Monterey Bay Aquarium
Seafood Watch

Environmental sustainability assessment of wild-caught Red king crab from Norway caught using pots

Species:	Red king crab *(Paralithodes camtschaticus)*
Location:	Norway: Barents Sea
Gear:	Pots
Type:	Wild Caught
Author:	Seafood Watch
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Assessed using Seafood Watch Fisheries Standard v4

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About Seafood Watch

Monterey Bay Aquarium's Seafood Watch program evaluates the environmental sustainability of wild-caught and farmed seafood commonly found in the United States marketplace. Seafood Watch defines sustainable seafood as originating from sources, whether wild-caught or farmed, which can maintain or increase production in the long-term without jeopardizing the structure or function of affected ecosystems. The program's goals are to raise awareness of important ocean conservation issues and empower seafood consumers and businesses to make choices for healthy oceans.

Seafood Watch's science-based ratings are available at www.SeafoodWatch.org. Each rating is supported by a Seafood Watch assessment, in which the fishery or aquaculture operation is evaluated using the Seafood Watch standard.

Seafood Watch standards are built on our guiding principles, which outline the necessary environmental sustainability elements for fisheries and aquaculture operations. The guiding principles differ across standards, reflecting the different impacts of fisheries and aquaculture.

- Seafood rated Best Choice comes from sources that operate in a manner that's consistent with our guiding principles. The seafood is caught or farmed in ways that cause little or no harm to other wildlife or the environment.

- Seafood rated Good Alternative comes from sources that align with most of our guiding principles. However, one issue needs substantial improvement, or there's significant uncertainty about the impacts on wildlife or the environment.

- Seafood rated Avoid comes from sources that don't align with our guiding principles. The seafood is caught or farmed in ways that have a high risk of causing harm to wildlife or the environment. There's a critical conservation concern or many issues need substantial improvement.

Each assessment follows an eight-step process, which prioritizes rigor, impartiality, transparency and accessibility. They are conducted by Seafood Watch scientists, in collaboration with scientific, government, industry and conservation experts and are open for public comment prior to publication. Conditions in wild capture fisheries and aquaculture operations can change over time; as such assessments and ratings are updated regularly to reflect current practice.

More information on Seafood Watch guiding principles, standards, assessments and ratings are available at www.SeafoodWatch.org.

Guiding Principles

Seafood Watch defines sustainable seafood as originating from sources, whether fished[1] or farmed, that can maintain or increase production in the long term without jeopardizing the structure or function of affected ecosystems.

The following guiding principles illustrate the qualities that fisheries must possess to be considered sustainable by the Seafood Watch program (these are explained further in the Seafood Watch Standard for Fisheries):

- Follow the principles of ecosystem-based fisheries management.
- Ensure all affected stocks are healthy and abundant.
- Fish all affected stocks at sustainable levels.
- Minimize bycatch.
- Have no more than a negligible impact on any threatened, endangered, or protected species.
- Managed to sustain the long-term productivity of all affected species.
- Avoid negative impacts on the structure, function, or associated biota of aquatic habitats where fishing occurs.
- Maintain the trophic role of all aquatic life.
- Do not result in harmful ecological changes such as reduction of dependent predator populations, trophic cascades, or phase shifts.
- Ensure that any enhancement activities and fishing activities on enhanced stocks do not negatively affect the diversity, abundance, productivity, or genetic integrity of wild stocks.

These guiding principles are operationalized in the four criteria in this standard.Each criterion includes:

- Factors to evaluate and score
- Guidelines for integrating these factors to produce a numerical score and rating

Once a rating has been assigned to each criterion, Seafood Watch develops an overall recommendation. Criteria ratings and the overall recommendation are color coded to correspond to the categories on the Seafood Watch pocket guides and online guide:

Best Choice/Green: Buy first; they're well managed and caught or farmed responsibly.

Good Alternative/Yellow: Buy, but be aware there are concerns with how they're caught, farmed or managed.

Avoid/Red: Take a pass on these for now; they're caught or farmed in ways that harm other marine life or the environment.

[1] "Fish" is used throughout this document to refer to finfish, shellfish and other invertebrates

Summary

The red king crab is a large crustacean that was intentionally introduced into the Barents Sea in the 1960s by Soviet scientists seeking to establish a valuable pot fishery. Initially, the principal countries of Norway and Russia set cooperative management measures to jointly manage the growing stock and better understand its westward invasion into Norwegian waters, because a commercial fishery had not been developed yet. Starting in 2007, after the initiation of Norwegian and Russian commercial red king crab fisheries, Norway and Russia agreed to manage the stock separately within their respective economic zones, with each pursuing its own management objectives. Since the advent of the commercial fisheries, Russian landings and imports of red king crab into the United States have been greater than those from Norway.

Because of red king crab's status as an invasive nonnative species with harmful ecosystem impacts, its abundance and fishing mortality are of low concern. The use of pot trap gear for catching red king crab has little impact on bottom habitat, because harvesters fish on mud substrates with little structure. Bycatch species are not well known, although this gear type typically has low amounts in other areas of the world, especially when outfitted with biodegradable panels and other management measures to reduce interaction. But, the risk that crab pot gear poses to marine mammals is of concern because of these species' high vulnerability to entanglement and their presence in Norwegian waters.

Norwegian managers currently pursue a dual management approach: balancing the commercial exploitation of red king crab east of 26° E. (by harvesting at MSY, maximum sustainable yield) while reducing the further spread of red king crab in areas west of 26° E. (via an open-access fishery). This dual approach is reflected in allowances for the removal of females, reduced regulations west of 26° E., and higher quotas than what would typically be implemented for a native fishery species. Although sustaining some populations of this invasive species may have negative local ecological impacts, these practices have generally been implemented successfully, with minimal risk of bycatch and entanglement of marine mammals in pot gear. Therefore, Norway's red king crab fishery has earned a "Best Choice" recommendation.

Final Seafood Recommendations

SPECIES | FISHERY	C 1 TARGET SPECIES	C 2 OTHER SPECIES	C 3 MANAGEMENT	C 4 HABITAT	OVERALL	VOLUME (MT) YEAR
Red king crab | Barents Sea | Atlantic, Northeast | Pots | Norway	5.000	2.644	3.000	3.000	**Best Choice (3.303)**	Unknown

Summary

The red king crab is a large crustacean that was intentionally introduced into the Barents Sea in the 1960s by Soviet scientists seeking to establish a valuable pot fishery. Both Norway and Russia currently harvest this invasive nonnative species.

The "Best Choice" rating for the red king crab pot fishery reflects Norway's current dual management approach of maintaining a low biomass to prevent further westward establishment of the species and sustaining a long-term fishery in this part of its territorial seas—while minimizing the risk of bycatch and entanglement of marine mammals with crab pot gear.

Scoring Guide

Scores range from zero to five where zero indicates very poor performance and five indicates the fishing operations have no significant impact.

Final Score = geometric mean of the four Scores (Criterion 1, Criterion 2, Criterion 3, Criterion 4).

Best Choice/Green = Final Score >3.2, and no Red Criteria, and no Critical scores

Good Alternative/Yellow = Final score >2.2-3.2, and neither Harvest Strategy (Factor 3.1) nor Bycatch Management Strategy (Factor 3.2) are Very High Concern2, and no more than one Red Criterion, and no Critical scores

Avoid/Red = Final Score ≤2.2, or either Harvest Strategy (Factor 3.1) or Bycatch Management Strategy (Factor 3.2) is Very High Concern or two or more Red Criteria, or one or more Critical scores.

[2] Because effective management is an essential component of sustainable fisheries, Seafood Watch issues an Avoid recommendation for any fishery scored as a Very High Concern for either factor under Management (Criterion 3).

Introduction

Scope of the analysis and ensuing recommendation

This reports covers recommendations for the Barents Sea red king crab (*Paralithodes camtschaticus*) landed by Norway and caught using crab pot gear.

Species Overview

The red king crab was intentionally introduced into the Barents Sea, near Kola Bay and the adjacent areas of Western Murman, by Soviet researchers in the 1960s. The goal was to increase economic opportunities for communities in coastal parts of the Barents Sea by establishing a new fishery. The species started to grow and spread west into Norwegian waters and first became abundant in that region in the 1990s (Jørgensen 2013)(Sundet and Hoel 2016). By 1994, an experimental research fishery was occurring, during which both countries agreed to keep landing levels conservative to increase the population (Sundet and Hoel 2016).

This was changed in 2002 with the initiation of the commercial fishery, for which Norway and Russia agreed to a single quota in the Joint Russian-Norwegian Fishery Commission. This ended in 2007, when both countries started to pursue management of the stock separately, and independently determined fishery management goals, quotas, and assessment methodologies, although cooperative research still continued across the two countries (Jørgensen and Nilssen 2011)(Sundet and Hoel 2016).

Red king crab distribution now covers approximately 12% of the Barents Sea. Almost 23,500 km^2 of that area is under Norwegian management, including both an open-access fishery area (to limit further westward expansion) and a quota-regulated area (to maintain a viable long-term fishery) (Figure 1) (Skonhoft and Kourantidou 2021)(Sundet and Hoel 2016).

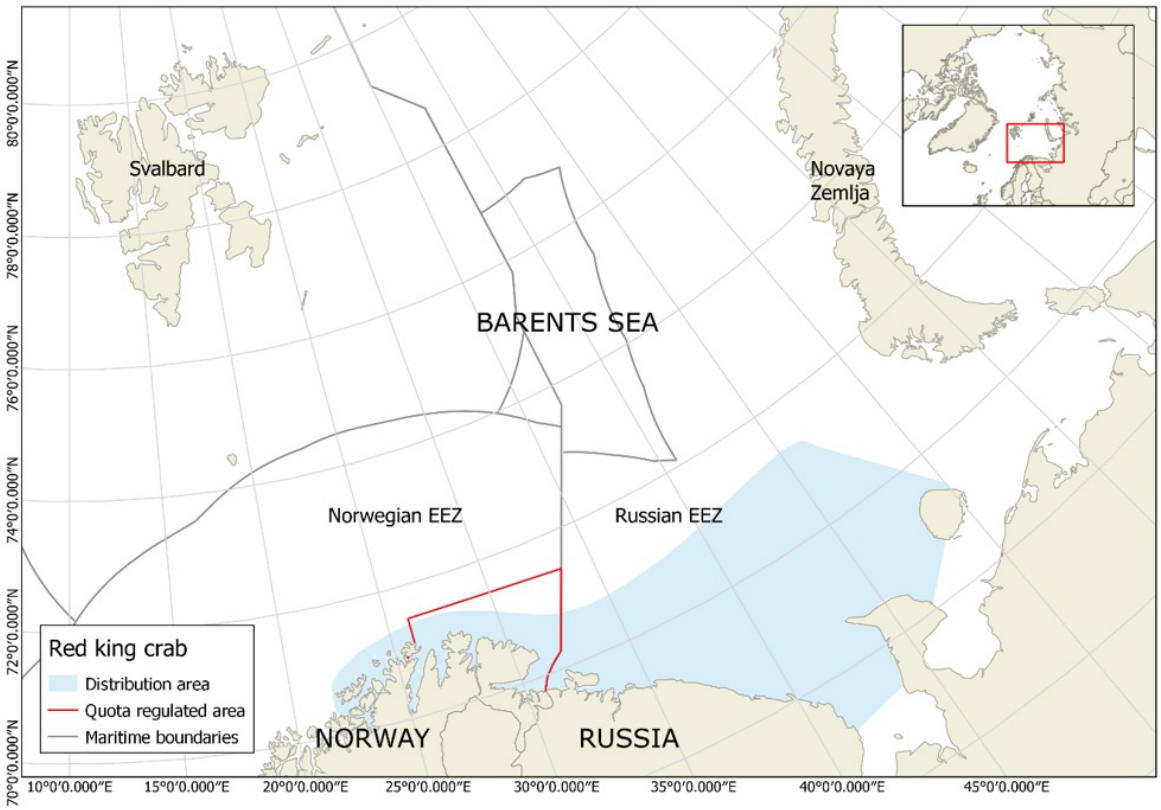

Figure 1: Red king crab distribution in Norwegian and Russian waters. Distribution in Norwegian waters is located inside the large fjords and along the coast. The quota regulated fishing area is outlined in red (pers. comm., A. Hjelset, March 30, 2023).

Production Statistics

Norway landings of red king crab have recently hovered around 2,000 tons annually (OECD 2022).

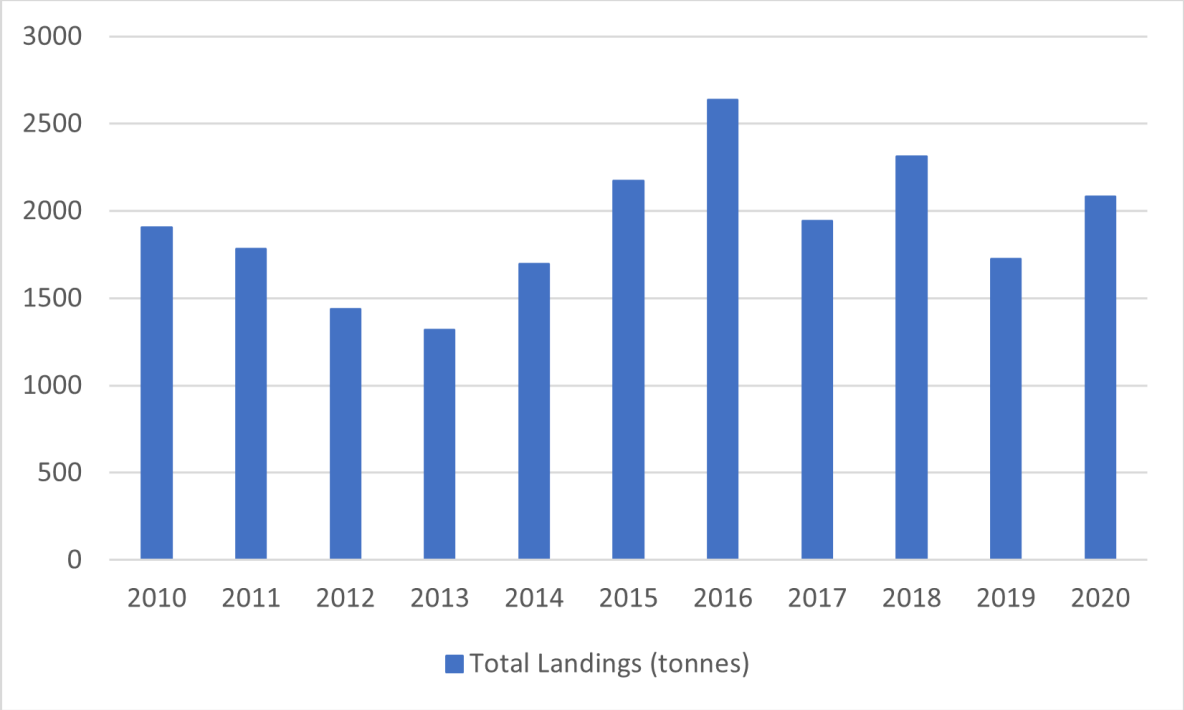

Figure 2: Annual total landings of red king crab in Norway from 2010 to 2020. Data from (OECD 2022).

Importance to the US/North American market.

Import/export statistics and analysis of king crab is complicated by market name/species ambiguity, trade data discrepancies, and illegal activity (WWF 2014). Nonetheless, some inferences can be drawn. The majority of live red king crab caught in Norway is destined for the export market of South Korea, followed by the United States, while Japan is the primary market for frozen cluster exports (Lorentzen et al. 2018). Over the past decade, of the 1,900 t average annual landings, approximately 6.8% (130 t on average) was destined for the U.S. market (OECD 2022)(U.S. Census Bureau 2022).

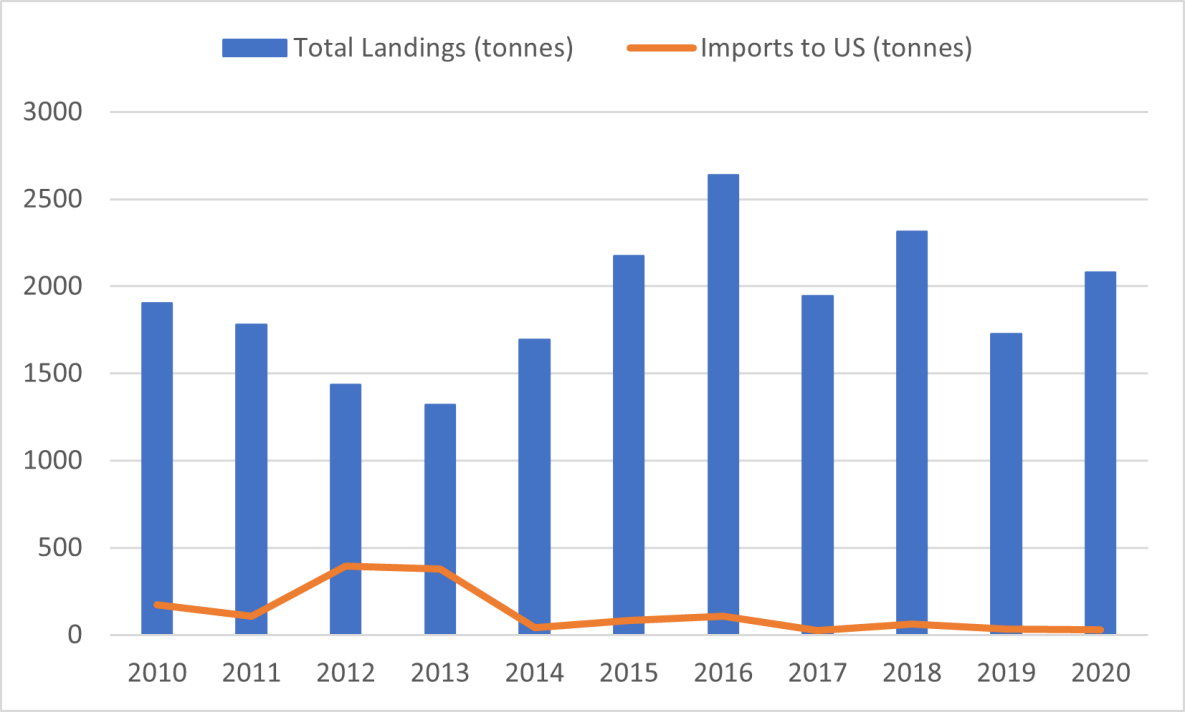

Figure 3: Total annual landings (tonnes) of red king crab in Norway (blue bars) and annual imports to the United States (tonnes) of Norwegian red king crab (orange line) from 2010 to 2020. Data from (OECD 2022) and (U.S. Census Bureau 2022).

Because of reductions in worldwide red king crab quotas, more live exports, and the shift of the Norwegian crab season to begin in January (a season that typically lacks supply worldwide), the importance of Norwegian red king crab in U.S. markets is expected to rise (Voldnes et al. 2020) (Lorentzen et al. 2018).

Common and market names.

Red king crab is commonly referred to by that name or simply as king crab. It may also appear as Kamchatka crab or Alaskan king crab when mislabeled (Jørgensen 2013).

Primary product forms

Common product forms include either live crab or cooked, frozen clusters (Lorentzen et al. 2018) (Voldnes et al. 2020).

Assessment

This section assesses the sustainability of the fishery(s) relative to the Seafood Watch Standard for Fisheries, available at www.seafoodwatch.org. The specific standard used is referenced on the title page of all Seafood Watch assessments.

Criterion 1: Impacts on the species under assessment

This criterion evaluates the impact of fishing mortality on the species, given its current abundance. When abundance is unknown, abundance is scored based on the species' inherent vulnerability, which is calculated using a Productivity-Susceptibility Analysis. The final Criterion 1 score is determined by taking the geometric mean of the abundance and fishing mortality scores. The Criterion 1 rating is determined as follows:

- ***Score >3.2=Green or Low Concern***
- ***Score >2.2 and ≤3.2=Yellow or Moderate Concern***
- ***Score ≤2.2 = Red or High Concern***

Rating is Critical if Factor 1.3 (Fishing Mortality) is Critical.

Guiding principles

- *Ensure all affected stocks are healthy and abundant.*
- *Fish all affected stocks at sustainable level*

Criterion 1 Summary

RED KING CRAB			
REGION / METHOD	**ABUNDANCE**	**FISHING MORTALITY**	**SCORE**
Barents Sea | Atlantic, Northeast | Pots | Norway	5.000: Very Low Concern	5.000: Low Concern	Green (5.000)

As an invasive nonnative species with harmful ecological impacts, red king crab's stock abundance and fishing mortality are of low concern. Therefore, the impacts to this stock warrant a Green rating.

Criterion 1 Assessments

SCORING GUIDELINES

Factor 1.1 - Abundance
Goal: Stock abundance and size structure of native species is maintained at a level that does not impair recruitment or productivity.

- *5 (Very Low Concern) — Strong evidence exists that the population is above an appropriate target abundance level (given the species' ecological role), or near virgin biomass.*
- *3.67 (Low Concern) — Population may be below target abundance level, but is at least 75% of the target level, OR data-limited assessments suggest population is healthy and species is not*

highly vulnerable.

- *2.33 (Moderate Concern) — Population is not overfished but may be below 75% of the target abundance level, OR abundance is unknown and the species is not highly vulnerable.*
- *1 (High Concern) — Population is considered overfished/depleted, a species of concern, threatened or endangered, OR abundance is unknown and species is highly vulnerable.*

Factor 1.2 - Fishing Mortality
Goal: Fishing mortality is appropriate for current state of the stock.

- *5 (Low Concern) — Probable (>50%) that fishing mortality from all sources is at or below a sustainable level, given the species ecological role, OR fishery does not target species and fishing mortality is low enough to not adversely affect its population.*
- *3 (Moderate Concern) — Fishing mortality is fluctuating around sustainable levels, OR fishing mortality relative to a sustainable level is uncertain.*
- *1 (High Concern) — Probable that fishing mortality from all source is above a sustainable level.*

Red king crab

Factor 1.1 - Abundance

Barents Sea | Atlantic, Northeast | Pots | Norway

Very Low Concern

Barents Sea red king crab has been shown to reduce species diversity and biomass, negatively affect habitats, and alter population-level dynamics (Falk-Petersen et al. 2011)(Jørgensen & Spiridonov 2013)(Oug et al. 2018). Although sustaining some populations of this invasive species may have negative local ecological impacts, annual stock assessments confirm that this population is stable and managed within limits to maintain good reproductive capacity, yet does not continue to expand westward (Norwegian Ministry of Climate and Environment 2020)(Sundet and Hoel 2016). Therefore, stock abundance warrants a score of very low concern.

Factor 1.2 - Fishing Mortality

Barents Sea | Atlantic, Northeast | Pots | Norway

Low Concern

The Barents Sea red king crab is an invasive, nonnative species that is harvested within quota regulations east of the 26° E. boundary (to maintain a fishery that supports local communities) and without limits west of the 26° E. boundary (to reduce the species' further westward spread) (Jørgensen and Nilssen 2011)(Sundet and Hoel 2016). The total allowable catch in the quota-regulated zone has increased in recent years, including year-round harvests and females, although fishing mortality has been kept at or above the rate that maintains the maximum sustainable yield (Hjelset 2014)(Kourantidou and Kaiser 2021)(Lorentzen et al. 2018)(Voldnes et al. 2020). Despite uncertainty surrounding fishing mortality in the open-access fishery west of 26° E., red king crab is an invasive nonnative species, so its overall fishing mortality is of low concern.

Criterion 2: Impacts on Other Species

All main retained and bycatch species in the fishery are evaluated under Criterion 2. Seafood Watch defines bycatch as all fisheries-related mortality or injury to species other than the retained catch. Examples include discards, endangered or threatened species catch, and ghost fishing. Species are evaluated using the same guidelines as in Criterion 1. When information on other species caught in the fishery is unavailable, the fishery's potential impacts on other species is scored according to the Unknown Bycatch Matrices, which are based on a synthesis of peer-reviewed literature and expert opinion on the bycatch impacts of each gear type. The fishery is also scored for the amount of non-retained catch (discards) and bait use relative to the retained catch. To determine the final Criterion 2 score, the score for the lowest scoring retained/bycatch species is multiplied by the discard/bait score. The Criterion 2 rating is determined as follows:

- ***Score >3.2=Green or Low Concern***
- ***Score >2.2 and ≤3.2=Yellow or Moderate Concern***
- ***Score ≤2.2 = Red or High Concern***

Rating is Critical if Factor 2.3 (Fishing Mortality) is Crtitical

Guiding principles

- *Ensure all affected stocks are healthy and abundant.*
- *Fish all affected stocks at sustainable level.*
- *Minimize bycatch.*

Criterion 2 Summary

Criterion 2 score(s) overview

This table(s) provides an overview of the Criterion 2 subscore, discards+bait modifier, and final Criterion 2 score for each fishery. A separate table is provided for each species/stock that we want an overall rating for.

RED KING CRAB			
REGION / METHOD	**SUB SCORE**	**DISCARD RATE/LANDINGS**	**SCORE**
Barents Sea | Atlantic, Northeast | Pots | Norway	2.644	1.000: < 100%	Yellow (2.644)

Criterion 2 main assessed species/stocks table(s)

This table(s) provides a list of all species/stocks included in this assessment for each 'fishery' (as defined by a region/method combination). The text following this table(s) provides an explanation of the reasons the listed species were selected for inclusion in the assessment.

BARENTS SEA | ATLANTIC, NORTHEAST | POTS | NORWAY			
SUB SCORE: 2.644	DISCARD RATE: 1.000	**SCORE: 2.644**	
SPECIES	**ABUNDANCE**	**FISHING MORTALITY**	**SCORE**
Marine mammals	2.330: Moderate Concern	3.000: Moderate Concern	Yellow (2.644)
Benthic inverts	2.330: Moderate Concern	5.000: Low Concern	Green (3.413)
Finfish	2.330: Moderate Concern	5.000: Low Concern	Green (3.413)
Red king crab	5.000: Very Low Concern	5.000: Low Concern	Green (5.000)

The bycatch and retained species caught in the Barents Sea red king crab pot fishery are generally unknown. Bycatch is scored according to the Seafood Watch Unknown Bycatch Matrix, based on a synthesis of peer-reviewed literature and expert opinion on the bycatch impacts of each gear type. The Unknown Bycatch Matrix ranks the bycatch susceptibility of different taxonomic groups in various gear types. More information is available in Appendix 2 of the Seafood Watch Criteria.

The taxa that are most likely to interact with the Barents Sea red king crab pot fishery include marine mammals, benthic invertebrates, and finfish. For the Barents Sea red king crab pot fishery, marine mammals limit the score for Criterion 2 because of their high vulnerability and potential to interact with this gear type, although these interactions are extremely rare and not likely to have a significant impact on these populations. Therefore, the impacts on other species in this fishery warrant a Yellow rating.

Criterion 2 Assessment

SCORING GUIDELINES

Factor 2.1 - Abundance
(same as Factor 1.1 above)

Factor 2.2 - Fishing Mortality
(same as Factor 1.2 above)

Factor 2.3 - Modifying Factor: Discards and Bait Use
Goal: Fishery optimizes the utilization of marine and freshwater resources by minimizing post-harvest loss. For fisheries that use bait, bait is used efficiently.

Scoring Guidelines: The discard rate is the sum of all dead discards (i.e. non-retained catch) plus bait use divided by the total retained catch.

Ratio of bait + discards/landings	Factor 2.3 score
<100%	1
>=100	0.75

Benthic inverts

Factor 2.1 - Abundance

Barents Sea | Atlantic, Northeast | Pots | Norway

Moderate Concern

The drop and haul of pots have been shown to have some impacts on benthic invertebrates, but the magnitude of the impacts is highly dependent on ocean conditions, substrate, and pot design (Eno et al. 2001)(Fuller et al. 2008). Although significant potential impacts of the invasive red king crab on benthic invertebrates may be avoided by maintaining this fishery, most stocks of benthic invertebrates are moderately vulnerable to interactions with pot fishing gear. Therefore, abundance of this taxonomic group is scored a moderate concern.

Factor 2.2 - Fishing Mortality

Barents Sea | Atlantic, Northeast | Pots | Norway

Low Concern

This score was calculated using the Seafood Watch Unknown Bycatch Matrix. Benthic invertebrates generally have a low susceptibility to interactions with pot fisheries. Also, despite the potential impacts to benthic invertebrates through drops and hauls of pot fishing gear, the magnitude of impacts is considered to be less in soft-bottom habitats, and recovery times remain unknown (Stevens 2021)(Fuller et al. 2008). Therefore, fishing mortality of benthic invertebrates warrants a score of low concern.

Finfish

Factor 2.1 - Abundance

Barents Sea | Atlantic, Northeast | Pots | Norway

Moderate Concern

Most stocks of teleost fish are moderately vulnerable to interactions with pot fishing gear; therefore, this taxonomic group warrants a score of moderate concern.

Factor 2.2 - Fishing Mortality

Barents Sea | Atlantic, Northeast | Pots | Norway

Low Concern

Finfish have a low susceptibility to interactions with pot fisheries, so fishing mortality is scored a low concern.

Marine mammals

Factor 2.1 - Abundance

Barents Sea | Atlantic, Northeast | Pots | Norway

Moderate Concern

Marine mammal species that frequent the region and are primarily at risk of entanglement in the red king crab pot fishing gear include humpback whale, fin whale, minke whale, and harbor seal (Blanchet et al. 2021)(Løviknes et al. 2021). Marine mammals are highly vulnerable to interactions with pot fishing gear, although this fishery has few documented instances of bycatch or entanglement (pers. comm., A. Hjelset, November 25, 2022) (NAMMCO 2021). It can be difficult to maintain a comprehensive database of gear entanglements, but it is likely that the rare interactions between marine mammals and this crab pot fishery will have a minimal impact on these populations, which are of "Least Concern" according to the International Union for the Conservation of Nature (IUCN) (Stelfox et al. 2016). Therefore, abundance is scored a moderate concern.

Factor 2.2 - Fishing Mortality

Barents Sea | Atlantic, Northeast | Pots | Norway

Moderate Concern

Marine mammals are highly vulnerable to interactions with trap/pot fisheries in nearly all regions. Along with the occasional entanglement report in the media, a ghost gear retrieval trip in 2019 found one deceased humpback whale entangled in pot trap ropes and one deceased seal in one of the traps, although these instances have not been attributed to the red king crab fishery (Directorate of Fisheries 2020b). Annual reports of the North Atlantic Marine Mammal Commission reveal no reports of marine mammal bycatch attributed to the Norwegian crab pot fishery between 2002 and 2019, and only three entanglements attributed to the nearby Russian red king crab fishery; these results suggest that these interactions are rare (NAMMCO 2021).

The threat of entanglement is of unknown magnitude, and information regarding interactions between this fishery and marine mammals is limited; however, this fishery has few documented instances of bycatch or entanglement, and these are not likely to have a significant impact on marine mammal populations (pers. comm., A. Hjelset, November 25, 2022). Therefore, fishing mortality is scored a moderate concern.

Factor 2.3 - Discard Rate/Landings

Barents Sea | Atlantic, Northeast | Pots | Norway

< 100%

Discard rates are not reported, but quota fishers are allowed to catch and land up to 9% damaged male crabs and 5% female crabs, which are calculated from the catch of blemish-free male crabs each week (Ministry of Trade, Industry, and Fisheries 2015). The primary bait in this fishery is herring, and of the approximately 800,000 tons landed annually in Norway, it is expected that the amount used for the red king crab fishery is negligible (ICES 2022) (pers. comm., A. Hjelset, November 25, 2022). The discard rate and bait use for this fishery can be assumed to be of a moderate value that is less than 100%, so it receives a score of 1.

Criterion 3: Management Effectiveness

Five factors are evaluated in Criterion 3: Management Strategy and Implementation, Bycatch Strategy, Scientific Research/Monitoring, Enforcement of Regulations, and Inclusion of Stakeholders. Each is scored as either 'highly effective', 'moderately effective', 'ineffective,' or 'critical'. The final Criterion 3 score is determined as follows:

- *5 (Very Low Concern) — Meets the standards of 'highly effective' for all five factors considered.*
- *4 (Low Concern) — Meets the standards of 'highly effective' for 'management strategy and implementation' and at least 'moderately effective' for all other factors.*
- *3 (Moderate Concern) — Meets the standards for at least 'moderately effective' for all five factors.*
- *2 (High Concern) — At a minimum, meets standards for 'moderately effective' for Management Strategy and Implementation and Bycatch Strategy, but at least one other factor is rated 'ineffective.'*
- *1 (Very High Concern) — Management Strategy and Implementation and/or Bycatch Management are 'ineffective.'*
- *0 (Critical) — Management Strategy and Implementation is 'critical'.*

The Criterion 3 rating is determined as follows:

- ***Score >3.2=Green or Low Concern***
- ***Score >2.2 and ≤3.2=Yellow or Moderate Concern***
- ***Score ≤2.2 = Red or High Concern***

Rating is Critical if Management Strategy and Implementation is Critical.

Guiding principle

- The fishery is managed to sustain the long-term productivity of all impacted species.

Five factors are evaluated in Criterion 3: Management Strategy and Implementation, Bycatch Strategy, Scientific Research/Monitoring, Enforcement of Regulations, and Inclusion of Stakeholders. Each is scored as either 'highly effective', 'moderately effective', 'ineffective,' or 'critical'. The final Criterion 3 score is determined as follows:

Criterion 3 Summary

FISHERY	MANAGEMENT STRATEGY	BYCATCH STRATEGY	DATA COLLECTION AND ANALYSIS	ENFORCEMENT	INCLUSION	SCORE
Barents Sea | Atlantic, Northeast | Pots | Norway	Moderately Effective	Moderately Effective	Moderately Effective	Highly effective	Highly effective	**Yellow (3.000)**

Although the enforcement of regulations and the inclusion of stakeholders in the management process are highly effective, the overall management strategy, bycatch strategy, and approach to data collection and analysis are moderately effective. Therefore, the management effectiveness of this fishery warrants a Yellow rating.

Bycatch and discards in the Norwegian fishery are not well known, but is thought to be very small given the type of gear used the location of fishing, and other factors.

Red king crab in the Barents is managed by Norway and Russia. Until 2005 both countries jointly managed the stock with a goal of maximizing economic output. Since then, each country has managed this invasive species differently with different goals. Norway sets quotas maximum economic yield near the Russian border but a policy of eradication outside this zone. Russian fishery managers set quotas to increase abundance and density for maximum long-term economic output and spread. Russia additionally has released larval crabs and has further documented the spread of the species eastward.

Criterion 3 Assessment

SCORING GUIDELINES

Factor 3.1 - Management Strategy and Implementation

Considerations: What type of management measures are in place? Are there appropriate management goals, and is there evidence that management goals are being met? Do manages follow scientific advice? To achieve a highly effective rating, there must be appropriately defined management goals, precautionary policies that are based on scientific advice, and evidence that the measures in place have been successful at maintaining/rebuilding species.

Factor 3.2 - Bycatch Strategy

Considerations: What type of management strategy/measures are in place to reduce the impacts of the fishery on bycatch species and when applicable, to minimize ghost fishing? How successful are these management measures? To achieve a Highly Effective rating, the fishery must have no or low bycatch, or if there are bycatch or ghost fishing concerns, there must be effective measures in place to minimize impacts.

Factor 3.3 - Scientific Research and Monitoring

Considerations: How much and what types of data are collected to evaluate the fishery's impact on the species? Is there adequate monitoring of bycatch? To achieve a Highly Effective rating, regular, robust population assessments must be conducted for target or retained species, and an adequate bycatch data collection program must be in place to ensure bycatch management goals are met.

Factor 3.4 - Enforcement of Management Regulations

Considerations: Do fishermen comply with regulations, and how is this monitored? To achieve a Highly Effective rating, there must be regular enforcement of regulations and verification of compliance.

Factor 3.5 - Stakeholder Inclusion

Considerations: Are stakeholders involved/included in the decision-making process? Stakeholders are individuals/groups/organizations that have an interest in the fishery or that may be affected by the management of the fishery (e.g., fishermen, conservation groups, etc.). A Highly Effective rating is given if the management process is transparent, if high participation by all stakeholders is encouraged, and if there a mechanism to effectively address user conflicts.

Factor 3.1 - Management Strategy And Implementation

Barents Sea | Atlantic, Northeast | Pots | Norway

Moderately Effective

The Barents Sea red king crab is considered to be established in the region. Efforts to completely remove it in Norwegian waters would be futile, due to the influx of crabs from Russian territory, and may even have negative impacts for local fishing communities and ecosystems, which have grown accustomed to the crabs' presence as a predator (Jørgensen 2013)(Jørgensen and Nilssen 2011). But, there remain potential negative ecological consequences as a result of sustaining this invasive nonnative species.

The quota-regulated zone east of the 26° E. boundary is managed within safe biological limits so that the established crab stocks have the reproductive capacity to maintain the local fishery and that mortality is kept at a rate that maintains the maximum sustainable yield (MSY) (Norwegian Ministry of Climate and Environment 2020). The Institute of Marine Research annually estimates these stocks for the Directorate of Fisheries, which advises the Ministry of Fisheries and Coastal Affairs for setting the total allowable catch (TAC) each year (Kourantidou and Kaiser 2021). The 2023 TAC in the quota-regulated area has been set at 2,375 metric tons for male red king crab and 120 metric tons for female red king crabs.

The open-access region west of this boundary was established to prevent further westward establishment of the crab population and is considered to have been generally successful over the past decade, because the crab population is stable and its westward spread is limited. But, there have been instances of crabs appearing in regions farther west, and the role of ballast water transfer is unknown at this time (Jørgensen 2013)(Jørgensen and Nilssen 2011)(Norwegian Ministry of Climate and Environment 2020).

Although TAC is the primary management approach, fishery managers also use closed areas, gear modifications, and soak time limits for traps to manage the red king crab fishery (Directorate of Fisheries 2008)(Ministry of Trade, Industry, and Fisheries 2015) (pers. comm., A. Hjelset, December 13, 2022). Therefore, management strategy and implementation is scored moderately effective.

Factor 3.2 - Bycatch Strategy

Barents Sea | Atlantic, Northeast | Pots | Norway

Moderately Effective

There is little bycatch or entanglement documented in the Barents Sea red king crab pot fishery, although there are many instances in other regions where pot fishery equipment leads to the landing of nontarget species or the entanglement of vulnerable species (pers. comm., A. Hjelset, November 25, 2022) (George et al. 2020). One ghost gear retrieval trip in 2019 found one

deceased humpback whale entangled in pot trap ropes and one deceased seal in one of the traps in Norwegian waters (Directorate of Fisheries 2020b).

Annual retrieval trips have been conducted for more than four decades, and in 2020, 100 tons of lost fishing equipment were retrieved. Of this, 2,669 pot traps were removed, of which 119 were from the red king crab fishery specifically (Directorate of Fisheries 2020b). Ghost fishing as a result of lost pot fishing gear is of concern for the Norwegian government, so measures to mitigate this are regularly enforced, including the annual retrieval trips, the obligation of fishers to search for lost gear, and the legal requirement to report the details if gear cannot be found (Directorate of Fisheries 2008)(Directorate of Fisheries 2020a). As of 2022, all traps are required to be equipped with biodegradable cotton thread to avoid ghost fishing (pers. comm., A. Hjelset, December 13, 2022).

Additional requirements in place to reduce bycatch include the use of collapsible traps with escape vents and a soak time limit for the traps (pers. comm., A. Hjelset, December 13, 2022). Aside from the efforts to minimize ghost fishing impacts and the implementation of closed areas and some gear limitations, the effectiveness of bycatch reduction measures is relatively unknown for this fishery, so its strategy is scored moderately effective.

Factor 3.3 - Scientific Data Collection and Analysis

Barents Sea | Atlantic, Northeast | Pots | Norway

Moderately Effective

Norway's Institute of Marine Research regularly collects data and performs research to inform scientific opinions and management strategies, including annual scientific cruises to estimate stock abundance and health and to further inform management strategies (Kourantidou and Kaiser 2021)(Oug et al. 2018). In addition, Norway participates in the joint IMR-PINRO (Institute of Marine Research-Polar Research Institute of Marine Fisheries and Oceanography), which documents distribution and abundance for several stocks in the Barents Sea.

The Forum for Integrated Ocean Management, in coordination with a number of Norwegian ministries and advisory groups, draws upon this scientific basis to further develop ocean management plans (Norwegian Ministry of Climate and Environment 2020). Historically, less research has been conducted in the open-access fishing region because of a lower abundance of red king crab; however, when data are limited, catch rates and other relevant sources have been used to infer the stock status (OECD 2021)(Skonhoft and Kourantidou 2021).

Although there are requirements in place for the reporting of all fishing activity and lost fishing gear, the data regarding ghost fishing, bycatch, and potential range expansion through ballast water transfer are limited and unclear (Jørgensen and Nilssen 2011). Interactions between pot fishing gear and marine mammals are known; however, the impact of these interactions is uncertain, so improved data collection in this area may help better understand the extent of any impacts. Therefore, scientific data collection and analysis in this fishery warrants a score of moderately effective.

Factor 3.4 - Enforcement of and Compliance with Management Regulations

Barents Sea | Atlantic, Northeast | Pots | Norway

Highly effective

Norwegian managers use logbooks, landing and sales notes, and a vessel monitoring system (VMS) to track catch and landings, and all catches of fish must be landed (Directorate of Fisheries 2008)(Directorate of Fisheries 2015). All vessels must submit reporting regularly to the Directorate of Fisheries, which can also inspect any stage of the fishing process and place observers on vessels to ensure compliance and detect and prevent illegal fishing. The Directorate of Fisheries may also assign fines and penalties in case regulations are not adhered to (Directorate of Fisheries 2008)(Ministry of Trade, Industry, and Fisheries 2015).

Although the Barents Sea red king crab is an invasive nonnative species, it is understood that total eradication is not possible or desirable, so the current management and enforcement plan adheres to the voluntary international Convention of Biodiversity agreement to control alien species "as far as possible and as appropriate" (Sundet and Hoel 2016). Therefore, the enforcement of and compliance with management regulations is scored highly effective.

Factor 3.5 - Stakeholder Inclusion

Barents Sea | Atlantic, Northeast | Pots | Norway

Highly effective

Integrated ocean management plans are developed through collaboration of all relevant parts of public administration, including multiple government ministries, the Forum for Integrated Ocean Management, the Institute of Marine Research, and an advisory group on monitoring (Norwegian Ministry of Climate and Environment 2020). After considering monitoring data, the Directorate of Fisheries proposes annual regulations and participation conditions at two regulatory meetings per year, when stakeholders from administration, industry, and environmental interests can provide input before regulations and conditions are finalized and implemented (Kourantidou and Kaiser 2021)(Directorate of Fisheries 2022). Because Norway has an inclusive process that is transparent and allows for stakeholder input, stakeholder inclusion is scored highly effective.

Criterion 4: Impacts on the Habitat and Ecosystem

This Criterion assesses the impact of the fishery on seafloor habitats, and increases that base score if there are measures in place to mitigate any impacts. The fishery's overall impact on the ecosystem and food web and the use of ecosystem-based fisheries management (EBFM) principles is also evaluated. Ecosystem Based Fisheries Management aims to consider the interconnections among species and all natural and human stressors on the environment. The final score is the geometric mean of the impact of fishing gear on habitat score (factor 4.1 + factor 4.2) and the Ecosystem Based Fishery Management score. The Criterion 4 rating is determined as follows:

- ***Score >3.2=Green or Low Concern***
- ***Score >2.2 and ≤3.2=Yellow or Moderate Concern***
- ***Score ≤2.2 = Red or High Concern***

Guiding principles

- Avoid negative impacts on the structure, function or associated biota of marine habitats where fishing occurs.
- Maintain the trophic role of all aquatic life.
- Do not result in harmful ecological changes such as reduction of dependent predator populations, trophic cascades, or phase shifts.
- Ensure that any enhancement activities and fishing activities on enhanced stocks do not negatively affect the diversity, abundance, productivity, or genetic integrity of wild stocks.
- Follow the principles of ecosystem-based fisheries management.

Rating cannot be Critical for Criterion 4.

Criterion 4 Summary

FISHERY	FISHING GEAR ON THE SUBSTRATE	MITIGATION OF GEAR IMPACTS	ECOSYSTEM-BASED FISHERIES MGMT	FORAGE SPECIES?	SCORE
Barents Sea | Atlantic, Northeast | Pots | Norway	Score: 3	Score: 0	Moderate Concern		**Yellow (3.000)**

Managers have prioritized the incorporation of ecosystem-based fisheries management methods for this invasive nonnative species, but have not implemented significant mitigation efforts to limit the impacts of pot fishing gear on the substrate, which are generally of moderate concern. Therefore, the impacts on the habitat and ecosystem warrant a Yellow rating.

Criterion 4 Assessment

SCORING GUIDELINES

Factor 4.1 - Physical Impact of Fishing Gear on the Habitat/Substrate
Goal: The fishery does not adversely impact the physical structure of the ocean habitat, seafloor or associated biological communities.

- *5 - Fishing gear does not contact the bottom*
- *4 - Vertical line gear*
- *3 - Gears that contacts the bottom, but is not dragged along the bottom (e.g. gillnet, bottom longline, trap) and is not fished on sensitive habitats. Or bottom seine on resilient mud/sand habitats. Or midwater trawl that is known to contact bottom occasionally. Or purse seine known to commonly contact the bottom.*
- *2 - Bottom dragging gears (dredge, trawl) fished on resilient mud/sand habitats. Or gillnet, trap, or bottom longline fished on sensitive boulder or coral reef habitat. Or bottom seine except on mud/sand. Or there is known trampling of coral reef habitat.*
- *1 - Hydraulic clam dredge. Or dredge or trawl gear fished on moderately sensitive habitats (e.g., cobble or boulder)*
- *0 - Dredge or trawl fished on biogenic habitat, (e.g., deep-sea corals, eelgrass and maerl) Note: When multiple habitat types are commonly encountered, and/or the habitat classification is uncertain, the score will be based on the most sensitive, plausible habitat type.*

Factor 4.2 - Modifying Factor: Mitigation of Gear Impacts
Goal: Damage to the seafloor is mitigated through protection of sensitive or vulnerable seafloor habitats, and limits on the spatial footprint of fishing on fishing effort.

- *+1 —>50% of the habitat is protected from fishing with the gear type. Or fishing intensity is very low/limited and for trawled fisheries, expansion of fishery's footprint is prohibited. Or gear is specifically modified to reduce damage to seafloor and modifications have been shown to be effective at reducing damage. Or there is an effective combination of 'moderate' mitigation measures.*
- *+0.5 —At least 20% of all representative habitats are protected from fishing with the gear type and for trawl fisheries, expansion of the fishery's footprint is prohibited. Or gear modification measures or other measures are in place to limit fishing effort, fishing intensity, and spatial footprint of damage caused from fishing that are expected to be effective.*
- *0 —No effective measures are in place to limit gear impacts on habitats or not applicable because gear used is benign and received a score of 5 in factor 4.1*

Factor 4.3 - Ecosystem-Based Fisheries Management
Goal: All stocks are maintained at levels that allow them to fulfill their ecological role and to maintain a functioning ecosystem and food web. Fishing activities should not seriously reduce ecosystem services provided by any retained species or result in harmful changes such as trophic cascades, phase shifts or reduction of genetic diversity. Even non-native species should be considered with respect to ecosystem impacts. If a fishery is managed in order to eradicate a non-native, the potential impacts of that strategy on native species in the ecosystem should be considered and rated below.

- *5 — Policies that have been shown to be effective are in place to protect species' ecological roles and ecosystem functioning (e.g. catch limits that ensure species' abundance is maintained at sufficient levels to provide food to predators) and effective spatial management is used to protect spawning and foraging areas, and prevent localized depletion. Or it has been scientifically demonstrated that fishing practices do not have negative ecological effects.*
- *4 — Policies are in place to protect species' ecological roles and ecosystem functioning but have*

not proven to be effective and at least some spatial management is used.

- *3 — Policies are not in place to protect species' ecological roles and ecosystem functioning but detrimental food web impacts are not likely or policies in place may not be sufficient to protect species' ecological roles and ecosystem functioning.*
- *2 — Policies are not in place to protect species' ecological roles and ecosystem functioning and the likelihood of detrimental food impacts are likely (e.g. trophic cascades, alternate stable states, etc.), but conclusive scientific evidence is not available for this fishery.*
- *1 — Scientifically demonstrated trophic cascades, alternate stable states or other detrimental food web impact are resulting from this fishery.*

Factor 4.1 - Physical Impact of Fishing Gear on the Habitat/Substrate

Barents Sea | Atlantic, Northeast | Pots | Norway

Score: 3

Barents Sea red king crab is harvested using square pot traps, which are considered to be lighter and have less benthic disturbance than traps used for fish species, particularly in soft bottom habitats (Fuller et al. 2008)(Lorentzen et al. 2018). Square pot traps contact the seafloor but are not actively dragged, although the potential for dragging on the seafloor by strong tides, storm swell, or trap retrieval may magnify habitat impacts (Eno et al. 2001)(Stevens 2021). Therefore, the physical impact of fishing gear on the habitat and substrate warrants a score of 3.

Factor 4.2 - Modifying Factor: Mitigation of Gear Impacts

Barents Sea | Atlantic, Northeast | Pots | Norway

Score: 0

Norwegian fishery managers utilize satellite-based vessel monitoring, closed areas, gear limits, and other measures to reduce the impact of this gear on the seafloor and associated habitat (Directorate of Fisheries 2008). The open-access approach west of the 26° E. boundary to prevent further spread of red king crab has led to an increase in fishing effort in the area, potentially increasing habitat impacts. The use of pot traps is generally considered to have low to medium impacts on soft bottom habitats and their associated species, although the magnitude of these impacts is unknown and dependent on many factors, including the amount of fishing pressure, storm swell, tides, and dragging during retrieval (Eno et al. 2001)(Fuller et al. 2008)(Stevens 2021). Therefore, the efforts to mitigate this fishery's impacts on benthic habitat result in a score of 0.

Factor 4.3 - Ecosystem-based Fisheries Management

Barents Sea | Atlantic, Northeast | Pots | Norway

Moderate Concern

Red king crab has been shown to have detrimental food web impacts once it is introduced to an ecosystem, including the reduction of species richness and biomass, shifts in community compositions, changes in population dynamics, and an increase in hypoxic conditions (Falk-Petersen et al. 2011)(Jørgensen & Spiridonov 2013)(Oug et al. 2018). Despite these documented impacts, in regions where the species has been established for decades, such as the quota-regulated zone, total eradication would likely not be possible or desired due to an influx of crabs from Russian waters in the east, economic impacts on local fishers, and the potential for trophic cascades (because the crab is already an established predator) (Sundet and Hoel 2016). In the quota-regulated region, red king crab populations have been managed within limits so that the spawning stock maintains reproductive capacity (Norwegian Ministry of Climate and Environment 2020).

The open-access region for red king crab harvest aims to prevent the further westward expansion of the species; this effort has slowed the rate of invasion but not prevented it entirely, because red king crab is appearing in new areas and altering community composition (Jørgensen 2013) (Jørgensen and Nilssen 2011)(Skonhoft and Kourantidou 2021)(Sundet and Hoel 2016). The open-access approach has been effective in preventing the long-term establishment of red king crab populations farther west, but the heightened fishing presence introduces the potential for other negative impacts on the ecosystem and native species. It is unclear if the impacts of a heightened pot fishing presence are reversible, and the recovery times of species have yet to be identified (Sundet and Hoel 2016)(Stevens 2021).

Therefore, the policies to manage this invasive nonnative species and the associated fishery warrant a score of moderate concern.

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