MONTEREY BAY AQUARIUM®

Seafood WATCH

Snow and Tanner Crab

Chionoecetes opilio, C. bairdi, C. angulatus, C. tanneri

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Alaska, Bering Sea

Traps

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Disclaimer

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Final Seafood Recommendation

This report covers the snow crab (*Chionoecetes opilio*) trap fishery of Alaska in the eastern Bering Sea (EBS). Eastern Bering Sea snow crab is a **Best Choice**.

Stock	Fishery	Impacts on the Stock Rank (Score)	Impacts on other Species Lowest scoring species Rank*, Subscore, Score	Manage-ment Rank Score	Habitat and Ecosystem Rank Score	Overall Recommendation Score
Snow crab – USA/Eastern Bering Sea	USA – Eastern Bering Sea (EBS) – Trap	Green 4.28	Tanner crab Green 4.28,4.07	Green 3.46	Green 3.61	**BEST CHOICE 3.74**

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

Table of Contents

Executive Summary

This report covers wild trap fisheries for the four species that are commonly marketed as "snow crab": true snow crab (*Chionoecetes opilio*), the southern Tanner crab (*C. bairdi*), grooved Tanner crab (*C. tanneri*), and triangle Tanner crab (*C. angulatus*). However, as the commercial fishery for *C. bairdi* is currently closed and landings for *C. tanneri* and *C. angulatus* are too low to warrant assessment, recommendations are only provided for the true snow crab, *C. opilio*, referred to as "snow crab" for the remainder of this report. The geographic scope of this report includes the snow crab fishery of Alaska in the eastern Bering Sea (EBS).

Snow crabs have high inherent vulnerability to fishing pressure. Males reach sexual maturity at 4–10 years and can live up to 20 years. Females are highly fecund, producing just over 80,000 eggs on average in their lifetime. Fertilized eggs are brooded by the females outside their bodies under an abdominal flap. Larvae are released to the water column where they spend several months before settling. Snow crabs are not broadcast spawners and as such may require minimum densities in order to achieve viable mating aggregations, which raises the potential for depensatory population dynamics at low population sizes.

Stock assessments are performed annually on the EBS snow crab stock. The most recent assessments show that the fishery recovered from an overfished condition in 2011. The stock was above $B_{35\%}$ (the B_{MSY} proxy used in this fishery) in 2009–2011 and was at 95% of $B_{35\%}$ in 2012. Fishing effort is well below the F_{MSY} proxy of $F_{35\%}$ used in the EBS snow crab fishery and has consistently been so for over a decade. However, there is uncertainty about the level of fishing that would compromise the future of the fishery.

Bycatch in the EBS snow crab fishery is limited mostly to southern Tanner crab (*C. bairdi*) and under-sized male snow crabs. Bycatch of female snow crabs is very low, as they generally live in different habitats than the commercially targeted males. Other bycatch, such as groundfish, amount to less than 1% of landings, and no species listed under the USA Endangered Species Act (ESA) are caught. Tanner crabs demonstrate medium vulnerability to fishing pressure. Overfishing is not currently occurring, but sufficient bycatch of Tanner crabs in the snow crab fishery could result in overfishing, even with the closure of the directed commercial fishery for Tanner crabs. The overall discard rate for the EBS snow crab fishery averaged 28% over the 2006–2010 seasons.

The EBS snow crab fishery is managed under a federal Fisheries Management Plan (FMP) that establishes joint management between the National Marine Fisheries Service (NMFS) and the Alaska Department of Fish and Game (ADFG), overseen by the North Pacific Fisheries Management Council (NPFMC). The FMP lays out clear goals for the fishery, including ensuring the long term reproductive viability of snow crab populations, preserving habitat, providing for rigorous scientific backing, and maximizing economic and social benefits over time. Scientific monitoring in the fishery is highly robust, with annual stock assessments conducted using both fishery-dependent and independent data. Under the FMP, management decisions are closely

tied to the results of completed stock assessments. Compliance with management measures is verified through on-board and dockside observer coverage along with mandatory electronic logbooks and vessel monitoring systems (VMS). The fishery has responded well to the challenges of managing snow crab populations, which are known to have strong natural fluctuations. While the fishery has only been rebuilding for two years, the future outlook is good. Management has been able to successfully rebuild the fishery from its previous overfished status. Stakeholder inclusion in this process is strong; reports and minutes are publicly available online, and collaborative partnerships exist between fishing organizations and management.

The EBS snow crab industry is a trap fishery, which can impact marine habitats. As the fishery is conducted on sandy and/or muddy substrates, the impact of these traps is likely limited. In addition, pots are constructed with raised frames that reduce the surface area of the trap that comes into contact with the bottom, although this increases the pressure applied by the trap at its contact points. The FMP mandates identification of essential fish habitat (EFH), and as a result, portions of the EBS fishing grounds are closed to snow crab traps. However, these closures cover a small area and are not present in regions of high snow crab fishing pressure. Ecosystem-based management is not clearly or directly included in the management of the fishery, but ecosystem factors are taken into consideration in the overall assessment of the resource conducted by the NPFMC.

Introduction

Scope of the analysis and ensuing recommendation

This report covers wild trap fisheries for the four species that are commonly marketed as "snow crab": true snow crab (*Chionoecetes opilio*), southern Tanner crab (*C. bairdi*), grooved Tanner crab (*C. tanneri*), and triangle Tanner crab (*C. angulatus*). However, as the commercial fishery for *C. bairdi* is currently closed, and landings for *C. tanneri* and *C. angulatus* are too low to warrant assessment (ADFG 2012), recommendations are only provided for the true snow crab, *C. opilio*, referred to as "snow crab" for the remainder of this report. The geographic scope of this report includes the snow crab fishery of Alaska in the eastern Bering Sea (EBS).

Species overview

Ecology of snow crabs (C. opilio)
Snow crabs are disc-shaped crabs reaching widths of up to 15 cm and living up to 20 years (Turnock & Rugolo 2011). In the North Pacific snow crabs are found throughout the continental shelf of the Bering, Chukchi, and Beaufort Seas, as well as the Sea of Okhotsk (the snow crab population in the Sea of Japan is a subspecies, *Chionoecetes opilio elongates*). In the Atlantic, they are found along the eastern seaboard of North America as far south as Maine and as far north as Greenland (NOAA 2012) (Fig. 1). Snow crabs have four pairs of legs and one pair of large claws that become disproportionally larger in males when they reach their final molt at approximately 4–15 cm in width, by which time they have also generally developed functional sperm (DFO 2012a). Snow crabs grow by molting, undergoing several molts before reaching a terminal molt. After each molt, the crab's new shell is soft (during which time they are called soft crab), making them vulnerable to handling, predation, or environmental hazards. Snow crabs feed on a wide variety of material, including fish, crustaceans (including other crabs), algae, and on occasion, sponges. Snow crab predators include fish, seals, sea otters, and octopus. Smaller-sized crabs are the most frequent target of predation (NOAA 2012).

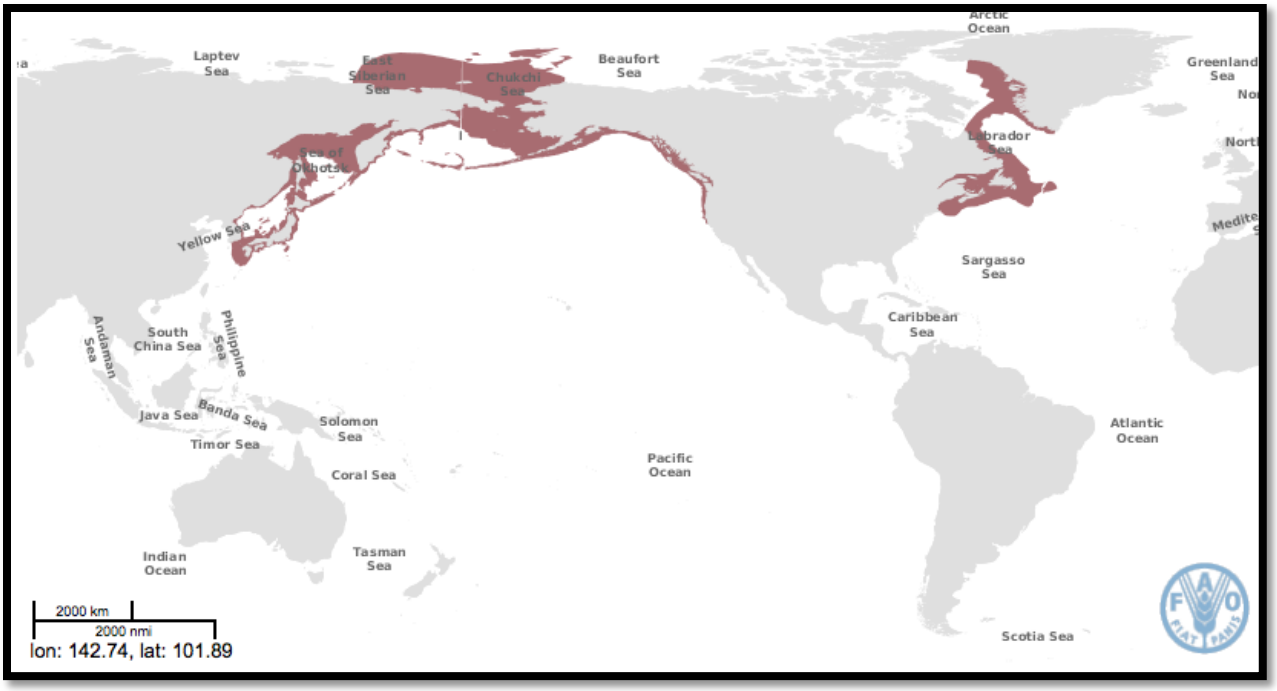

Figure 1. Geographic distribution of snow crabs, *C. opilio*. Figure from FAO (2012a). Snow crabs are also reported in the Barents Sea.

Snow crabs typically inhabit temperatures from -1 to 5 degrees C (Weston 2011). Adult males generally live along mud or silt bottoms at depths less than 200 m where they can burrow and feed. Adult females live in habitats apart from the adult males for much of the year (Poulsen 2012). During mating, females form large mounds, and generally only the largest males participate in mating. After mating, females can brood fertilized eggs on their abdomen outside their body for nearly one year (females living in extremely cold water may even brood their embryos for two years), eventually releasing larvae to the water column where they spend several months undergoing molts until they reach sufficient size to settle (Choi & Zisserson 2012). Juveniles live in shallower protected waters where they can bury themselves in fine sediments to provide better protection from predators.

Snow crab fisheries are marked by strong boom-bust dynamics, in which periods of high productivity are followed by phases of low recruitment (Sainte-Marie, Sévigny, Smith & Lovrich 1996; Turnock & Rugolo 2011). The drivers and timing of these cycles are not yet well understood, though factors such as compensatory density dependence, cod predation, and water temperature may all play roles (Boudreau, Anderson & Worm 2011; Sainte-Marie, Raymond & Brêthes 1995; Sainte-Marie et al. 1996)

Ecology of Tanner crabs

Tanner crabs are distributed throughout the Northern Pacific Ocean, including the Bering Sea and Gulf of Alaska. They generally inhabit continental shelf habitat at depths from the subtidal down to over 400 m. Tanner crabs have similar life histories to snow crabs. Males reach sizes up

to 20 cm in width, with growth occurring through molting. Mating occurs in the spring when females form dense mating aggregations for protection and the attraction of mates (Donaldson, Cooney & Hilsinger 1981; NPFMC 2011a; Urban & Hart 1999).

History & management of fishery

The Alaskan snow crab fishery is a trap (pot) fishery, targeting snow crabs along the continental shelf in the Bering Sea. The commercial snow crab industry in the EBS began with Japanese fishing from 1960 until 1980 after which the passage of the Magnuson Fishery Conservation Act (1976) prohibited the presence of the Japanese fleet within US waters. In the following years, the domestic industry began to grow, reaching a production peak in 1991. Catches declined thereafter, reaching a low in the early 2000s when the fishery was classified as overfished. The fishery has been recovering in the years leading up to the present (Fig. 2) (Turnock & Rugolo 2011).

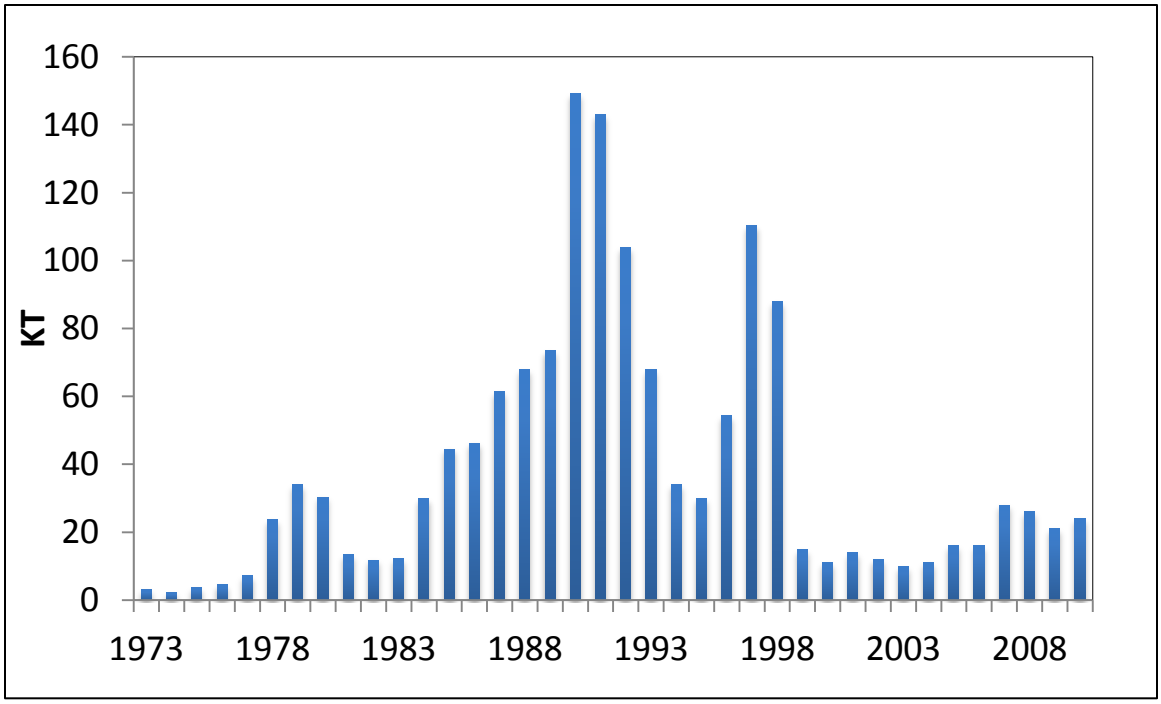

Figure 2. History of commercial landings for EBS snow crab (Turnock & Rugolo 2011).

Snow crab is managed under a cooperative partnership between the National Marine Fisheries Service (NMFS) and the Alaska Department of Fish and Game (ADFG). This partnership is formalized for by the federal Fishery Management Plan (FMP) for the Commercial King and Tanner Crab Fisheries in the Bering Sea/Aleutian Islands (BSAI), overseen by the North Pacific Fishery Management Council (NPFMC). Under the FMP, responsibilities such as permitting, federal observer programs, and identification of essential Habitat and Areas of Particular

Concern (HAPC) are left to the federal government, whereas the majority of the in-season management actions, such as the establishment of total allowable catches (TACs), seasons, and size limits, are left to the ADFG (NPFMC 2011a).

The EBS Tanner crab fishery began in the 1970s and quickly expanded until the stock collapsed in 1985, resulting in the closure of the fishery. Following a rebuilding phase, the fishery reopened until it once again collapsed and was closed from 1997 to 2004. The fishery subsequently reopened, but closed again in 2010 due to depressed stock size. The fishery currently remains closed to targeted commercial capture (Rugolo & Turnock 2011; Turnock 2012)

Production and markets

Global production is dominated by Canada and is sold primarily to the US and Japanese markets (Weston 2011). Consumption of snow crab in the US was over 101 kt live weight in 2009. The Alaskan EBS snow crab fishery provides approximately 14% of this total. The majority of imports making up the balance of US consumption come from Canada and Russia. Roughly 50% of US snow crab landings are exported, primarily to China and Japan (Sea Fare Group 2011). Wholesale prices in the US have fluctuated between $3.00 and $6.00 USD/lb (Seafood Market Bulletin 2012).

Global production has generally increased over time, reaching a peak of over 110 kt in 2002 (FAO 2012b). Global production of snow crab has historically been dominated by Canada, with Russia and the USA also providing substantial shares (Pinfold 2006). Snow crab production in the USA dropped to historic lows during the early 2000s in response to the overfished condition of the stock. Production has increased since 2005, however, with the most recent completed season bringing in 26.2 kilotons (kt) (Turnock & Rugolo 2011). Exports of US snow crab are predominately destined for Japan. In 2011, US production totaled 24.7 (kt).

The US and Japan each account for nearly half of global snow crab consumption (Pinfold 2006). The majority of snow crab sold in the USA is in section form (four legs and a claw; other forms include live whole, frozen whole, and extracted meat). Primary markets are mid-level seafood restaurants, buffets and casinos in the USA, and luxury and sushi restaurants in Japan (Pinfold 2006). The meat is often described as sweet and flaky. In the US market, prices have generally fluctuated between a low of $2.00/lb and a high of $5.00/lb, with recent US import values nearing $5.00/lb wholesale (NMFS 2012). Imports to the USA are primarily from Russia and Canada.

Common market names

Snow and Tanner crabs are also marketed as queen and spider crabs. In sushi form, crabs are generically referred to as *kani*.

Analysis

Scoring guide

- All scores result in a zero to five final score for the criterion and the overall final rank. A zero score indicates poor performance, while a score of five indicates high performance.
- The full Seafood Watch Fisheries Criteria that the following scores relate to are available on our website at www.seafoodwatch.org.

Criterion 1: Stock for which you want a recommendation

Guiding principles

- The stock is healthy and abundant. Abundance, size, sex, age, and genetic structure should be maintained at levels that do not impair the long-term productivity of the stock or the fulfillment of its role in the ecosystem and food web.
- Fishing mortality does not threaten populations or impede the ecological role of any marine life. Fishing mortality should be appropriate given current abundance and inherent resilience to fishing while accounting for scientific uncertainty, management uncertainty, and non-fishery impacts such as habitat degradation.

Stock	**Fishery**	**Inherent Vulnerability** Rank	**Stock Status** Rank (Score)	**Fishing Mortality** Rank (Score)	**Criterion 1** Rank Score
Snow Crab - USA / Eastern Bering Sea	USA - Eastern Bering Sea (EBS) - Trap	High	Very Low Concern (5)	Low Concern (3.67)	Green 4.28

Justification of Ranking

Factor 1.1. Inherent vulnerability: High

Key relevant information:

Resilience attribute	Score	Rationale	Source
Average age at maturity	2	Crabs are difficult to age, but estimated values are 5.5–6.5 years	(Orensanz, Ernst & Armstrong 2007)
Average maximum age	2	Max age estimated as 20 years by stock assessment	(NPFMC 2011b)
Fecundity	NA	6,000–140,000 eggs produced	(NOAA 2012)
Reproductive strategy	2	Eggs are fertilize and brooded by female; larvae spend several months in water column	(Incze, Armstrong & Smith 1987; NOAA 2012)
Density dependence	1	Weak stock recruitment dynamics evident. However, due to need for physical copulation, mating could be compromised at low population densities	(Orensanz et al. 2007; Turnock 2012; Zheng & Kruse 2003)
Total score	**1.75**	**High vulnerability**	

Factor 1.2. Stock status: Very low concern

Key relevant information:

Biomass has been estimated to be above $B_{35\%}$ since 2008 (Figure 4).

Detailed rationale

Stock assessments are performed annually on the EBS snow crab stock using both fishery-dependent and independent data. Under the crab Fishery Management Plan (FMP), fisheries are classified in one of five available tiers based on the quality of information available (where one is highest and five is lowest). The EBS snow crab stock is classified as tier three, meaning that an empirical stock recruitment curve cannot be determined. As a result, the fishery is managed through proxies for B_{msy} and F_{msy}. In this case, a 35% control rule is applied, in which $F_{35\%}$ is the fishing effort that would result in egg production equal to 35% of the egg production that would occur in the unexploited population (NPFMC 2011b).

Following these metrics, the stock assessment for EBS snow crab uses mature male biomass (MMB) to evaluate the state of the stock relative to the $B_{35\%}$ level of MMB (MMB_{35}). Numerous models are fit to available data (including landings, catch per unit effort, size frequency data, and fishery-independent survey data) to develop estimates of the current and past status of the EBS snow crab stock. Under all model scenarios, MMB has been above $MMB_{35\%}$ since 2008 (Fig. 3) (Turnock & Rugolo 2011). As such, the fishery has been declared recovered. However, this finding is highly dependent on assumptions underlying the model such as the selectivity of the fishery-independent survey gear. In addition, future projections based on alternative harvest strategies for the EBS snow crab indicate that MMB will likely dip below $MMB_{35\%}$ following the 2012 season. Recovery to levels above $MMB_{35\%}$ is also likely, however, dependent on future recruitment (Turnock 2012).

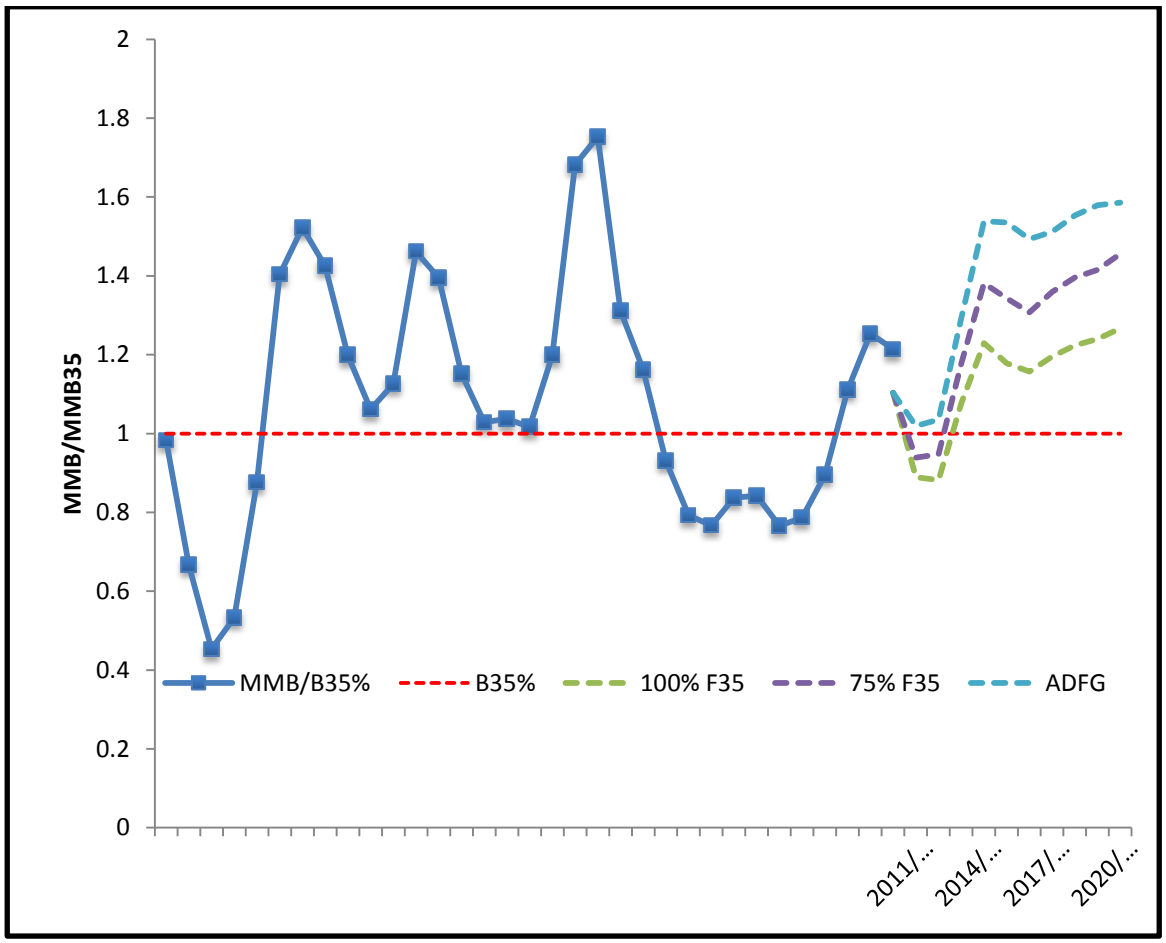

Figure 3. Trends in MMB over $MMB_{35\%}$ from stock assessment model 7 (adapted from Turnock & Rugolo 2011).

Factor 1.3. Fishing mortality: Low concern

<u>Key relevant information:</u>

The ratio of $F/F_{35\%}$ has been consistently below 1 since 1999, but there is substantial uncertainty in the value of the overfishing limit (OFL) on which $F_{35\%}$ depends. Current fishing is likely at a sustainable level, in spite of significant uncertainty about estimates of key parameters.

Detailed rationale

Estimates of $F_{35\%}$ are made based on the OFL, which is in turn based on estimates of MMB and $MMB_{35\%}$. The value of F is then calculated from landings and estimates of MMB. Results from these model parameters indicate that F is below $F_{35\%}$ (Fig. 4). However, uncertainty in the underlying parameters makes the true value of the OFL difficult to ascertain, with estimates ranging from 57,200 to 29,400 tons, depending on the model used. Thus, substantial uncertainty remains in the determination of the OFL (Turnock & Rugolo 2011).

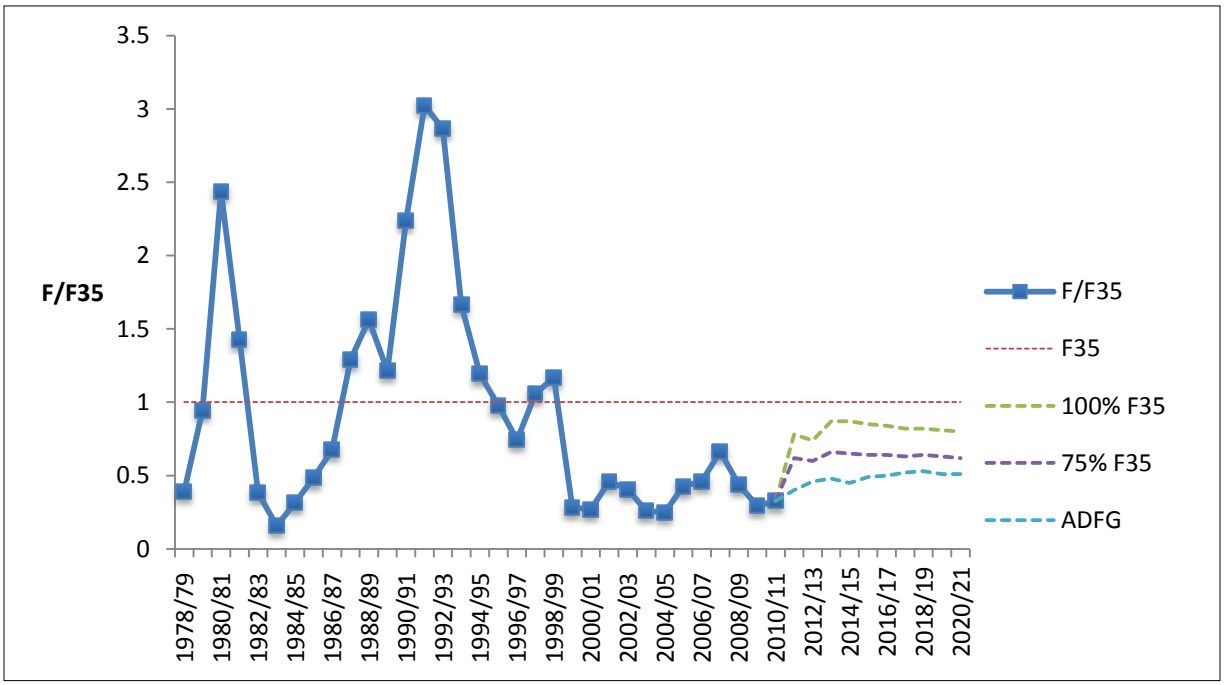

Figure 4. Trends and projections in EBS F/F_{35} over time (adapted from Turnock & Rugolo 2011).

Criterion 2: Impacts on other retained and bycatch stocks

Guiding principles

- The fishery minimizes bycatch. Seafood Watch® defines bycatch as all fisheries-related mortality or injury other than the retained catch. Examples include discards, endangered or threatened species catch, pre-catch mortality, and ghost fishing. All discards, including those released alive, are considered bycatch unless there is valid scientific evidence of high post-release survival, and there is no documented evidence of negative impacts at the population level.
- Fishing mortality does not threaten populations or impede the ecological role of any marine life. Fishing mortality should be appropriate given each impacted species' abundance and productivity, accounting for scientific uncertainty, management uncertainty, and non-fishery impacts such as habitat degradation.

Stock	**Inherent Vulnerability** Rank	**Stock Status** Rank (Score)	**Fishing Mortality** Rank (Score)	**Subscore**	**Score** (subscore*discard modifier)	**Rank** (based on subscore)
Southern Tanner Crab - USA/Eastern Bering Sea	Medium	Low Concern (4)	Low Concern (3.67)	3.83	3.64	Green

Synthesis

Bycatch in the EBS snow crab fishery is limited to southern Tanner crabs (*C. bairdi*) and under-sized male snow crabs. Bycatch of female snow crabs is very low, as they generally live in different habitats than the commercially targeted males. Other bycatch, such as groundfish, amount to less than 1% of landings, and no species listed under the USA Endangered Species Act (ESA) are caught. Bycatch of Tanner crabs in the snow crab fishery can negatively affect the Tanner crab population. Tanner crabs demonstrate medium vulnerability to fishing pressure. Overfishing is not currently occurring, but sufficient bycatch of Tanner crabs in the snow crab fishery could result in overfishing, even with the closure of the directed commercial Tanner crab fishery. The overall discard rate for the EBS snow crab fishery averaged 28% during the 2006–2010 seasons.

Justification of Ranking

Tanner crab (C. bairdi) – EBS

Factor 2.1. Inherent vulnerability: medium

Key relevant information:

Resilience	Score	Rationale	Source
Average age at maturity	2	6–8 years average age at maturity	(Zheng & Kruse 2003)
Average maximum age	2	Max age 12–20 years	(NPFMC 2011a)
Fecundity	NA	Females carry clutches of >50,000 eggs	(Rugolo & Turnock 2011; Turnock & Rugolo 2011)
Reproductive strategy	2	Females brood eggs, then release larvae to water column; larval stage 2–7 months	(NPFMC 2011a)
Density dependence	2	Ricker-curve dynamics evident, suggesting decreased spawning at high and low sizes; Allee effects possible but not demonstrated	(Turnock 2012; Zheng & Kruse 2003)
Total score	2	Medium	

Factor 2.2. Stock status: Low concern

The EBS *C. bairdi* stock was previously classified as overfished by the NPFMC, but this designation was revoked in October 2012. The fishery was closed from 1997–2005 due to low abundance and declared overfished in 1999. In 2005, the fishery reached a level that allowed fishing but subsequently declined. The fishery was closed again in 2010 when it was determined to be overfished (Rugolo & Turnock 2011). The most recent assessment approved by the Scientific and Statistical Committee (SSC) of the NPFMC in October 2012 uses a new model that has been under development for several years. The new model indicates that the stock status has changed and that the stock is neither overfished nor below B_{msy}. Thus, at present, the *C. bairdi* stock is no longer considered overfished.

Factor 2.3. Fishing mortality: Low concern

Overfishing is not occurring. However, forecasts show the possibility of overfishing occurring due to uncertainty in bycatch from the snow crab fishery, even if all commercial catch is closed (Rugolo & Turnock 2011).

Factor 2.4. Overall discard rate: 20-40%

Key relevant information:
The overall discard rate for EBS traps is 29% (Rugolo & Turnock 2011; Turnock & Rugolo 2011).

Detailed rationale (optional)
Tanner crab discards from pot fisheries were obtained from Rugolo & Turnock (2011).

Calculation of discard rates (Rugolo & Turnock 2011; Turnock & Rugolo 2011)

	2010	2009	2008	2007	2006
Tanner crab discards (1000 t)	0.69	0.82	0.91	2.01	1.37
Snow crab discards (1000 t)	2.05	4.09	6.86	8.42	5.9
Total discards (1000 t)	2.74	4.91	7.77	10.43	7.27
Retained catch (1000 t)	24.67	21.82	26.56	28.6	16.5
Annual discard rate	11%	23%	29%	36%	44%
Mean discard rate from 2006–2010	**29%**				

Criterion 3: Management effectiveness

Guiding principle

- The fishery is managed to sustain the long-term productivity of all impacted species. Management should be appropriate for the inherent resilience of affected marine life and should incorporate data sufficient to assess the affected species and manage fishing mortality to ensure little risk of depletion. Measures should be implemented and enforced to ensure that fishery mortality does not threaten the long-term productivity or ecological role of any species in the future.

Summary

Fishery	**Management: Harvest Strategy** Rank (Score)	**Management: Bycatch** Rank (Score)	**Criterion 3** Rank Score
USA - Eastern Bering Sea (EBS) - Trap	Low Concern (4)	Moderate Concern (3)	Green 3.46

Synthesis

The EBS snow crab fishery is managed under an FMP established by NMFS and ADFG with oversight by the NPFMC. This FMP lays out clear goals for the fishery, including ensuring the long-term reproductive viability of snow crab populations, preserving habitat, providing for rigorous scientific backing, and maximizing economic and social benefits over time. Scientific monitoring in the fishery is highly robust, with annual stock assessments conducted using both fishery-dependent and independent data. Under the FMP, management decisions are closely tied to the results of completed stock assessments. Compliance with management measures is verified using on-board and dockside observer coverage along with mandatory electronic logbooks and vessel monitoring systems (VMS). The fishery has responded well to the challenges of managing snow crab populations, which are known to exhibit strong natural fluctuations. While the fishery has only been rebuilding for three years, the future outlook is good. Management has been able to successfully rebuild the fishery from its previous overfished status. Stakeholder inclusion in the management process is strong; reports and minutes are publicly available online and collaborative partnerships exist between fishing organizations and management.

Justification of ranking

Factor 3.1. Management of fishing impacts on retained species: Low concern

Fishery	Mgmt strategy and implementation	Recovery of stocks of concern	Scientific research and monitoring	Scientific advice	Enforcement	Track record	Stakeholder inclusion
USA – Eastern Bering Sea (EBS) – Trap	Highly effective	N/A	Highly effective	Highly effective	Highly effective	Moderately effective	Highly effective

Key relevant information:

Management strategy and implementation[1]*: Highly effective*
The EBS snow crab fishery is managed under the Fishery Management Plan (FMP) for the Commercial King and Tanner Crab fisheries in the Bering Sea/Aleutian Islands (BSAI). Under this arrangement, management responsibilities are shared by a partnership between NMFS and ADFG, although the FMP itself is overseen by the NPFMC. The FMP identifies seven management objectives (NPFMC 2011a):

1. Ensure the long term reproductive viability of crab populations
2. Maximize economic and social benefits to the nation over time
3. Minimize gear conflict among fisheries
4. Preserve the quality and extent of suitable habitat
5. Ensure the ability of the public to be involved in the development of vessel safety considerations
6. Ensure that the public has access to due process and redress with respect to the management process
7. Provide the research, data, and analysis to ensure that management has sufficient information for decision making

Three general tiers of management actions exist within the FMP. Category 1 refers to management measures used in the EBS snow crab fishery that are fixed in the FMP and cannot be changed except by an amendment to the Plan. This includes permitting, federal observer programs, and identification of essential Habitat and Areas of Particular Concern (HAPC). In

[1] (NPFMC 2011a, 2011b)

particular, under Category 1 the FMP identifies HAPCs and establishes management practices to prevent their degradation by fishing. Category 2 contains many of the in-season management measures, which may be modified by the State following criteria defined by the FMP. These include size limits, seasons, harvest levels, and areas closed to fishing. Category 3 refers to measures that are not explicitly specified by the FMP and include state observer programs and bycatch limits for the crab fisheries (NPFMC 2011a, 2011b).

Within this overall system, on-the-ground management decisions concerning catch specifications are based on a five-tier system, the goal of which is to provide a framework for identifying overfishing and overfished conditions as well as the rules that will be implemented in response to the fishery's condition. Each year, the fishery is assigned to a tier based on the availability of reliable information for that fishery. Tiers 1–4 provide methods for the calculation of F_{ofl} (the fishing pressure that will result in the fishery being classified as overfished) depending on the condition of the stock. The stock condition may be classified as ***a***, ***b***, or ***c***, where ***a*** indicates that the stock status is above B_{msy}, ***b*** indicates that the stock is below B_{msy} but above the defined critical biomass threshold, and ***c*** indicates that the biomass is below the critical threshold. Under condition ***c***, direct fishing is discontinued and indirect mortality is mitigated to ensure the rebuilding of the species. As an enforcement measure in setting the ABC, excess catch from the prior season is applied to the total catch estimate used in the stock assessment, effectively lowering the maximum ABC for the current season (NPFMC 2011a, 2011b).

Once an appropriate rule for determining F_{ofl} has been set, stock assessments are used to find the biological overfishing limit (the amount of catch that would constitute overfishing, OFL). Estimates of the OFL are selected so as to be risk neutral and tested under a full range of outcomes and assumptions. Acceptable biological catch (ABC) is the level of annual catch that ensures with greater than 50% probability that the overfishing limit (OFL) will not be exceeded. The ABC is set by the ABC control rule, which is adjusted according to the level of scientific uncertainty present in the fishery. Stock assessments are then reviewed by the Crab Plan Team (CPT), which evaluates the assumptions, probability distributions, and methods for quantifying uncertainty. The CPT, together with the Scientific and Statistical Committee (SSC), then sets an OFL and an ABC for the year (NPFMC 2011a, 2011b).

Overfishing is defined as total capture greater than the OFL for the current year. The fishery also evaluates whether catch levels exceeded the annual catch limit (ACL), where catch includes all direct and indirect estimates of fishing mortality. A stock is classified as overfished if the stock size has fallen below the minimum stock size threshold (MSST), which is determined by the guidelines of the tier program. Per the Magnuson-Stevens Act, if overfishing is occurring or if the stock is overfished, overfishing must end immediately and a plan must be implemented to rebuild the stock. This assessment is repeated annually (NPFMC 2011a, 2011b).

In order to address overcapacity in the crab fishing fleet, an industry-funded vessel buyback program was implemented in 2004 that permanently removed 25 vessels from the fishery. In a further effort to rationalize the fishery, a community quota system was implemented under

which 10% of the yearly crab TAC is allocated to cooperatives made up of regional coastal communities (NPFMC 2011a; Poulsen 2012)

The EBS snow crab fishery has clear and detailed management practices and goals in place. The fishery also has a track record of taking necessary steps to achieve these objectives. The recovery of the stock and positive outlook for its future suggest that management goals are being successfully implemented.

Recovery of stocks of concern: N/A
Snow crab is not currently an overfished, depleted, endangered, or threatened species. The fishery targets no other stocks of concern.

Scientific research and monitoring: Highly effective
Stock assessments are conducted annually for the snow crab fishery. The stock assessment uses a variety of fishery-dependent and independent data sources to fit its models. Fishery-dependent data include total catch (both retained and discarded crabs), estimates of discard rates, gear selectivity, and sex and size composition of the total catch, as recorded by on-board observers (in place since 1990). Fishery-independent data come from annual bottom trawl surveys conducted by NMFS. Detailed records of the methods of these trawls can be found in NPFMC (2011b). These surveys collect data on densities, sex, and size frequencies at sites throughout the EBS (Rugolo, MacIntosh, Armisted, Otto & Otto 2011). The fishery also employs both on-board and dockside observers. However, substantial uncertainty remains in parameters such as individual growth rates, reproductive potential, and natural mortality (Turnock 2012).

Data are fit to a sex-specific length-based model using ADModel Builder (ADMB), a robust and highly trusted optimization program. Alternative models are constructed reflecting different assumptions for model parameters and uncertainty. Methods and results for each model are reviewed by an independent Science and Statistical Committee (SSC) of the NPFMC. Following approval of model structures, the Crab Plan Team (CPT) then recommends final control rules for the fishery based on the model results; these are reviewed and finalized by the SSC.

Due to the presence of heavily reviewed annual stock assessments, incorporating both fishery-dependent and independent data, scientific research and monitoring in the EBS fishery is classified as highly effective.

Scientific advice: Highly effective
The process for setting the annual OFL determined by the CPT is established by the FMP control rules. As such, determination of the OFL is somewhat removed from political processes. However, discretion is left to the CPT in determining an ABC that prevents exceeding the OFL with adequate certainty; this allows for some negotiation in the process of setting catch limits. The OFL control rule specified in the FMP ensures that the agreed upon catch remains less than the credible OFL, and that management has a demonstrated record of setting catch limits below the OFL provided by the stock assessment process (Fig. 6) (NPFMC 2011b).

Due to the clear regulations in place for incorporating scientific advice as well as for management's track record of not exceeding scientific recommendations for capture, scientific advice in the EBS fishery is classified as highly effective.

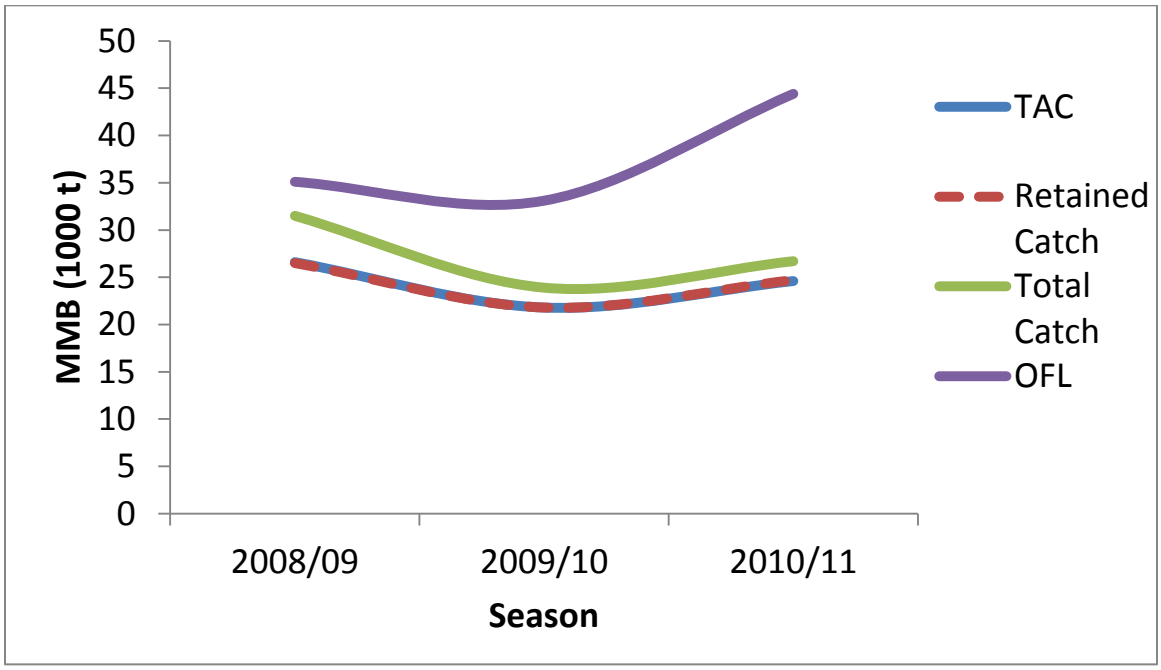

Figure 6. Trends in snow crab fishing regulations and retained catch over time (adapted from (Turnock & Rugolo 2011).

Enforcement: Highly effective

All crab landings are required to be logged in a confidential electronic fish ticket, which records vessel specific information together with the number and weight of crabs landed and the date and location of capture. State-mandated on-board observers are required on all catcher/processor and floating processor vessels. However, the snow crab fishery itself randomly assigns observer coverage to vessels to achieve 20% observer coverage (NPFMC 2011b). Registered vessels in the snow crab fishery must have an active VMS approved by NMFS (ADFG 2011). Strong observer coverage, together with VMS systems and mandatory electronic logging, makes enforcement in the EBS snow crab fishery highly effective.

Track record: Moderately effective

The EBS snow crab fishery has a strong track record and has proven reasonably responsive and effective in the management of snow crabs to date. Using definitions provided by the snow crab FMP, the stock was declared overfished in 1999 due to survey estimates of mature biomass being below the MSST. A recovery plan was put in place and the most recent stock assessment indicates that the stock has successfully rebuilt and that biomass was above B_{msy} from 2008–2011 (NPFMC 2011a). The fishery has a strong track record of compliance with catch regulations (Fig. 11). Due to the demonstrated ability of management to recover the fishery

from depleted levels, while still taking into account the short duration of this recent recovery, the track record of the EBS snow crab fishery is classified as moderately effective.

Stakeholder inclusion: Highly effective
Stock assessments and proceedings from relevant meetings are posted online and available to the public. Stakeholders are able to voice their opinions in the management process. Recently, management entered in to an agreement with the local crab fishing cooperative in which the industry self-funded research activities to improve knowledge of the stock (Poulsen 2012). Due to the high level of transparency and opportunity for public comment, stakeholder inclusion in the EBS snow crab fishery is classified as highly effective.

Factor 3.2. Management of fishing impacts on bycatch species: Moderate concern

Fishery	**All species retained?**	**Critical?**	Mgmt strategy and implementation	Scientific research and monitoring	Scientific advice	Enforcement
USA – Eastern Bering Sea (EBS) – Trap	No	No	Moderately effective	Highly effective	Highly effective	Highly effective

Key relevant information:

Management strategy and implementation: Moderately effective
No direct measures for the prevention of Tanner crab bycatch in the snow crab fishery are in place. However, gear restrictions are in place to minimize the overall impact of bycatch in the snow crab fishery. Traps must have a mesh size sufficient to allow the escape of undersized crabs, and they must have escape rings built into the structure (NPFMC 2011b). In addition, biodegradable mesh is now used to prevent the risk of ghost fishing. Industry reforms have also helped reduce the extent of bycatch. Due to decreased effort, fewer pots are now soaked for longer, which increases the probability that undersized individuals will escape once the bait runs out. Industry led efforts have also pushed the snow crab cooperative to avoid regions where high densities of Tanner crab have been observed (Poulsen 2012). The presence of bycatch reduction methods, without a clear and direct measure for controlling Tanner bycatch, makes the bycatch strategy implementation and management for the EBS snow crab fishery moderately effective.

Scientific research and monitoring: Highly effective
Observer coverage in the fishery is over 20%, allowing for adequate monitoring of bycatch rates. Results are well incorporated into stock assessments of Tanner crab populations. Strong observer coverage and data collection make scientific research and monitoring for bycatch in the EBS snow crab fishery highly effective.

Scientific advice: Highly effective
See Factor 3.1.

Enforcement: Highly effective
See Factor 3.1.

Criterion 4: Impacts on the habitat and ecosystem

Guiding principles

- The fishery is conducted such that impacts on the seafloor are minimized and the ecological and functional roles of seafloor habitats are maintained.
- Fishing activities should not seriously reduce ecosystem services provided by any fished species or result in harmful changes such as trophic cascades, phase shifts, or reduction of genetic diversity.

Fishery	**Impact of gear on the substrate** Rank (Score)	**Mitigation of gear impacts** Rank (Score)	**EBFM** Rank (Score)	**Criterion 4** Rank Score
USA - Eastern Bering Sea (EBS) - Trap	Low Concern (3)	Minimal mitigation (0.25)	Low Concern (4)	Green 3.61

Synthesis

The EBS snow crab industry is a trap fishery, which can impact marine habitats. Because the fishery is conducted on sandy and/or muddy substrates, the impact of these traps is likely limited. In addition, pots are constructed with raised frames that reduce the surface area of the trap that comes into contact with the bottom, although the pressure applied by the trap is increased in contact areas. The FMP mandates the identification of Essential Fish Habitat (EFH). As a result, portions of the EBS fishing grounds are now closed to snow crab traps. However, these closures cover a small area and are not present in regions of high snow crab fishing pressure. Effort has been reduced in recent years as a result of vessel buy-back schemes and active efforts by industry. Ecosystem-based management is not clearly or directly included in the management of the fishery, but ecosystem factors are taken into consideration in the overall assessment of the resource conducted by the NPFMC.

Justification

Factor 4.1. Impact of the fishing gear on the substrate: Low concern

Key relevant information:

Chuenpagdee, Morgan, Maxwell, Norse & Pauly (2003) rank pots and traps as a three out of five on a habitat impacts scale. Most fishing in the EBS region is on silt and mud bottoms, which reduces the potential habitat impacts of the fishing gear (Fig. 7 & 8). However, no studies have

been conducted measuring the number of pots, pot size or pot weight used in Alaskan waters. Trap mesh is elevated from the substrate by a frame so that the contact area is minimized, but the weight of the trap is concentrated on the frame edges. These frame edges can cause habitat damage, especially if the pot is dragged across the floor during bad weather or during the setting and retrieval of gear. Given the size of the pots and these potential gear effects, pots may have an impact on the order of a small pelagic trawl.

Detailed rationale

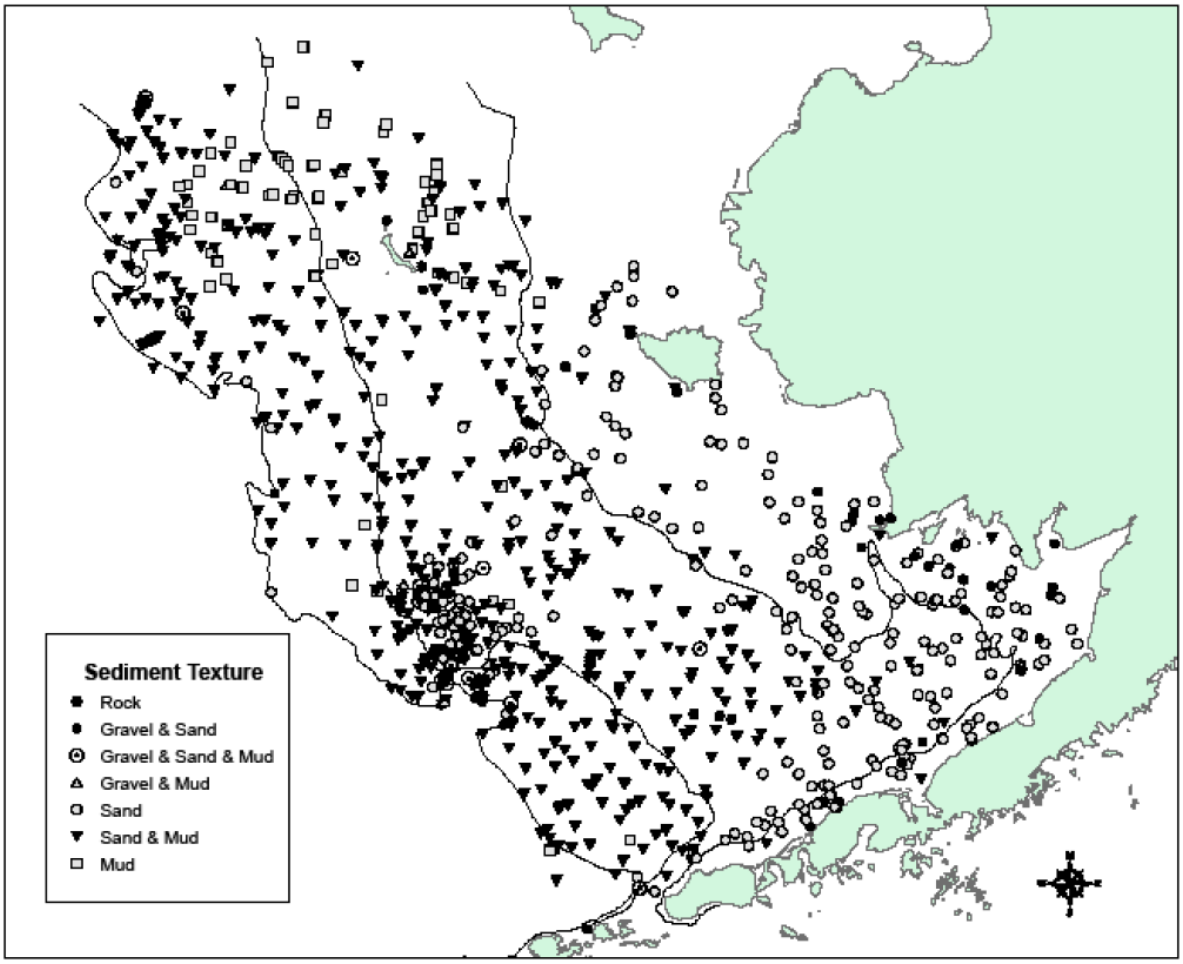

Figure 7. Map of sediment characteristics in the EBS region (Smith & McConnaughey 1999).

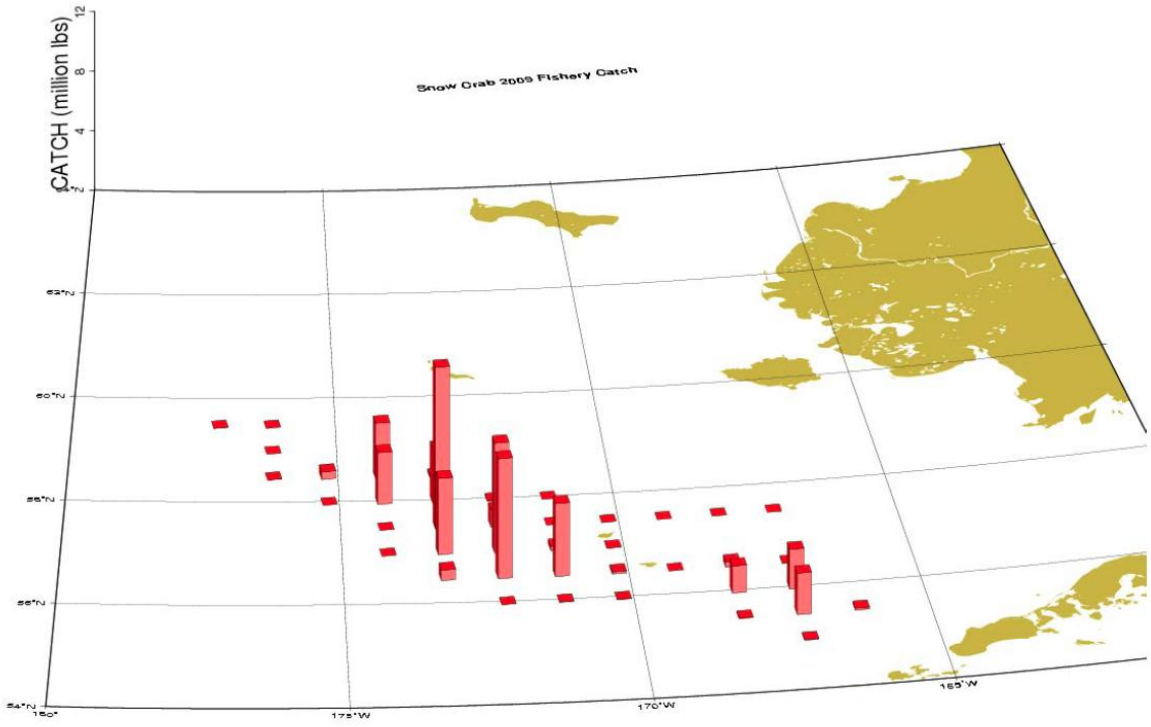

Figure 8. Map of fishing intensity for the 2008/09 snow crab pot fishery in the EBS region (Turnock & Rugolo 2011).

Factor 4.2. Modifying factor: Mitigation of fishing gear impacts: Minimal mitigation

Key relevant information:

The FMP mandates the identification of Essential Fish Habitat (EFH). The current FMP has closed coral protection areas (Fig. 9) and seamount habitats (Fig. 10) to pot fishing, but these regions make up a small percentage of habitat fished by the snow crab industry (NPFMC 2011b; Smith & McConnaughey 1999). Fishing effort is effectively controlled through the limited entry program, a well-controlled TAC, a fishery buyback program, and the CDQ system. Therefore, mitigation of fishing gear impacts is ranked as minimal (NPFMC 2011a).

Detailed rationale

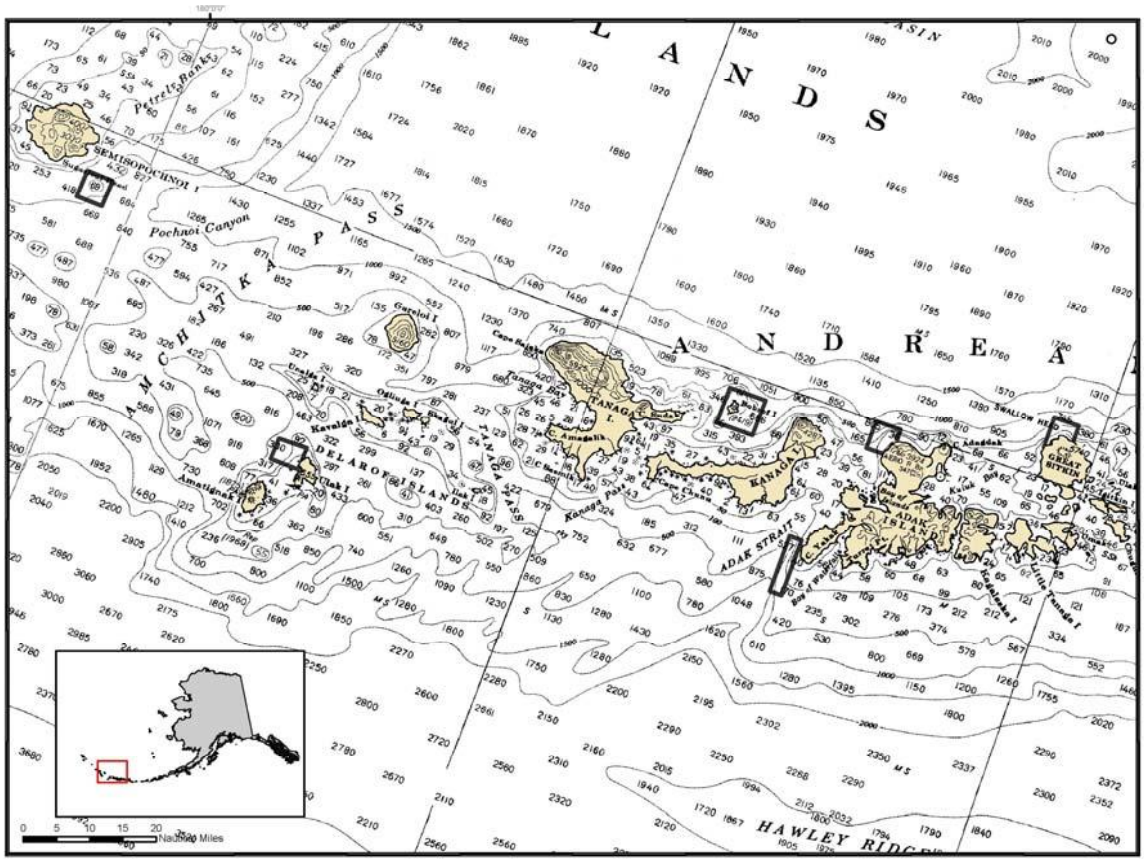

Figure 9. Coral protection areas in the range of the EBS snow crab fishery (NPFMC 2011a).

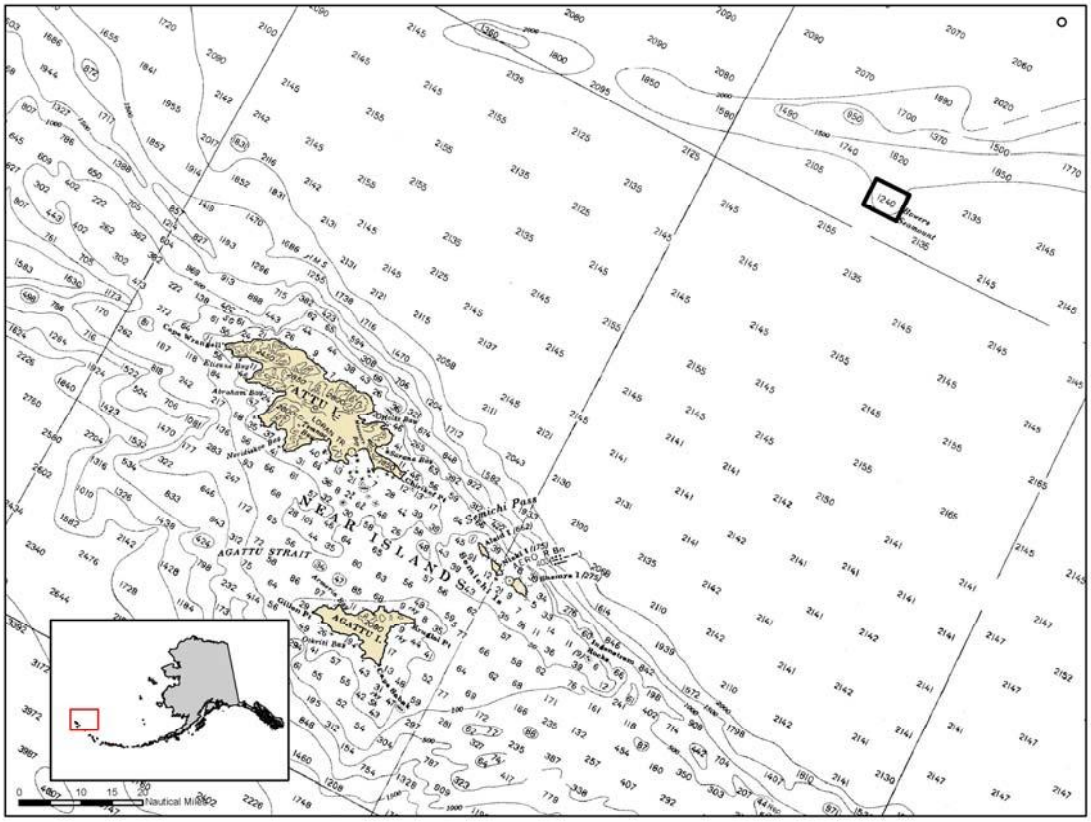

Figure 10. Seamount protection area in the range of the EBS snow crab fishery (NPFMC 2011a).

Factor 4.3. Ecosystem and food web considerations: Low concern

Key relevant information:

No exceptional species are caught in the fishery. The snow crab FMP does not currently directly manage the fishery from an ecosystem-based perspective. However, the annual assessment report includes assessments of broader ecosystem considerations such as food webs and habitat availability. Therefore, assessments to account for the ecological role of snow crabs are underway (NPFMC 2011a). In Alaska, management regulations already include ecosystem-based fishery management measures such as control of directed and incidental catches; prohibition on fishing of forage species (on which other fish, seabirds, and marine mammals depend); protection of habitat for fish, crabs and marine mammals; and, temporal and spatial controls on fishing (Witherell and Woodby 2005; Pikitch et al. 2004).

Overall Recommendation

The overall recommendation for the fishery is as follows:

- **Best Choice** = Final Score between 3.2 and 5, **and** no Red Criteria, **and** no Critical scores
- **Good Alternative** = Final score between 2.2 and 3.199, **and** Management is not Red, **and** no more than one Red Criterion other than Management, **and** no Critical scores
- **Avoid** = Final Score between 0 and 2.199, **or** Management is Red, **or** two or more Red Criteria, **or** one or more Critical scores.

Acknowledgements

Scientific review does not constitute an endorsement of the Seafood Watch® program, or its seafood recommendations, on the part of the reviewing scientists. Seafood Watch® is solely responsible for the conclusions reached in this report.

Seafood Watch® would like to thank Edward Poulsen, Dr. Gordon Kruse of the University of Alaska Fairbanks, and an anonymous reviewer for graciously reviewing this report for scientific accuracy.

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Appendix A: Review Schedule

Assessments of the EBS snow crab and tanner crab fishery are performed annually. The CPT publishes the results of the stock assessments its final regulation decisions annual in the crab SAFE document (http://www.fakr.noaa.gov/npfmc/resources-publications/safe-reports.html).

About Seafood Watch®

Monterey Bay Aquarium's Seafood Watch® program evaluates the ecological 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. Seafood Watch® makes its science-based recommendations available to the public in the form of regional pocket guides that can be downloaded from www.seafoodwatch.org. 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.

Each sustainability recommendation on the regional pocket guides is supported by a Seafood Report. Each report synthesizes and analyzes the most current ecological, fisheries and ecosystem science on a species, then evaluates this information against the program's conservation ethic to arrive at a recommendation of "Best Choices", "Good Alternatives" or "Avoid". The detailed evaluation methodology is available upon request. In producing the Seafood Reports, Seafood Watch® seeks out research published in academic, peer-reviewed journals whenever possible. Other sources of information include government technical publications, fishery management plans and supporting documents, and other scientific reviews of ecological sustainability. Seafood Watch® Research Analysts also communicate regularly with ecologists, fisheries and aquaculture scientists, and members of industry and conservation organizations when evaluating fisheries and aquaculture practices. Capture fisheries and aquaculture practices are highly dynamic; as the scientific information on each species changes, Seafood Watch®'s sustainability recommendations and the underlying Seafood Reports will be updated to reflect these changes.

Parties interested in capture fisheries, aquaculture practices and the sustainability of ocean ecosystems are welcome to use Seafood Reports in any way they find useful. For more information about Seafood Watch® and Seafood Reports, please contact the Seafood Watch® program at Monterey Bay Aquarium by calling 1-877-229-9990.

Disclaimer

Seafood Watch® strives to have all Seafood Reports reviewed for accuracy and completeness by external scientists with expertise in ecology, fisheries science and aquaculture. Scientific review, however, does not constitute an endorsement of the Seafood Watch® program or its recommendations on the part of the reviewing scientists. Seafood Watch® is solely responsible for the conclusions reached in this report.

Seafood Watch® and Seafood Reports are made possible through a grant from the David and Lucile Packard Foundation.

Guiding Principles

Seafood Watch™ defines sustainable seafood as originating from sources, whether fished[2] 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 capture fisheries must possess to be considered sustainable by the Seafood Watch program:

- *Stocks are healthy and abundant.*
- *Fishing mortality does not threaten populations or impede the ecological role of any marine life.*
- *The fishery minimizes bycatch.*
- *The fishery is managed to sustain long-term productivity of all impacted species.*
- *The fishery is conducted such that impacts on the seafloor are minimized and the ecological and functional roles of seafloor habitats are maintained.*
- *Fishing activities should not seriously reduce ecosystem services provided by any fished species or result in harmful changes such as trophic cascades, phase shifts, or reduction of genetic diversity.*

Based on these guiding principles, Seafood Watch has developed a set of four sustainability **criteria** to evaluate capture fisheries for the purpose of developing a seafood recommendation for consumers and businesses. These criteria are:

1. Impacts on the species/stock for which you want a recommendation
2. Impacts on other species
3. Effectiveness of management
4. Habitat and ecosystem impacts

Each criterion includes:

- Factors to evaluate and rank
- Evaluation guidelines to synthesize these factors and to produce a numerical score
- A resulting numerical score and **rank** for that criterion

Once a score and rank has been assigned to each criterion, an overall seafood recommendation is developed on additional evaluation guidelines. Criteria ranks and the overall recommendation are color-coded to correspond to the categories on the Seafood Watch pocket guide:

Best Choices/Green: Are well managed and caught or farmed in environmentally friendly ways.

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

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

Avoid/Red: Take a pass on these. These items are overfished or caught or farmed in ways that harm other marine life or the environment.