishery's management, the MSY sets a reasonable minimum for quotas in areas

[3] This could have the additional benefit of increasing information about the population and spread of the crab, and the costs of harvest, for future management choices.

where population densities are at or above Bmsy. Increasing the quota from these levels would increase the balance toward the precautionary approach to support ecological goals (Criteria 2). If the precedent of the Red King Crab management were to be followed, then some portion of the area could in fact become open access harvesting in an effort to try to stem further spread of the invasion. On the other hand, if the quotas are set below MSY for the areas where the populations have reached at least Bmsy, then neither environmental nor economic goals would be met. Thus the analysis presented in Table 6 can be summarized in Table 12 as reasonable minimum quotas in the years 2021 and 2030 for the areas of interest.

Table 12: MSY-based ranges for Snow Crab Quota

	MSY-based Quota Ranges	
Area	2021	2030
Loophole (Entire)	7 320 - 10 164	7 320 - 10 164
Loophole (Norwegian)	1 098 - 1 524	1 098 - 1 524
SFPZ	18 440 - 36 881	35 770 - 64 745

6. Discuss North Star's integrated business model as compared with competitors (in particular Norwegian competitors).

a. Was North Star the only company in a joint venture with an onshore snow crab transformation company (Seagourmet)?

88. North Star operated in a joint venture with onshore snow crab transformation company Seagourmet. According to the Norwegian Fisheries Council (Norges Råfisklaget), at the end of 2016 90% of Norwegian catch of snow crab was on-board production, with 80% of total production frozen on-board. The main actors were Arctic Catch, Norway Seafoods, and Seagourmet Norway. The vessel Røstnesvag delivered unprocessed live crab to shore, while Arctic Pioneer, Polaris, Northeaster, Polarstar and Prowess performed onboard processing. In total, 6 Norwegian vessels and 11 foreign vessels landed crab in Norwegian harbors. There were transshipments from 7 Russian vessels (**BK-0050**).

b. What are the advantages (and disadvantages if any) of such a business model vs. the rest of the industry?

Norwegian vessels lacked know-how

89. At the time, Norwegian companies had no experience with snow crab fishing or markets. The promise of the fishery, as expressed through predictions such as those from IMR in presentations like the one made by Carsten Hvingel to SINTEF in 2016 (**BK-0029**) suggesting that a sustainably developed Barents Sea snow crab fishery could have a value of 2.5 billion NOK and an average catch potential of 100 ktons/year, created excitement and investment in projects like CrabTech, in which the Norwegian Research Council invested 11.1 million NOK in a 3 year grant to SINTEF (independent research organization), Opilio AS (company owning the fishing vessel Northeastern), Fitjar Mekaniske Verksted AS and Mustad Autoline AS (marine technicians), and UiT The Arctic University of Norway and the Marine Institute at Memorial University, St John's, Canada (universities) for the principle purpose of developing "a profitable and sustainable technology platform for harvesting snow crab based on Norwegian demands for EHS, salaries and product quality." Additional objectives included reducing the labor force on deck (from 5 to 3 per shift) and in the factory (from 6 to 3 per shift), and to "eliminate all processes on board which cause unacceptable risk for crewmembers" (**BK-0051**).

Despite Investment in Productivity (Catchability and Labor), Costs continue to rise

90. Labor costs per day at sea in the Norwegian fishery have increased since 2015, as shown in Figure 22.

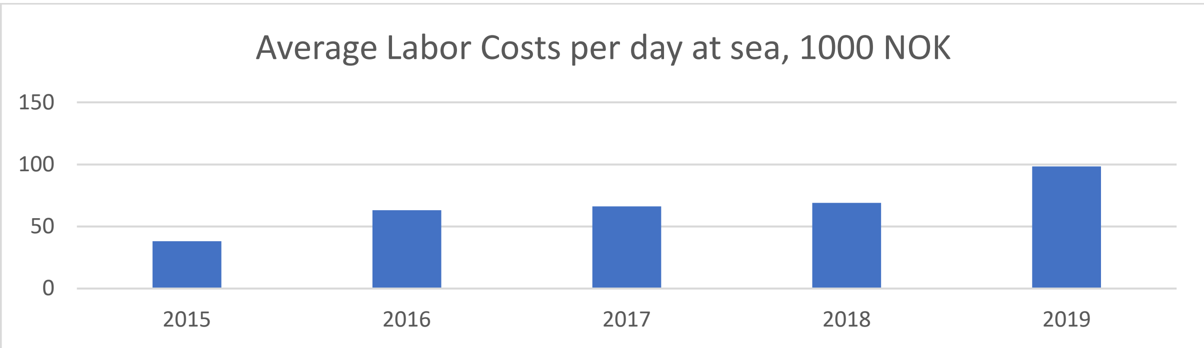

Figure 22: Average Labor Costs per Day at Sea, 1000 NOK. Calculated from the Snow Crab Fishery Profitability Surveys, 2015-2019. Labor costs include wages, provisions, pensions and social costs.

91. While considerable research has been conducted to develop better and cheaper baits **(BK-0052, BK-0053, BK-0054**), progress is not clearly translating into improved profitability. Figure 23 shows no clear trend in total expenditures or per unit expenditures (either by day at sea or by crab catch) over time. There is thus no evidence in the progress of the fishery that the market share of North Star should decrease per unit of effort.

92. The main advantage of having an onshore partnership as a business model that connects harvest to end customers for seafood is the reduction in transaction costs between catch, processing and delivery that result in cheaper distribution of higher quality products. That is, live and fresh snow crab products command significantly higher prices than frozen. They have, however, a much shorter product life and significant losses can arise from disruptions in the path from sea to fork. Business organization that reduces the time taken from catch to end user and that reduces the chances for disruptions in this path should increase profitability.

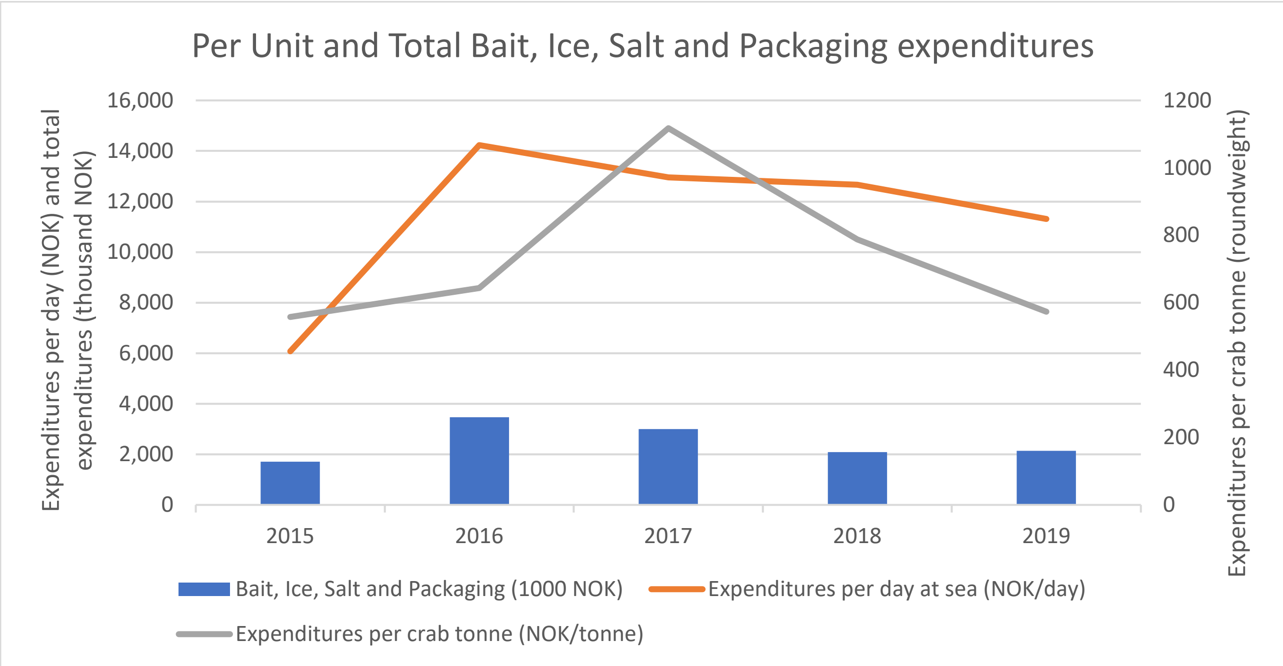

Figure 23: Bait and Preservation costs, 2015-2020.

7. Can this model explain North Star's lead in terms of productivity and expected profitability?

93. Because this model reduces transactions costs and because there is no evidence of significant productivity improvement by the Norwegian vessels remaining in the industry, one could expect North Star's lead to remain and profitability to outpace the existing Norwegian fleet. The current and expected continued profitability of the Russian fleet also suggest that as the densities increase in the SFPZ through continued spread of the Snow Crab, that the industry has significantly greater profitability potential in the Norwegian CS than the current industry financial records suggest.

8. In your opinion, are the Norwegian quotas for snow crabs justified based on either environmental or economic factors?

94. No. If environmental factors were the primary motivation, then one should expect to see an open access fishery that aims to push the invasive species to commercial extinction, at least at the invasion frontier, which corresponds to the Loophole and SFPZ. One might even expect a subsidy (bounty) system that pays fishers to remove the crab[4]. If environmental factors were a partial consideration, one would expect to see quota choices that push the higher end of the uncertainty rather than the lower end.

95. If economic considerations were the primary motivation, then again one should expect to see higher quotas to support the fishermen in the fleet. The data support that harvesting is below Fmsy. While catch levels in the Norwegian fleet are not pushing up against their quota, prices have grown at an average of 18% per annum over the past 5 years. There are several other possible explanations besides that of too few crabs available, including but not limited to a lack of profitability from the existing market structure and fleet composition. The vessels are old, with an average fleet age over 40 years (**BK-0005**, Vessel Group 14 (G22)), and unlike the Russian fleet, which also fishes for the profitable Red King Crab in the Russian EEZ, the snow crab vessels do not have a significantly diversified profile. The Russian expectations are sufficiently high that a Far Eastern crab association has moved vessels from the Bering Sea region (which has significantly lower costs for delivering crab to Asian markets) to the Barents in 2020 in order to fish snow crab and Red King Crab, and two associations are incurring significant costs in obtaining MSC certification for their vessels in the fishery.

96. While there is some possible evidence that fishing in the Loophole in 2013-2016, which in total exceeded 55000 tonnes in a concentrated area in the short period, reduced average daily catch rates from 2014 levels by 10-20% in 2015-2016, the evidence remains inconclusive as data both in the Barents and elsewhere indicate a cyclicality to snow crab populations separate from any direct fishing pressures **(BK-0045)**. With no fishing in the Loophole occurring since 2017, it is difficult to compare catch rates being experienced elsewhere in the Barents with these earlier rates, a fact pointed out by both the Norwegian and the Russian stock assessment efforts.

9. In light of historical industry catches, is it reasonable to think that Norway would have adopted the same quotas if it had considered the interests of all industry participants on an equal footing?

97. With the uncertainty that runs throughout regarding the ecological consequences and in light of international agreements regarding prevention and control of the spread of invasive species, the logically consistent policy path for Norway, regardless of the participants, would have been considerably higher catches. These would not realistically have threatened hopes for a long-term fishery.

[4] In practice bounty systems may have the reverse effect as intended, if fishers try to prolong the benefits by facilitating growth of the bountied species. It is rarely a recommended strategy by resource economists but has been used in many cases nonetheless, including to pay for the harvest of undersized and damaged Red King Crab in Norway in the open access fishing zone.

98. The fact that harvests have been below quotas, which have been at the low end of the recommended IMR quota advice, which has been highly conservative itself, suggests that there is considerable room for the initial industry participants to have continued and succeeded in the fishery.

Brooks A Kaiser

Dr. Brooks A. Kaiser

Kolding, 11 March 2021

Annexes

Annex 1: Curriculum Vitae, Brooks A. Kaiser

Brooks Alexandra Kaiser

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ACADEMIC DEGREES	
6/1998	PhD in Economics (**Northwestern University**, Evanston, IL USA)
5/1991	AB. Major: Economics, with departmental and general honors. Phi Beta Kappa**.** (**Vassar College**, Poughkeepsie, NY).

PROFESSIONAL APPOINTMENTS	
4/2020-present	Professor, **University of Southern Denmark** (Esbjerg, DK) - link
11/2011-4/2020	Professor WSR, **University of Southern Denmark** (Esbjerg, DK)
1/2019-6/2019	Visiting Professor, **University of British Columbia** (Vancouver, BC, CA)
6/2013-present	Affiliate Researcher, **University of Hawaii Economic Research Organization** (Manoa, HI USA).
1/2006-9/2013	Associate Professor**, Gettysburg College** (Gettysburg, PA, US)
1/2004-1/2018	Affiliate Graduate Faculty, **University of Hawaii, Manoa** (Manoa, HI, US)
9/2009-7/2010	Visiting Scholar, **University of Copenhagen** (Copenhagen, DK)
9/2009-7/2010	Visiting Faculty**, Danish Institute for Study Abroad** (Copenhagen, DK)
1/-8/2004, 6/-8/2005	Visiting Scholar, **University of Hawaii, Manoa**, Department of Economics (Manoa, HI, US)
6/-8/2002, 6/-8/2003	Visiting Research Associate, **University of Hawaii, Manoa,** Water Resources Research Center
9/2000-1/2006	Assistant Professor, **Gettysburg College** (Gettysburg, PA, US)
9/1999-8/2000	Visiting Assistant Professor, **Vassar College** (Poughkeepsie, NY, US)
8/1998-5/1999	Research Associate, **University of Hawaii Economic Research Organization**
1/-8/1997	Visiting Instructor, **Vassar College**

MANAGEMENT AND WORKSHOP/CONFERENCE HOSTING EXPERIENCE	
2014-present	Management and Economics of Resources and the Environment (MERE), **Department of Environmental and Business Economics**, Research Group Leader (equivalent of associate chair).
2017-	Thematic Network Lead Researcher, Global ecological and economic connections in Arctic and sub-Arctic crab fisheries UArctic Thematic Network
2016	Organizer, Blue SDU Think Tank Student-Industry Challenge, Fyn, DK, October 2016.
2010–2011	Department Chair. Department of Economics, **Gettysburg College**.
2007-2009	Secretary, **Phi Beta Kappa**, Iota Chapter of Pennsylvania. (elected position)
2008-2009	Faculty Personnel Committee, **Gettysburg College**. Evaluation of campus-wide candidates for promotion and tenure. (elected position).
Full International Workshops organized or co-organized:	
2020	Sustainable Arctic Marine Tourism Workshop III, Faroe Islands, originally May 24-27, 2020 (moving to virtual space)
2019	Sustainable Arctic Marine Tourism Workshop II, Iceland, Mar 17-23, 2019 Global ecological and economic connections in Arctic and sub-Arctic crab fisheries Workshop II, Seattle, WA, Jan 30-Feb 1, 2019.

2018	Future Energy Transitions, Oct. 17-18, Tampere Finland. With Pami Aalto, University of Tampere Sustainable Arctic Tourism, Finnmark, Norway, April 26-30. With Chris Horbel, SDU Present Energy Transitions, April 23-25, Oslo, NO. With Mads Greaker, University of Oslo.
2017	Global ecological and economic connections in Arctic and sub-Arctic crab fisheries (WKCRABCON), Copenhagen, DK, Dec 11-13, 2017. (ICES Chair) Past Energy Transitions, Esbjerg, DK, Mar 8-10, 2017.
2015	Arctic Marine Resource Governance. Reykjavik, IS, Oct 12-14, 2015.
2014	Ancient Economy and Early Economic Developments, Esbjerg, DK, Oct 1-2, 2014.
	Spatial Issues in Arctic Marine Resource Governance, Stockholm, SE Sept 4-6, 2014
2013	Marine Invasive Species in the Arctic, Esbjerg, DK, Oct 24-26, 2013.
2009	Second Conference on Early Economic Developments, Vancouver, CA, July 24-26, 2009
2009	Conference Host (Gettysburg College) Cliometric Society Meetings.

EXTERNAL GRANTS

2020-23	Participatory Modelling of Integrated Ecoystem-Based Management Regime for Invasive Crabs (PICO), **Norwegian Research Council**. Consortium member (Lead: Kofi Vondolia, Norwegian Institute for Water Research, 11.9m NOK)
2018-19	When and how to worry about ocean acidification: Bio-economic foundations for sustainable development goals. **Independent Research Fund DK, Research Stay [UBC]** (153,360 DKK).
2017-21	Co-PI, Sustainable Tourism Development in the Arctic, with C. Horbel. **UArctic Project Danish Agency for Science and Higher Education grant** (299,300 DKK); **Nordregio Arctic Cooperation Programme grant** (950,000 DKK) and **Danish Ministry for Higher Education and Science**. **International Network Programme grants** (576,000 DKK); with C. Horbel and Y. Liu, **UArctic Project Norwegian Research Council grant** (345,000 NOK).
2017-19	PI, Global ecological and economic connections in Arctic and sub-Arctic crab fisheries, **UArctic Project Danish Agency for Science and Higher Education grant** (499,235 DKK); **Carlsberg Foundation. Basic research (conference) grant** (60,000 DKK). **Danish Ministry for Higher Education and Science**. **International Network Programme grant**. (288,000 DKK).
2016-18	PI**.** Past, Present, and Future Energy Transitions **Nordisk samarbeidsnemnd for humanistisk og samfunnsvitenskapelig forskning (NOS-HS), Exploratory Conference Program**. (447,000 SEK).
2016	PI, Blue SDU Think Tank **Den Danske Maritime Fond** (415,000 DKK).
2015-2020	Co-PI, Bioeconomic analysis for Arctic Marine Resource Governance and Policy **Belmont Forum** (NSF, NRC, Nordic Council) **research grant.** With Linda Fernandez, VCU, USA, Jan Sundet, Institute for Marine Research (Norway) and Niels Vestergaard, SDU. (€ 529,000).
2012-2015	PI, **Danish Ministry for Science, Technology, and Innovation**. **International Network Programme grant**, (288,000 DKK).**Carlsberg Foundation. Basic research (conference) grant** (60,000 DKK), **Nordisk samarbeidsnemnd for humanistisk og samfunnsvitenskapelig forskning (NOS-HS), Exploratory Conference Programme** (210,000 NOK), **Nordic Council of Ministers' Arctic Co-operation Programme**, (750,000 DKK),with Niels Vestergaard, USD, Linda Fernandez, VCU, USA *Arctic Marine Resources*
2007	**CPC (Central Pennsylvania Consortium) Mellon Grant** ($6000 USD)
2003-2006	Co-PI, PREISM Cooperative Agreement, **ERS/USDA**, FY 2003-2006 ($200,000 USD) with James Roumasset. Management and execution of research grant on economics of invasive species.
2003-2005	Co-PI, **Sea Grant** (National Oceanic and Atmospheric Administration), University of HI, Manoa, ($67,000 USD) with James Roumasset. Management and execution of research grant on economics of integrated watershed management

PERIODS OF LEAVE

6/2009-7/10	Maternity Leave	6/2006-8/07	Sabbatical (1/2 time)

EDITORSHIPS, BOARD MEMBERSHIPS AND SELECTED PROFESSIONAL SERVICE ACTIVITIES

2020-	**International Arctic Science Committee,** Social and Human Working Group representative for the Kingdom of Denmark
2016-	**Polar Research and Policy Initiative,** Unit Lead and Expert, Fisheries**.**
2015-	**AMAP (Arctic Monitoring and Assessment Programme)** Arctic Council Working Group**,** Arctic Ocean Acidification Social Impacts Expert Group Member.
2015-	Editor, www.mereconomics.com
2015-	Saturna Environmental Corporation, Bellingham, Washington. Governor
2014	Arctic Summer College Fellow, Ecologic Institute.
2013 –	BIOdiversity and ECONomics for CONservation (BIOECON) Network, Scientific Committee Member
2007-	Saturna Capital Corporation, Bellingham Washington, Council of Economic Advisors.
2004 -	Professional and University Committees: SDU-SDG Network Steering committee, 2021-; Faculty Study Board, 2020-; Sustainable Markets Cluster Development committee, 2020-; BlueSDU steering committee, 2014-; World Congress of Environmental and Resource Economists, Program Committee, 2018; Economic History Assn., Program Committee, 2009, Membership Committee, 2004-2007; Cliometric Society, Program Committee, 2010, 2009; Phi Beta Kappa Chapter Secretary, 2007-9
1996-Present	**Journal Refereeing:** Agricultural and Resource Economics Review, American Journal of Agricultural Economics, Arctic Yearbook, Canadian Journal of Agricultural Economics, Climatic Change, Contemporary Economic Policy, Ecological Applications, Ecological Economics, Energy Reports, Environment and Development Economics, Environmental Management (Springer), Environmental and Resource Economics, Land Economics, Invasive Plant Science and Management, Journal of Asian Economics, Journal of Economic Growth, Journal of Economic History, Journal of Environmental Economics and Management, Journal of Environmental Economics and Policy, Journal of Environmental Management (Elsevier), Resource and Energy Economics, Sustainability, Structure and Dynamics: eJournal of Anthropological and Related Sciences **Other Refereeing:** UKRI Sustainable Management of UK Marine Resources Grant Proposal Reviewer (2021); BIOECON conference paper selection (2013-present); EAERE conference paper selection (2013-14); Norwegian Research Council Grant Program (2012); NOAA Sea Grant (Oregon) grant proposal reviews (2005); PREISM ERS/USDA grant proposal reviews (2004); NAREA Invasive Species Workshop Papers (2005); Pelagic Fisheries Regulation Program, NOAA Grants Advisory Panel (2004)

OTHER SCIENTIFIC QUALIFICATIONS, ACADEMIC AWARDS AND HONORS

2002-2006	**Johnson Center for Creative Teaching** Fellowship, Gettysburg College, PA
2001	**Environmental Systems Research Institute** Geographical Information Systems (GIS) Certificates.
1994	**Western Washington University** (Bellingham, WA), Field Research, Pacific Ocean, Reef Ecology

SCIENTIFIC FOCUS AREAS

Resource Economics	Bio-Economics, Public Goods Provision, Arctic, Invasive Species, Endangered Species, Integrated Forest Watershed Management, Natural Capital, Nearshore and Marine Resource Use (Hawaii, Arctic), Sustainability, Socio-Ecological Systems, Arctic, Hawaii, Barents Sea
Economic History and Development	Historical Use, Institutions for and Regulation of Natural Resources (primarily Water, Forests, Fisheries, Biodiversity, Whales), Economic Development and Governance in Marine Resource Economies, Public Lands Use and Development, Sustainability in Historic Context, Arctic, Hawaii

TEACHING AND SUPERVISION OF STUDENTS

BA level:	Economics, Microeconomics, Energy Economics (200 level), Environmental and Resource Economics (200- and 300- level), Text Analysis for Energy Management (300 level), Spatial Environmental Economics, American Economic History (200- and 300- level), Government Intervention in the Economy, Quantitative Methods,

	Econometrics, Honors Theses (10+), First Year Seminar in Social Satisfaction: Creating Economic Landscapes, Senior Seminar in Microeconomics (Game Theory), Senior Seminar in Microeconomics (Energy and Electricity Markets).
MA level:	Sustainability, Risk Management, Spatial Environmental Economics, Program Evaluation (Public Health), American Economic History, Theses Supervisor (20+)
PhD level:	Environmental and Resource Economics
Supervision of PhDs:	Kimberly Burnett, University of Hawaii, PhD 2007 (secondary) Melina Kourantidou, University of Southern Denmark, PhD 2019 (primary) Simon Sølvsten, University of Southern Denmark, Current (primary)

PEER REVIEWED JOURNAL PUBLICATIONS

Kaiser, BA and M Kourantidou (2021). Invasive alien species in changing marine Arctic economies and ecosystems. *CAB Reviews: Perspectives in Agriculture, Veterinary Science, Nutrition and Natural Resources* 16, 022, pp 1-12.

Kaiser, BA, Kourantidoy, M, Ahsan, D, Bakanev, S, Burmeister, AD, Eckert, G, Fernandez, LM et al. (2021). Global ecological and economic connections in Arctic and sub-Arctic crab markets. Marine Policy 127: 104442.

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Annex 2: Fishing behavior in the SFPZ relating to the stock assessment zone

Though the vessels holding licenses are allowed to fish in any part of the Norwegian continental shelf, the advice is given only for the area deemed of greatest commercial interest, as shown in (**BK-0001**) and Figure 6. Vessel behavior identified by viewing AIS tracks for 2017-2021 suggest that while the vessels do for the most part fish in the area to which the advice pertains directly, there appears to be some effort in trying locations outside the area. The fishing track shown in Figure 25 is for the fishing vessel, the Prowess, which IMR used for the 2018 survey (Figure 5). As can be seen by looking at the two figures, Snow Crab were present throughout the investigated region. As temperature has been determined as the main limiting factor, there is no reason to expect that these populations will fail to grow to higher densities if they are not heavily fished. Indeed, the expectation is that they will grow to significantly higher levels.

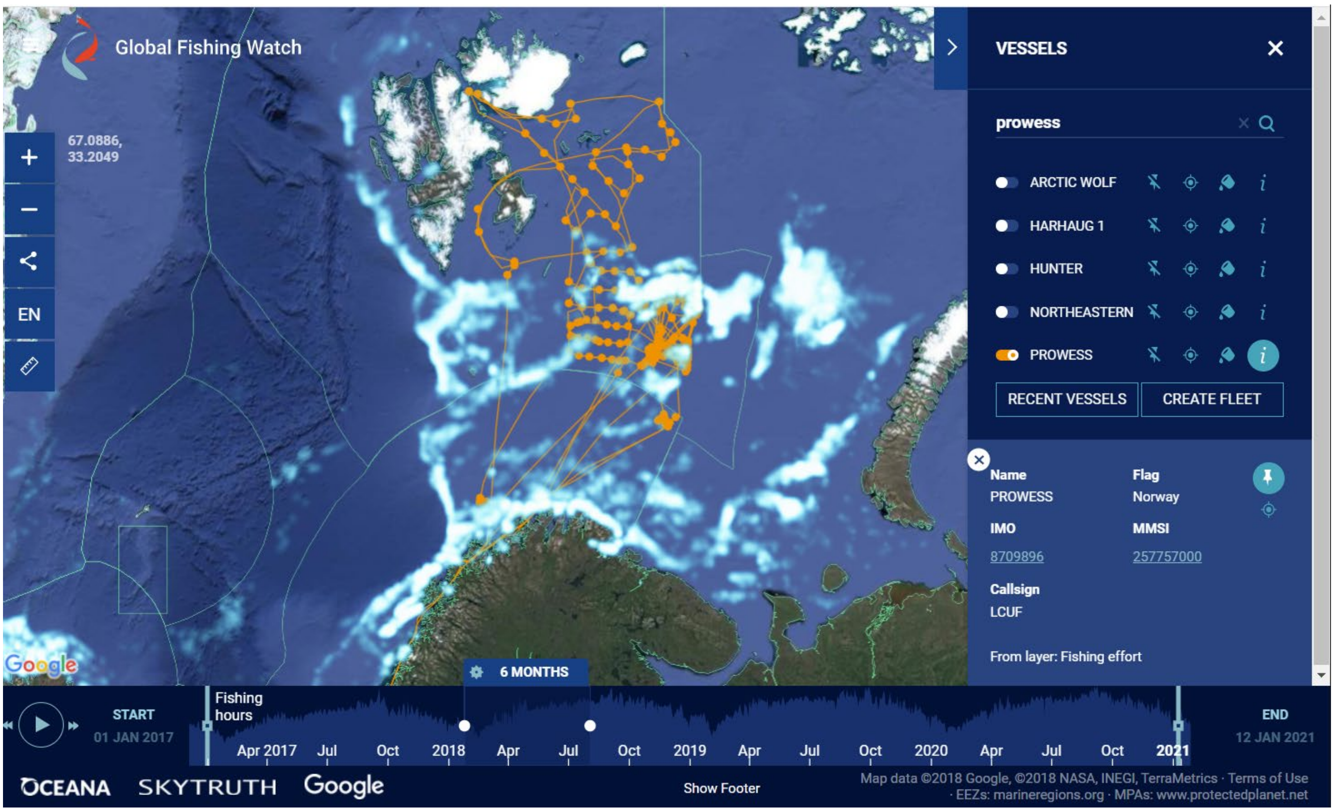

Figure 24: AIS Fishing track of the Prowess, Norwegian fishing vessel used in June 2018 to survey snow crab on the Norwegian continental shelf (in the Svalbard Fisheries Protection Zone area).

Annex 3: Bayesian Surplus Production Model

The PINRO preliminary stock assessments used in the MSC fisheries assessments **(BK-0015**, p. 29-42, **BK-0016**, p. 93-98) and the IMR stock assessment estimates used in the Norwegian advice (**BK-0001**, p. 10, **BK-0027**, p. 8, **BK-0028**, p. 8) are based on a logistic surplus production model with Bayesian inference first developed for use with the Northern shrimp (*Pandalus borealis*) fisheries (**BK-0029, BK-0031**). A logistic surplus production model estimates, for a given space, the population growth given an initial population stock over time, net of harvesting. The "surplus" is the growth above the harvest, available to increase the population. A Bayesian surplus production model parsimoniously estimates the biomass, or in some cases a biomass index, the latter reducing some uncertainties in the 'catchability' parameter (**BK-0031**, p. 78-79). The model relies on estimates of the stock population, the catchability given the technology available, and he estimated carrying capacity.

The catchability parameter determines the efficiency of catch effort – that is, given a population of crabs, and a set of crab pots, what portion of the population will the 'effort' of the pots catch?

The choice variable in the model is effort; that is, as you change effort (number of crab pots or soak-time, measured via CPUE), how will that change the harvest, and then in turn, how will this change the population for the next period's growth and harvest? This this is how estimated outcomes from fishing quotas are determined. As the IMR assessments until 2020 were that the stock lies below Bmsy, growth was expected to be positive and increasing; it has been so. With 2021's estimate that the stock is at Bmsy, growth should be expected to be increasing but at a decreasing rate; this should not be confused with declining productivity. (Note that the assumption that growth is always positive reflects an assumption that extinction of the species in the area is not likely to be achieved as the population would need to be driven to zero).

In simple terms, this model assumes that there is some carrying capacity (K) for the population in a given area, and that at low levels of population, growth accelerates via an intrinsic growth rate while at levels of population close to the carrying capacity, additions to the population will occur more slowly. If the population growth is not particularly density dependent, or in other words, growth does not depend on how far apart individual crabs are from one another within the assessment area (which has been the assumption in the applications here), then Bmsy is K/2, with an established safe MSY equal to ~0.15 of this MSY population (**BK-0015**, p. 96).

The Bayesian inference portion of the model aims to counter uncertainty in the parameters. The model parameters, including carrying capacity, population, and catchability, are assumed to be random variables whose means and distributions are estimated from existing data from e.g. surveys and fishery statistics. These means are then used, along with the associated standard deviations, to estimate the population and its growth over time without assuming a deterministic (pin-pointed) framework.

Annex 4: Estimation of the spread in the SFPZ

The χ^2 distribution in combination with Monte Carlo simulation can be used to generate a simple mean estimate of the invaded area at full density. The potential spread is estimated to cover 279.1 thousand square kilometers using GIS, which can eventually be assumed to reach carrying capacity (if unharvested) or Bmsy (if sustainably harvested). We use this as an upper limit for the area that could reach full density by 2030, and I assume that a mean estimate of how much area will in fact reach full density that has a χ^2 distribution should not exceed 279.1 thous. km^2 with 95% confidence. Using Monte Carlo simulations to replicate 50,000 estimations of the area that could reach full capacity, I estimate that a mean of 240 thous. km^2 full-density equivalent area meets this requirement. Thus the full-density equivalent area of 279.1 thous. km^2 of spread by 2030 is estimated to be 240 thous. km^2.

Annex 5: Quota setting in the Red King Crab, an illuminating comparison

For deeper insight into the management goals of the Snow Crab, it is useful to look at the relationship between IMR advice and Fisheries Directorate quota setting for the same period. The species are both high-valued commodities, but also invasive species with unknown impacts on their ecosystems and their productivity. Both are not subject to agreement with other countries, including the Russian Federation. The Red King Crab has come to be a widely used localized resource with several hundred boats in a coastal fishery, and tourism quotas in the eastern portion of the Barents (to the 26°E line), while at the same time being targeted for its invasive properties in western and northern waters.

Table 13

Norwegian Quota and Advice for the Red King Crab Management Area**

Year	IMR Advice	Quota Limit	% of highest advice level
2009	600 t	1185 t	198%
2010	0 t	900 t	-
2011	900-1800 t	1100 t	61%
2012	500 t	900 t	180%
2013	900 t	1000 t	111%
2014	1000 t	1000 t	100%
2015	1250 t	1040 t	83%
2016	2000 t	2000 t	100%
2017	1500 t	2000 t	133%
2018	1250 t	1750 t	140%
2019	1400 t	1980 t	141%
2020	1530 t	1650 t	108%
2021	1780 t	1810 t	102%

** The Red King Crab Management Area extends East to West from the 26°E line to the Russian border and North to South from the 71°30' to shore. Areas outside the management area are open access.

The Red King Crab quotas are consistently higher than the IMR advice. In most years, the quota is also exceeded, as fishing costs are low and profits are significant, particularly for live crab.

As the Red King Crab invasion has been ongoing for about two decades longer, and was initially an intentional introduction tracked by the Russian scientists who brought it to the Barents Sea, there is considerably less uncertainty about the Red King Crab in comparison to the Snow Crab. That said, there remains considerable uncertainty at the invasion frontier in terms of whether the generally lower catches recorded in the open access area actually reflect lower Red King Crab population levels, or rather some other dynamic of the fishery relating to costs and/or the logistics of moving live crabs to end markets **(BK-0048, BK-0055**).

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