Snow Crab Rebuilding
Adopt Alternatives for Analysis

May 2022[1]

1 Introduction

On October 19, 2021, NMFS notified the Council that Eastern Bering Sea (EBS) snow crab status has been changed to overfished. The EBS snow crab assessment shows that mature male biomass (MMB) is 50,600 metric tons (mt), which is less than the minimum stock size threshold (MSST) of 76,700 mt, therefore the stock is overfished. The stock is not subject to overfishing.

The Magnuson-Stevens Fishery Conservation and Management Act (MSA) requires that a rebuilding plan be developed and put in place within two years of the stock being declared overfished. The rebuilding plan should specify a time period for rebuilding the fishery, not to exceed ten years. To facilitate development of the EBS snow crab rebuilding plan, the Council at this meeting will select alternatives for the rebuilding analysis.

This paper is an update of the progress report on the EBS snow crab rebuilding plan that was provided during the February 2022 Council meeting. In February, the Crab Plan Team and the SSC had not yet approved the stock assessment model needed to estimate the time frame for rebuilding the EBS snow crab stock. The Crab Plan Team has now provided this recommendation, and the SSC will review the model and its parameters at this meeting. The progress report provides an overview of the Magnuson-Stevens language on rebuilding overfished stocks and National Standard 1 guidelines for determination of rebuilding requirements, current stock status for EBS snow crab, sources of EBS snow crab mortality, and next steps in selecting alternatives for analysis for rebuilding snow crab.

2 Background

2.1 Rebuilding Crab Stocks

Rebuilding of overfished stocks is required by the MSA section 304. The National Standard 1 guidelines indicate that once biomass falls below the MSST, then remedial action is required "to rebuild the stock or stock complex to the MSY level within an appropriate time frame." Rebuilding should take place in as short a time as possible, taking into account the status and biology of any overfished stocks of fish, the needs of fishing communities, recommendations by international organizations in which the United States participates, and the interaction of the overfished stock of fish within the marine ecosystem. A stock is considered "rebuilt" when the stock reaches B_{MSY} for two consecutive years.

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A rebuilding plan for any crab stock is incorporated by an amendment to the Bering Sea/Aleutian Islands King and Tanner Crab Fishery Management Plan (FMP). If associated regulations that affect other fisheries (i.e. groundfish) are necessary, additional implementation of regulations would be required.

Magnuson-Stevens Language on Rebuilding Overfished Stocks

Section 304(e)(3) of the MSA requires the Council and Secretary of Commerce (Secretary) to develop and implement a rebuilding plan within two years of receiving notification from the Secretary that a stock is overfished, approaching an overfished condition, or has not made adequate progress towards rebuilding.
The applicable section of the Act is provided below.
(e) REBUILDING OVERFISHED FISHERIES—

> (1) The Secretary shall report annually to the Congress and the Councils on the status of fisheries within each Council's geographical area of authority and identify those fisheries that are overfished or are approaching a condition of being overfished. For those fisheries managed under a fishery management plan or international agreement, the status shall be determined using the criteria for overfishing specified in such plan or agreement. A fishery shall be classified as approaching a condition of being overfished if, based on trends in fishing effort, fishery resource size, and other appropriate factors, the Secretary estimates that the fishery will become overfished within two years.
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> (2) If the Secretary determines at any time that a fishery is overfished, the Secretary shall immediately notify the appropriate Council and request that action be taken to end overfishing in the fishery and to implement conservation and management measures to rebuild affected stocks of fish. The Secretary shall publish each notice under this paragraph in the Federal Register.
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> (3) Within two years of an identification under paragraph (1) or notification under paragraphs (2) or (7), the appropriate Council (or the Secretary, for fisheries under section 302(a)(3)) shall prepare a fishery management plan, plan amendment, or proposed regulations for the fishery to which the identification or notice applies—
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> > (A) to end overfishing in the fishery and to rebuild affected stocks of fish; or
> >
> > (B) to prevent overfishing from occurring in the fishery whenever such fishery is identified as approaching an overfished condition.
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> (4) For a fishery that is overfished, any fishery management plan, amendment, or proposed regulations prepared pursuant to paragraph (3) or paragraph (5) for such fishery shall—
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> > (A) specify a time period for ending overfishing and rebuilding the fishery that shall—
> >
> > > (i) be as short as possible, taking into account the status and biology of any overfished stocks of fish, the needs of fishing communities, recommendations by international organizations in which the United States participates, and the interaction of the overfished stock of fish within the marine ecosystem; and
> > >
> > > (ii) not exceed 10 years, except in cases where the biology of the stock of fish, other environmental conditions, or management measures under an international agreement in which the United States participates dictate otherwise;

(B) allocate both overfishing restrictions and recovery benefits fairly and equitably among sectors of the fishery; and

(C) for fisheries managed under an international agreement, reflect traditional participation in the fishery, relative to other nations, by fishermen of the United States.

(5) If, within the 2-year period beginning on the date of identification or notification that a fishery is overfished, the Council does not submit to the Secretary a fishery management plan, plan amendment, or proposed regulations required by paragraph (3)(A), the Secretary shall prepare a fishery management plan or plan amendment and any accompanying regulations to stop overfishing and rebuild affected stocks of fish within 9 months under subsection (c).

(6) During the development of a fishery management plan, a plan amendment, or proposed regulations required by this subsection, the Council may request the Secretary to implement interim measures to reduce overfishing under section 305(c) until such measures can be replaced by such plan, amendment, or regulations. Such measures, if otherwise in compliance with the provisions of this Act, may be implemented even though they are not sufficient by themselves to stop overfishing of a fishery.

(7) The Secretary shall review any fishery management plan, plan amendment, or regulations required by this subsection at routine intervals that may not exceed two years. If the Secretary finds as a result of the review that such plan, amendment, or regulations have not resulted in adequate progress toward ending overfishing and rebuilding affected fish stocks, the Secretary shall—

(A) in the case of a fishery to which section 302(a)(3) applies, immediately make revisions necessary to achieve adequate progress; or

(B) for all other fisheries, immediately notify the appropriate Council. Such notification shall recommend further conservation and management measures which the Council should consider under paragraph (3) to achieve adequate progress

National Standard 1 Guidelines

Further clarification on stock rebuilding under the Magnuson-Stevens Act for National Standard 1 (NS1) is provided in the excerpt below from the Final Rule on National Standard Guidelines published in the Federal Register on October 18, 2016 (81 FR 71858) and available on the NOAA Fisheries website: https://www.fisheries.noaa.gov/national/laws-and-policies/national-standard-guidelines
Sec. 600.310 National Standard 1— Optimum Yield.

(j) *Council actions to address overfishing and rebuilding for stocks and stock complexes*—

(1) *Notification*. The Secretary will immediately notify in writing a Regional Fishery Management Council whenever the Secretary determines that:

(i) Overfishing is occurring;

(ii) A stock or stock complex is overfished;

(iii) A stock or stock complex is approaching an overfished condition; or

(iv) Existing remedial action taken for the purpose of ending previously identified overfishing or rebuilding a previously identified overfished stock or stock complex has not resulted in adequate progress (see MSA section 304(e)).

(2) *Timing of actions*—

(i) *If a stock or stock complex is undergoing overfishing.* Upon notification that a stock or stock complex is undergoing overfishing, a Council should immediately begin working with its SSC (or agency scientists or peer review processes in the case of Secretarially-managed fisheries) to ensure that the ABC is set appropriately to end overfishing. Councils should evaluate the cause of overfishing, address the issue that caused overfishing, and reevaluate their ACLs and AMs to make sure they are adequate.

(ii) *If a stock or stock complex is overfished or approaching an overfished condition. Upon* notification that a stock or stock complex is overfished or approaching an overfished condition, a Council must prepare and implement an FMP, FMP amendment, or proposed regulations within two years of notification, consistent with the requirements of section 304(e)(3) of the Magnuson-Stevens Act. Council actions should be submitted to NMFS within 15 months of notification to ensure sufficient time for the Secretary to implement the measures, if approved.

(3) *Overfished fishery.*—

(i) Where a stock or stock complex is overfished, a Council must specify a time period for rebuilding the stock or stock complex based on factors specified in Magnuson-Stevens Act section 304(e)(4). This target time for rebuilding (T_{target}) shall be as short as possible, taking into account: The status and biology of any overfished stock, the needs of fishing communities, recommendations by international organizations in which the U.S. participates, and interaction of the stock within the marine ecosystem. In addition, the time period shall not exceed 10 years, except where biology of the stock, other environmental conditions, or management measures under an international agreement to which the U.S. participates, dictate otherwise. SSCs (or agency scientists or peer review processes in the case of Secretarial actions) shall provide recommendations for achieving rebuilding targets (see Magnuson-Stevens Act section 302(g)(1)(B)). The above factors enter into the specification of T_{target} as follows:

(A) *The minimum time for rebuilding a stock (T_{min}).* T_{min} means the amount of time the stock or stock complex is expected to take to rebuild to its MSY biomass level in the absence of any fishing mortality. In this context, the term “expected” means to have at least a 50 percent probability of attaining the B_{msy}, where such probabilities can be calculated. The starting year for the T_{min} calculation should be the first year that the rebuilding plan is expected to be implemented.

(B) *The maximum time for rebuilding a stock or stock complex to its B_{msy} (T_{max}).*

(1) If T_{min} for the stock or stock complex is 10 years or less, then T_{max} is 10 years.

(2) If T_{min} for the stock or stock complex exceeds 10 years, then one of the following methods can be used to determine T_{max}:

(i) T_{min} plus the length of time associated with one generation time for that stock or stock complex. "Generation time" is the average length of time between when an individual is born and the birth of its offspring,

(ii) The amount of time the stock or stock complex is expected to take to rebuild to B_{msy} if fished at 75 percent of MFMT, or

(iii) T_{min} multiplied by two.

(3) In situations where T_{min} exceeds 10 years, T_{max} establishes a maximum time for rebuilding that is linked to the biology of the stock. When selecting a method for determining T_{max}, a Council, in consultation with its SSC, should consider the relevant biological data and scientific uncertainty of that data, and must provide a rationale for its decision based on the best scientific information available. One of the methods listed in subparagraphs (j)(3)(i)(B)(2)(*ii*) and (*iii*) may be appropriate, for example, if given data availability and the life history characteristics of the stock, there is high uncertainty in the estimate of generation time, or if generation time does not accurately reflect the productivity of the stock.

(C) *Target time to rebuilding a stock or stock complex (T_{target}).* T_{target} is the specified time period for rebuilding a stock that is considered to be as short a time as possible, taking into account the factors described in paragraph (j)(3)(i) of this section. T_{target} shall not exceed T_{max}, and the fishing mortality associated with achieving T_{target} is referred to as $F_{rebuild}$.

(ii) Council action addressing an overfished fishery must allocate both overfishing restrictions and recovery benefits fairly and equitably among sectors of the fishery.

(iii) For fisheries managed under an international agreement, Council action addressing an overfished fishery must reflect traditional participation in the fishery, relative to other nations, by fishermen of the United States.

(iv) *Adequate Progress.* The Secretary shall review rebuilding plans at routine intervals that may not exceed two years to determine whether the plans have resulted in adequate progress toward ending overfishing and rebuilding affected fish stocks (MSA section 304(e)(7)). Such reviews could include the review of recent stock assessments, comparisons of catches to the ACL, or other appropriate performance measures. The Secretary may find that adequate progress is not being made if $F_{rebuild}$ or the ACL associated with $F_{rebuild}$ is exceeded, and AMs are not correcting the operational issue that caused the overage, nor addressing any biological consequences to the stock or stock complex resulting from the overage when it is known (see paragraph (g)(3) of this section). A lack of adequate progress may also be found when the rebuilding expectations of a stock or stock complex are significantly changed due to new and unexpected information about the status of the stock. If a determination is made under this provision, the Secretary will notify the appropriate Council and recommend further conservation and management measures, and the Council must develop and implement a new or revised rebuilding plan within two years (see MSA sections 304(e)(3) and (e)(7)(B)). For Secretarially-managed fisheries, the Secretary would take immediate action necessary to achieve adequate progress toward rebuilding and ending overfishing.

(v) While a stock or stock complex is rebuilding, revising rebuilding timeframes (i.e., T_{target} and T_{max}) or $F_{rebuild}$ is not necessary, unless the Secretary finds that adequate progress is not being made.

(vi) If a stock or stock complex has not rebuilt by T_{max}, then the fishing mortality rate should be maintained at its current $F_{rebuild}$ or 75 percent of the MFMT, whichever is less, until the stock or stock complex is rebuilt or the fishing mortality rate is changed as a result of the Secretary finding that adequate progress is not being made.

(4) *Emergency actions and interim measures*. If a Council is developing a rebuilding plan or revising an existing rebuilding plan due to a lack of adequate progress (see MSA section 304(e)(7)), the Secretary may, in response to a Council request, implement interim measures that reduce, but do not necessarily end, overfishing (see MSA section 304(e)(6)) if all of the following criteria are met:

(i) The interim measures are needed to address an unanticipated and significantly changed understanding of the status of the stock or stock complex;

(ii) Ending overfishing immediately is expected to result in severe social and/or economic impacts to a fishery; and

(iii) The interim measures will ensure that the stock or stock complex will increase its current biomass through the duration of the interim measures.

(5) *Discontinuing a rebuilding plan based on new scientific information.* A Council may discontinue a rebuilding plan for a stock or stock complex before it reaches B_{msy} if the Secretary determines that the stock was not overfished in the year that the overfished determination (see MSA section 304(e)(3)) was based on and has never been overfished in any subsequent year including the current year.

(k) *International overfishing.* If the Secretary determines that a fishery is overfished or approaching a condition of being overfished due to excessive international fishing pressure, and for which there are no management measures (or no effective measures) to end overfishing under an international agreement to which the United States is a party, then the Secretary and/or the appropriate Council shall take certain actions as provided under Magnuson-Stevens Act section 304(i). The Secretary, in cooperation with the Secretary of State, must immediately take appropriate action at the international level to end the overfishing. In addition, within one year after the determination, the Secretary and/or appropriate Council shall:

(1) Develop recommendations for domestic regulations to address the relative impact of the U.S. fishing vessels on the stock. Council recommendations should be submitted to the Secretary.

(2) Develop and submit recommendations to the Secretary of State, and to the Congress, for international actions that will end overfishing in the fishery and rebuild the affected stocks, taking into account the relative impact of vessels of other nations and vessels of the United States on the relevant stock. Councils should, in consultation with the Secretary, develop recommendations that take into consideration relevant provisions of the Magnuson-Stevens Act and NS1 guidelines, including section 304(e) of the Magnuson-Stevens Act and paragraph (j)(3)(iii) of this section, and other applicable laws. For highly migratory species in the Pacific, recommendations from the Western Pacific, North Pacific, or Pacific Councils must be developed and submitted consistent with Magnuson-Stevens Reauthorization Act section 503(f), as appropriate.

(3) *Considerations for assessing "relative impact."* "Relative impact" under paragraphs (k)(1) and (2) of this section may include consideration of factors that include, but are not limited to: Domestic and international management measures already in place, management history of a given nation, estimates of a nation's landings or catch (including bycatch) in a given fishery, and estimates of a nation's mortality contributions in a given fishery. Information used to determine relative impact must be based upon the best available scientific information.

(l) *Exceptions to requirements to prevent overfishing.* Exceptions to the requirement to prevent overfishing could apply under certain limited circumstances. Harvesting one stock at its optimum level may result in overfishing of another stock when the two stocks tend to be caught together (This can occur when the two stocks are part of the same fishery or if one is bycatch in the other's fishery). Before a Council may decide to allow this type of overfishing, an analysis must be performed and the analysis must contain a justification in terms of overall benefits, including a comparison of benefits under alternative management measures, and an analysis of the risk of any stock or stock complex falling below its MSST. The Council may decide to allow this type of overfishing if the fishery is not overfished and the analysis demonstrates that all of the following conditions are satisfied:

(1) Such action will result in long-term net benefits to the Nation;

(2) Mitigating measures have been considered and it has been demonstrated that a similar level of long-term net benefits cannot be achieved by modifying fleet behavior, gear selection/configuration, or other technical characteristics in a manner such that no overfishing would occur; and

(3) The resulting rate of fishing mortality will not cause any stock or stock complex to fall below its MSST more than 50 percent of the time in the long term, although it is recognized that persistent overfishing is expected to cause the affected stock to fall below its B_{msy} more than 50 percent of the time in the long term.

Establishing a Timeline

A rebuilding plan must be consistent with the MSA and NS1 Guidelines on time for rebuilding, specifically rebuilding within a time (T_{target}) that is as short as possible, taking into account the status and biology of any overfished stocks of fish, the needs of fishing communities, recommendations by international organizations in which the United States participates, and the interaction of the overfished stock of fish with the marine ecosystems. The fastest rebuilding time (T_{min}), is calculated based on no fishing mortality (F=0). If $T_{min} > 10$ years, then the NS1 Guidelines provide other methods for defining maximum rebuilding time (T_{max}).

Monitoring Requirements

As required under NS1 Guidelines, the Secretary must ensure that progress made under a rebuilding plan is adequate. The NMFS eastern Bering Sea bottom-trawl survey provides data for annual assessments of the status of crab stocks in the BSAI, including EBS snow crab, and would continue throughout rebuilding. Although the Region is responsible for reporting stock status and progress towards the rebuilding level, the BSAI Crab Plan Team reports stock status and progress towards the rebuilt level in the Stock Assessment and Fishery Evaluation (SAFE) Report for the king and Tanner crab fisheries of the BSAI to assist the Region in making this determination. State and federal observer and EM programs monitor bycatch with State coverage of the crab fisheries and federal monitoring of the groundfish trawl, pot and longline fisheries. Estimates of crab bycatch from all commercial fisheries will be reported annually in the SAFE and the BSAI Crab Plan Team will assess that bycatch relative to the expectations and assumptions of the rebuilding plan.

Management measures under the purview of ADF&G and NMFS contain levels of catch and bycatch at levels prescribed in a rebuilding plan. If the combination of catch and bycatch were to approach the maximum level within any given year under the rebuilding plan, harvest can be capped through closure of directed harvest and area restrictions, if necessary, to reduce bycatch.

Processing for Determining Status of BSAI Crab Stocks

Each crab stock is annually assessed by the CPT and SSC to determine its status regarding whether (1) overfishing is occurring or the rate or level of fishing mortality for the stock is approaching overfishing, (2) the stock is overfished, or the stock is approaching an overfished condition, and (3) the catch has exceeded the annual catch limit (ACL). If overfishing occurred or the stock is overfished, the MSA requires the NPFMC to immediately end overfishing and/or develop a plan to rebuild affected stocks. Status determination criteria for crab stocks are calculated using a five-tier system described below that accommodates varying levels of uncertainty of information. The five-tier system incorporates new scientific information and provides a mechanism to continually improve the status determination criteria as new information becomes available. Under the five-tier system, overfishing and overfished criteria and ABC levels for most stocks are annually formulated. The ACL for each stock equals the ABC for that stock. For crab stocks, The Overfishing Level (OFL) equals the maximum sustainable yield (MSY) and overfishing is determined by comparing the OFL with the catch estimates for that crab fishing year. Catch includes all fishery removals, including retained catch and discard mortality. Discard mortality is determined by multiplying the appropriate handling mortality rate by observer-based estimates of discards.

The OFL and ABC for each stock is estimated for the upcoming crab fishing year using a five-tier system, detailed in Table 1 and Table 2. First, a stock is assigned to one of the five tiers based on the availability of information for that stock and model parameter choices are made. Tier assignments and model parameter choices are recommended through the CPT process to the SSC. The SSC recommends tier assignments, stock assessment and model structure, and parameter choices, including whether the information is "reliable," for the assessment authors to use for calculating OFL and ABC.

For Tiers 1 through 4, once a stock is assigned to a tier (EBS snow crab is in Tier 3), the determination of stock status level is based on recent survey data and assessment models, as available. The stock status level determines the equation (Table 1) used in calculating the F_{OFL}. Three levels of stock status are specified and denoted by “a,” “b,” and “c” and the F_{MSY} control rule assigns F_{OFL} according to stock status level (Table 1). At stock status level “a,” current stock biomass exceeds the B_{MSY}. For stocks in status level “b,” current biomass is less than B_{MSY} but greater than a level specified as the “critical biomass threshold” (β). In stock status level “c,” the ratio of current biomass to B_{MSY} (or a proxy for B_{MSY}) is below β. At stock status level "c," directed fishing is prohibited and an F_{OFL} at or below F_{MSY} would be determined for all other sources of fishing mortality in the development of the rebuilding plan.

Table 1. Five-Tier System for setting overfishing limits (OFLs) and Acceptable Biological Catches (ABCs) for crab stocks. The tiers are listed in descending order of information availability.

Information available	Tier	Stock status level	F_{OFL}	ABC control rule
B, B_{MSY}, F_{MSY}, and pdf of F_{MSY}	1	a. $\frac{B}{B_{msy}} > 1$	$F_{OFL} = \mu_A$ =arithmetic mean of the pdf	ABC≤(1-b_y) * OFL
		b. $\beta < \frac{B}{B_{msy}} \le 1$	$F_{OFL} = \mu_A \frac{B/B_{msy} - \alpha}{1-\alpha}$	
		c. $\frac{B}{B_{msy}} \le \beta$	*Directed fishery F = 0* $F_{OFL} \le F_{MSY}$†	
B, B_{MSY}, F_{MSY}	2	a. $\frac{B}{B_{msy}} > 1$	$F_{OFL} = F_{msy}$	ABC≤(1-b_y) * OFL
		b. $\beta < \frac{B}{B_{msy}} \le 1$	$F_{OFL} = F_{msy} \frac{B/B_{msy} - \alpha}{1-\alpha}$	
		c. $\frac{B}{B_{msy}} \le \beta$	*Directed fishery F = 0* $F_{OFL} \le F_{MSY}$†	
B, $F_{35\%}^*$, $B_{35\%}^*$	3	a. $\frac{B}{B_{35\%^*}} > 1$	$F_{OFL} = F_{35\%}{}^*$	ABC≤(1-b_y) * OFL
		b. $\beta < \frac{B}{B_{35\%}{}^*} \le 1$	$F_{OFL} = F^*_{35\%} \frac{\frac{B}{B^*_{35\%}} - \alpha}{1-\alpha}$	
		c. $\frac{B}{B_{35\%}{}^*} \le \beta$	*Directed fishery F = 0* $F_{OFL} \le F_{MSY}$†	
B, M, $B_{msy^{prox}}$	4	a. $\frac{B}{B_{msy^{prox}}} > 1$	$F_{OFL} = \gamma M$	ABC≤(1-b_y) * OFL
		b. $\beta < \frac{B}{B_{msy^{prox}}} \le 1$	$F_{OFL} = \gamma M \frac{B/B_{msy^{prox}} - \alpha}{1-\alpha}$	
		c. $\frac{B}{B_{msy^{prox}}} \le \beta$	*Directed fishery F = 0* $F_{OFL} \le F_{MSY}$†	
Stocks with no reliable estimates of biomass or M.	5		OFL = average catch from a time period to be determined, unless the SSC recommends an alternative value based on the best available scientific information.	ABC≤0.90 * OFL

Table 2. A guide for understanding the five-tier system

- F_{OFL} — the instantaneous fishing mortality (F) from the directed fishery that is used in the calculation of the overfishing limit (OFL). F_{OFL} is determined as a function of:
    - F_{MSY} — the instantaneous F that will produce MSY at the MSY-producing biomass
        - A proxy of F_{MSY} may be used; e.g., $F_{x\%}$, the instantaneous F that results in x% of the equilibrium spawning per recruit relative to the unfished value
    - B — a measure of the productive capacity of the stock, such as spawning biomass or fertilized egg production.
        - A proxy of B may be used; e.g., mature male biomass
    - B_{MSY} — the value of B at the MSY-producing level
        - A proxy of B_{MSY} may be used; e.g., mature male biomass at the MSY-producing level
    - β — a parameter with restriction that $0 \leq \beta < 1$.
    - α — a parameter with restriction that $0 \leq \alpha \leq \beta$.
- The maximum value of F_{OFL} is F_{MSY}. $F_{OFL} = F_{MSY}$ when $B > B_{MSY}$.
- F_{OFL} decreases linearly from F_{MSY} to $F_{MSY} \cdot (\beta-\alpha)/(1-\alpha)$ as B decreases from B_{MSY} to $\beta \cdot B_{MSY}$
- When $B \leq \beta \cdot B_{MSY}$, F = 0 for the directed fishery and $F_{OFL} \leq F_{MSY}$ for the non-directed fisheries, which will be determined in the development of the rebuilding plan.
- The parameter, β, determines the threshold level of B at or below which directed fishing is prohibited.
- The parameter, α, determines the value of F_{OFL} when B decreases to $\beta \cdot B_{MSY}$ and the rate at which F_{OFL} decreases with decreasing values of B when $\beta \cdot B_{MSY} < B \leq B_{MSY}$.
    - Larger values of α result in a smaller value of F_{OFL} when B decreases to $\beta \cdot B_{MSY}$.
    - Larger values of α result in F_{OFL} decreasing at a higher rate with decreasing values of B when $\beta \cdot B_{MSY} < B \leq B_{MSY}$.
- The parameter, b_y, is the value for the annual buffer calculated from a P* of 0.49 and a probability distribution for the OFL that accounts for scientific uncertainty in the estimate of OFL.
- P* is the probability that the estimate of ABC, which is calculated from the estimate of OFL, exceeds the "true" OFL (noted as OFL') (P(ABC>OFL').

2.2 Stock Status

In the Bering Sea, snow crab are distributed widely over the continental shelf and are common at depths less than ~200 meters. Smaller crabs tend to occupy more inshore northern regions and mature crabs occupy deeper areas to the south of the juveniles (Zheng et al. 2001, as cited in Szuwalski 2020). The eastern Bering Sea population within U.S. waters is managed as a single stock; however, the distribution of the population may extend into Russian waters to an unknown degree.

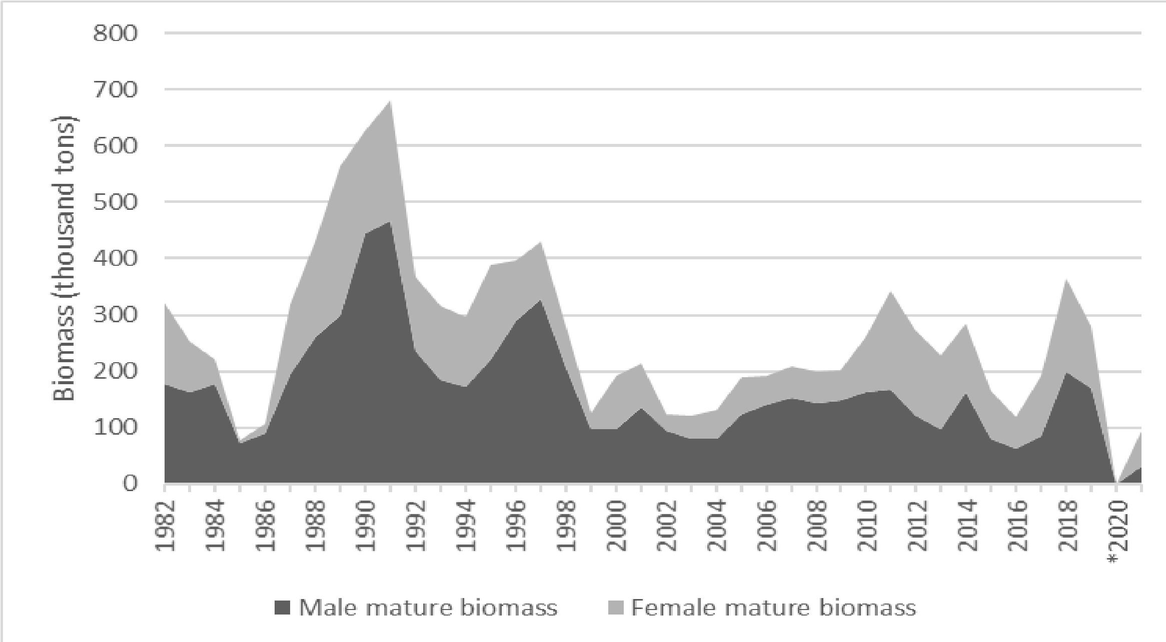
According to Szuwalski 2020, survey data show spatial gradients by maturity and size for both sexes of snow crab. Larger males have been more prevalent on the southwest portion of the shelf while smaller males have been more prevalent on the northwest portion of the shelf. Females have exhibited a similar pattern. Distributions of crab by size and maturity have also changed temporally. The centroids of abundance in the summer survey have moved over time. Centroids of mature female abundance early in the history of the survey were farther south but moved north during the 1990s. Since the late 1990s and early 2000s, the centroids moved south again, but not to the extent seen in the early 1980s. This phenomenon was mirrored in centroids of abundance for large males. AFSC 2020 includes maps on the total density of legal, mature, and immature snow crab by sex at each station sampled in the 2019 bottom trawl survey.

Total snow crab mature male biomass has varied considerably since 1990 from a high of 626.7 kt to a low of 50.6 kt in 2021 (Figure 1). Observed MMB in the survey increased from an average of 234.14 kt in the early to mid-1980s to historical highs in the 1990s. The stock was declared overfished in 1999 in response to the total mature biomass dropping below the 1999 minimum stock size threshold. Observed MMB slowly increased after 1999, and the stock was declared rebuilt in 2011 when estimated MMB at mating was above B35%. However, after 2011, the stock declined and the observed MMB at the time of survey dropped to an all-time low in 2021.

In recent years, MMB was increasing as a large recruitment moved through the size classes, but that recruitment event has since disappeared and the observed mature male biomass at the of the 2021 survey was 50.6 kt, a new all-time low. In addition, several unprecedented events in the snow crab population in the EBS have occurred. This is the first time a mass mortality event appears to have occurred for snow crab since the survey began and the biomass of important size categories of crab are at historic lows. For example, the observed biomass of males greater than 101mm carapace width was 12,437 tons in 2021. The second lowest observed of male greater than 101mm carapace width was biomass was 20,520 tons in 2017. When the stock was declared overfished in 1999, the observed male biomass greater than 101mm carapace width was 52,530 tons. Females are also currently at historic lows.

Based on anecdotes from the 2021 survey, variation in catchability as a result of movement into the northern BS cannot explain the disappearance of the 2015 cohort. It is possible the crab moved west off of the shelf, but data are lacking to explore this hypothesis and historical slope surveys generally found very few snow crab.

The updated estimate of MMB using the preferred model (February 15, 2021) was 26.74 kt which placed the stock at 17 percent of $B_{35\%}$. Projected MMB on February 15, 2022, from this assessment's chosen model was 50.64 kt after fishing at the OFL, which will place the stock at 33 percent of $B_{35\%}$. As a result, the stock was declared overfished.



Source: Eastern Bering Sea Snow Crab SAFE, September 13, 2021
*The 2020 NMFS summer surveys were canceled in 2020 due to the coronavirus pandemic.

Figure 1 Observed mature male and female snow crab biomass (1,000t) in the Bering Sea at the time of the survey from 1982-2021

2.3 Sources of Mortality

2.3.1 Natural Mortality

Historically, a single natural mortality was estimated in the assessment for EBS snow crab, but the status quo model would not converge in 2021 using this assumption. Based on the best available information, additional mortality events were estimated in 2018 and 2019 for snow crab, which allowed the model to converge. This is not an unprecedented practice for Bering Sea crab, for example, Bristol Bay red king crab includes an estimated mortality even in the early 1980s. Variation in natural mortality over time has been estimated for snow crab (e.g. Murphy et al., 2018), but catchability, a process confounded with mortality, was not also allowed to vary over time in that study. Somerton et al. (2013) showed that catchability should vary over time and space for snow crab in the EBS. Currently, analyses are underway to understand the feasibility of estimating both time-varying mortality and time-varying catchability within a population dynamics model given the data available for snow crab. The ultimate goal of these analyses is to provide evidence to support or refute the assumptions about variation in mortality made in the stock assessment about elevated natural mortality in recent years. Hypotheses related to temperature, disease, bycatch, discards, cannibalism, and predation are being explored.

2.3.2 Directed Fishery

Management of Directed Fisheries

The directed BSAI crab fisheries are managed under different management areas and seasons than established for the groundfish fisheries. Figure 2 provides the directed snow crab fishery boundary for Western subdistrict and Eastern subdistrict. In contrast, Figure 7 provides the management area defined by the *C. opilio* Bycatch Limitation Zone (COBLZ) which do not line up precisely with the management area define by the directed snow crab fishery. As for season dates for the directed fisheries, ADF&G typically establishes the snow crab season start date for October 15 and, in general, the snow crab fishery ends on May 15 for the Eastern subdistrict and May 31 for the Western subdistrict. In contrast, Federal regulations specify the general groundfish seasons to begin January 1 and end December 31, and the total allowable catch (TAC)-setting and specifications process are designed around this schedule.

The crab directed fisheries are currently managed according to the "three S's"—size, sex, and season. These measures help ensure that crab are able to reproduce and replace the ones that are harvested. Only male crab may be harvested. Fishing is not allowed during mating and molting periods (spring). Size limits and seasons for the 2021-2022 snow crab fishery are:

- Snow crab (opilio) ≥3.1 inches (~78mm) carapace width
    - Oct 15- May 15 (Eastern subdistrict)/May 31 (Western subdistrict)

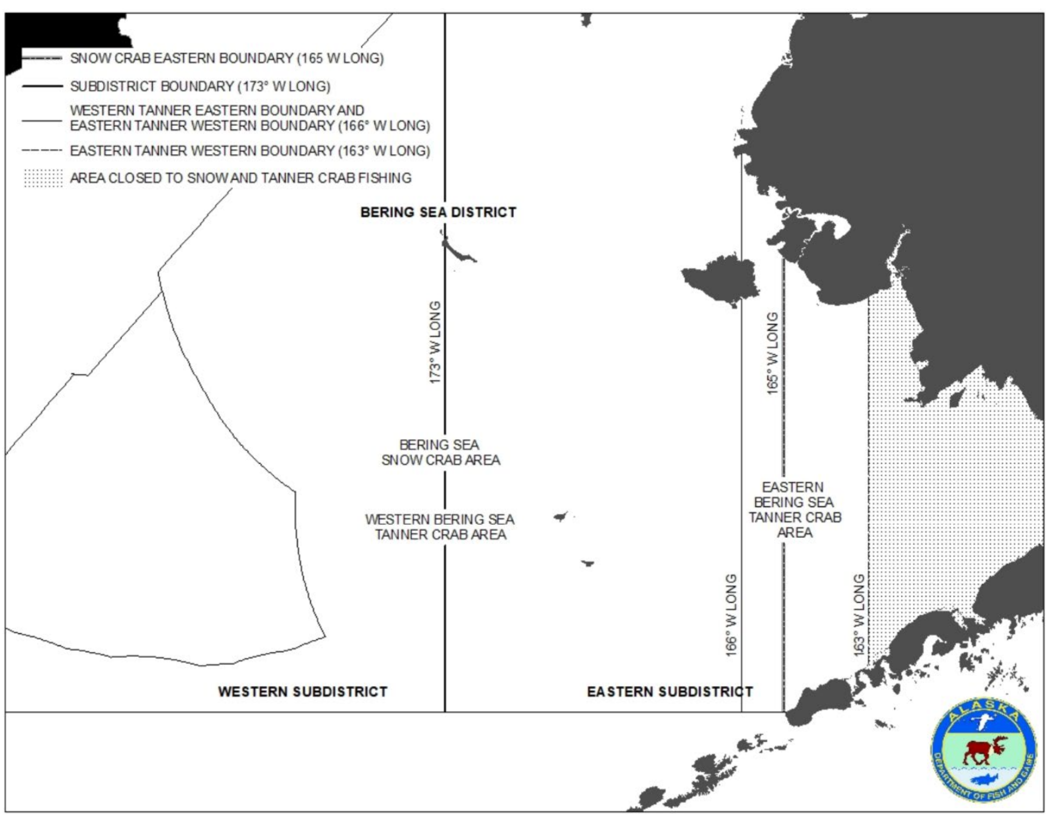


Figure 2 **ADF&G management areas**

State of Alaska's Harvest Strategies

As laid out under the BSAI Crab FMPs State/Federal cooperative management regime, the OFL and ACL[2] for the Federal crab stocks are recommended to the Council by the Scientific and Statistical Committee (SSC).

The annual harvest levels and other management actions for the FMP crab stocks are determined by ADF&G according to State commercial fishery regulations. These regulations are established by the Alaska Board of Fisheries (BOF) and subject to the constraint that such harvest levels and management actions are consistent with provisions of the FMP, the National Standards of the MSA, and other applicable federal laws.

The FMP list out eight categories of factors the State of Alaska should take into account, to the extent information is available, in developing harvest strategies or setting TACs and guideline harvests (GHLs). This includes:

(1) whether the ACL for that stock was exceeded in the previous year;

(2) stock status relative to the OFL and ACL;

(3) estimates of exploitable biomass;

(4) estimates of recruitment;

(5) estimates of thresholds;

(6) market and other economic considerations;

(7) additional uncertainty; and

(8) any additional factors pertaining to the health and status of the stock or the marine ecosystem.

Additional uncertainty includes

(1) management uncertainty (i.e., uncertainty in the ability of managers to constrain catch so the ACL is not exceeded, and uncertainty in quantifying the true catch amount) and

(2) scientific uncertainty identified and not already accounted for in the ABC (i.e., uncertainty in bycatch mortality, estimates of trends and absolute estimates of size composition, shell-condition, molt status, reproductive condition, spatial distribution, bycatch of non-target crab stocks, environmental conditions, fishery performance, fleet behavior, and the quality and amount of data available for these variables).

The FMP directs the State to establish an annual TAC for each crab stock at a level sufficiently below the ACL so that the sum of the catch[3] and the State's assessment of additional uncertainty do not exceed the ACL. The State may establish the annual TACs below such a level to account for the other factors identified above. If an ACL is exceeded, the State will implement accountability measures in the fishing season following the overage to account for the overage through a downward adjustment to the TAC for that species by an amount sufficient to remedy the biological consequences of the overage.

[2] Under the Crab FMP, the ACL is equal to the annually recommended ABC level.
[3] As used here, the term "catch" refers to all sources of fishing mortality included in the ACL for a given stock. Thus, for a stock with a total catch ACL, "catch" includes each of the three catch components (non-directed fishery discard losses, directed fishery removals, and directed fishery discard losses). For a stock with a retained catch ACL, "catch" includes only the directed fishery removals.

Within these parameters laid out in the FMP, the State has further identified a process to establish annual harvest levels for each crab fishery. The process employed by the State begins with a review of stock status indicators derived from the recent assessments, including estimates of BMSY (or its proxy), MSST, critical biomass threshold, and OFL (including a breakdown of the total OFL into subcomponents – estimates of future retained catch, discard mortality in directed fisheries, and non-target fishery bycatch). The State also relies on guidance provided in the annual NMFS stock status notification letter that is prepared for the Secretary of Commerce by the NMFS Alaska Region summarizing stock status relative to overfishing, OFLs for the 10 FMP crab stocks, and special concerns for stocks under rebuilding plans.

Annual biomass estimates in MMB provide a projection of stock status at the time of mating while the OFL estimate is a total catch level that may not be exceeded by the sum of all sources of fishing mortality. The OFL subcomponents provide additional information on the total catch OFL calculation for information relative to the directed fishing mortality estimate.

The State has adopted harvest strategies for the crab fisheries which consist of rules in state regulation for computing TAC from survey and stock assessment data and identifying conditions under which the fishery would not open. Harvest strategy elements may include:

- a stock threshold for opening the fishery,
- rules for setting exploitation rate on abundance/biomass of mature-sized males,
- an exploitation rate dependent on stock index estimated from survey data,
- a cap on legal male exploitation rate, and
- a minimum TAC for fishery opening.

Both State harvest strategy thresholds and stock abundance or biomass estimates for computation of TACs reference stock biomass or abundance at the time of survey. State staff prepare annual assessments describing the requirements, process, and data needed to set TAC in manner that prevents overfishing. These assessments summarize stock status relative to OFL and document how the State sets TAC to account for uncertainty in stock biomass estimates and to ensure total removals remain below OFL. The assessments are internal documents discussed with State, Federal, and Council staff during a series of teleconferences leading up to the announcement of TAC in early October. Details of the State TAC-setting process are publicly reviewed during an annual meeting with the BSAI crab industry after TACs are announced.

For EBS snow crab fishery to open, the preseason survey data must indicate that ESB snow crab is at least 25% of the BMSY. The harvest strategy also includes thresholds for levels of exploitation based on different levels of ESB relative to the BMSY. While the EBS snow crab harvest strategy was developed in 2002 (J. Zheng et al. 2002), ADF&G have applied different versions of population estimates to the harvest strategy overtime. The State of Alaska's Bering Sea snow crab harvest strategy is provided in the Alaska Administrative Code at 5 AAC 34.917 (below).

Section 5 AAC 35.517 – Bering Sea *C. opilio* Tanner crab harvest strategy.

> (a) In the Bering Sea District, the commercial *C. opilio* Tanner crab fishery may open only if the department's analysis of preseason survey data indicates the population of C. *opilio* Tanner crab
>
> > (1) contains an estimated spawning biomass of at least 25 percent of Bmsy;
> >
> > (2) repealed 6/10/2010.
>
> (b) If the estimated spawning biomass of *C. opilio* Tanner crab is

(1) at least 25 percent of Bmsy, but less than Bmsy, the total allowable catch will be (Fmsy /3+(Bt-0.25 x Bmsy) x 0.417 x Fmsy /(0.75 x Bmsy)) x 100 percent of the estimated mature male biomass or 58 percent of exploited legal males, whichever is less;

(2) at or above Bmsy, the total allowable catch will be (0.75 x Fmsy) x 100 percent of the estimated mature male biomass or 58 percent of the exploited legal males, whichever is less.

(c) In implementing this harvest strategy, the board directs the department to use the best scientific information available and to consider the reliability of estimates of *C. opilio* Tanner crab, the manageability of the fishery, and any other factors the department determines necessary to be consistent with the sustained yield principles.

(d) For the purposes of this section,

(1) "Bmsy" means the population biomass of mature male and female *C. opilio* Tanner crab that could produce maximum sustained yield under prevailing environmental conditions;

(2) "Bt" means the biomass of mature male and female *C. opilio* Tanner crab in a given year;

(3) "estimated mature male biomass" means the estimated biomass of all morphometrically mature male *C. opilio* Tanner crab;

(4) "estimated spawning biomass" means the estimated biomass of all morphometrically mature male *C. opilio* Tanner crab and all morphometrically mature female *C. opilio* Tanner crab;

(5) "exploited legal males" means 100 percent of the new-shell male *C. opilio* Tanner crab that are at least 102 millimeters (four inches) in width of shell, plus a percentage of old-shell male *C. opilio* Tanner crab that are at least 102 millimeters in width of shell estimated at the time of the survey; the percentage of old-shell male *C. opilio* Tanner crab will be based on the expected fishery selectivity for old-shell verses new-shell male C. opilio Tanner crab;

(6) "Fmsy" means the fishing mortality of the mature male *C. opilio* Tanner crab stock that could produce maximum sustained yield under prevailing environmental conditions.

There are various abundance estimates available for TAC-setting including raw survey area-swept estimates, model-based survey estimates, and model-based population estimates that account for survey selectivity[16]. Because these estimates can vary greatly, the resulting TAC can vary depending which estimates are used as harvest strategy inputs. In a given year, it may be difficult to know which estimate is closer to the true population size.

The snow crab fishery has calculated TAC using a range of the different estimates, which has paralleled with changes to model developments and model performance. Figure 3 lists the history of abundance estimates used in the snow crab TAC-setting process.

Through 2005/06: **(area-swept)**
- all that was available

2006/10 – 2009/10: **model survey**
- Approval of snow crab assessment model by CPT/SSC in fall 2006
- Survey-predicted estimates = population estimates; Q = 1

2010/11 – 2012/13 (TAC 54, 89, 66 mil lb): **model population** (with Q < 1)

2013/14 (TAC 54 mil lb): model survey
- Trend in model estimates versus area-swept & very low Q

2014/15 (TAC 68 mil lb): **model observed (area-swept)**
- Trend in estimates of year from subsequent models (retrospective pattern)

2015/16 (TAC 41 mil lb): **mid-point between model survey and model observed**
- High uncertainty with model estimates

2016/17 (TAC 22 mil lb): **10% buffer on model survey**
- High uncertainty with model estimates

2017/18 (TAC 19 mil lb): **model observed (area-swept)**
- High uncertainty with model estimates
- Fishery performance (declining trend in CPUE, reports from fishery = low performance in historic areas)

2018/19 (TAC 27 mill lb): **model observed (area-swept)**
- Uncertainty with model estimates
- Confidence with estimates of MMB and 4 inch males

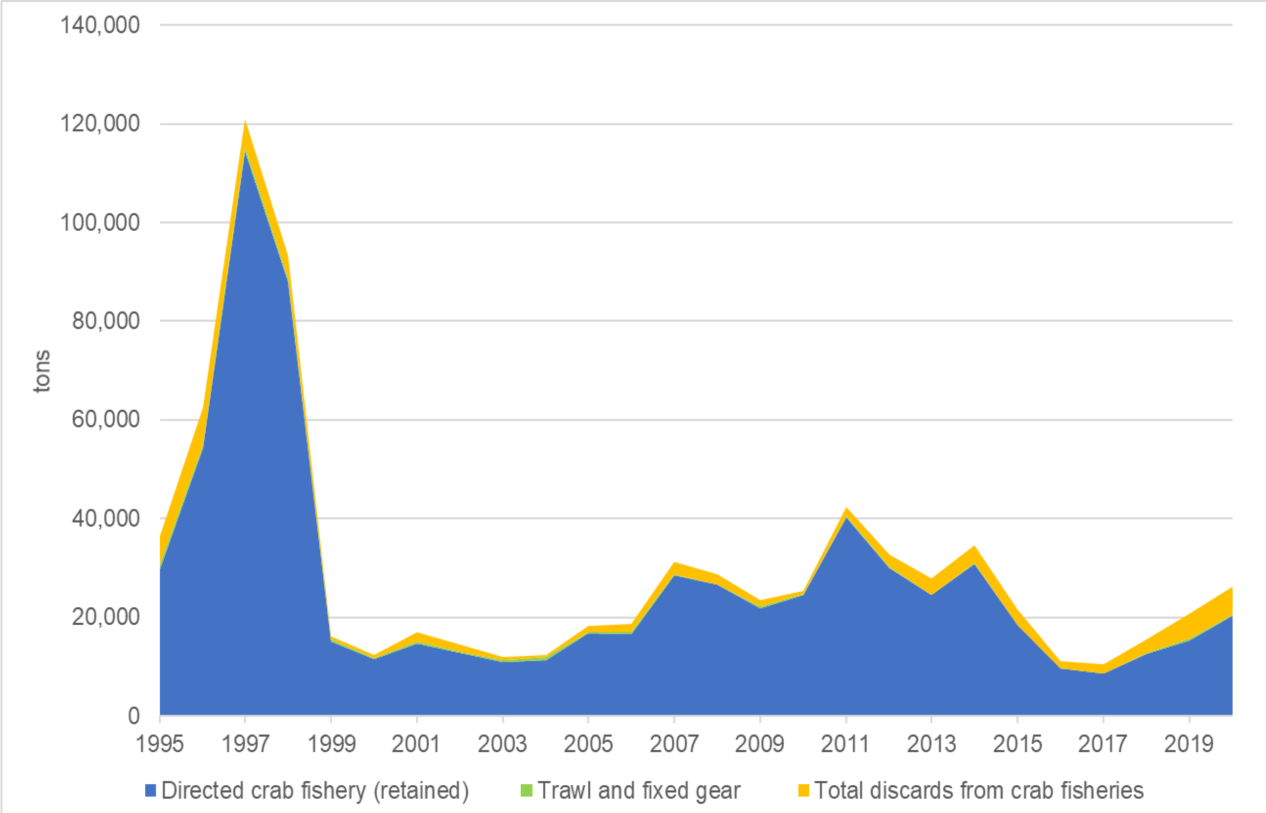
2019/20 (TAC 34 mill lb): **model observed (area-swept)**
- Uncertainty with model estimates
- Confidence with estimates of MMB and 4 inch males

Figure 3 Historical summary of estimates used for setting snow crab TAC

Source: Slide 37, ADF&G presentation to the BSAI crab industry, Review of TACs Bering Sea Crab: 2020/21 season http://www.adfg.alaska.gov/static/fishing/PDFs/commercial/bering_aleutian/2020_bsai_crab_tac_industry_meeting.pdf

Status of EBS Snow Crab Fishery

Over the past five years, the directed fishery for EBS snow crab accounted for 74-87% of fishing mortality. Fishing mortality due to interactions with fishing gear, including discards in crab directed fishing and bycatch in the trawl and fixed gear groundfish fisheries, is estimated every year using the following discard mortality rates: Snow crab discard mortality for the purposes of the stock assessment is estimated at 30% in the directed crab fisheries, 80% for trawl gear, and 50% in fixed gear groundfish fisheries. Snow crab catch primarily occurs in the directed fishery and to a lesser extent in the other directed crab fisheries and the groundfish trawl and fixed gear fisheries as bycatch (Figure 4). Estimates of combined trawl and fixed gear bycatch in recent years are less than 1% of the total snow crab catch. Discard of snow crab in groundfish fisheries has been highest in the yellowfin sole trawl fishery, and decreases down through the flathead sole trawl fishery, Pacific cod bottom trawl fishery, rock sole trawl fishery, and the Pacific cod hook-and-line and pot fisheries, respectively. Fixed gear bycatch in groundfish fisheries has historically been relatively low. Table 3 provides retained catch inside and outside the C. opilio Bycatch Limitation Zone (COBLZ) and discarded catch in the directed snow crab fishery and bycatch of snow crab in the Tanner and Bristol Bay red king crab (BBRKC) fisheries in tons from the 2011/2012 season through the 2020/2021 season. Discards and bycatch mortality estimates are derived from at-sea observer data and assume a 30 percent handling mortality rate.



Source: Eastern Bering Sea Snow Crab SAFE, September 13, 2021 (Table 7)

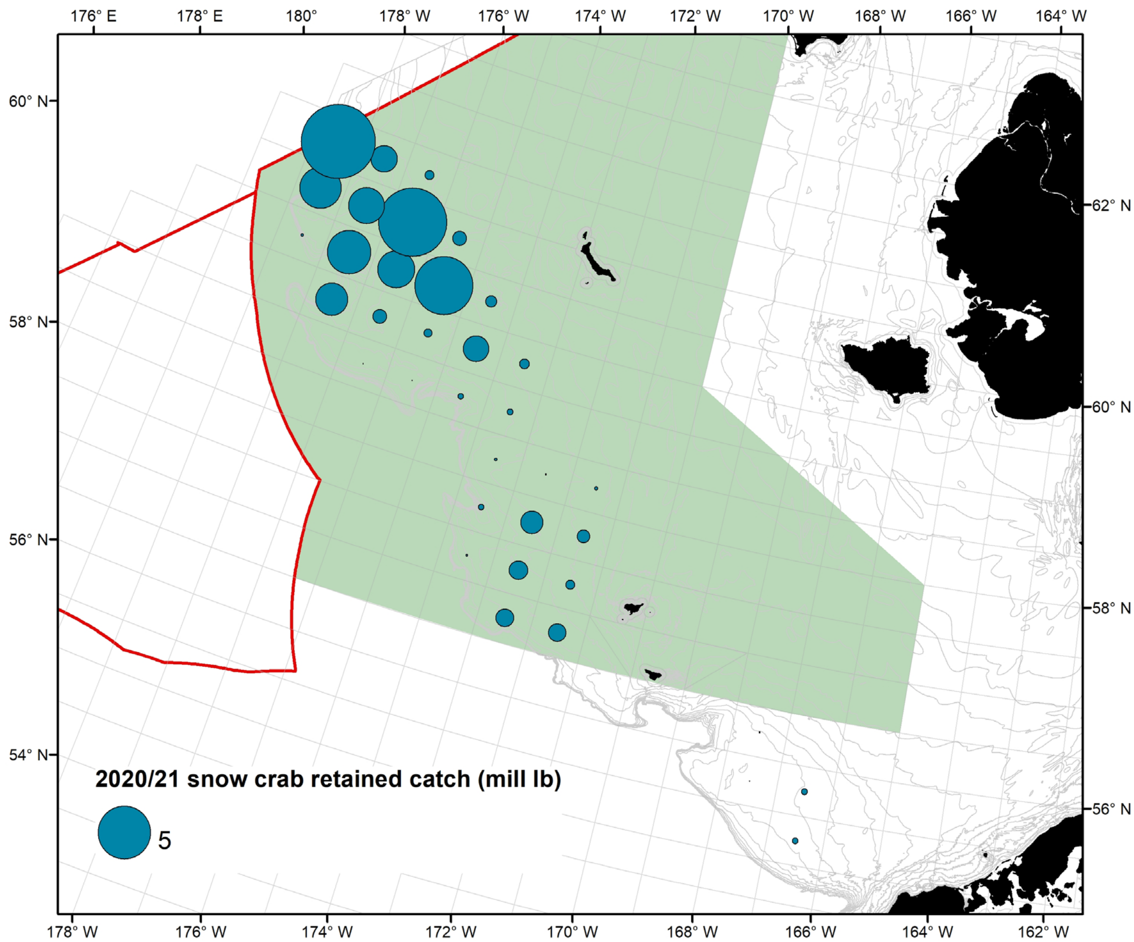
Figure 4. Directed snow crab catch and other sources of morality including discards from directed crab fisheries and trawl and fixed gear bycatch in groundfish fisheries, 1995 through 2020

Table 3 Retained and discarded catch in the directed snow crab fishery and bycatch of snow crab in the other crab fisheries. Values are tons. Discards and bycatch mortality estimates are derived from at-sea observer data and assume a 30% handling mortality rate.

Year	TAC	Directed fishery					Tanner fishery		BBRKC fishery	
		Ret Catch Inside COBLZ	Ret Catch Outside COBLZ	Total retained catch	Discard	Discard mortality	Bycatch	Bycatch mortality	Bycatch	Bycatch mortality
2011/12	40,322	33,715	6,578	40,293	3,919	1,176	0	0	4	1
2012/13	30,096	25,744	4,308	30,053	5,504	1,651	0	0	8	2
2013/14	24,486	22,035	2,452	24,486	10,599	3,180	277	83	1	0
2014/15	30,822	18,124	12,694	30,818	11,779	3,534	1,786	536	1	0
2015/16	18,421	12,221	6,200	18,421	10,946	3,284	3,221	966	1	0
2016/17	9,784	7,223	2,562	9,784	4,517	1,355	0	0	3	1
2017/18	8,601	7,781	820	8,602	5,863	1,759	235	71	6	2
2018/19	12,511	11,503	1,007	12,509	8,635	2,591	732	220	2	1
2019/20	15,431	15,161	272	15,433	15,525	4,657	0	0	1	0
2020/21	20,412	20,334	78	20,412	6,062	1,819	484	145	3	1

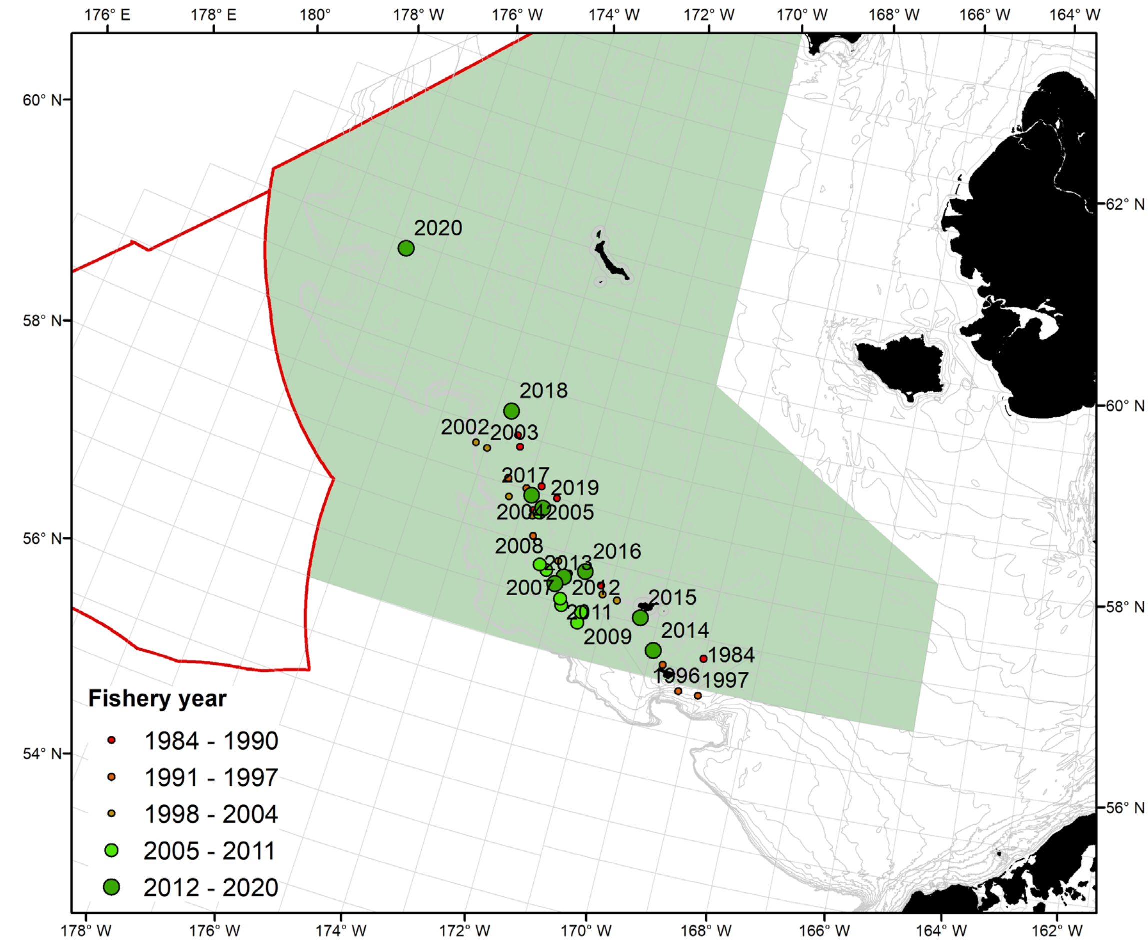
Source: Ben Daly, ADF&G, Jan 19, 2022.
BBRKC = Bristol Bay Red King Crab

Figure 5 and Figure 6 illustrate the spatial distribution of the directed snow crab fisheries in the BSAI overlayed on the shaded COBLZ area. Figure 5 shows the statistical areas with retained catch from the 2020/21 season (with statistical areas that include at least three vessels) and Figure 6 demonstrates the weighted center of catch over time. The footprint of the crab directed snow crab fishery have remained fairly consistent over time. Snow crab fishing occurs over a wide distribution on and near the shelf edge and north toward Saint Matthew Island. The 2020/21 fishery occurred much farther north than in historic years (Figure 6).



Source: 202/21 BSAI crab catch (Ben Daly, ADF&G, Jan 19, 2022)

Figure 5 **Retained catch of EBS snow crab in the directed fishery, 2020/21, where size of the blue dot corresponds to the magnitude of catch in each ADF&G statistical area (grid). Shaded area represents the COBLZ.**



Source: Ben Daly, ADF&G, Jan 19, 2022.

Figure 6 Weighted center of EBS snow crab catch in the directed fishery for 1984-2020. Shaded area represents the COBLZ.

2.3.3 EBS Snow crab bycatch in groundfish trawl fisheries

Crab bycatch management measures exist for the protection of Bristol Bay Red king crab (BBRKC), EBS Tanner crab, and EBS snow crab stocks in the BSAI and include triggered area closures for BSAI groundfish trawl fisheries. Retention of crab bycatch is prohibited, so crab bycatch is also referred to as Prohibited Species Catch (PSC). For BBRKC, snow and Tanner crab, triggered crab PSC limits exist for all trawl fishing within specified areas. Trawl PSC accrues within these areas and these areas are closed to nonpelagic trawl directed fishing for groundfish in the fishery/sector that reaches its specified PSC limit. An area closure for EBS snow crab is triggered if the groundfish trawl fisheries by target/sector reach their allocated PSC limit for the COBLZ (Figure 7). PSC limits are based on a calendar year and not a crab year (July 1 – June 30). The limit accrues only for snow crab PSC taken within the COBLZ. No measures are currently in place for any non-trawl gear fisheries, nor are there overall limits placed on bycatch of snow crab species outside of COBLZ.

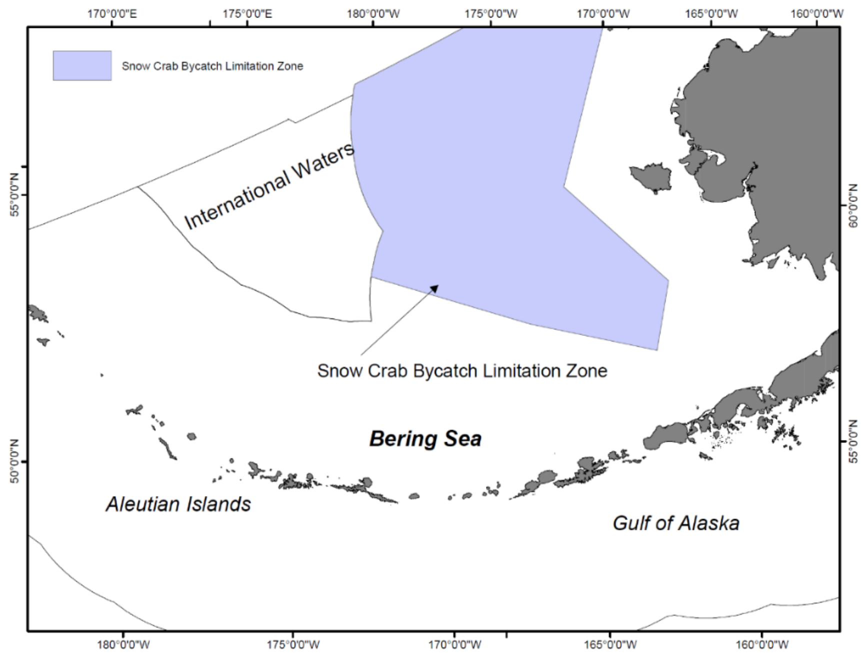


Figure 7 ***C. opilio*** **Bycatch Limitation Zone (COBLZ)**

The crab PSC limits are set each year in December during the harvest specifications process and apportioned across groundfish sectors. To determine PSC limits, stock assessment authors provide NMFS Inseason Management and/or Council staff with the abundance or biomass values necessary to compare to PSC thresholds established in Federal regulations. The total abundance or biomass values are calculated differently for each stock and have produced the abundance/biomass estimates.

Table 4 provides the estimates of abundance for snow crab and the snow crab COBLZ PSC limit from 2012 through 2021. Historically, these estimates were derived from area-swept estimates of the NMFS bottom trawl survey. Presently, they are derived from model-based estimates, whether population totals or survey abundance.

EBS snow crab PSC limits are based on total abundance of snow crab as indicated by the NMFS standard trawl survey. The limit in COBLZ is set annually at 0.1133% of the snow crab modeled abundance estimate from the NMFS standard summer trawl survey minus 150,000 crab, unless a minimum or maximum abundance threshold is reached.

- If 0.1133% multiplied by the total abundance is less than 4.5 million, then the minimum PSC limit will be 4.350 million animals.
- If 0.1133% multiplied by the total abundance is greater than 13 million, then the maximum PSC limit will be 12.850 million animals.[4]

Snow crab bycatch that occurs outside COBLZ does not accrue towards the COBLZ limit.

[4] 50 CFR 679.21(e)(1)(iii)

Table 4 Snow crab abundance and COBLZ PSC limit, 2012-2021

Year	Snow crab abundance estimate (in billions of animals)	EBS snow crab in COBLZ PSC limits (number of animals)
2012	6.3	7,029,520
2013	9.4	10,501,333
2014	10	11,185,892
2015	9.9	11,011,976
2016	4.3	4,708,314
2017	8.2	9,105,477
2018	8.2	9,120,539
2019	10.7	11,916,450
2020	7.7	8,580,898
2021	1.4	**4,350,000**

Source: NMFS, Alaska groundfish harvest specifications

Bold text indicates the PSC limit was set to its lowest threshold

Prior to implementation of Amendment 40, snow crab PSC limits did not exist for BSAI groundfish trawl fisheries. The Final Rule for Amendment 40 (62 FR 66829) explains that bottom trawl survey data from 1996 was indicating an abundance of adult males, but females and pre-recruits (males that have not reached legal commercial size) were becoming less abundant. This trend was troubling because it could indicate declining abundance over a longer term. The Council relied on an industry work group to review proposed PSC limits for snow crab. The group met November 6–7, 1996, and came to a consensus on a PSC limit for snow crab. The group negotiated based on the range included in Amendment 37 (0.005% to .25% of the total snow crab population) and past PSC use at different abundance levels.

Based on industry recommendations and Council and Secretary approval, Amendment 40 established a snow crab PSC limit as a rate that fluctuated with snow crab abundance and was applied within the newly defined area of the *C. opilio* Bycatch Limitation Zone (COBLZ). The PSC limit was established as 0.1133% of the total abundance under Amendment 40. However, the rule also included a lower bound (4.5 million animals) and an upper bound (13 million animals). Upon attainment of the snow crab bycatch limit as apportioned to a particular trawl fishery category, the COBLZ would be closed to directed fishing for species in that trawl fishing category, except for pollock with pelagic trawl gear. Snow crab PSC limits were later adjusted under Amendment 57. The amendment package reduced snow crab PSC limits in COBLZ by 150,000 animals. This Amendment 57 limit are the numbers that exist in current regulations.

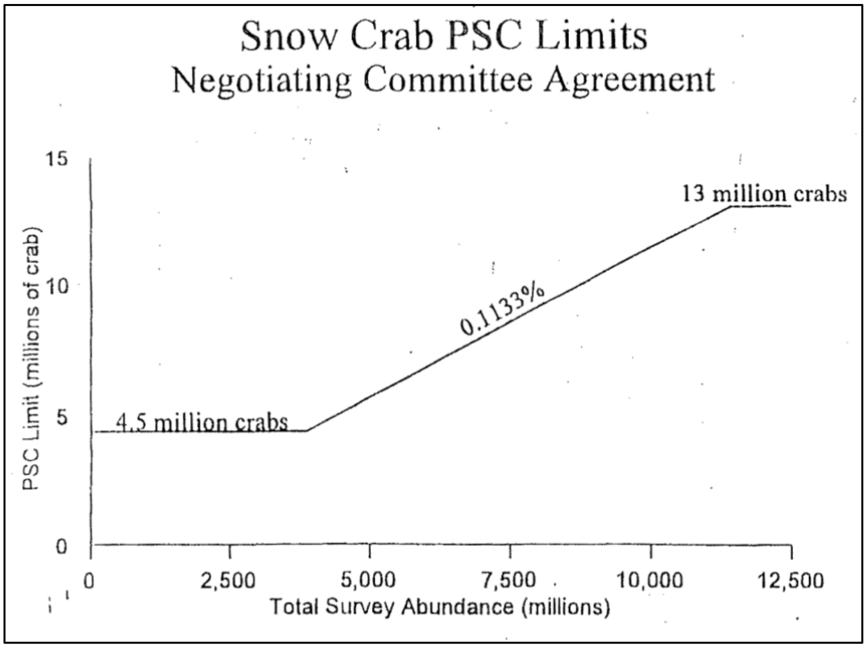


Figure 8 PSC limits for EBS snow crab within the COBLZ, as implemented under Amendment 40 (later amended to the current limits as described in Section)

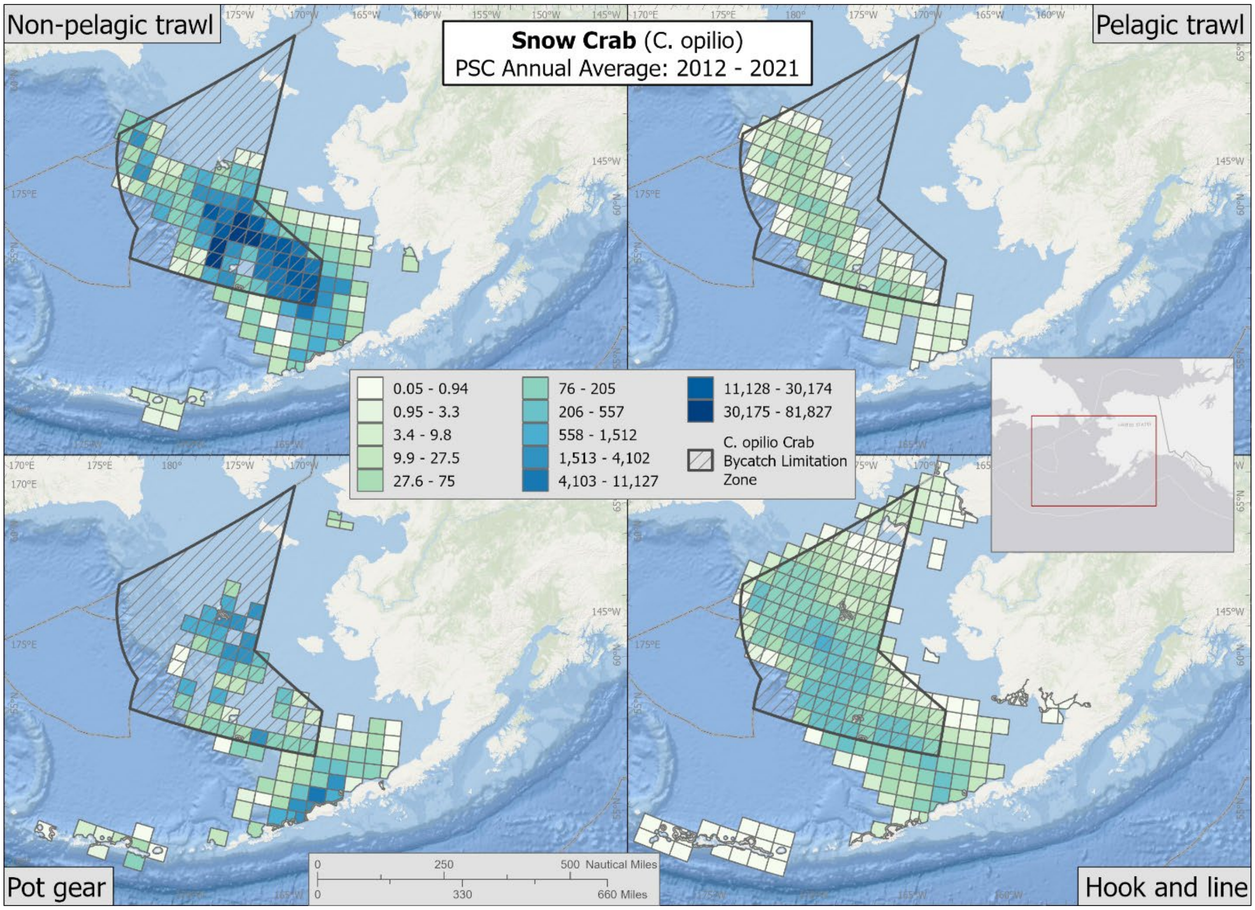
Table 5 provides PSC (number of snow crab) in the BSAI nonpelagic trawl (NPT), pelagic trawl, pot, and hook-and-line fisheries inside and outside the COBLZ from 2012 through 2021.

Table 5 Snow crab PSC in the BSAI nonpelagic trawl, pelagic trawl, pot, and hook and line fisheries from 2012 through 2021 inside and outside the COBLZ, (# of crabs)

Year	Non-pelagic trawl PSC (# of crabs)		Pelagic trawl PSC (# of crabs)		Pot PSC (# of crabs)		H&L PSC (# of crabs)		Groundfish total (# of crabs)
	COBLZ	Outside COBLZ	COBLZ	Outside COBLZ	COBLZ	Outside COBLZ	COBLZ	Outside COBLZ	
2012	592,238	30,585	2,578	583	1	16,538	0	29,622	672,145
2013	644,451	43,296	3,568	398	0	14,796	0	18,280	724,788
2014	446,309	34,856	2,811	520	0	85,013	0	20,496	590,005
2015	482,551	6,113	2,906	55	0	121,525	0	16,495	629,645
2016	160,604	5,485	733	151	0	20,039	10	23,069	210,093
2017	150,218	9,125	248	86	1,396	144,362	17	21,969	327,421
2018	1,576,295	5,854	247	30	25	52,738	48	13,776	1,649,013
2019	933,480	7,748	48	21	0	72,390	13	15,819	1,029,519
2020	751,592	27,263	1,657	57	75	142,613	12	11,602	934,871
2021	228,293	14,218	449	73	1	67,763	17	12,635	323,449

Source: NMFS Alaska Region Catch Accounting System, data compiled by AKFIN in Comprehensive_PSC [Crab_PSC_AREA(11-13-20)]

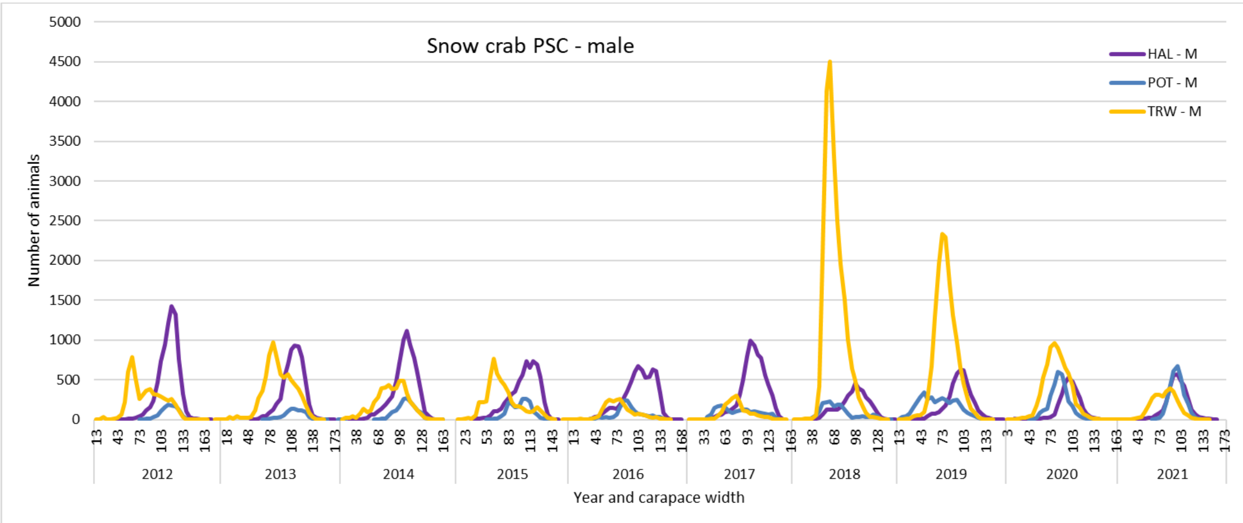
For snow crab, NPT PSC occurs primarily in the southeast portion of the COBLZ and extends northwest throughout the Zone and to the north, east, and south of the COBLZ (Figure 9). In pelagic trawl gear, snow crab PSC follows a similar spatial pattern but to a much smaller magnitude and does not spread as far around the southeast border of the COBLZ. PSC in pot gear is distributed throughout the southern two-thirds of the COBLZ and beyond the southeast border of the COBLZ along the Aleutian peninsula. Snow crab PSC in HAL gear seems to have the largest spatial distribution, which is likely due to the spatial distribution of effort in the HAL fisheries in these areas.



Source: NMFS Alaska Region Catch Accounting System, data compiled by AKFIN in Comprehensive_PSC Maps produced by PSFMC.

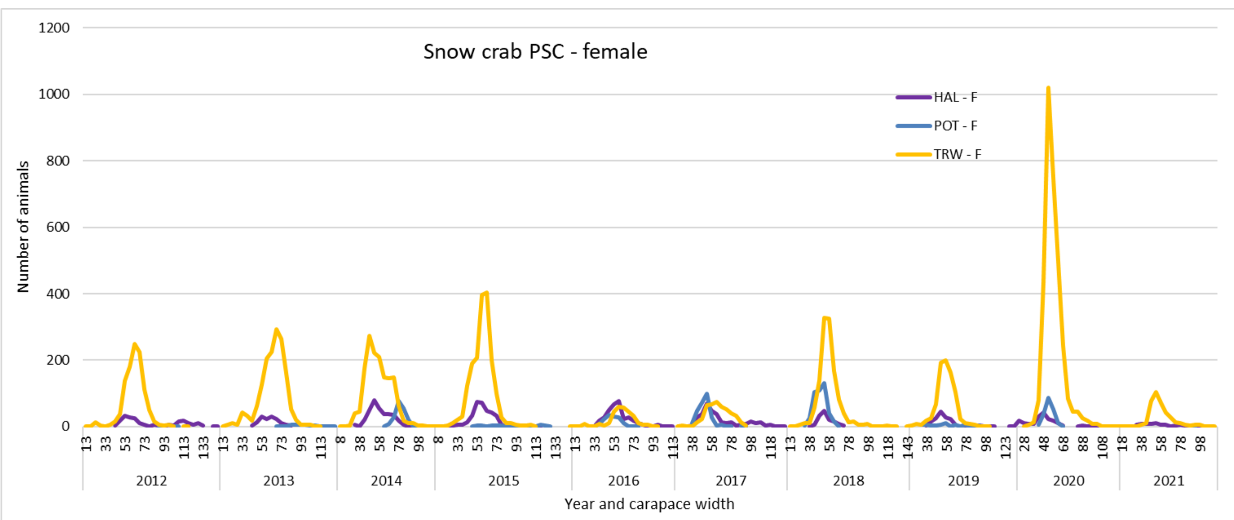
Figure 9 EBS snow crab PSC (average annual #crab) by gear type, 2012-2021

Figures 10 and 11 provide some data on size and sex composition of observed EBS snow crab PSC in the groundfish fisheries by gear. Information in the figures shows that snow crab PSC in trawl gear has been mostly males. Most of these male crabs have been between 50-99mm carapace width, though during the earlier part of this time series, male crab 75-124mm seemed to make up a larger proportion of the PSC. Male snow crab over 100mm are making up a smaller proportion of the observed PSC over time. The majority of observed females in the snow crab PSC catch are between 50-74mm. Of the total observed snow crab PSC in trawl gear (n=89,039), approximately 43% were male crab >78mm, the legal size limit in the directed snow crab fishery.



Source: Observer data, data compiled by AKFIN. Source file is Crab_PSC_Lengths(12-15-20)_Frequency1_6(MF_1-12-22)

Figure 10 Number of male snow crab PSC by gear, 2012-2021



Source: Observer data, data compiled by AKFIN. Source file is Crab_PSC_Lengths(12-15-20)_Frequency1_6(MF_1-12-22)

Figure 11 Number of female snow crab PSC by gear, 2012-2021

Table 6 demonstrate that nonpelagic trawl fisheries accounted for the greatest levels of snow crab in groundfish fisheries from 2012 through 2021. There are no crab PSC limits in place for fixed gear fisheries.

Table 6 Snow crab PSC in COBLZ by gear type and target species from 2012 through 2021 (# of crab)

Gear type	NAME	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	Average
HAL	Halibut	0	0	0	0	10	17	48	13	12	16	12
	Sablefish	0									1	0
NPT	Alaska Plaice - BSAI	2,098	7,257		21,117	2,519	140	5,279	1,925	1,964	13,266	5,557
	Arrowtooth Flounder	2,744	8,892	6,459	3,987	2,761	33,442	465	6,205	30,646	1,557	9,716
	Atka Mackerel									0		0
	Flathead Sole	25,684	67,376	79,904	20,802	10,537	30,510	279,286	217,865	197,199	53,071	98,223
	Greenland Turbot - BSAI			0	0	117	2,002	78	38	3,008	162	541
	Kamchatka Flounder - BSAI			0			0	457	1,188	190	0	183
	Other Flatfish - BSAI										0	0
	Other Species									0		0
	Pacific Cod	415	6,712	6,658	4,636	1,869	900	6	45,175	1,567	115	6,805
	Pollock - bottom	1,874	1,888	15,300	5,296	190	3,058	4,866	6,006	38,288	3,867	8,063
	Pollock - midwater	0										0
	Rock Sole - BSAI	0	1,807	8,024	6,107	27,468	19,118	2,454	10,421	18,191	7,830	10,142
	Rockfish		73	0	0	17	0	14,408	652	92	487	1,573
	Sablefish									0		0
	Yellowfin Sole - BSAI	559,423	550,446	329,964	420,605	115,127	61,049	1,268,997	644,006	460,446	147,936	455,800
POT	Pacific Cod	1					1,396	25		47	1	147
	Sablefish									28	0	3
PTR	Flathead Sole									0		0
	Pollock - bottom	73	140	0	19	51	46	0	0	0	0	33
	Pollock - midwater	2,505	3,428	2,811	2,887	682	202	247	48	1,657	449	1,492
	Rockfish	0						0		0		0
	Yellowfin Sole - BSAI										0	0
Total		594,817	648,019	449,120	485,458	161,347	151,879	1,576,615	933,542	753,336	228,760	598,289

Source: AKFIN (12-22-2001)
C indicates confidential data, HAL = hook and line, NPT = non-pelegic trawl, pot = pot gear, PTR = pelagic trawl

2.3.4 Unobserved Crab Mortality

Fishing activities lead to crab mortality in ways that are not directly observed. This includes both post-release mortality of discarded crab (which is estimated through a discard mortality rate) and crab that are never captured by fishing gear but die due to gear interactions or sustained damages that cause delayed mortality. The potential for unobserved mortality of crabs that encounter bottom trawls but are not captured has long been a concern for the management of groundfish fisheries in the Bering Sea (Witherell and Pautzke, 1997; Witherell and Woodby, 2005). Unobserved mortality is not accounted for in crab stock assessments and is not accrued towards trawl PSC limits.

Rose (1999) – in a paper studying the injury rates of RKC that passed under non-pelagic trawl footropes – provided the following introductory statement: "The inability to accurately estimate unaccounted mortality does not preclude its consideration in management and fishing decisions. Unfortunately, the lack of information on unaccounted mortality means that those participating in such decisions have to combine and weigh a mixture of related knowledge, opinions, and suppositions to substitute for conclusive facts. This can be a source of considerable dispute and reservations about the ultimate decisions." A short overview of research on unobserved crab mortality by non-pelagic gear is provided later in this subsection. Since the time of that writing, the Council has taken action to address crab mortality by raising non-pelagic trawl gear off the seafloor in a variety of ways.

The topic of unobserved mortality was most recently addressed in a Council analysis when crab PSC limits for trawl fisheries were reviewed in February 2021 prior to taking no action (see Section 3.4.6 and Appendix 4 in NPFMC 2021a). The SSC's February 2021 report noted that including any future estimation of unobserved crab mortality (from both groundfish and directed crab fishing) in a stock assessment would require extensive evaluation to understand how the assessment's parameters for factors like catchability, natural mortality and reference points would be affected. The SSC noted that "unobserved mortality is a source of both assessed and unassessed uncertainty throughout the history of the assessments (e.g., currently attributed to natural mortality), and that the ABC/TAC buffers in place are an appropriate process to account for sources of uncertainty that cannot be explicitly described in the assessment." Finally, the SSC supported further research on the topic by industry and NMFS and encouraged consideration of this source of uncertainty when setting harvest buffers.

Appendix 4 to the trawl PSC limit analysis (NPFMC 2021a) includes a sensitivity analysis conducted by the BBRKC stock assessment author in response to the Crab Plan Team's request to better understand potential stock impacts from theoretical unobserved fishing mortality levels. The author recreated the preferred 2020 stock assessment model but increased the input level of trawl and fixed-gear bycatch biomass by amounts ranging from 100% to 1,000%. The author found that the model's terminal mature male biomass (MMB) and OFL levels did not change much if bycatch biomass was doubled or increased by a lesser amount (decrease < 3% of MMB compared to no change in bycatch). Increasing the bycatch biomass by 500% reduced the model's terminal MMB to decrease by 14% or more, with the author noting that the change could be much larger in some years throughout the model's run.

Published studies on the impacts of trawl gear on crab have generally focused on non-pelagic gear, including studies in the Bering Sea and in the shrimp fishery off the east coast of Canada. Studies have utilized bottom and wing recapture nets to collect impacted crab that would not have ended up in the trawl net, cameras to visualize crab that were avoiding the trawl net, and even submersible camera-equipped vehicle dives to compare damage to crabs before and after trawling in an area.

Rose (1999) cites an earlier study (Donaldson 1990) as a "preliminary estimate" of the rate of unobserved crab injuries, wherein RKC were tethered to the seafloor, a trawl net was towed over the area, and divers attempted to recover the crab. Of 169 crab, 21% were captured in the net, 46% were recovered by the divers, and 33% could not be located. While only two of the 78 recovered crabs were injured, Rose noted the ambiguity posed by the fate of the unrecovered crabs relative to the sample size. An unpublished video study (Rose 1995) found that sweep diameter was the main factor in whether crab could escape over the sweep (note that sweeps were not elevated during this period). The study was not able to determine the frequency, nature, or severity of injuries to crabs that went under the sweep. The Rose (1999) study in Bristol Bay used a recapture net to assess injury rates to crab that pass under different types of footrope. Eight experimental tows yielded injury rates of between 5% and 10% of the recaptured crab.

Subsequent work by Rose et al. (2013) provided estimates of the unobserved mortality rates of crabs swept over by trawl gear common to bottom trawl fisheries in the Bering Sea. This research demonstrated that mortality rates varied by crab species (red king, Tanner, and snow) but depended mainly on that part of the trawl system crab encountered. Additionally, reduction of crab mortality rates by altering specific gear designs showed that gear modifications, such as raised sweeps, can mitigate unobserved mortality (Rose et al 2014, Rose et al 2013; Rose et al 2010;). The finding was that mortality was much higher for crab that passed under the footrope (particularly the wing section) than for crab that were struck by the sweeps that herd flatfish. One supposition was that effective herding can reduce overall crab mortality because it reduces the amount of footrope-swept area needed to catch the same number of flatfish. This study used an assessment method[5] onboard the vessel to predict the delayed mortality of recaptured crab that would have been impacted by the trawl but not captured by normal fishing. The study also evaluated crab caught in a control net where they did not encounter the trawl gear (footrope, sweeps) to adjust observed mortality rates for the effects of capture and handling. The study results were that the experimental trawls produced more mortalities of RKC than either snow or tanner crab, which was expected due to their larger, less flat body shape. The raw mortality rate for RKC that passed under the footrope wing was the highest, at 32%. The study concluded that RKC estimated unobserved mortality rates, adjusted for the area swept by each trawl component (i.e., footrope center, wing, and sweep) were reduced to 6% when sweeps were elevated, which is now required for BSAI non-pelagic trawls.

The remote-video study of shrimp trawl interactions with snow crab off St. Mary's Bay in southeastern Canada only assessed areas swept by the trawl footrope (Dawe et al. 2007). The study did not collect a large sample of direct post-trawl observations but did not report any dead crab in the trawl corridor or crab with carapace damage. The authors note that the study area has a soft mud substrate and that a similar early study (Schwinghamer et al. 1998) did observe dead crab in a dense sand substrate on the northern Grand Bank. The study did not find a reduced density of snow crab in the trawled bays after trawling occurred. However, the study concluded that intensive trawling could increase crab leg-loss by about 10%.

A trawl-mounted video study in the same part of Canada looked at how snow crab physically reacted to shrimp bottom trawls (Nguyen et al. 2014). This study was also limited to the footrope portion of the trawl and concluded that about 54% of observable crab interacted with the footgear (e.g., elevating discs, spacers, or chains). The majority of video-observed crabs actively responded to the approaching trawl and tried to escape. The study was unable to estimate the severity or likelihood of mortality after passing under footgear. This study, and references to herding in Rose et al. (2013), highlights the relevance of crab shell condition to susceptibility to unobserved trawl mortality. In a time/area where crab are likely to be in a soft-shell condition and less mobile, unobserved mortality rates could be higher than the ranges estimated in the studies available.

Other types of gear contact the seafloor and may affect snow crab in ways that are not captured by observed crab bycatch mortality data. The benthic impacts of fishing gears other than trawl and dredges (i.e., scallop gear) has been less studied. In a discussion paper on assessing the effects of fishing on

[5] Reflex Action Mortality Predictor (RAMP); see Davis and Ottmar (2006) and Stoner et al. (2008).

essential fish habit in Alaska for 2022 (Olson et al., 2022) two studies were cited that may indicate the potential for impacts to crab. The first study is a hook-and-line longline research project from Australia (Welsford et al. 2014) and the second study is a sablefish longline-pot research research from British Columbia, Canada (Doherty et al. 2017). The hook-and-line study identified line shear and hooking that could impact structure-forming invertebrates. Such impacts might relate to crab as they rely on structure for safety after molting. The average lateral line movement in Welsford et al. was 6.2 meters, and virtually all lateral movement occurred during deployment or retrieval. Lateral line movement can result from currents or from captured fish. Bycatch of sessile benthos (e.g., sponges, corals) are sometimes observed in the Alaska longline fishery so it is known that seafloor interactions do occur. The longline-pot study (Doherty) noted that hauling speed and direction, combined with environmental factors like depth, slope, and current affects a pot's footprint. The BC pot study was assessing conical pots that are significantly smaller than most Bering Sea crab pots but similar to smaller groundfish pots (e.g., sablefish). Doherty estimated the mean bottom-contact area for a 54-inch pot at $53m^2$, or roughly 36 times its static footprint of 1.47 x 1.47 meters. The longline-pots were observed to drag for between 0.4 and 5.9 minutes when hauling. For comparison, Doherty et al. specifically cites Alaska king crab pots as having a roughly 2.4 x 2.4 meter size. The analysts note that the effect of pot dragging would greatly depend on hauling conditions and also note that less dragging would be expected for pots that are not connected to one another by a groundline.

3 Selection of alternatives and options

At this meeting, the Council will select alternatives and options for the rebuilding plan analysis. The alternative set must include the no action alternative, and a rebuilding plan alternative that is consistent with the MSA and NS1 Guidelines. The rebuilding plan will require an amendment to the BSAI Crab FMP.

Draft Alternative 1: No action; State harvest strategy with no rebuilding plan

Under the no action alternative, the Council would not develop a rebuilding plan, and there would be no Federal management response to address an overfished stock. Including a no action alternative in the analysis is required, however it is a violation of the MSA to take no action to establish a rebuilding plan for an overfished stock. The State harvest strategy would continue to determine directed snow crab harvest levels under the no-action alternative, unless the threshold falls below the beta threshold level listed in the FMP which triggers closure of the directed fishery regardless of the State's harvest strategy. However, without the adoption of a rebuilding plan, there would not necessarily be a mechanism to address operational issues that may constrain rebuilding, if such operational issues exist.

Draft Alternative 2: Set target rebuilding time frame for the number of years necessary to rebuild the stock to the B_{MSY} level at a probability ≥50%. The stock will be considered "rebuilt" once it reaches B_{MSY}.

To comply with the MSA, a rebuilding plan alternative would be established that would have greater than a 50% probability of rebuilding the EBS snow crab stock to B_{MSY} within a timeframe based on NS1 Guidelines. Under the Guidelines, rebuilding would ideally be achieved in less than 10 years (T_{max} = 10 years). If, however, the "biology of the stock, other environmental conditions, or management measures under an international agreement to which the U.S. participates, dictate otherwise," rebuilding can take more than 10 years. The fastest rebuilding time (T_{min}), is calculated based on F=0 (no fishing mortality of any kind). If T_{min} > 10 years, then the NS1 Guidelines provide for alternative calculations for rebuilding time (i.e., T_{max}), as described in Section 2.1.

The SSC at this meeting will review EBS snow crab rebuilding projections from the May 2022 Crab Plan Team (CPT) meeting to provide recommendations and guidance to the Council in selecting EBS snow crab rebuilding alternatives for analysis. During the May 2022 CPT meeting, the CPT supported a rebuilding plan that is based on a snow crab stock assessment using Generalized Model for Assessing Crustacean Stocks (GMACS). Of the rebuilding projections presented at the May CPT meeting, the CPT noted the projections that result in a T_{min} of less than 10 years were likely more representative of snow crab over the next 20 years, so if the SSC concurs with the CPT, the T_{max} for the rebuilding plan would be 10 years.

In the cases where the difference between T_{min} and T_{max} is sufficient to accommodate a level of fishing mortality (direct or incidental harvest, or bycatch) above 0 and not still exceed T_{max}, the Council could allow EBS snow crab fishing mortality under their rebuilding plan alternative. The Council could include different harvest strategies for analysis as options under Draft Alternative 2. Based on the Council's analytical range in the St Matthew blue king crab rebuilding plan in 2020, the Council might consider the following options:

Draft Option 1: No directed snow crab fishing until the stock is rebuilt.

Draft Option 2: Allow the directed snow crab fishery to open based on the state harvest strategy while the stock is rebuilding.

To cover the widest range of mortality options, the CPT supported analyzing a range of harvest strategies to include:

(a) no snow crab removals at all (F=0),

(b) bycatch only in groundfish and crab fisheries (F=bycatch),

(c) a directed snow crab fishery using an approximation of the current State of Alaska harvest strategy (e.g., the ABC control rule multiplied by the average of the TAC to ABC ratios; F=State harvest strategy), and

(d) a directed snow crab fishery using the ABC control rule (F=ABC).

If the rebuilding plan allows a directed snow crab fishery to open, it would continue to be governed by a state harvest strategy under the process described in the BSAI Crab FMP. In this case, the rebuilding plan and amended FMP language could either: 1) identify a specific formula for opening the EBS snow crab fishery that would be incorporated into the State harvest strategy, or 2) state that no change in the current State harvest strategy may occur which would result in departure from the Council's intended rebuilding timeline (see harvest strategy in Section 2).

With respect to fishing mortality associated with bycatch of EBS snow crab in the groundfish fisheries and directed Tanner and BBRKC fisheries, preliminary discussions at the CPT regarding the sensitivity of EBS snow crab bycatch on T_{min} indicate that the Council may have discretion to allow bycatch of EBS snow crab associated with these fisheries to continue without affecting the rebuilding timeframe. If, however, the Council chooses a rebuilding option that disallows any snow crab removals including bycatch (F=0), this would likely close some groundfish and crab fisheries. In this case, the rebuilding plan would additionally necessitate an amendment to the groundfish FMP to change snow crab PSC measures, as well as regulatory amendments.

Even without eliminating snow crab fishing mortality attributable to bycatch in the groundfish fisheries, the Council could still consider measures in the rebuilding plan to reduce snow crab mortality in the groundfish fisheries. As above, however, any changes to bycatch measures in the groundfish fisheries would require an amendment to the groundfish FMP and would also need to be implemented in regulation. The Council should weigh the additional analytical complexity and required time for Council deliberation from including groundfish PSC management changes in the rebuilding plan, against the conservation benefit to the snow crab stock, and the risk of not meeting the MSA requirement to implement a rebuilding plan within two years.

Upon Council selection of EBS snow crab rebuilding alternatives and options for analysis at this meeting, staff will prepare an analysis of the impacts of the rebuilding alternative for a scheduled initial review during the October 2022 Council meeting. Once an approved rebuilding alternative is adopted, the rebuilding plan will be incorporated into the BSAI Crab FMP as an amendment.

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