Appendix 1 Crab PSC in the BSAI TLAS Fisheries

Table A1-1 Use of crab PSC in the BSAI TLA fisheries, relative to the lowest PSC threshold and based on conventional apportionments, 2008-2020

Zone 1 Red King Crab PSC									
Year	Yellowfin Sole			Pollock/Atka Mackerel/Other			Pcod		
	Lowest limit	Catch	Percent	Lowest limit	Catch	Percent	Lowest limit	Catch	Percent
2008	7,699	3,321	43%	65	34	52%	975	1,165	120%
2009	7,699	2,231	29%	65	36	56%	975	-	0%
2010	7,699	-	0%	65	21	32%	975	0	0%
2011	7,699	1,366	18%	65	-	0%	975	1,971	202%
2012	7,699	102	1%	65	3	5%	975	-	0%
2013	7,699	69	1%	65	15	23%	975	-	0%
2014	7,699	92	1%	65	-	0%	975	85	9%
2015	7,699	6	0%	65	-	0%	975	51	5%
2016	7,699	842	11%	65	6	9%	975	547	56%
2017	7,699	3,626	47%	65	39	60%	975	280	29%
2018	7,699	778	10%	65	14	22%	975	199	20%
2019	7,699	1,604	21%	65	18	28%	975	466	48%
2020	7,699	3,034	39%	65	9	14%	975	175	18%

Snow crab PSC in COBLZ									
Year	Yellowfin Sole			Pollock/Atka Mackerel/Other			Pcod		
	Lowest limit	Catch	Percent	Lowest limit	Catch	Percent	Lowest limit	Catch	Percent
2008	1,217,063	62,939	5%	20,690	5,380	26%	51,724	349	1%
2009	1,217,063	21,277	2%	20,690	2,859	14%	51,724	251	0%
2010	1,217,063	1,378,836	113%	20,690	3,959	19%	51,724	14	0%
2011	1,217,063	215,150	18%	20,690	4,220	20%	51,724	42	0%
2012	1,217,063	239,530	20%	20,690	2,263	11%	51,724	15	0%
2013	1,217,063	224,136	18%	20,690	3,255	16%	51,724	321	1%
2014	1,217,063	71,983	6%	20,690	2,599	13%	51,724	2,378	5%
2015	1,217,063	46,590	4%	20,690	2,540	12%	51,724	71	0%
2016	1,217,063	1,781	0%	20,690	665	3%	51,724	929	2%
2017	1,217,063	3,224	0%	20,690	239	1%	51,724	-	0%
2018	1,217,063	68,511	6%	20,690	237	1%	51,724	-	0%
2019	1,217,063	12,836	1%	20,690	127	1%	51,724	4,144	8%
2020	1,217,063	51,976	4%	20,690	2,426	12%	51,724	-	0%

Zone 1 Tanner crab PSC									
Year	Yellowfin Sole			Pollock/Atka Mackerel/Other			Pcod		
	Lowest limit	Catch	Percent	Lowest limit	Catch	Percent	Lowest limit	Catch	Percent
2008	257,904	14,233	6%	3,724	209	6%	44,694	25,897	58%
2009	257,904	7,794	3%	3,724	376	10%	44,694	4,729	11%
2010	257,904	-	0%	3,724	237	6%	44,694	14,169	32%
2011	257,904	12,668	5%	3,724	3,089	83%	44,694	8,809	20%
2012	257,904	5,425	2%	3,724	199	5%	44,694	3,146	7%
2013	257,904	13,242	5%	3,724	1,316	35%	44,694	3,022	7%
2014	257,904	5,286	2%	3,724	329	9%	44,694	5,064	11%
2015	257,904	9,761	4%	3,724	97	3%	44,694	5,195	12%
2016	257,904	1,566	1%	3,724	28	1%	44,694	8,145	18%
2017	257,904	46,072	18%	3,724	135	4%	44,694	7,605	17%
2018	257,904	2,244	1%	3,724	303	8%	44,694	1,613	4%
2019	257,904	1,644	1%	3,724	31	1%	44,694	2,317	5%
2020	257,904	2,716	1%	3,724	13	0%	44,694	1,631	4%

Zone 2 Tanner crab PSC									
Year	Yellowfin Sole			Pollock/Atka Mackerel/Other			Pcod		
	Lowest limit	Catch	Percent	Lowest limit	Catch	Percent	Lowest limit	Catch	Percent
2008	826,258	54,586	7%	3,485	906	26%	34,849	8,170	23%
2009	826,258	47,868	6%	3,485	982	28%	34,849	1,586	5%
2010	826,258	65,421	8%	3,485	1,177	34%	34,849	4,815	14%
2011	826,258	59,432	7%	3,485	1,861	53%	34,849	3,166	9%
2012	826,258	39,376	5%	3,485	831	24%	34,849	4,343	12%
2013	826,258	66,541	8%	3,485	1,681	48%	34,849	2,980	9%
2014	826,258	91,009	11%	3,485	764	22%	34,849	4,109	12%
2015	826,258	20,599	2%	3,485	1,130	32%	34,849	4,680	13%
2016	826,258	2,084	0%	3,485	412	12%	34,849	3,004	9%
2017	826,258	24,066	3%	3,485	163	5%	34,849	1,519	4%
2018	826,258	8,784	1%	3,485	530	15%	34,849	472	1%
2019	826,258	6,605	1%	3,485	87	3%	34,849	411	1%
2020	826,258	24,470	3%	3,485	1,698	49%	34,849	538	2%

Source: NMFS Alaska Region Catch Accounting System, data compiled by AKFIN in Comprehensive_PSC [Seondary_PSC_Accounts(12-10-20).xlsx]

Note that 0.16% of the snow crab PSC and 0.08% of the Zone 2 Tanner crab PSC have typically been apportioned to the directed rockfish TLA fishery. That fishery has used virtually none of its crab PSC in the past and therefore it was not included in these tables.

Appendix 2 Overfishing and Rebuilding

A2.1. Process 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 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. Table A2-1 shows the OFL levels calculated for the BBR, BSS, and BST crabs for 2019/2020. 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.

Table A2-1 OFL for BBR, BSS, and BST Crab 2019/2020

	OFL (1,000t)	OFL (million lbs)
BBR	3.40	7.50
BSS	54.9	121.03
BST	28.86	63.62

Source: Bristol Bay Red King Crab SAFE 2020; Eastern Bering Sea Snow Crab SAFE 2020; Eastern Bering Sea Tanner Crab SAFE 2020

The OFL and ABC for each stock are estimated for the upcoming crab fishing year using a five-tier system, detailed in Table A2-2. 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, 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 A2-2) used in calculating the FOFL. Three levels of stock status are specified and denoted by “a,” “b,” and “c” and the FMSY control rule assigns FOFL according to stock status level (Table A2-2). At stock status level “a,” current stock biomass exceeds the BMSY. For stocks in status level “b,” current biomass is less than BMSY but greater than a level specified as the “critical biomass threshold” (β). In stock status level “c,” the ratio of current biomass to BMSY (or a proxy for BMSY) is below β. At stock status level “c,” directed fishing is prohibited and an FOFL at or below FMSY would be determined for all other sources of fishing mortality in the development of the rebuilding plan.

Table A2-2 Five-Tier System for setting overfishing limits for crab stocks. The tiers are listed in descending order of information availability.

Information available	**Tier**	**Stock status level**	***F_{OFL}***
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
		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. $\frac{B}{B_{msy}} > 1$	$F_{OFL} = F_{msy}$
		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. $\frac{B}{B_{35\%*}} > 1$	$F_{OFL} = F_{35\%}{*}$
		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. $\frac{B}{B_{msy^{prox}}} > 1$	$F_{OFL} = \gamma M$
		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.

*35% is the default value unless the SSC recommends a different value based on the best available scientific information.

† An $F_{OFL} \le F_{MSY}$ will be determined in the development of the rebuilding plan for that stock.

As of 2020/21, BBRKC is listed as a Tier 3b stock. The fishing mortality rate that reduces spawning-stock biomass to 35% of the unfished level ($F_{35\%}$ = 0.36) is used as F_{MSY} proxy, $B_{35\%}$ = 35,317 t is a B_{msy} proxy, and M = 0.18. The control rule prescribes a linear decline in F, as biomass declines below $B_{35\%}$, to β, below which no directed fishing is allowed. If the minimum stock size threshold (MSST, specifically defined as B/B_{MSY}) < 50%, the stock will be declared overfished and rebuilding plan will be required by Section 304 of the MSA. The BBRKC stock has been approaching this threshold. For 2020/2021, MSST = 59%.

A2.2 Rebuilding

Rebuilding of overfished stocks is required by the MSA section 304. The National Standard 1 guidelines indicate that once biomass falls below the minimum stock size threshold (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.

A rebuilding plan for any crab stock is incorporated by an amendment to the Crab FMP. If associated regulations that affect other fisheries (i.e. groundfish) are necessary, additional implementing regulations would be required. Rebuilding plans must consider the following three components to improve the status of the stock: a harvest strategy, bycatch control measures, and habitat protection measures. Not all rebuilding plans will amend current management measures to all three components. In the Saint Matthew Blue King Crab rebuilding plan, it was determined that bycatch in other fisheries had no appreciable impact on the timeline for stock rebuilding, so no regulatory changes to bycatch measures were made.

A2.2.1 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.
>
> (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.

(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—

(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.

(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—

(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

A2.2.2 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.

A2.2.3 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}).

A2.2.4 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 BBRKC, and would continue throughout rebuilding. The BSAI Crab Plan Team would report 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. State and federal observer 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.

A2.3 Bristol Bay Red King Crab

In 1983, the Bristol Bay King Crab fishery was closed due to conservation concerns. At the time, red king crab harvest range was based on (1) standard errors of the mean legal-sized male abundance estimates from population estimates derived from trawl surveys, (2) harvest rate, and (3) in-season CPUE. In the mid-1990s, a length-based assessment was developed based on a population dynamics model incorporating growth, mortality, and recruitment. This model provided more consistent stock estimates and enabled the forecasting of stock status under different exploitation scenarios. Results indicated a severe decline in abundance of mature males and females and ESB and the fishery was closed again in 1994 and 1995.

A rebuilding plan was adopted in 1996 that involved a State plan targeting the direct crab fishery and federal bycatch controls placed on the groundfish fishery (The Red King Crab Savings Area [RKCSA] and Nearshore Bristol Bay Trawl Closure Area [NBBTCA]). The State of Alaska has authority to establish management measures concerning size limits, sex restrictions, fishing seasons, and harvest levels if specific provisions in the crab FMP are followed. State regulations are adopted by the Alaska Board of Fisheries and implemented by the Alaska Department of Fish and Game. Crab bycatch in groundfish fisheries is regulated under the federal groundfish FMP for the Bering Sea and Aleutian Islands. Two key components of the rebuilding plan was the State stair-stepped harvest strategy (see Chapter 3.3 of this analysis) and the Federal PSC limits determined by a stair-step of 35,000, 100,000, and 200,000 (adjusted in 2000 by Amendment 57 to 32,000, 97,000, and 197,000) red king crabs corresponding to the levels of ESB used in the state harvest strategy for the directed fishery.

In 2003, the Bristol Bay red king crab stock was declared rebuilt, but downward population trends have occurred over the last few years as the stock has approached "overfished" status. If the minimum stock size threshold (MSST, specifically defined as B/B_{MSY}) < 50%, the stock will be declared overfished and rebuilding plan will be required by Section 304 of the MSA. For 2020/2021, MSST = 59% for the BBRKC. ADFG reported in their 2020/2021 TAC setting presentation[1] that the BBRKC may face additional challenges to rebuilding as King crab populations in general show little resilience, have low estimated recruitment, females are nearing harvest strategy closure thresholds, and fluctuating environmental conditions and warming are projected for the near future.

If required, a rebuilding plan would be established that would be consistent with the MSA and NS1 Guidelines on time for rebuilding. Within 2 years of being declared overfished or approaching overfished, MSA section 304(e) requires that *the Council shall prepare an FMP, plan amendment, or proposed regulation to either (A) end overfishing immediately, or (B) prevent overfishing from occurring if identified as approaching overfished condition.* The plan must specify the time period is as short as possible considering extraneous factors and take no more than 10 years. Overfishing restrictions and recovery benefits must also be allocated fairly among sectors. If the time to rebuild the population to B_{MSY} with a greater than 50% probability at F=0 (T_{min}) is greater than 10 years, rebuilding times for the alternatives are evaluated relative to T_{max} as defined in the NS1 Guidelines as "T_{min} plus the length of time associated with one generation time for that stock or stock complex." The estimated generation time for BBRKC is approximately 14.2 years, and therefore T_{max} would be calculated at ([Tmin] + 14.2 years).

In the development of a rebuilding plan, the current harvest strategy, bycatch control measures, and habitat protection measures must be evaluated. The harvest strategy for the Bristol Bay red king crab (5 AAC 34.816) implemented by the state of Alaska requires a minimum threshold level of abundance of 8,400,000 mature female red king crab and 14,500,000 pounds of ESB for the season to open. The maximum legal males available to harvest are based on a stair-step model. When ESB is at least 14,500,000 million pounds up to 34.75 million pounds, the max legal males available for harvest is set at 10% of mature male abundance. When ESB is at least 34,750,000 million pounds up to 55,000,000 pounds, max the max legal males available for harvest are set at 12.5% of mature male abundance, and when the ESB is greater than 55,000,000 million pounds, the max legal males available for harvest are set at 15% of mature male abundance. The harvest level is capped at 50% of legal male abundance at all levels and set to whichever number is less (Table A2-3).

1 http://www.adfg.alaska.gov/static/fishing/PDFs/commercial/bering_aleutian/2020_bsai_crab_tac_industry_meeting.pdf

Table A2-3 Bristol Bay Red King Crab Harvest Strategy

Estimated Spawning Biomass	Max legal males available for harvest (percent mature male abundance)[1]
14.5 – 34.75 million pounds	10%
34.75 – 55 million pounds	12.5%
>55 million pounds	15%

[1] Or no more than 50% legal-sized male abundance, whichever is less

Current habitat protection and bycatch control measures include area closures and PSC limits in the groundfish fisheries. The Bristol Bay Red King Crab Savings Area (RKCSA) closure was designed to protect stock and habitat for molting and mating periods. Nonpelagic trawling is prohibited year-round within the RKCSA with the exception that a subarea between 56ºN. and 56º10'N. latitude and 162º W. and 164ºW. longitude (the ten-minute strip, see 3.2.3) may be opened to nonpelagic trawl by the NMFS Alaska Regional Administrator in consultation with the Council if the commercial crab fishery was open the previous year. This is done during the annual specifications process by the Council in December. 25% of the RKC PSC allowance can be allocated to the subarea, and since the implementation of Amendment 80, the full 25% has been allocated. The subarea has not been closed as a result of the PSC limit being reached since 2006. 100% observer coverage is required for all pot and longline vessels fishing in the RKCSA, and all trawl vessels fishing in the subarea.

The Nearshore Bristol Bay Trawl Closure (NBBTC) was implemented in 1997 and designed to protect juvenile red king crab habitat. The NBBTC includes an exception for the Togiak subarea (Nearshore Bristol Bay Trawl Area [NBBTA]) bounded by 159˚ to 160˚W and 58˚ to 58˚43’ N (see 3.2.3) that remains open to trawling April 1 to June 15. The NBBTA is known to have high catches of flatfish and low bycatch of other species (Ackley & Witherell, 1999). Any catcher vessel or catcher processor used to fish for groundfish in the trawl closure area must carry an observer during 100% of its fishing days in which the vessel uses trawl gear.

A rebuilding plan would require the Council to look at the maximum amount of bycatch that may occur each year and project that rate forward to see if it would impact rebuilding. If the answer is no, then the Council does not have to consider bycatch in other fisheries when developing a rebuilding plan (see Saint Matthew’s Blue King Crab analysis). If the answer is yes, the Council will have to look more closely at groundfish limits and adjust how limits are set and/or the level they are set at in order to rebuild the BBRKC stock in the timeline prescribed by the MSA and NS1. Rebuilding would also require the State of Alaska to examine the current harvest strategy. Currently, the harvest strategy and bycatch limits are aligned – the stair-steps utilized to determine the PSC limits for the BBRKC are aligned with the ESB used in the state harvest strategy - but if this harvest strategy is changed this may no longer be the case and would need to be considered when changing bycatch regulations.

Appendix 3 Additional Crab Bycatch Tables and Figures Across Gear Types

Size and Sex Distribution of Crab Bycatch in the Groundfish Fisheries

At the May 2020 Crab Plan Team (CPT) meeting,[2] there was some discussion regarding the changes in size composition of bycatch over time. It is unclear whether changes in size composition are due to crab population size or fishing practices. Size composition may also be important to consider when understanding conservation concerns because the PSC limits are based on numbers of crab regardless of size. As a result, the directed fishery may be closed due to a low abundance of mature crab, but abundance of juvenile and female crab may be high, resulting in high bycatch amounts of smaller crab, which are then unable to recruit into the directed fishery. The CPT stated that this information has been requested in the past several times and might be good to further investigate even if it does not fit into this specific Council action.

Figures A3-1 through A3-12 below show data on size and sex composition of crab PSC by gear type. They include observed size distribution of BBRKC, snow crab, and Tanner crab PSC in the BSAI groundfish hook-and-line, pot, and trawl fisheries from 2009-2020, by sex. Y-axes are “frequency” and x-axes are crab size in mm (explained below). All data are from source: NMFS AFSC Observer Program, data compiled by AKFIN in Comprehensive_NORPAC [Crab_PSC_Lengths(12-15-20)].

These data may inform this analysis in a few ways, however, there are a few caveats. These show the actual observed records and are not extrapolated to the entire fishery. Therefore, comparison across gear types is not accurate due to differences in observer coverage and sampling across gear types. Additionally, crabs are measured using slightly different methods by the State and Federal groundfish observers.[3] The main difference is that the State measurements include spines, while observers in the groundfish fisheries do not include spines. Therefore, while these data can provide information on general size composition of crab PSC they can only be approximately compared to the legal size limits in the directed crab fisheries. Lastly, a more detailed understanding of size and sex composition of crab PSC would benefit from a more quantitative statistical analysis of these data.

Figure A3-1 shows that BBRKC PSC in trawl gear is largely male crab, particularly since 2017. There were roughly twice as many males than females observed, though the sex ratios were closer between 2012-2016. Most males in these data are between 125-174mm. While there are fewer female BBRKC caught as trawl PSC, they are generally in the 100-149mm size range. As described in Zheng & Siddeek 2020, for management purposes, males >119 mm and females >89 mm are assumed to be mature for Bristol Bay RKC. It would appear, based on these data, that BBRKC PSC in the trawl fisheries tends to be mostly mature crab. Of the total observed BBRKC trawl PSC (n=8109), roughly 35% were females over 89mm. Noting the caveat of slight differences in measurements between agencies, male red king crab 6.5 inches (165mm, measured with spines) or greater in width of shell may be taken or possessed in the crab directed fishery. Roughly 20% of the observed males in these data were >165mm, which is

[2] Link to CPT report from May 2020: https://meetings.npfmc.org/CommentReview/DownloadFile?p=fa83196d-dd52-4829-a253-3ffc7cb817d0.pdf&fileName=C2%20CPT%20Report%20May%202020.pdf

[3] In ADF&G regulations, measurement of king crab shall be the straight-line distance across the carapace at a right angle to a line midway between the eyes to the midpoint of the posterior portion of the carapace and shall include the spines. Measurement of Tanner crab shall be the greatest straight-line distance across the carapace at a right angle to a line midway between the eyes to the midpoint of the posterior portion of the carapace and shall include the spines. In these data, king crab are measured from the right eye socket to the middle of the posterior margin of the carapace. Tanner and snow crab are measured across the widest part of the carapace on the lower lateral margin.

approximately 12% of the total observed PSC (n=8109). Therefore, some of the trawl PSC is roughly the same size as the BBRKC caught in the directed fishery.

Figure A3-5 shows that snow crab PSC in trawl gear has been mostly males, a trend that has increased over the past three years. Most of these male crabs have been between 50-99mm, 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=116,443), approximately 40% were male crab >78mm, the legal size limit in the directed snow crab fishery.

Figure A3-9 shows that Tanner crab PSC in trawl gear is predominantly made up of male crab (with the exception of 2017). Generally, over this time period male crab have been between 75-124mm. Fewer crab are over this size. Most females in these data are between 75-99mm, and across the time series there were consistently very few over 100mm. Of the total observed Tanner crab PSC in trawl gear (n=82,749), approximately 24% were males >111mm, which is roughly equal to a size limit of 4.4 inches. Stockhausen 2020 also includes bycatch size compositions normalized by fleet, by sex and shell condition, for the directed crab fisheries, and annual bycatch size compositions in the groundfish fisheries by sex and gear type, expanded to total bycatch starting in 1990.

Figure A3-1

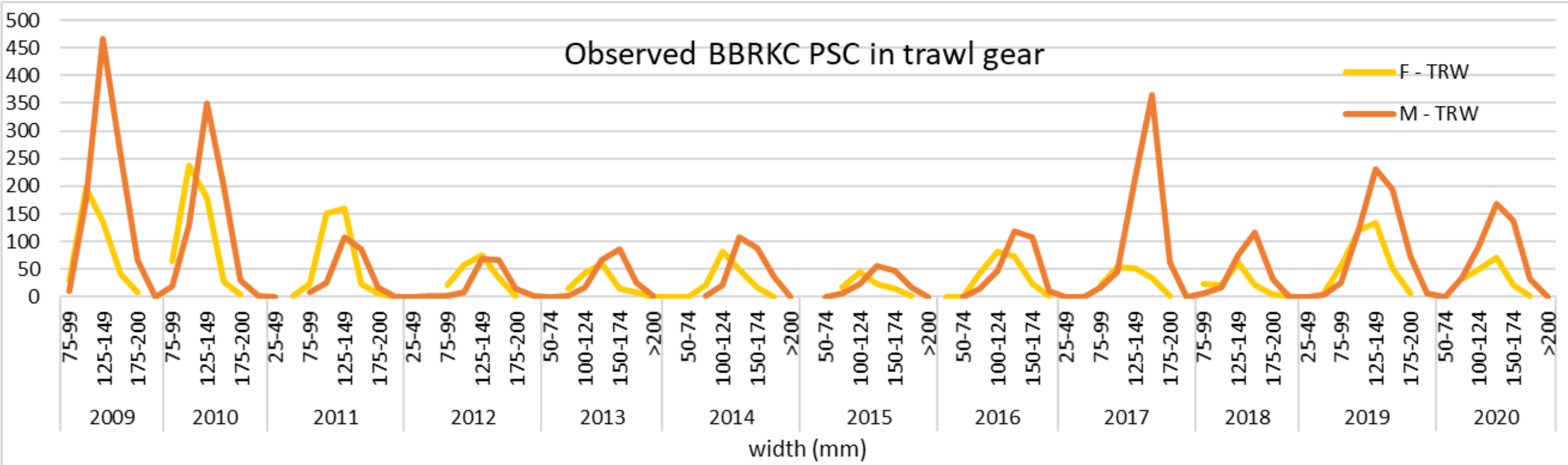


Figure A3-2

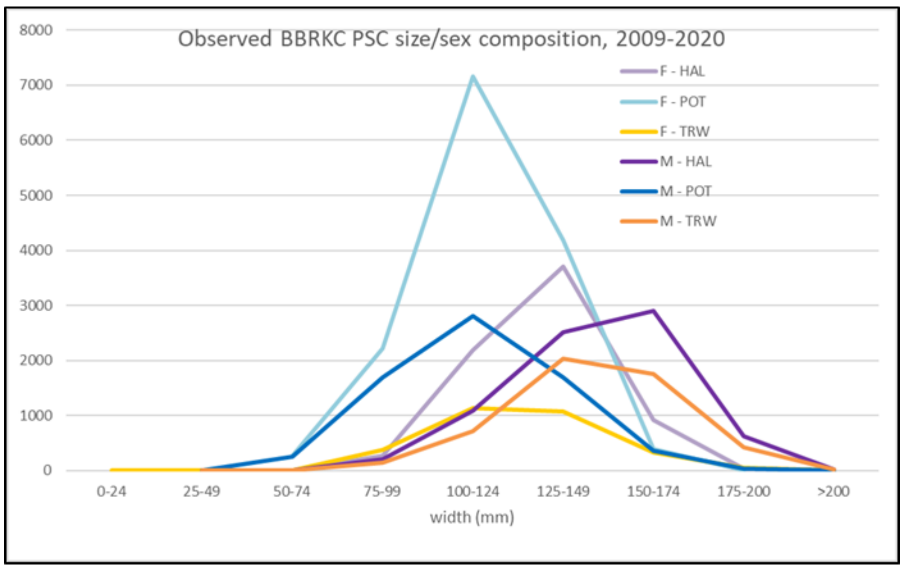


Figure A3-3

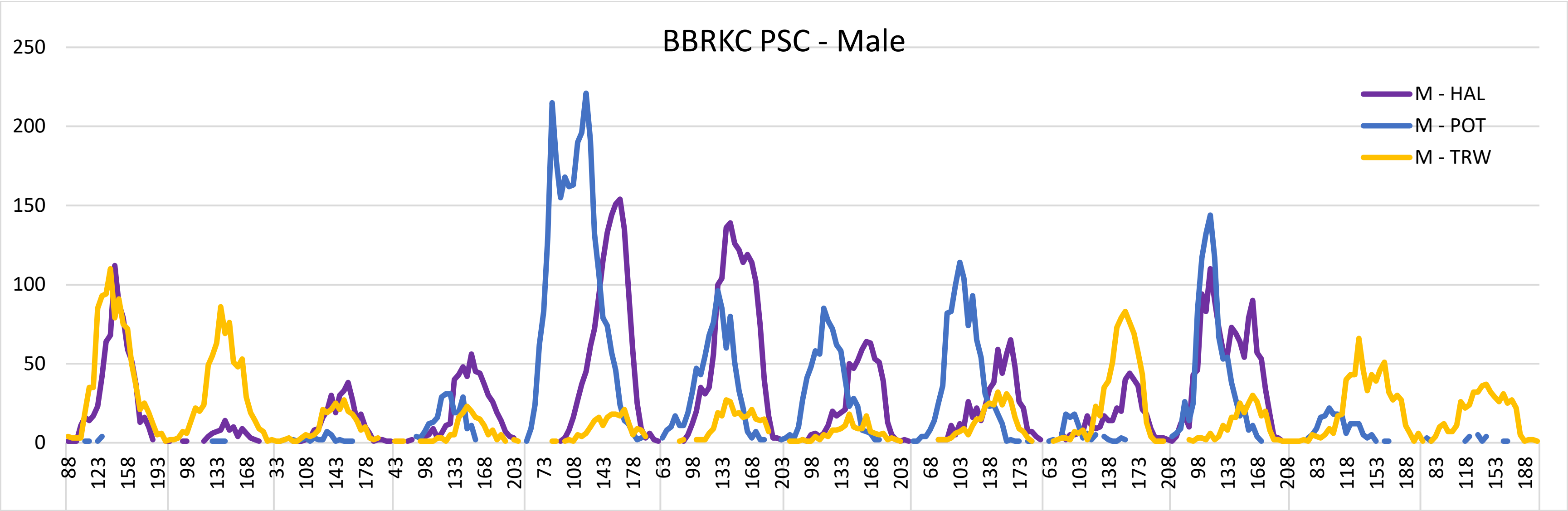


Figure A3-4

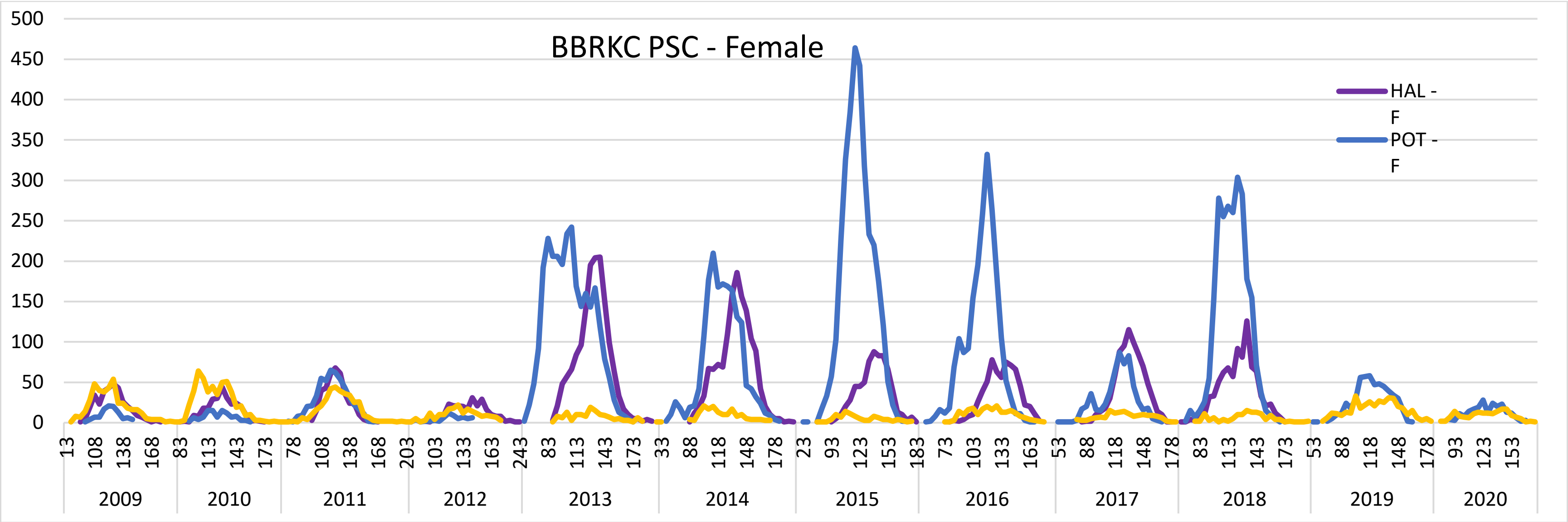


Figure A3-5

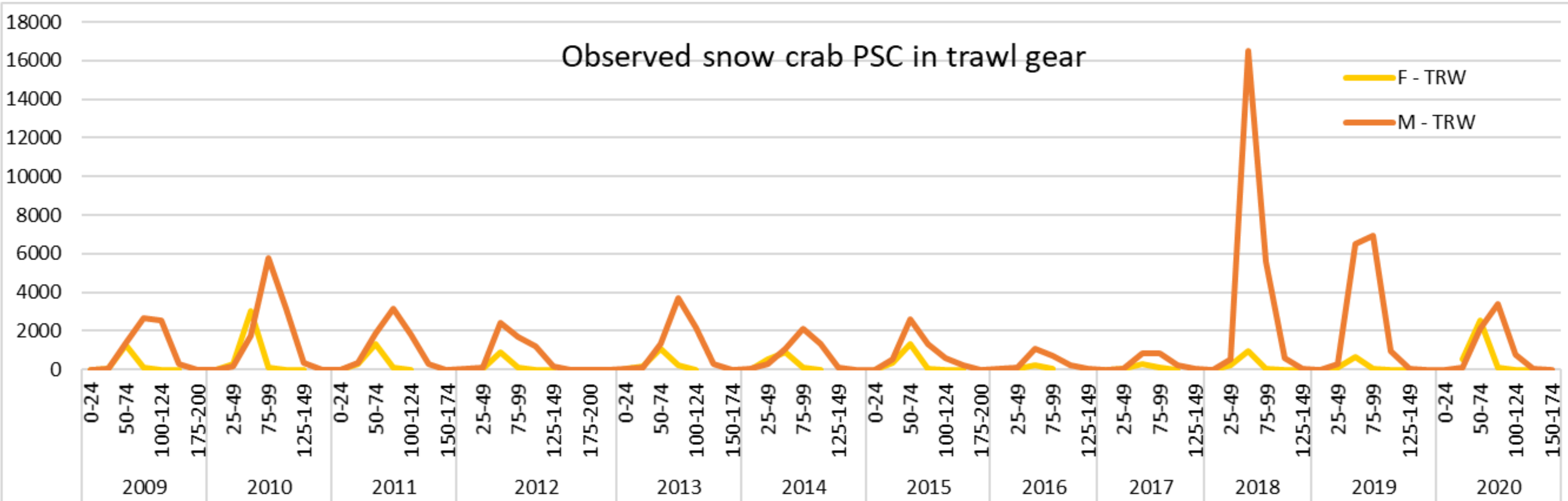


Figure A3-6

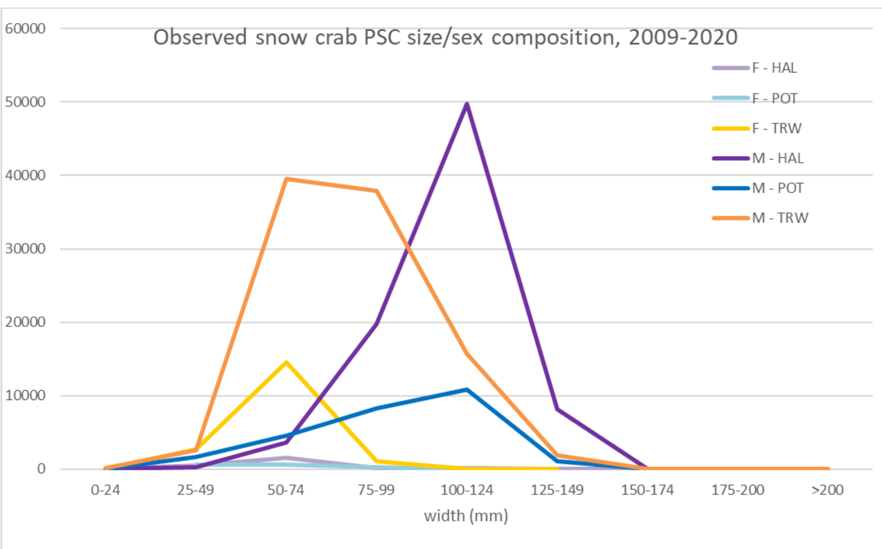


Figure A3-7

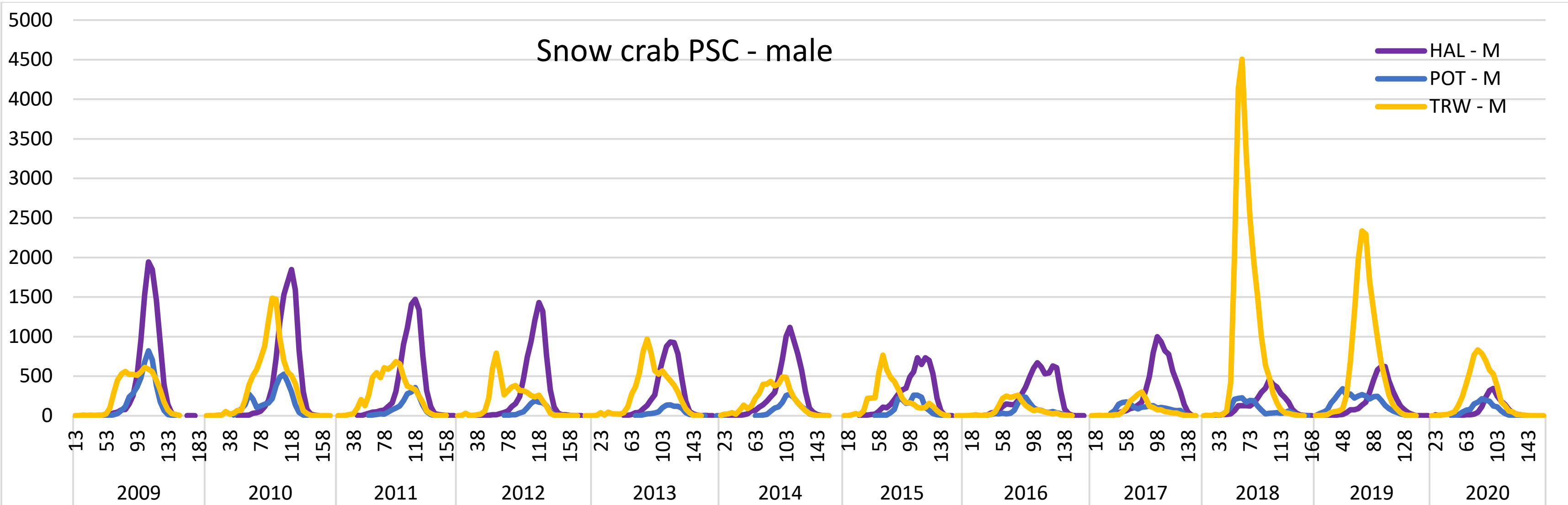


Figure A3-8

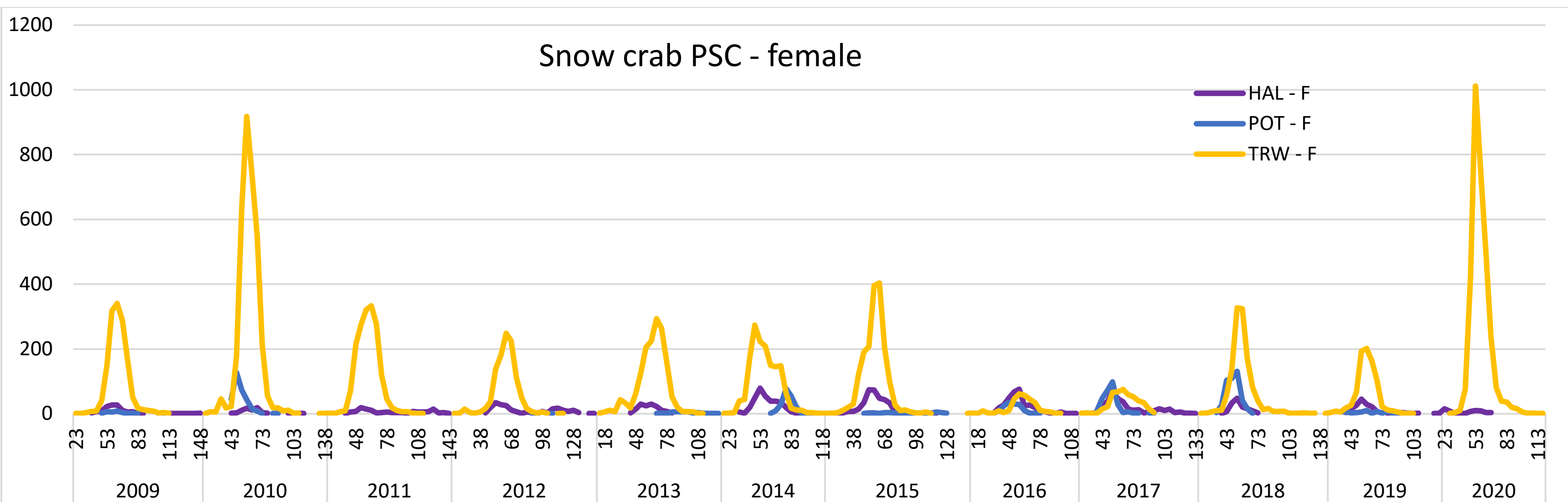


Figure A3-9

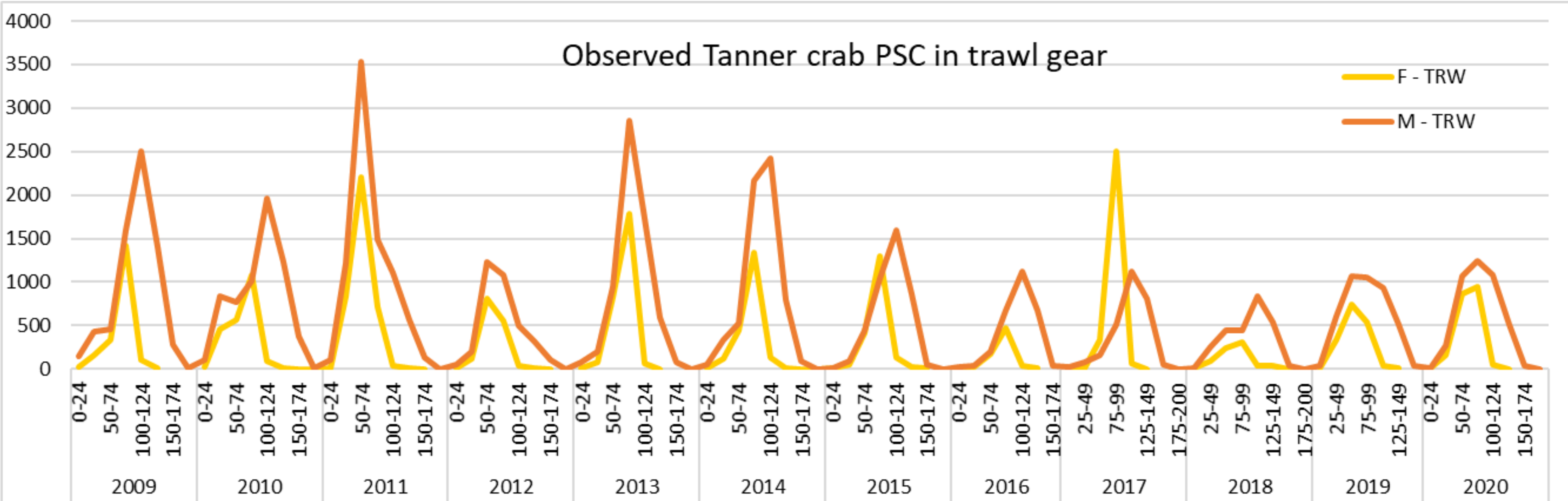


Figure A3-10

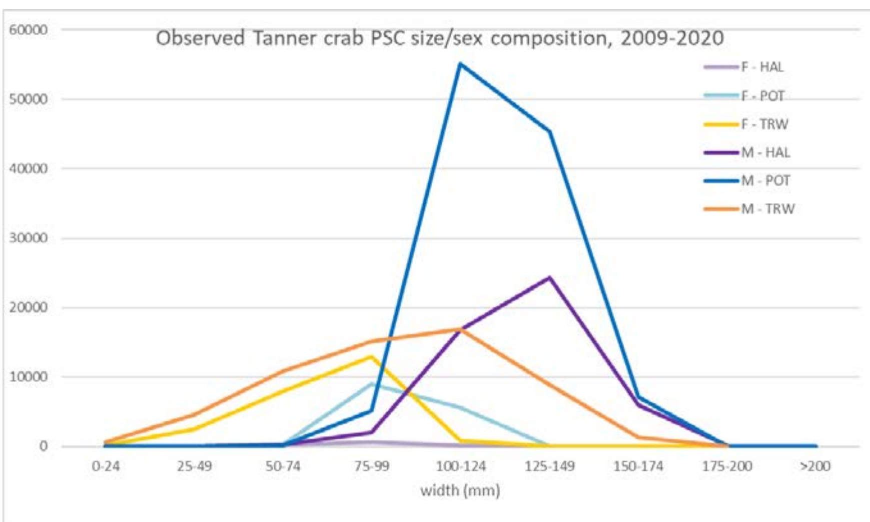


Figure A3-11

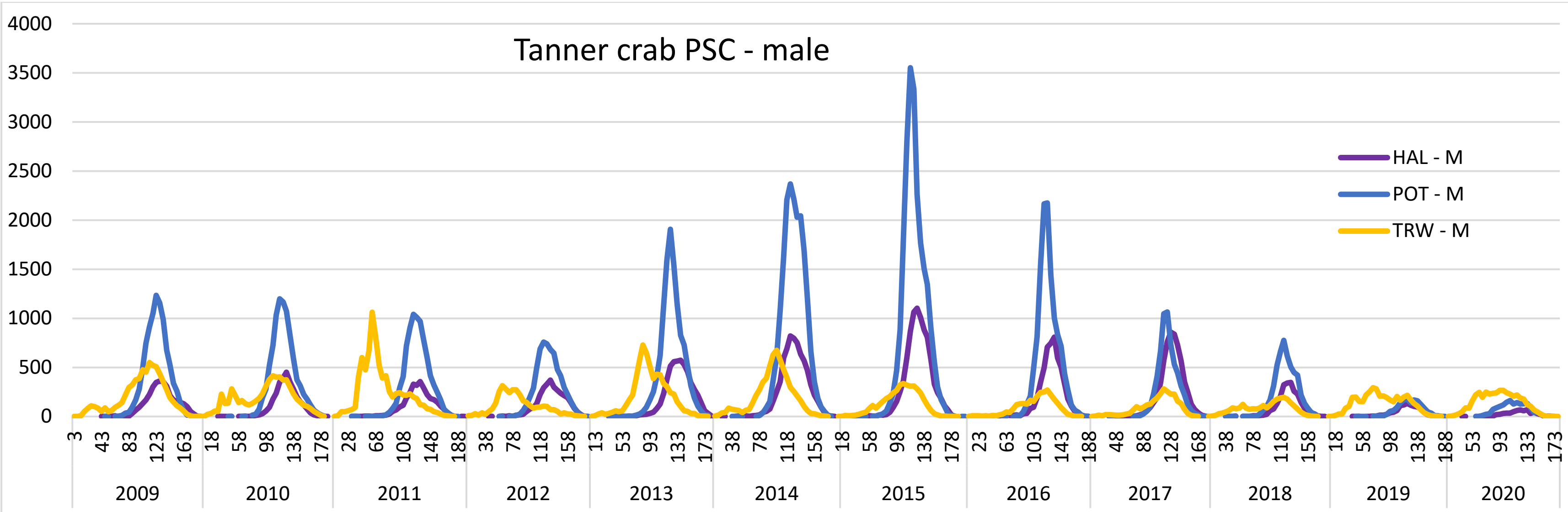
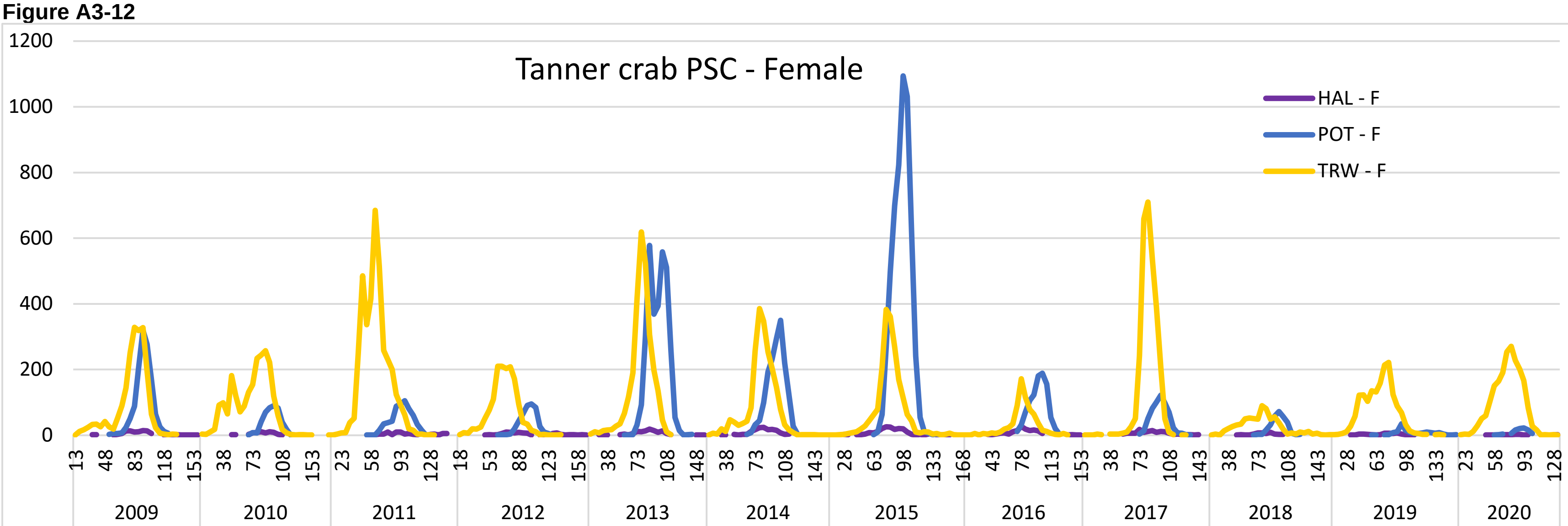


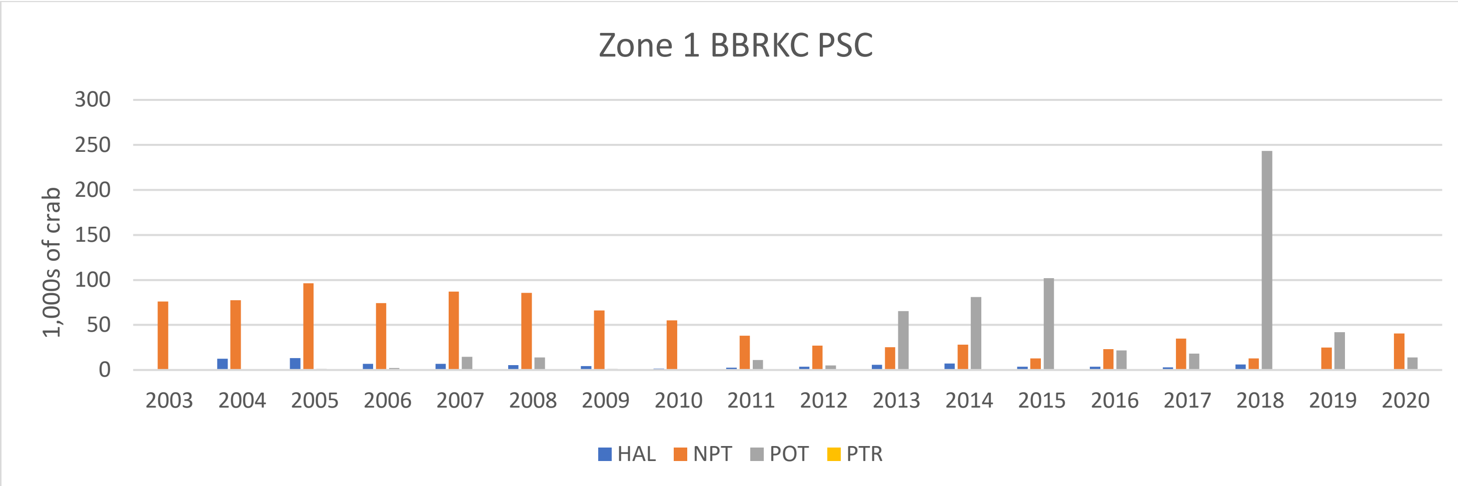
Figure A3-12



Crab bycatch in the groundfish fisheries by target species and gear type

Figure and Table A3-13 through A3-16 demonstrate that in the early 2000s, nonpelagic trawl fisheries accounted for the greatest levels of BBRKC, snow crab and Zone 1 Tanner crab. In the more recent years, the Pacific cod pot fishery has produced spikes of BBRKC PSC in Zone 1. In recent years, pot vessels have also accounted for greater or comparable levels of Tanner crab PSC in Zone 1 relative to trawl fisheries. As the Pacific cod TAC has declined in recent years, these pot seasons have become shorter and more competitive. There are no crab PSC limits in place for fixed gear fisheries. If it is the intention of the proposed action to minimize PSC in times when the directed crab fishery is closed, PSC in fixed gear sectors may be relevant to the proposed action. For instance, if the action alternative drops the trawl fisheries to the lowest PSC limit, but a fixed gear groundfish fisheries have a “lighting strike” catch of crab, these measures may not result in the crab PSC savings as intended.

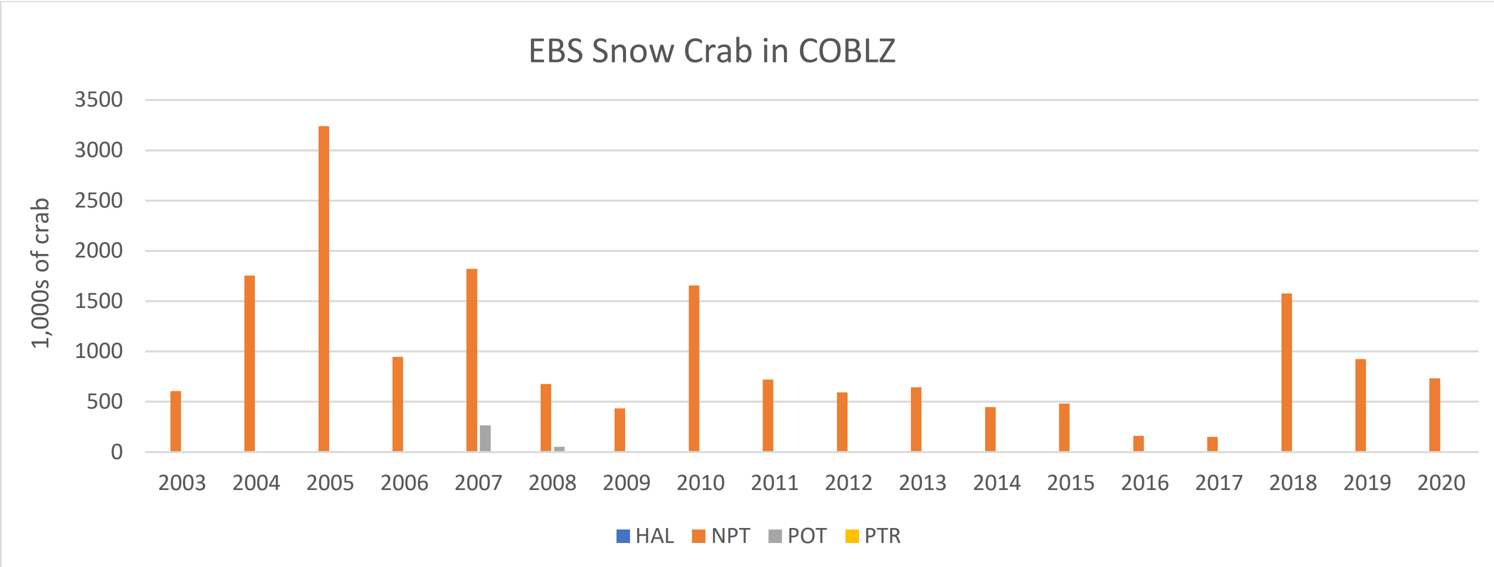
Figure and Table A3-13 Zone 1 BBRKC PSC usage by gear type and target species (# of crab)



Gear Type	Target Species	2012	2013	2014	2015	2016	2017	2018	2019	2020
HAL	Pacific Cod	3,456	5,739	7,105	3,515	3,532	2,933	6,130	0	0
NPT	Flathead Sole	-	C	C	-	C	C	778	C	-
	Pacific Cod	C	374	C	308	711	416	217	741	390
	Pollock - bottom	C	C	C	-	337	125	360	154	-
	Rock Sole - BSAI	22,585	17,307	24,310	8,978	12,644	6,679	3,488	2,826	8,087
	Yellowfin Sole - BSAI	4,185	6,947	2,995	3,468	9,391	27,763	7,882	21,099	31,997
POT	Pacific Cod	5,188	65,244	80,896	101,956	21,814	18,175	243,467	41,965	13,967
PTR	Pollock - midwater	C	-	C	-	6	23	14	25	6

Source: NMFS Alaska Region Catch Accounting System, data compiled by AKFIN in Comprehensive_PSC [Crab_PSC_AREA(11-13-20)]
C indicates confidential data, HAL = hook and line, NPT = nonpelagic trawl, pot = pot gear, PTR = pelagic trawl

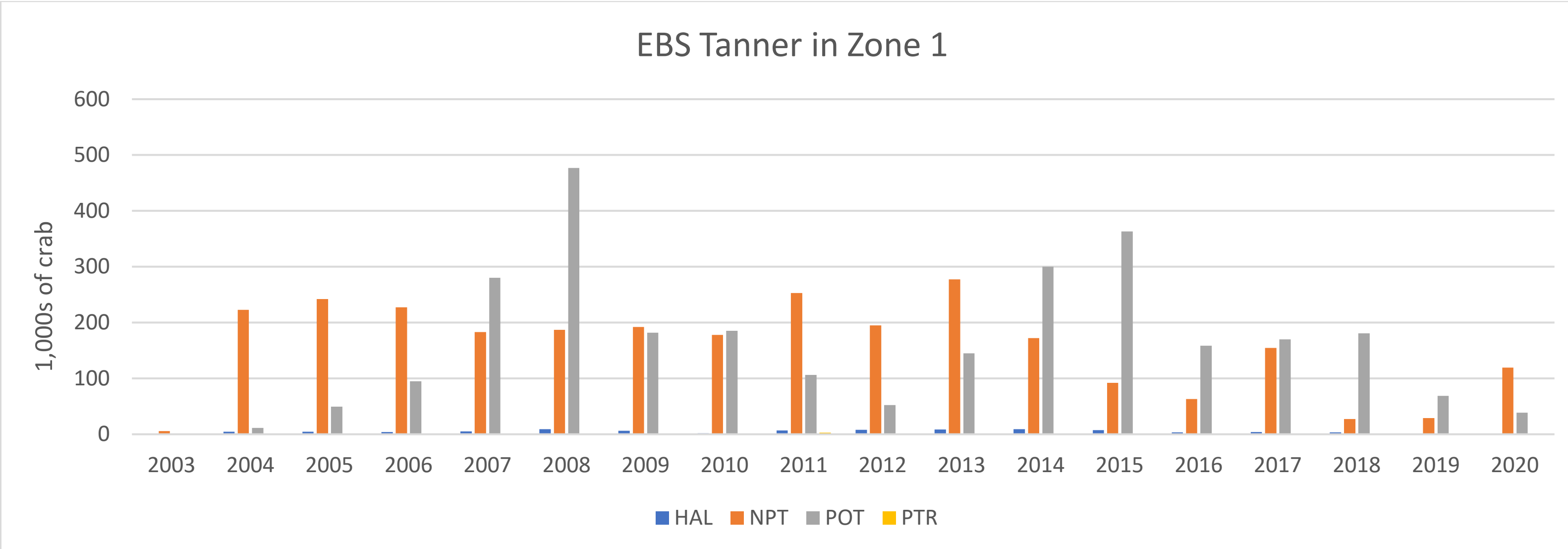
Figure and Table A3-14 EBS snow crab PSC usage in COLBZ by gear type and target species (# of crab)



Gear type	Target Species	2012	2013	2014	2015	2016	2017	2018	2019	2020
HAL	Halibut	-	-	-	-	12	19	53	14	9
NPT	Alaska Plaice - BSAI	2,098	7,258	-	21,117	2,519	140	5,279	1,906	C
	Arrowtooth Flounder	2,518	8,892	6,440	3,786	2,761	33,442	404	6,205	30,646
	Flathead Sole	17,166	67,239	79,887	20,802	10,537	30,510	279,286	217,793	197,134
	Greenland Turbot - BSAI	-	-	-	-	117	1,675	78	C	3,008
	Kamchatka Flounder - BSAI	-	-	-	-	-	-	C	1,188	190
	Pacific Cod	415	6,170	6,657	4,464	1,869	900	-	11	1,454
	Pollock - bottom	C	1,888	15,301	5,296	190	3,058	4,866	6,006	38,288
	Rock Sole - BSAI	-	1,807	8,024	6,058	27,468	19,118	2,454	10,427	18,062
	Rockfish	-	C	-	-	17	-	14,408	652	92
	Yellowfin Sole - BSAI	559,559	550,261	329,488	420,528	115,127	61,049	1,268,997	636,312	441,783
PTR	Pollock - bottom	67	135	-	C	51	C	-	-	-
	Pollock - midwater	2,453	3,380	2,811	2,887	682	202	247	48	1,647

Source: NMFS Alaska Region Catch Accounting System, data compiled by AKFIN in Comprehensive_PSC [Crab_PSC_AREA(11-13-20)]
C indicates confidential data, HAL = hook and line, NPT = non-pelegic trawl, pot = pot gear, PTR = pelagic trawl

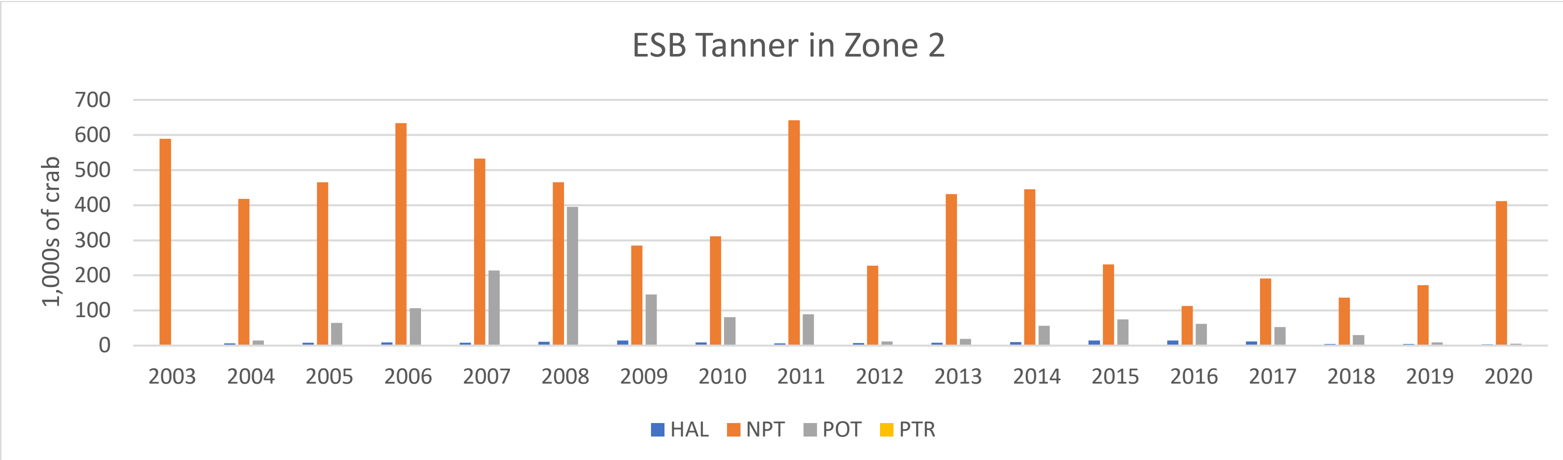
Figure and Table A3-15 Zone 1 EBS Tanner PSC usage by gear type and target species (# of crab)



EBS Tanner Zone 1	Target Species	2012	2013	2014	2015	2016	2017	2018	2019	2020
HAL	Pacific Cod	8,099	8,359	9,059	7,209	3,613	3,779	3,199	3	6
NPT	Flathead Sole	-	2,829	8,688	2,259	3,291	-	491	150	C
	Pacific Cod	3,809	4,098	10,489	5,495	9,012	8,316	2,045	3,638	1,689
	Pollock - bottom	1,389	5,689	2,947	4,820	631	1,127	109	479	280
	Rock Sole - BSAI	72,238	32,884	93,272	45,311	12,024	8,657	6,551	1,542	9,297
	Yellowfin Sole - BSAI	116,836	231,893	55,713	33,770	36,793	136,212	18,125	22,957	108,091
POT	Pacific Cod	52,520	145,231	300,177	363,300	158,554	169,857	180,870	68,654	38,547
PTR	Pollock - bottom	C	58	177	C	-	3	-	-	3
	Pollock - midwater	192	C	121	C	28	123	336	31	14

Source: NMFS Alaska Region Catch Accounting System, data compiled by AKFIN in Comprehensive_PSC [Crab_PSC_AREA(11-13-20)]
C indicates confidential data, HAL = hook and line, NPT = non-pelegic trawl, pot = pot gear, PTR = pelagic trawl

Figure and Table A3-16 Zone 2 EBS Tanner PSC usage by gear type and target species (# of crab)



Gear type	Target Species	2012	2013	2014	2015	2016	2017	2018	2019	2020
HAL	Greenland Turbot - BSAI	16	-	C	-	-	0	-	-	-
	Halibut	-	-	-	-	1	0	12	4	-
	Pacific Cod	6,831	7,863	10,141	14,495	14,206	11,893	4,193	4,543	3,538
NPT	Alaska Plaice - BSAI	C	5,497	-	-	C	-	554	C	2,645
	Arrowtooth Flounder	493	3,155	5,176	12,615	3,030	6,967	959	865	16,154
	Flathead Sole	26,076	69,325	76,496	51,306	12,187	17,970	35,087	99,020	64,501
	Greenland Turbot - BSAI	-	-	-	-	C	2,471	710	848	2,680
	Kamchatka Flounder - BSAI	-	-	-	-	-	C	-	104	C
	Other Flatfish - BSAI	C	-	-	C	-	501	C	237	C
	Pacific Cod	5,942	8,135	9,641	5,062	3,415	2,267	532	466	811
	Pollock - bottom	1,922	4,946	8,236	2,751	1,188	5,718	1,072	2,221	8,064
	Rock Sole - BSAI	C	13,709	14,498	2,313	21,112	47,487	5,050	4,925	10,382
	Rockfish	C	C	-	C	-	100	793	616	132
	Sablefish	-	-	-	-	-	-	5	-	-
	Yellowfin Sole - BSAI	190,411	326,709	330,418	156,505	70,653	107,407	91,476	162,145	301,950
POT	Pacific Cod	11,661	19,449	56,766	74,953	61,718	52,355	29,919	9,026	5,738
	Sablefish	-	C	-	-	-	C	-	C	17
PTR	Pollock - bottom	C	119	-	C	8	-	-	-	19
	Pollock - midwater	835	727	762	1,170	440	198	554	87	1,147

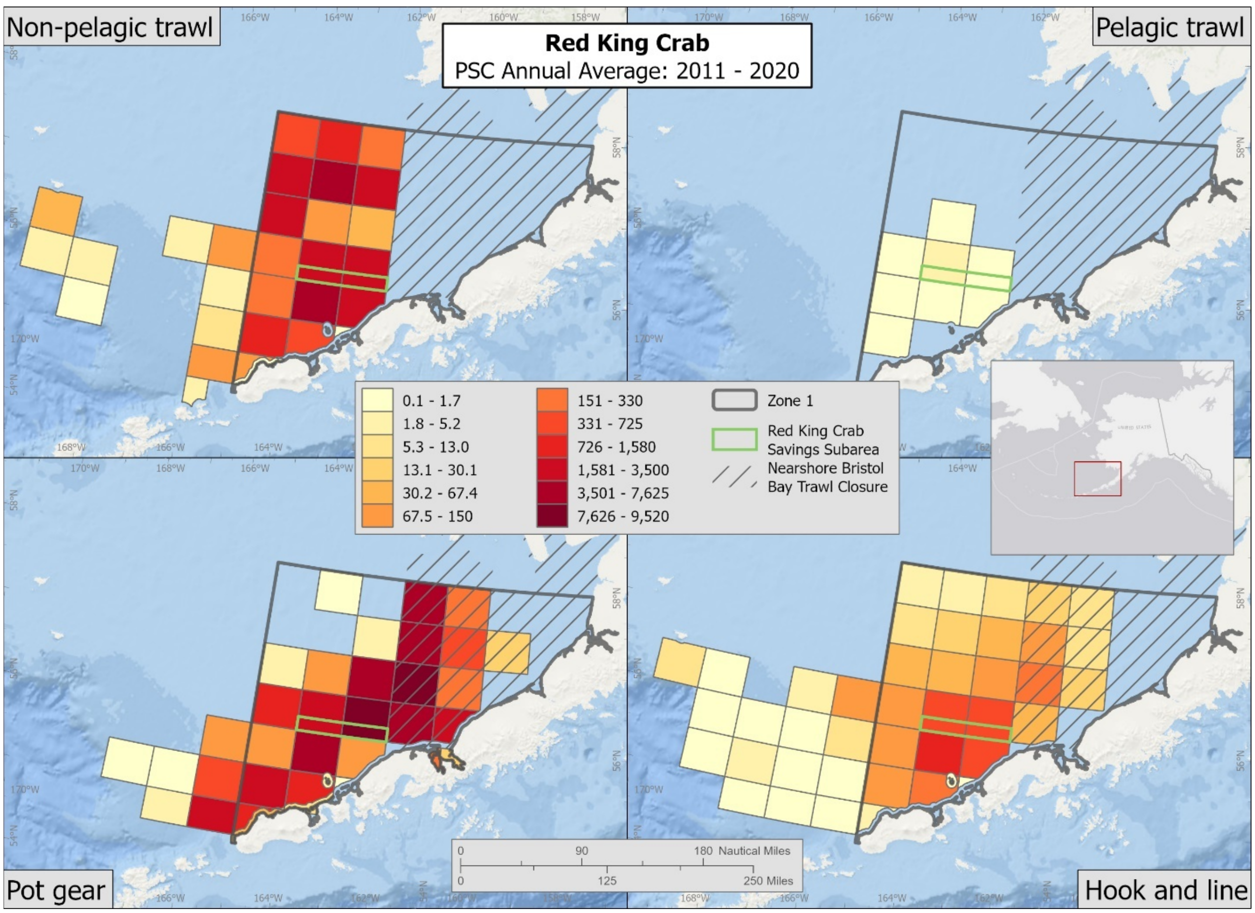
Source: NMFS Alaska Region Catch Accounting System, data compiled by AKFIN in Comprehensive_PSC [Crab_PSC_AREA(11-13-20)]

Spatial distribution of crab PSC by gear type

Additionally, Figures 29-30 show the spatial distribution of BBRKC, EBS snow, and EBS Tanner PSC in the groundfish fisheries by each gear – non-pelagic trawl (NPT), pelagic trawl, pot, and hook-and-line. These data could benefit from overlays of data on fishing effort in the directed groundfish fisheries, (as was done for EBS snow crab in NPFMC 2019c). This would allow for a further understanding of PSC CPUE in each area and spatial distribution of PSC and would show PSC distribution not influenced by effort.

For BBRKC (Figure A3-17), the majority of NPT PSC has occurred around the RKCSS and the northwest portion of Zone 1, and to a lesser extent in the rest of Zone 1 (excluding the NBBTC). BBRKC PSC has also occurred south and southeast of St. George in the NPT gear. BBRKC PSC in pot gear is distributed throughout Zone 1, running parallel to the Aleutian peninsula. Pelagic trawl and hook-and-line PSC of BBRCK is limited and the majority has occurred surrounding the RKCSS.

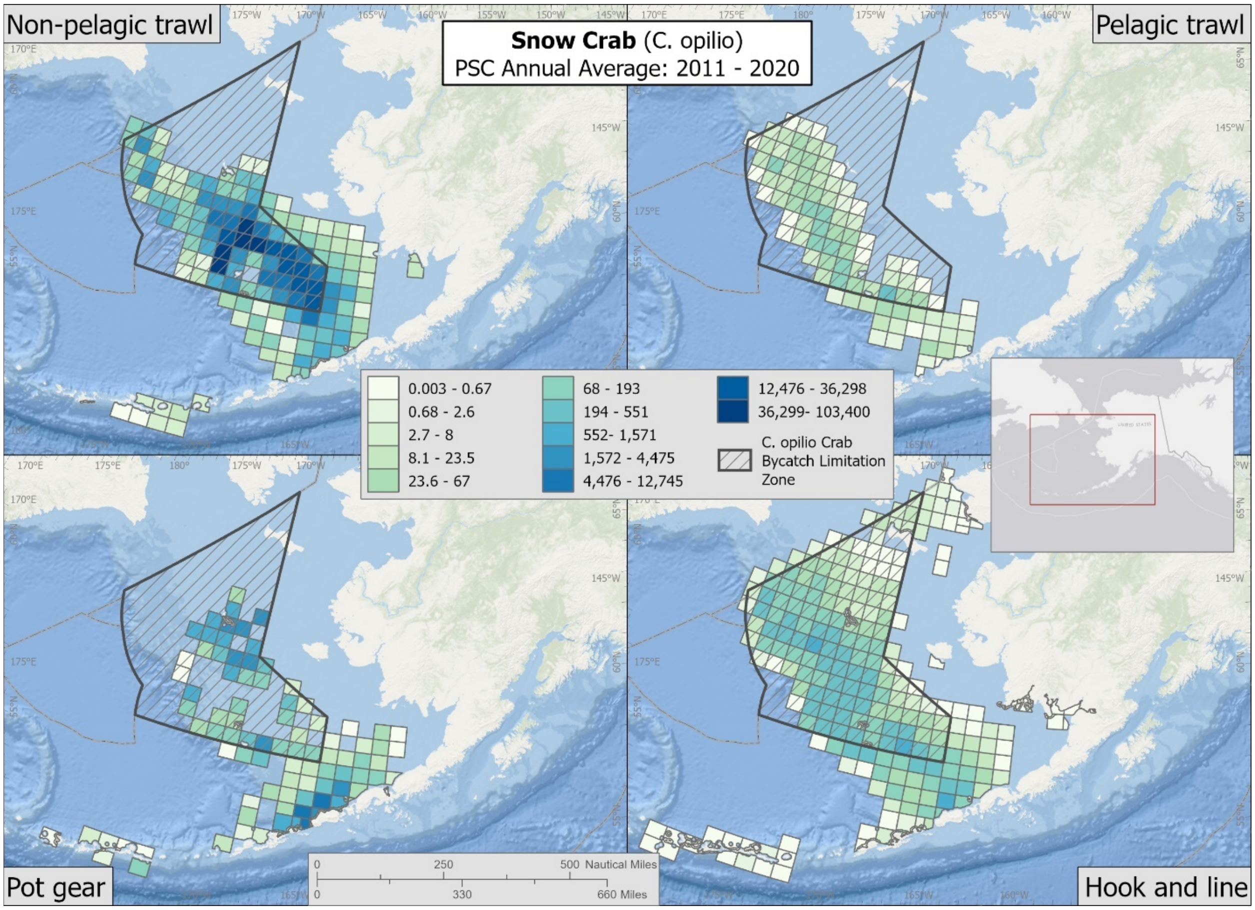
Figure A3-17 BBRKC PSC (average annual #crab) by gear type, 2011-2020.



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

For snow crab (Figure A3-18), 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. 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.

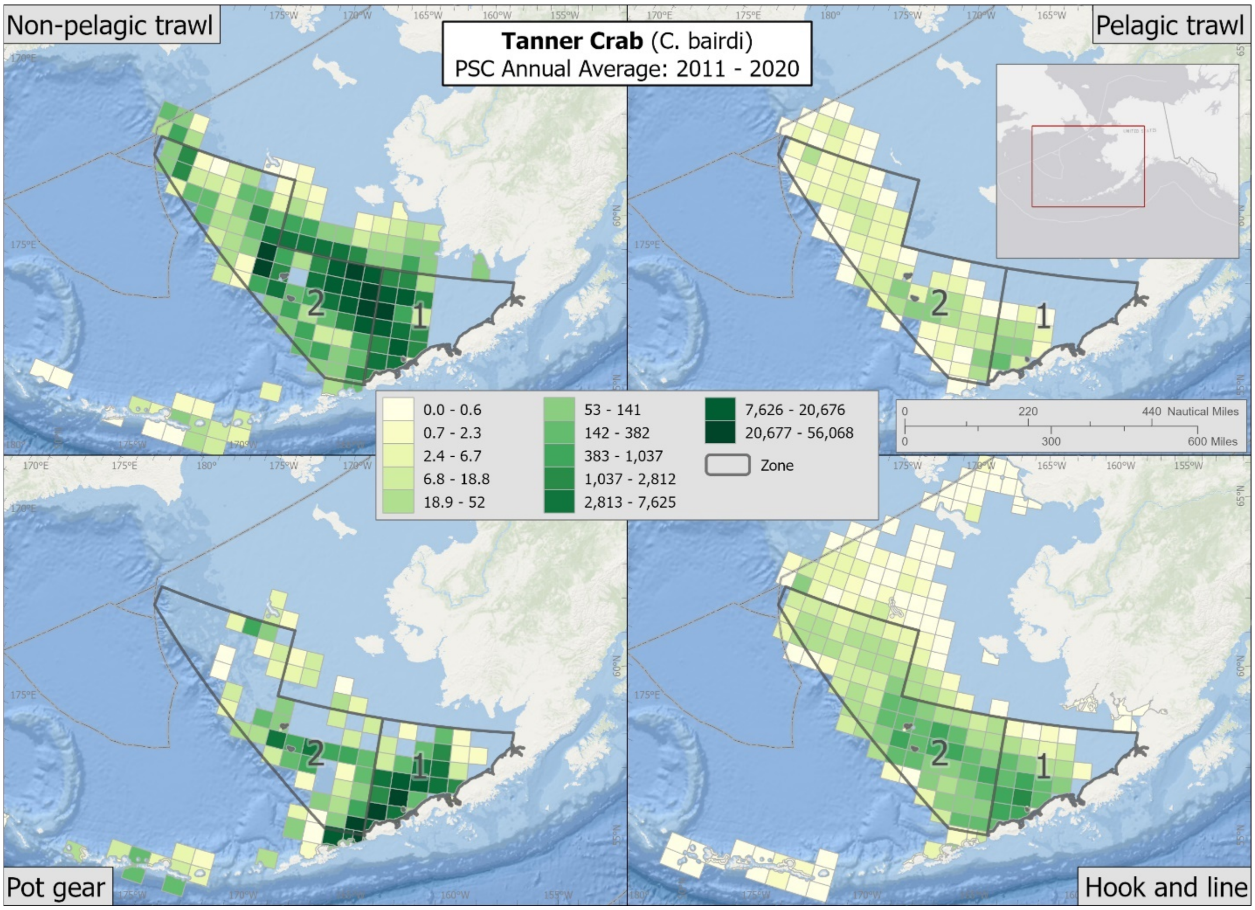
Figure A3-18 EBS snow crab PSC (average annual #crab) by gear type, 2011-2020



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

For Tanner crab, the areas of the highest annual averages of PSC occur in pot gear in the area north of Unimak Island and northeast along the Aleutian peninsula. In NPT gear, the highest annual averages of PSC are north/northwest of the Pribilof Islands and along the borders of Zone 1 and Zone 2. Tanner crab PSC in pelagic trawl gear is distributed throughout Zone 2, near the Pribilof Islands, and is mostly concentrated north of Unimak Island in Zone 1. Tanner crab PSC in HAL gear is throughout and extends beyond Zone 2, mostly in the southern half of the Zone, and high north of Unimak Island in Zone 1 extending to the northern boundary though diminishes along the boundary line.

Figure A3-19 EBS Tanner crab PSC (average annual #crab) by gear type, 2011-2020.



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

Appendix 4 Sensitivity Analyses

A4.1. Impacts of Assumed Crab Bycatch Levels in Groundfish Fisheries on Estimated Mature Male Biomass for Bristol Bay Red King Crab

Jie Zheng
ADF&G

A4.1.1 Approaches

Two approaches are used to examine the impacts of assumed groundfish fisheries bycatch levels on estimated mature male biomass for Bristol Bay red king crab. First, I increased the trawl and fixed gear bycatch biomass by 100%, 200%, 500%, and 1000% of the observed biomass and ran model 19.3 (CPT recommended for 2020) for each level of the bycatch. All parameters are estimated for this approach. Second, all estimated parameters were fixed at the estimated values with the observed bycatch biomass level except for all fishing mortality parameters. All fishing mortality parameters are estimated for above four levels of assumed bycatch biomass. To make everything be equal, I also re-estimated all fishing mortality parameters for the observed bycatch biomass level for the second approach. The first approach has the impacts of parameter interactions, and the second approach produces pure impacts of increased bycatch biomass on crab mature male biomass.

A4.1.2 Results

The results are summarized as:

1. Estimated *F35%* and *Fofl* values increase and terminal MMB decreases when the bycatch biomass increases under both approaches (Tables 1 and 2). The decrease in the terminal MMB is larger for the second approach than for the first approach (Tables 1 and 2; Figures 1 and 2).
2. OFL values increase under the first approach and generally decrease under the second approach when the bycatch biomass increases (Tables 1 and 2), although the OFL value with 1000% increased bycatch biomass increased slightly for the second approach.
3. Terminal MMB and OFL values do not change much if bycatch biomass is just doubled or less (<3% for terminal MMB) (Tables 1 and 2). Estimated MMB over time also does not change much if bycatch biomass is just doubled or less (Figures 1 and 2). When bycatch biomass increases by 500% or more, estimated MMB values in the terminal years for the second approach could decrease about 14% or more (Table 2; Figure 2); the decreases might be much larger for some years (Figure 2).

Table 1. Compairsions of $MMB_{35\%}$, MMB-terminal, %change of MMB-terminal relative to the base model, $F_{35\%}$, F_{OFL}, OFL, and survey catchability Q among four scenarios of increasing bycatch. These are results from the first approach. Model 19.3 is the base model for the first approach, the original model in May 2020, and percentages in the first row are assumed increased bycatch biomass percentages.

	19.3	19.3-100%	19.3-200%	19.3-500%	19.3-1000%
Mean R (million)	16.480	16.622	16.648	17.155	18.116
$MMB_{35\%}$ (t)	25705.71	25971.60	26303.06	27269.78	29060.73
MMB-terminal (t)	14757.65	14611.62	14443.01	14093.02	13585.89
%change	0.00%	-0.99%	-2.13%	-4.50%	-7.94%
$F_{35\%}$	0.305	0.308	0.311	0.322	0.341
F_{OFL}	0.167	0.170	0.173	0.187	0.217
OFL (t)	2155.37	2170.91	2176.28	2243.08	2482.75
Q-1982-now	0.950	0.951	0.955	0.948	0.935

Table 2. Compairsions of $MMB_{35\%}$, MMB-terminal, %change of MMB-terminal relative to the base model, $F_{35\%}$, F_{OFL}, OFL, and survey catchability Q among four scenarios of increasing bycatch. These are results from the first approach. Model 19.3-0 is the base model for the second approach, fixed all estimated parameters from model 19.3 except for all fishing mortality parameters, and percentages in the first row are assumed increased bycatch biomass percentages.

	19.3-0	19.3-0-100%	19.3-0-200%	19.3-0-500%	19.3-0-1000%
Mean R (million)	16.480	16.480	16.480	16.480	16.480
$MMB_{35\%}$ (t)	25705.71	25705.71	25705.71	25705.71	25705.71
MMB-terminal(t)	15073.83	14654.83	14240.97	13014.80	11053.46
%change	0.00%	-2.78%	-5.53%	-13.66%	-26.67%
$F_{35\%}$	0.304	0.307	0.310	0.320	0.341
F_{OFL}	0.169	0.170	0.171	0.178	0.204
OFL (t)	2282.86	2239.65	2205.68	2154.87	2206.91
Q-1982-now	0.950	0.950	0.950	0.950	0.950

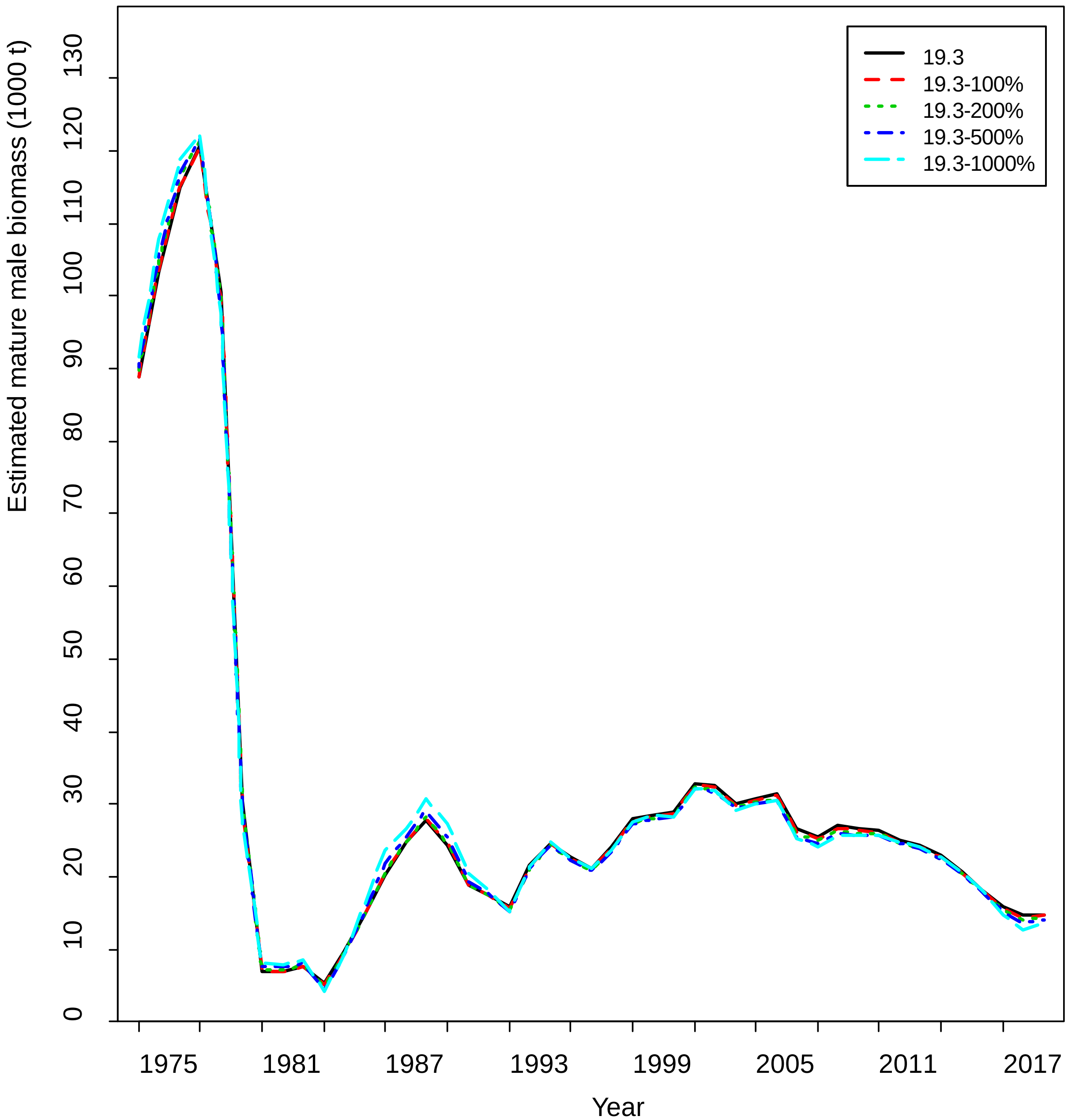


Figure 1. Estimated mature male biomass over time with four levels of assumed groundfish fisheries bycatch biomass under model 19.3 for the first approach. Mature male biomass is not shown for years 1975-1979 for a better scale.

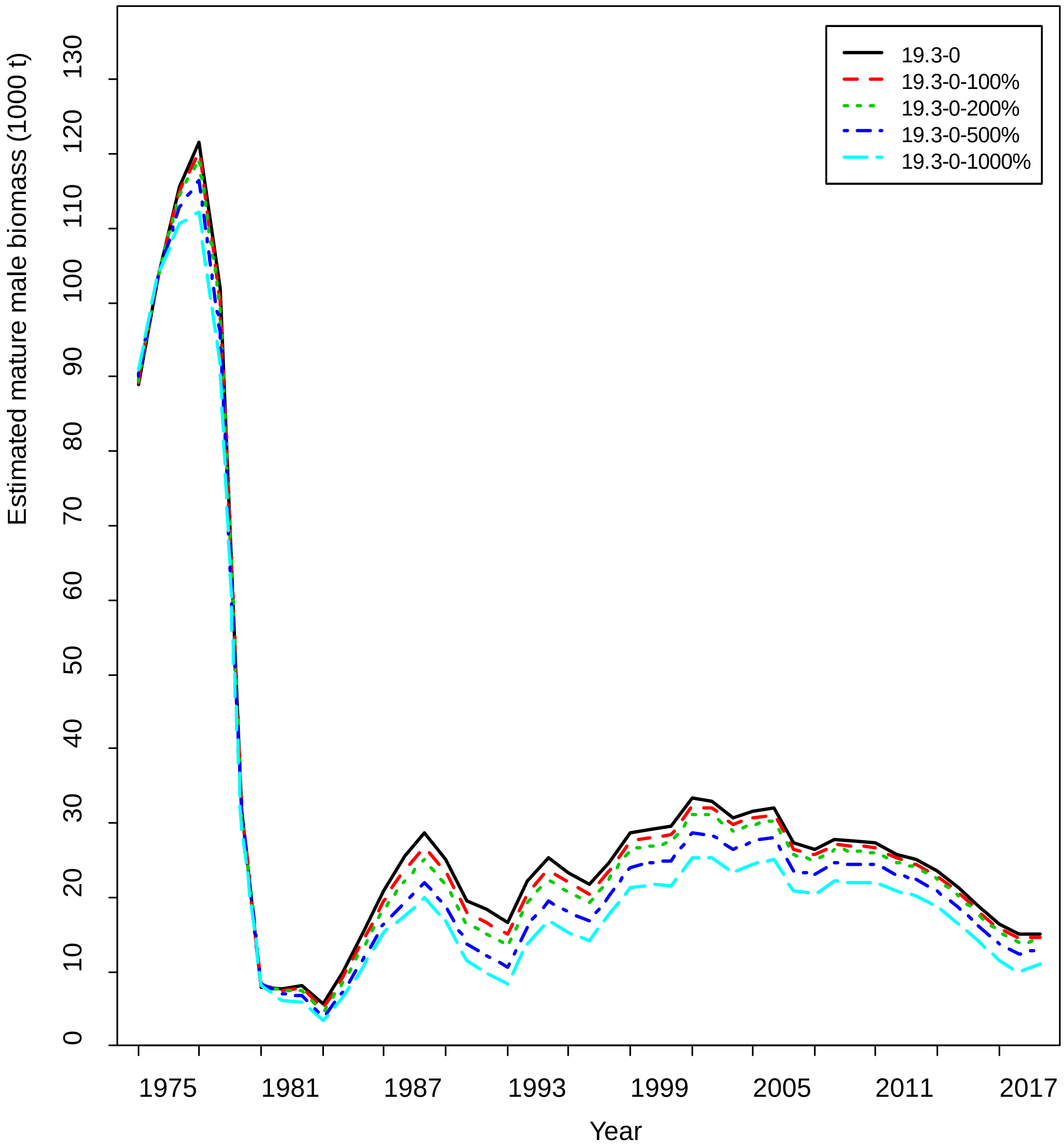


Figure 2. Estimated mature male biomass over time with four levels of assumed groundfish fisheries bycatch biomass under model 19.3 for the second approach. Mature male biomass is not shown for years 1975-1979 for a better scale.

A4.2. Tanner Crab Simulations: Effects of Bycatch in the Groundfish Fisheries

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Alaska Fisheries Science Center

November 2020

A4.2.1 Introduction

Sarah Marrinan and Sara Cleaver (North Pacific Fishery Management Council staff) presented information to the Crab Plan Team at its May 2020 meeting on a proposed Council action to change crab PSC (Prohibited Species Catch) limits in the groundfish fisheries to the lowest possible level when the directed crab fishery is closed. There are currently area PSC limits in place for Bristol Bay red king crab, Tanner crab, and snow crab for groundfish vessels using trawl gear. The current limits are rarely exceeded, and even if they were set at the lowest level would rarely be constraining. Council staff asked the CPT about the importance of bycatch in crab population dynamics. Currently there is very little crab bycatch in groundfish fisheries compared to the directed fisheries (~300 t/year average since 2010 across all groundfish fisheries), although rates have been substantially larger in the past (~9,000 t/year in the 1970s, 1,600 t/year in the 1990s). However, it was noted that there is very little information on the unobserved mortality of crab species. Thus, Council staff asked if assessment authors could examine the effects of increased bycatch on model results. In furtherance of this request, the Crab Plan Team (CPT) requested at its May 2020 meeting that:

> "Assessment authors should rerun the assessments for BBRKC, Tanner crab, and snow crab with higher assumed levels of bycatch abundance (increases of 50% and 100%) as a sensitivity analysis. These should be provided to Council staff within the next two months for inclusion in the October Council document."

A report addressing this issue for Tanner crab using the 2019 assessment model (19.03) was presented by Council staff at the Fall 2020 CPT and Council's SSC (Science and Statistical Committee) meetings. The results suggested the impact on Tanner crab population dynamics of even a 100% increase in PSC bycatch would be negligible. The It was then suggested that the analysis be re-run with increases in bycatch of 100%, 200%, 500%, and 1000% in order to detect the level at which the dynamics would be affected. This report addresses this updated request for Tanner crab using the accepted 2020 assessment model (20.07).

A4.2.2 Methods

As discussed in the earlier report, the request by the CPT in May to "rerun" the 2019 assessments with different levels of PSC did not address the issue of interest, which is "what effect would different levels of PSC have on the stock?"; rather, it addressed issues related to uncertainty in the model and effects on the assessment due to potential biases in the observed PSC bycatch, i.e. "how sensitive are the model results to mis-estimating the level of bycatch?". This is because "rerunning" the assessment with different levels of PSC involves re-estimating *all* model parameters, including those reflecting strictly biological processes. Here, following the earlier report, the attempt is to address the first question. This was done by using the estimated parameters for the biological processes (i.e., recruitment, natural mortality, growth, and molt-to-maturity) governing the Tanner crab stock in the 2020 assessment (model 20.07) as an "operating model" for the population in the absence of fishing mortality. The assessment model was then re-run for a set of scenarios with different levels of PSC bycatch. For each scenario, only fishery-related parameters (fishery capture rates, retention rates, and selectivity and retention curves) were estimated by fitting to the fishery data (catch biomass and size compositions). Retained and total annual catch data, as well as associated size compositions, were the same across all scenarios for the directed fishery, the snow crab fishery, and the Bristol Bay red king crab fishery, but varied by scenario with the assumed bycatch (PSC) in the groundfish fisheries.

Four "PSC" scenarios were considered at the request of Council staff. These assumed Tanner crab bycatch in the groundfish fisheries increased by 100%, 200%, 500%, and 1000% respectively (Figure 1).

A4.2.3 Results

The resulting time series for recruitment and various components of population biomass (including mature male biomass) are compared among the four PSC scenarios and the 2020 assessment in Figures 2 and 3. Recruitment was identical across all the scenarios because it is modeled as independent of stock size (Figure 2). Scenarios +100% and +200% indicate increases in bycatch in the groundfish fisheries of 100% and 200% would have little effect on Tanner crab stock dynamics and biomass trajectories across the entire time series (Figure 3). An increase to 500% in groundfish bycatch (Scenario +500%) resulted in a temporarily large effect on mature biomass during the mid-to-late 1970s, with mature male biomass (MMB) reduced by up to 28% compared with the assessment results (20.07), but the stock recovered by 1990 and average MMB during 2010-2020 was only 5% less than in the assessment. Not surprisingly, the effects were larger under the +1000% scenario, with MMB reduced up to 55% in the mid-1970s and by an average of 11% during 2010-2020.

The effects on OFL-related quantities as would have been determined for the 2020 assessment are illustrated in Table 1. As one should expect, average recruitment, B_{100}, and B_{MSY} are identical in all scenarios because these quantities do not depend on fishery-related quantities. Differences in the other quantities with respect to the 2020 assessment were generally quite small for the +100% and +200% scenarios when compared to the 2020 assessment results (< 2% smaller for current MMB and OFL). Differences for the +500% and +1000% scenarios were somewhat larger, with current MMB 6,000 t (9%) less and OFL 3,400 t (16%) less under the +1000% scenario.

A4.2.4 Discussion

Given current levels of groundfish observer coverage, it seems highly unlikely that actual PSC for Tanner crab in the groundfish fisheries is 5 or 10 times higher than that estimated by the Regional Office from observer data. Based on the simulation analysis reported here, even fairly large relative changes (at least a 200% increase) in assumed levels of Tanner crab bycatch in the groundfish fisheries appear to have little effect on stock dynamics and biomass trajectories. Indeed, an increase of 500% results in relatively small differences in recent (post-2010) biomass trajectories for all components of the stock (< 5% smaller).

Only the 1000% increase scenario considered here resulted in moderately decreased MMB during the last decade (~9%) when compared with the assessment.

These results also hold for current status and OFL, except that their proper interpretation needs to be based on a comparison between the assessment results and the PSC scenario, *with the PSC scenario regarded as truth*. Thus, if PSC were really 10 times larger than estimated (Scenario 1000%), MMB would have been *over*-estimated in the 2020 assessment by 9% and the OFL would have been set 15% *too high* relative to the "truth" (i.e., the OFL from Scenario 1000%). Under this scenario, if the OFL estimated by the assessment model using underestimated PSC were taken next year, then overfishing would occur relative to the (unknown) "true" OFL. Presumably such overfishing would continue into the near future (~2-3 years) if the "true" PSC continued to be underestimated, and current MMB would be fished down and approach B_{MSY}. However, the target biomass reference point, B_{MSY}, for a Tier 3 stock such as Tanner crab is based on unfished equilibrium considerations (i.e., $B_{MSY} = 0.35 \, x \, B_{100}$)—which do not depend on fishery characteristics or catch levels—and thus B_{MSY} is the same under all the scenarios considered here. Because the kink in the OFL control rule would decrease fishing mortality rates below F_{MSY} when current MMB eventually fell below B_{MSY}, this would allow the stock to rebuild back toward B_{MSY} (the exact trajectory would depend on recruitment, of course). Thus, even under an extreme scenario in which PSC is underestimated by a factor of 10, current management is such that the stock seems unlikely to become "overfished" at some point in the future.

Tables

Table 1. Comparison of results from the PSC scenarios for quantities related to status determination and OFL as determined for a "2020" assessment. Results for 20.07 are from the actual 2020 assessment.

Scenario	Avg. Recruitment (millions)	B100 (1000's t)	Bmsy (1000's t)	current MMB (1000's t)	Fmsy	MSY (1000's t)	Fofl	OFL (1000's t)	Projected MMB (1000's t)	status ratio
20.07	374.43	105.05	36.77	66.87	0.98	16.94	0.94	21.13	35.33	0.961
100%	374.43	105.05	36.77	66.62	0.97	16.92	0.93	21.00	35.28	0.959
200%	374.43	105.05	36.77	66.20	0.96	16.91	0.92	20.77	35.18	0.957
500%	374.43	105.05	36.77	64.25	0.93	16.87	0.87	19.69	34.68	0.943
1000%	374.43	105.05	36.77	60.68	0.87	16.84	0.79	17.80	33.69	0.916

Figures

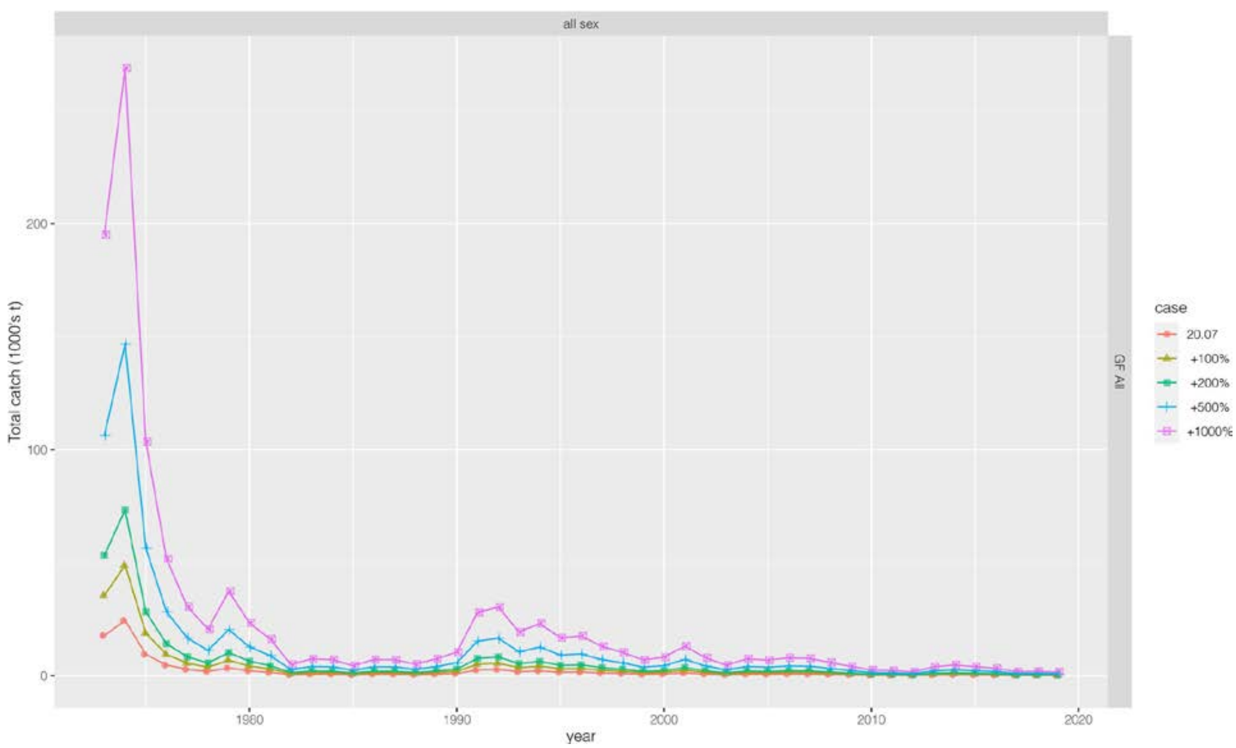

Figure 1. The recruitment time series for each scenario (all are identical).

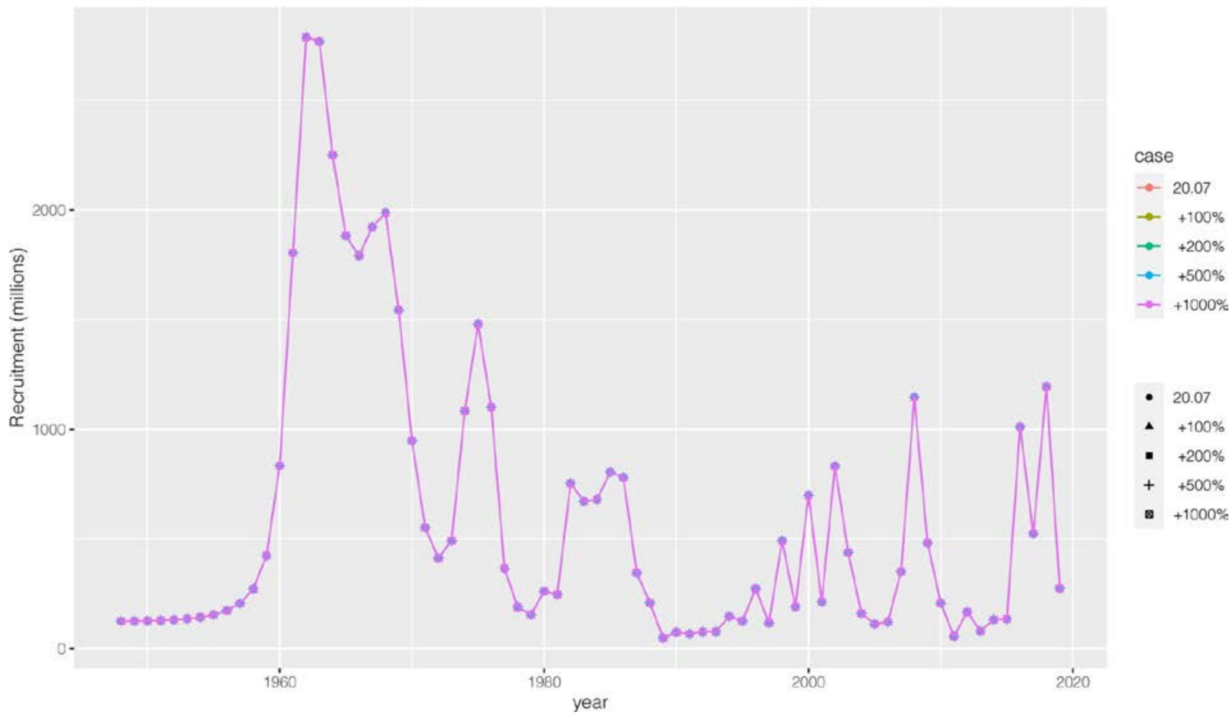

Figure 2. The recruitment time series for each scenario (all are identical).

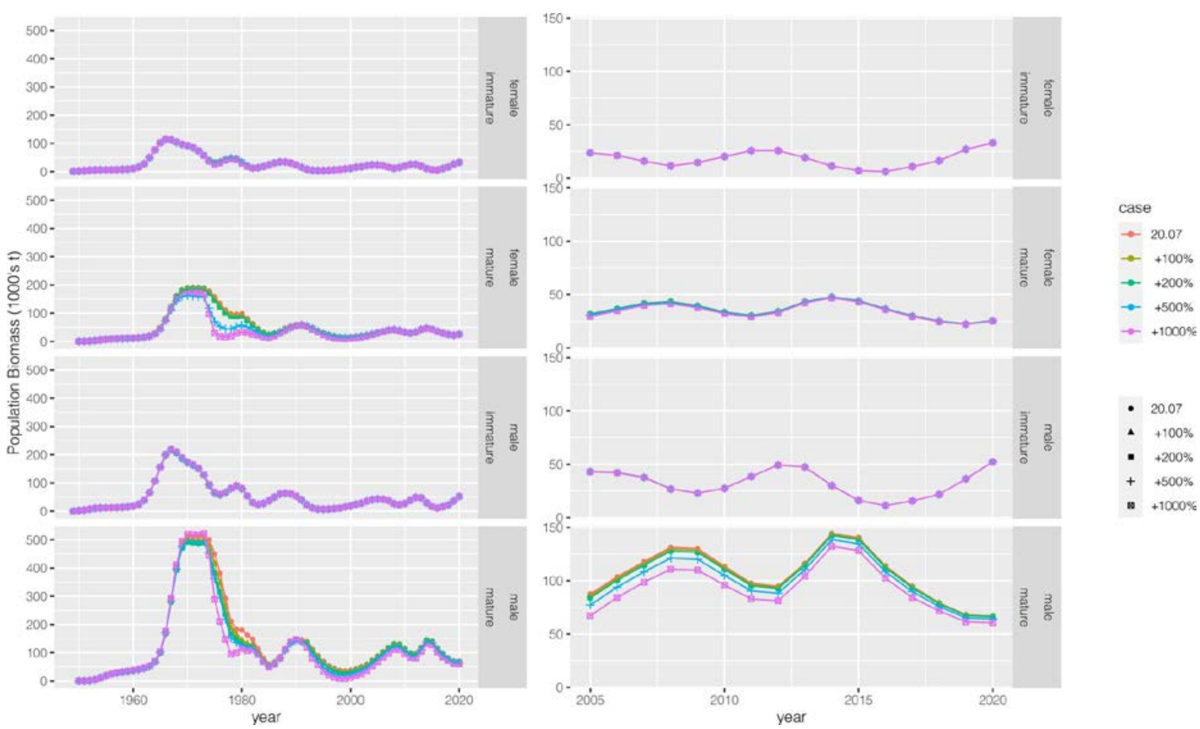

Figure 3. Comparison of time series of various population components from the PSC scenarios. Graphs in the lefthand column cover the entire model time period; graphs in the righthand column focus on the last 15 years.

A4.3. Snow crab simulations: effects of bycatch in the groundfish fisheries

Cody Szuwalski
July 2020

A4.3.1 Introduction

Sarah Marrinan and Sara Cleaver (North Pacific Fishery Management Council staff) presented information to the Crab Plan Team at its May 2020 meeting on a proposed Council action to change crab PSC (Prohibited Species Catch) limits in the groundfish fisheries to the lowest possible level when the directed crab fishery is closed. There are currently area PSC limits in place for Bristol Bay red king crab, Tanner crab, and snow crab for groundfish vessels using trawl gear. The current limits are rarely exceeded, and even if they were set at the lowest level would rarely be constraining. Council staff asked the CPT about the importance of bycatch in crab population dynamics. Currently there is very little crab bycatch in groundfish fisheries compared to the directed fisheries. However, it was noted that there is very little information on the unobserved mortality of crab species. Thus, Council staff asked if assessment authors could examine the effects of increased bycatch on model results. Consequently, the Crab Plan Team (CPT) requested at its May 2020 meeting that:

"Assessment authors should rerun the assessments for BBRKC, Tanner crab, and snow crab with higher assumed levels of bycatch abundance (increases of 50 and 100%) as a sensitivity analysis. These should be provided to Council staff within the next two months for inclusion in the October Council document."

This report addresses this request for snow crab.

A4.3.2 Methods

The methodology implemented here departs slightly from what the CPT requestions. The model was rerun with three bycatch scenarios in which the entire time series of historical bycatch was 100%, 200%, 500%, and 1000% larger. In these simulations, all parameters governing biological processes (e.g. recruitment, natural mortality, growth, maturity) were specified to the values estimated in the 2019 assessment. Most parameters governing fisheries selectivity were also fixed. Fishing mortality associated with the directed fishery, discards in the directed fishery and bycatch were the only parameters estimated when the model was rerun. All fishing mortalities were estimated to ensure that all input data sources of catch could be fit. Selectivities were not changed because changes in the selectivities can result in changes in the fishing mortality reference points.

A4.3.3 Results

Increases in bycatch resulted in a general scaling down of estimated mature male biomass (MMB) at the time of the survey (Figure 1). Females were not affected because the selectivity of the bycatch 'fleet' in the model generally excludes them from mortality (Figure 2). Estimated bycatch fishing mortality increased predictably with increases in the input bycatch (Figure 2). Notably, the estimated directed fishing mortality also increased when bycatch mortality increased (most drastically for the 1000% increase), likely as a result of less standing biomass supporting fixed catches.

The translation of these changes to most management quantities was also predictable (Table 1). Terminal year MMB decreased with increasing bycatch. B35% did not change because the biological processes deter- mining it were fixed. F35% decreased as bycatch levels increased because the variable portion F35% is only related to the directed fishery–discard and bycatch are specified as the average fishing mortalities for each process in the projections that calculate the reference points. As the 'expected' bycatch increases (which is determined by input levels in the scenarios presented), the fishing mortality allowed in the directed fishery has to decrease to compensate in calculations of F35%.

The changes in the overfishing level (OFL) were less intuitive. As bycatch increased, the OFL also increased, but only until the +500% bycatch scenario, afterwhich (the +1000% bycatch scenario). The OFL is calculated as the sum of the retained catch and mortality associated with discards in the directed fishery and bycatch elsewhere. So, the decreases in the retained portion of the OFL resulting from decreases in the FOFL were outpaced by the increases in the portion of the OFL allocated to bycatch.

An explanation for increases in the OFL with increases in bycatch relates to the selectivity of the bycatch– a fraction of the bycatch is not mature (Figure 2). The harvest control rule only considers MMB when calculating the FOFL, but the F allocated for bycatch is fixed and does not consider the amount of MMB (or immature biomass) available. So, as the F allocated to bycatch increases, increases in the contribution of bycatch to the OFL that is immature are possible. Increases in the amount of immature crab caught do not impact the MMB, so the OFL can increase as bycatch increases without impacting the 'status' of the fishery. This issue could be exacerbated by the large recruitment class coming through the population.

A4.3.4 Discussion

Based on these analyses, if a fraction of bycatch mortality has been unobserved and unaccounted for in the assessment, this would unsurprisingly have had the biggest impact during the period when bycatches were largest (e.g. the mid 1990s through the mid 2010s). In the most recent years, bycatch has been small enough that increasing the bycatch input by 1000% resulted in only a ~2% change in the terminal year of MMB. Given the manner in which the OFL increases with increasing bycatch, it might be useful to reconsider how immature bycatch is treated in the harvest control rule, particularly if bycatch was much higher than they have been in the recent past. However, the impact of this issue when bycatch levels are low (as they have been) is negligible.

Tables

Table 1: Changes in management quantities for each scenario con- sidered. Reported management quantities are derived from maxi- mum likelihood estimates.

Model	MMB	B35	F35	FOFL	OFL
Status quo	105.03	123.09	1.77	1.77	51.31
+100% bycatch	104.76	123.10	1.76	1.76	51.37
+200% bycatch	104.52	123.10	1.75	1.75	51.43
+500% bycatch	103.71	123.10	1.72	1.72	51.50
+1000% bycatch	102.38	123.10	1.69	1.69	51.43

Figures

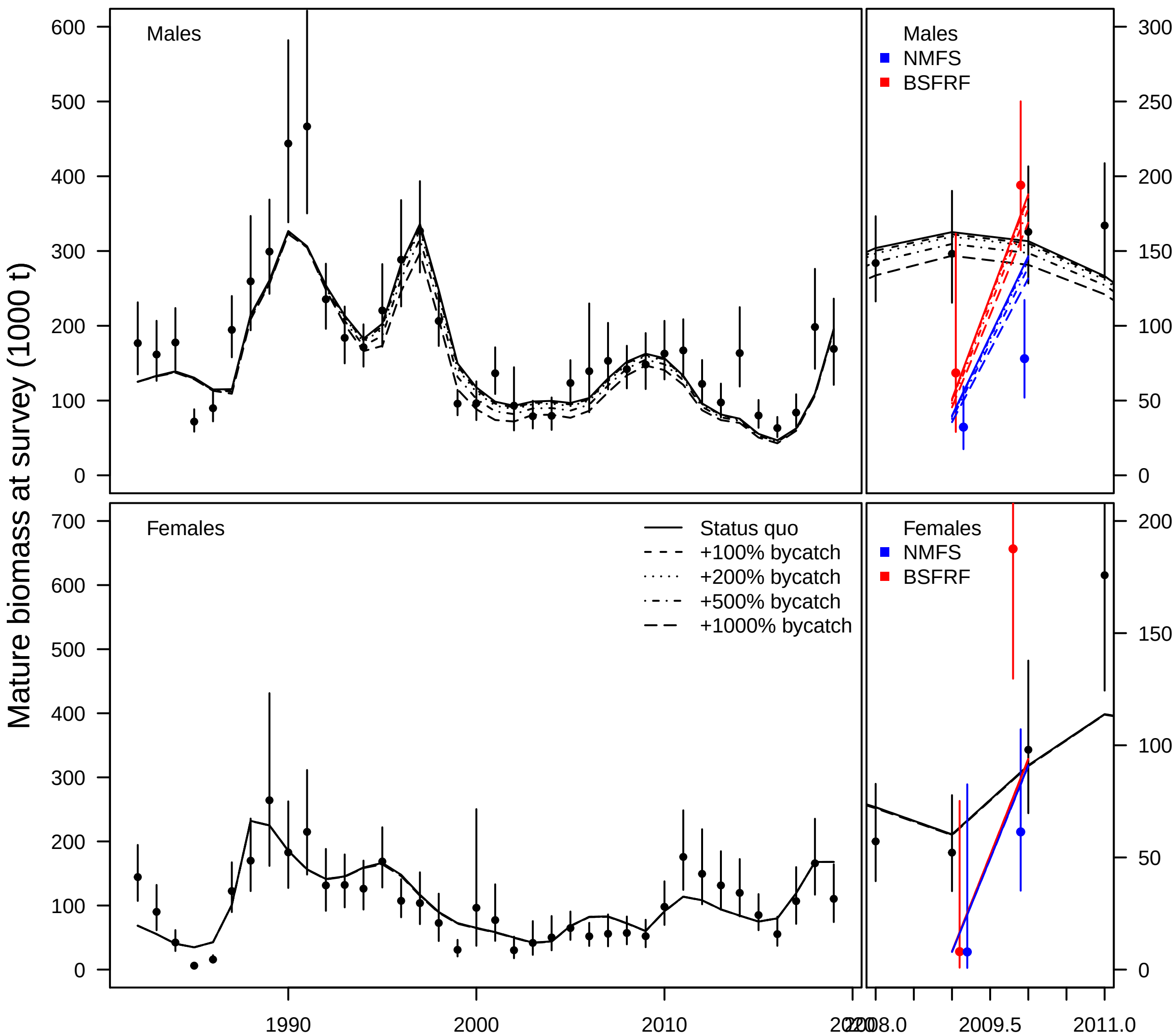

Figure 1: Model fits to the observed mature biomass at survey

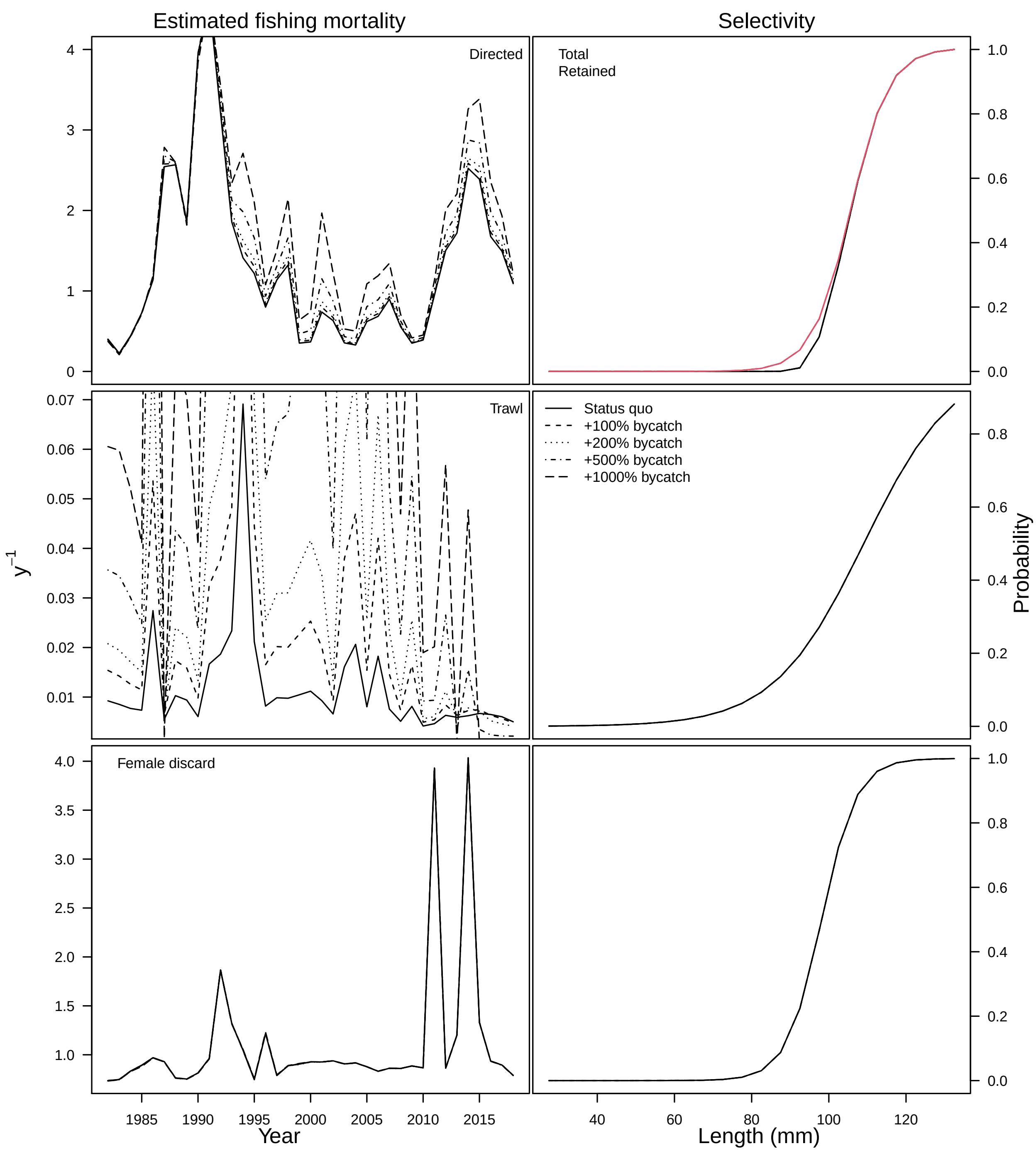

Figure 2: Model predicted fishing mortalities and selectivities for all sources of mortality