FINAL ENVIRONMENTAL ASSESSMENT

For

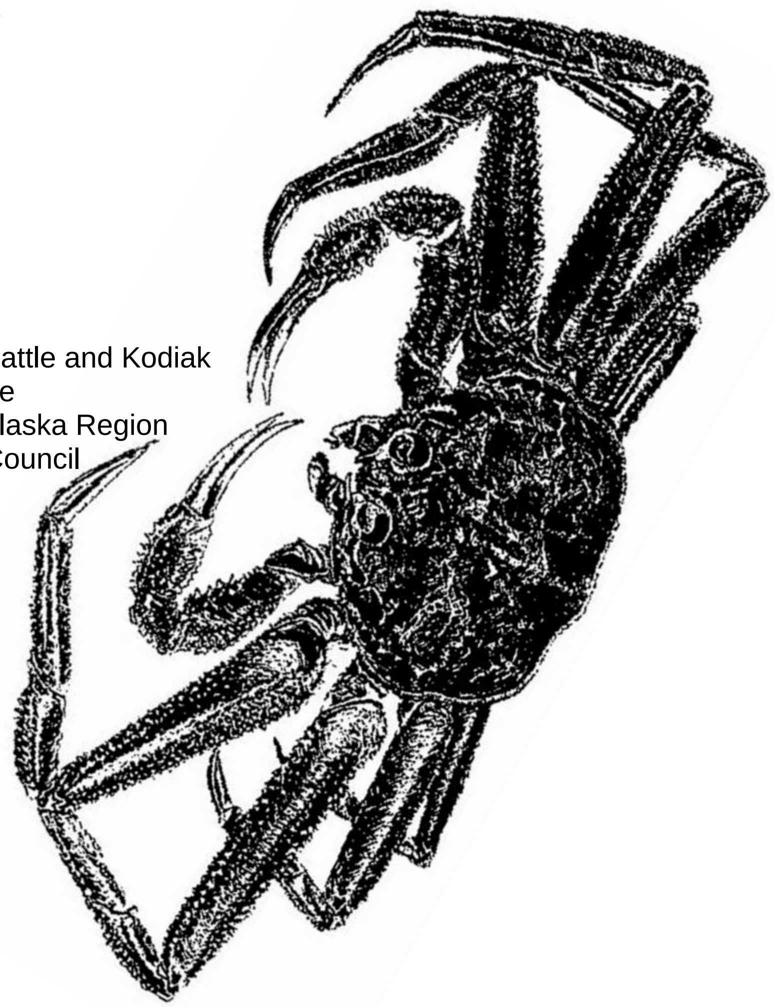
Amendment 24

To the Fishery Management Plan for

Bering Sea/Aleutian Islands
King and Tanner Crabs

to

Revise Overfishing Definitions



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Abstract: The Magnuson-Stevens Act Fishery Conservation and Management Act requires Fishery Management Plans to contain objective and measurable criteria for determining whether a stock is overfished or whether overfishing is occurring. The proposed action would amend the Fishery Management Plan for Bering Sea/Aleutian Islands King and Tanner Crabs (FMP) to establish overfishing definitions that contain objective and measurable criteria for each managed stock. The proposed action would also remove twelve state-managed stocks from the FMP. This Environmental Assessment provides decision makers and the public with an evaluation of the environmental, social, and economic effects of alternative overfishing definitions and removing specific stocks from the FMP. This document addresses the requirements of the National Environmental Policy Act.

5/30/2008

EXECUTIVE SUMMARY

The king and Tanner crab fisheries in the Exclusive Economic Zone (3 to 200 miles offshore) of the Bering Sea and Aleutian Islands (BSAI) off Alaska are managed under the Fishery Management Plan for Bering Sea/Aleutian Islands King and Tanner Crabs (FMP). The FMP establishes a State/Federal cooperative management regime that defers much of the management of the BSAI crab fisheries to the State of Alaska with Federal oversight using the following three categories of management measures:

1. Those that are fixed in the FMP and require an FMP amendment to change;
2. Those that are framework-type measures that the State can change following criteria set out in the FMP; and
3. Those measures that are neither rigidly specified nor frameworked in the FMP and are at the discretion of the State.

The proposed action is to establish overfishing levels (OFLs) that provide objective and measurable criteria for identifying when a BSAI crab fishery is overfished or when overfishing is occurring, in compliance with the Magnuson-Stevens Fishery Conservation and Management Act (Magnuson-Stevens Act). Section 303(a)(10) of the Magnuson-Stevens Act requires that FMPs specify objective and measurable criteria for identifying when the fishery is overfished (with an analysis of how the criteria were determined and the relationship of the criteria to the reproductive potential of the stock). The OFLs are a Category 1 measure in the FMP. As such, revisions to the OFLs require an FMP amendment.

Determinations of total allowable catches (TACs) and guideline harvest levels (GHLs) are a Category 2 management measure and are deferred to the State following the criteria in the FMP. Catch levels established by the State must be in compliance with OFLs established in the FMP to prevent overfishing. As described in Chapter 2, NMFS annually determines if total catch levels exceed OFLs or if stocks are overfished or are approaching an overfished condition. If either of these occurs, NMFS notifies the North Pacific Fishery Management Council (Council) and the Council must immediately end overfishing and develop an FMP amendment to rebuild the stock within two years.

Purpose and Need

Chapter 1 describes the proposed action and its purpose and need. The purpose of the proposed action is to establish status determination criteria in compliance with the Magnuson-Stevens Act and the national standard guidelines. The current OFLs were implemented under Amendment 7 to the FMP in 1998. In the environmental assessment (EA) for that amendment, the Crab Plan Team stated its intent to review the definitions after 5 years or when environmental conditions have changed such that revising the definitions may be necessary.

The need for the proposed action is explained in the Crab Plan Team's problem statement:

> *New overfishing definitions are necessary to reflect current scientific information and accomplish the following:*
>
> - *Provide an FMP framework for definition values to facilitate use of the best available scientific information as it evolves.*
> - *Provide a new tier system that accommodates varying levels of uncertainty of information and takes advantage of alternative biological reference points.*
> - *Define the status determination criteria and their application to the appropriate component of the population.*

Alternatives

Chapter 2 describes and compares the three alternatives and two sets of options. The alternatives and options analyzed in this EA are consistent with the Magnuson-Stevens Act and the national standard guidelines. Chapter 2 also provides (1) a comparison of the status determination criteria under each alternative, (2) a comparison of the two options for the OFL setting and review process under Options 1 and 2, and (3) a discussion of alternatives considered and eliminated from detailed study.

Table EX-1 Alternatives and Options analyzed in this Environmental Assessment. Options 1 and 2 apply to Alternatives 2 and 3 only. Options A and B apply to all alternatives.

<table>
<tr><td>Alternative 1: Status quo</td><td>N/A</td><td rowspan="3">Option A: Remove specific stocks from FMP

Or

Option B: Status quo - no removal of stocks</td></tr>
<tr><td>Alternative 2: Five-Tier System</td><td rowspan="2">Option 1: Council annually adopts OFLs in June

Or

Option 2: Council annually reviews OFLs in the fall</td></tr>
<tr><td>Alternative 3: Six-Tier System</td></tr>
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The three alternatives are summarized as follows:

Alternative 1: **(Status Quo)** Amendment 7 provided fixed values in the FMP for the status determination criteria: minimum stock size threshold (MSST), maximum sustainable yield (MSY), optimum yield (OY), and maximum fishing mortality threshold (MFMT) for the BSAI king and Tanner crab stocks.

Alternative 2: **(Preferred)** Five-Tier System. The FMP amendment would specify (1) the five-tier system, (2) a framework for annually assigning each crab stock to a tier and for setting the OFLs (either Option 1 or 2), and (3) the crab stocks under the FMP (either Option A or B).

Alternative 3: Six-Tier System. The FMP amendment would specify (1) the six-tier system, (2) a framework for annually assigning each crab stock to a tier and for setting the OFLs (either Option 1 or 2), and (3) the crab stocks under the FMP (either Option A or B). The six-tier system would provide an OFL for stocks with sufficient catch history and, in Tier 6, set a default OFL of zero for those stocks with insufficient information from which to set an OFL, unless the SSC recommends an OFL based on the best available scientific information.

The status determination criteria provided in Alternative 1 are fixed in the FMP and reflect the understanding of crab biology and abundance at the time that Amendment 7 was adopted. Alternatives 2 and 3 were designed to incorporate new scientific information and provide a mechanism to continually improve the status determination criteria as new information becomes available. Alternatives 2 and 3 use a tier system that accommodates varying levels of uncertainty of information and takes advantage of alternative biological reference points in setting the OFLs. The OFLs established under these alternatives would be specified for the appropriate component of the population.

The Alaska Fisheries Science Center (AFSC) reviewed the preferred Alternative 2 overfishing definitions for compliance with guidelines provided for National Standards 1 and 2 in 50 CFR part 600. On February

14, 2008, the AFSC certified that the proposed definitions (1) have sufficient scientific merit, (2) are likely to result in effective Council action to protect the stock from closely approaching or reaching an overfished status, (3) provide a basis for objective measurement of the status of the stock against the definition, and (4) are operationally feasible.

Table Ex-2 provides a comparison of the biological reference points provided in the alternatives. Additional information on the biological reference points for individual species is contained in the chapter for that species.

Table Ex-2 Comparison of biological reference points used in the alternatives.

Biological Reference Points	Alternative 1 (Status quo)	Alternatives 2 and 3
Maximum Sustainable Yield (MSY) or MSY proxy	Average of the annually computed sustained yield (SY) over the 15-year period, 1983-1997 (SY = total mature biomass * M)	Calculated by applying F_{MSY}† or F_{MSY} proxy† in tier system to appropriate biomass estimate
MSY Biomass (B_{MSY})	Average annual estimated total mature biomass for the 15-year period, 1983-1997	Mature male biomass† at MSY level
Minimum stock size threshold (MSST)	½ B_{MSY}	½ B_{MSY}
Maximum fishing mortality threshold (MFMT or F_{OFL} control rule)	MSY control rule applied to the current total mature biomass	F_{OFL} control rule calculated by applying tier system: Tiers 1 and 2 – mean of pdf of F_{MSY} and F_{MSY} Tier 3 - F_{MSY} proxy = $F_{35\%}$† Tier 4 - F_{MSY} proxy = γ† * M
MSY control rule	M	F_{OFL} control rule
Natural mortality rate (M)	0.2 for all species of king crab 0.3 for all *Chionoecetes* species	0.18† for all species of king crab 0.23† for male and 0.29† for female *Chionoecetes* species
OFL	SY = Total mature biomass * M	Total catch OFL calculated applying F_{OFL} control rule or mean retained catch determined for a specified period
Optimum yield (OY)	OY range 0 - MSY	OY range 0 - < OFL catch

† These parameters and assumptions are frameworked in the tier system and the values used for this analysis are based on the best available scientific information. Biological parameters change with new scientific information through the OFL setting process outlined in Options 1 or 2.

Timing of OFL setting and review

The timing of the OFL determinations is important because it determines two key factors: (1) who the decision-maker can be, and (2) what information is used in the OFL determinations. Timing also impacts the level and extent of peer review and information shared with the public. The OFL setting and review process establishes (1) the placement of stocks into tiers; (2) the information utilized in the projection models for OFL determination; (3) the setting of the OFLs; and (4) the determinations of the status of the stocks relative to the OFLs. This review process includes the Council and the Scientific and Statistical Committee review for determining appropriate tiers and OFLs on an annual basis.

The timing of the OFL determinations similarly affects the fisheries for the surveyed stocks, including Bristol Bay red king crab, snow crab, Eastern Bering Sea Tanner crab, Pribilof Islands red and blue king crabs, and St. Matthew blue king crab. Stocks not subject to the NMFS annual eastern Bering Sea trawl survey are not impacted by the timing of the OFL determinations.

Options 1 and 2 establish different processes for OFL setting and review by which stocks would be annually assigned to tiers, the OFLs would be set, and the timing of the annual review process by the Crab Plan Team, Scientific and Statistical Committee, and Council.

Option 1: Council annually adopts OFLs and MSST in June. In the spring, the previous year's data would be incorporated into the model used to estimate abundances and set OFLs and MSSTs. The abundance estimates would be compared to that MSST to evaluate the whether the stock are overfished. In the fall of the following year, the catch would be compared to that OFL to determine whether overfishing occurred.

Option 2: **(Prefered)** Council annually reviews OFLs and MSSTs in the fall. Each spring, assessment models and available information would be reviewed by the Crab Plan Team and tier assignments would be recommended by the Scientific and Statistical Committee. Each fall, the summer survey data would be incorporated in to the models used to estimate biomasses and set the OFLs and MSSTs.

Crab stocks under the FMP

The FMP manages 22 crab stocks. NMFS annually surveys six of these 22 stocks. Options A and B determine the stocks managed under the FMP, and therefore, determine the stocks for which OFLs are required.

Option A: **(Preferred)** Remove from the FMP the twelve state-managed stocks for which NMFS and the Council find that the State of Alaska has a legitimate interest in the conservation and management and for which there is either no directed fishery, a limited incidental or exploratory fishery, or the majority of catch occurs in State waters.

Option B: Maintain the status quo FMP species.

Summary of the environmental consequences of the alternatives

This EA evaluates the alternatives and options for their effects within the action area. The environmental consequences of each alternative for 22 crab stocks under the FMP, crab bycatch in the groundfish and scallop fisheries, and the economy, are assessed in Chapters 4 through 12 of this EA.

This EA tiers off of the Bering Sea Aleutian Islands Crab Fisheries Final Environmental Impact Statement (Crab EIS, NMFS 2004a) to focus the analysis on the issues ripe for decision and eliminate repetitive discussions. The Crab EIS provides the status of the environment and analyzes the impacts of the crab fisheries on the human environment, including habitat, the ecosystem, non-target species, safety, and community impacts. This EA details the specific impacts of the proposed action to establish status determination criteria for the crab stocks under the FMP.

The primary impact of the preferred alternative would be to improve our understanding of the status of the managed crab stocks and to prevent overfishing by accurately determining whether a crab stock is experiencing overfishing and to determine whether a stock is overfished and requires conservation and management measures necessary to rebuilding the stock.

Bristol Bay Red King Crab

Chapter 4 analyses the effects of the alternatives on Bristol Bay red king crab. Under Alternative 1, the B_{MSY} for Bristol Bay red king crab is 89.6 million pounds of total mature biomass and the MSST is 44.8 million pounds. The 2006 total mature biomass estimate is above B_{MSY} at 157.2 million pounds. Under Alternatives 2 and 3, the Bristol Bay red king crab estimate of B_{MSY} proxy would be 77.86 million pounds of mature male biomass. For comparison, the 2006 estimate of mature male biomass for this stock is 65.54 million pounds. Thus, this stock status would be below B_{MSY} proxy under the Alternative 2 and 3, rather than above it as with Alternative 1.

Under Alternative 1, overfishing would occur when the TAC is more than the estimated sustained yield (SY). The Bristol Bay red king crab TAC for the 2006/2007 fishery was 15.5 million pounds, which is less than the 2006 SY of 31.44 million pounds. Under Alternatives 2 and 3, overfishing would be defined as any amount of catch (retained catch plus discard losses) in excess of OFL as prescribed through the tier systems described in Chapter 2. The recommended OFL control rule for the Bristol Bay red king crab stock is an $F_{35\%}$ control rule. The control rule defines the full selection fishing mortality rate to apply to the exploitable stock at any level of the egg production index or its mature male biomass proxy.

To evaluate the historic impacts of the alternatives on Bristol Bay red king crab, the analysis compares the historic harvest and abundance under Alternative 1 with the estimated values from applying the Alternative 2/3 tier system to historic data (Table 4-1). For the 10-year period from 1997 to 2006, the total catch would have exceeded the OFL in three of the 10 years.

To evaluate the short-term (30-year) and long-term (100-year) impacts of the alternatives on Bristol Bay red king crab, eleven harvest strategy scenarios were investigated to predict the changes in stock abundance levels under various harvest rates (Table 4-4 through Table 4-7). For Alternative 1, two harvest control rules were simulated to predict the possible effects of this alternative on stock biomass; the status quo harvest strategy and fishing at the status quo OFL control rule. For Alternatives 2 and 3, an evaluation was made of control rules in Tiers 2 to 5.

The Alternative 2/3 harvest control rule scenarios produced higher retained yield and lower mean rebuilding time compared to the Alternative 1 scenarios. The status quo harvest strategy performed similarly to the Alternative 2/3 scenarios. Fishing under the Alternative 1 OFL control rule performed worst of all, with very low mean number of recruits, a higher overfished percentage, and no stock rebuilding.

To evaluate the immediate (six-year) impacts of the alternatives on Bristol Bay red king crab on retained catch and mature male biomass, five control rules were run (Table 4-8). The status quo harvest strategy constrained by the $F_{35\%}$ control rule recommended under Alternatives 2 and 3 resulted in slightly lower harvests in the first four years than status quo harvest strategy under Alternative 1, however, by the fifth year, the constrained harvest strategy resulted in a higher retained catch. This is most likely due to the conservation benefits of reducing harvests in the short term.

Pribilof Islands Red King Crab

Chapter 4 analyses the effects of the alternatives on Pribilof Islands red king crab. The Alternative 1 status determination criteria for Pribilof Island red king crab established a B_{MSY} of 6.6 million pounds of total mature biomass and an MSST of 3.3 million pounds. The 2006 total mature biomass estimate is above B_{MSY} at 19.0 million pounds. Under Alternatives 2 and 3, the Pribilof Islands king crab estimate of B_{MSY} proxy would be 7.82 million pounds of mature male biomass. For comparison, the 2006 estimate of mature male biomass for this stock is 6.43 million pounds. Thus, this stock status would be below B_{MSY}

proxy under the Alternatives 2 and 3, rather than above it as with Alternative 1. The stock would still be above its MSST proxy, and thus would not be considered overfished.

Other Red King Crab

Chapter 4 analyses the effects of the alternatives on other red king crab stocks. For the remaining red king crab stocks, no status determination criteria were established under Alternative 1. Under Alternatives 2 and 3, Norton Sound red king crab stocks would be managed under Tier 4, while Dutch Harbor and Adak red king crab would be managed under Tier 5. Status determination criteria are provided for Tier 4 stocks, while maximum fishing mortality rates would be prescribed by the Tier 4 and 5 formulas. Under Alternatives 2 and 3, the 2006 Norton Sound red king crab mature male biomass would be well above the B_{MSY} proxy and the MSST proxy.

Under Option A, Dutch Harbor red king crab would be removed from the FMP and managed by the State.

Snow Crab

Under Alternative 1, snow crab has been declared overfished and is under a rebuilding plan. The Alternative 1 status determination criteria for snow crab establish a B_{MSY} of 921.6 million pounds of total mature biomass and an MSST of 460.8 million pounds. The 2006 total mature biomass estimate is 547.6 million pounds, above the MSST for this stock but below the B_{MSY}. While the estimated total mature biomass under Alternative 1 is above MSST, and hence no longer in an overfished condition, this stock remains under a rebuilding plan until the stock is above B_{MSY} for two consecutive years.

The status of snow crab is similar under the three alternatives. Under Alternatives 2 and 3, B_{MSY} for snow crab would be measured by mature male biomass. The long-term B_{MSY} estimate for the stock would be 354.72 million pounds of mature male biomass. An MSST for this stock would be 177.36 million pounds. The 2006 mature male biomass estimate is 211 million pounds and above this MSST.

Under Alternative 1, overfishing would occur when the TAC is above the estimated SY. The snow crab TAC for the 2006/2007 fishery was 36.6 million pounds, which is below the 2006 SY of 164.3 million pounds. Under Alternatives 2 and 3, overfishing would be defined as any amount of fishing in excess of the OFL as prescribed through the tier system described in Chapter 2. The recommended OFL control rule for the snow crab stock is an $F_{35\%}$ control rule.

To evaluate the historic impacts of the alternatives on snow crab, the analysis compares the historic harvest and abundance under Alternative 1 with the estimated values from applying the Alternative 2/3 tier system to historic data (Table 5-1). For the period from 1997 to 2006, total catch would have exceeded the estimated OFL in five of the 10 years.

To evaluate the short-term (30-year) and long-term (100-year) impacts of the alternatives on snow crab, thirteen harvest strategy scenarios were investigated to predict the changes in stock abundance levels under various harvest rates. For Alternative 1, two harvest control rules were simulated to predict the possible effects of this alternative on stock biomass; the status quo harvest strategy, and fishing at the Alternative 1 OFL control rule. For Alternatives 2 and 3, an evaluation was made of the control rules in Tiers 2 to 5.

The Alternative 1 status quo harvest strategy control rule and the Alternative 2/3 $F_{35\%}$ control rule produced similar simulation results for rebuilding times, and short-term and long-term yields. Fishing at the Alternative 1 OFL control rule did not rebuild the stock.

To evaluate the immediate (five-year) impacts of the alternatives on snow crab, five control rules were run to analyze the impacts of the alternatives on retained catch and mature male biomass (Table 5-11). The status quo harvest strategy constrained by the $F_{35\%}$ control rule recommended under Alternatives 2 and 3 resulted in higher harvests in two of the five years projected compared to status quo harvest strategy under Alternative 1.

Tanner Crab

Under Alternative 1, Eastern Bering Sea (EBS) Tanner crab declared overfished in 1999 and was under a rebuilding plan until 2007 when the stock was above B_{MSY} for two consecutive years. The Alternative 1 status determination criteria for EBS Tanner crab establish a B_{MSY} of 189.6 million pounds of total mature biomass and an MSST of 94.8 million pounds. The 2006 total mature biomass estimate of 253.3 million pounds and the 2007 total mature biomass estimate of 251.1 were both above the B_{MSY} for this stock.

Under Alternatives 2 and 3, the EBS Tanner crab analyses were carried out separately for Tier 2 and Tier 3, and Tier 4 because the stock assessment parameters were available only for the Bristol Bay portion of the stock.

Under the Alternatives 2 and 3 status determination criteria, B_{MSY} for EBS Tanner crab would be measured in mature male biomass. The long-term B_{MSY} proxy estimate for the stock under Tier 3 would be 70.84 million pounds of mature male biomass, with an MSST of 35.42 million pounds. The long-term B_{MSY} proxy estimate for the stock under Tier 4 would be 82.26 million pounds of mature male biomass, with an MSST of 41.13 million pounds. For comparison, the 2006 estimate of Tanner crab mature male biomass is 62.76 million pounds. Therefore, under Alternatives 2 and 3, this stock would be above the MSST, but below its B_{MSY} proxy in 2006.

Under Alternative 1, overfishing occurs when the TAC is above the estimated SY. The EBS Tanner crab TAC for the 2006/2007 fishery was approximately 3 million pounds, which is below the 2006 SY of 76 million pounds. Under Alternatives 2 and 3, overfishing would be defined as any amount of catch in excess of the OFL catch as prescribed through the tier systems described in Chapter 2. Under Alternatives 2 and 3, either an $F_{35\%}$ control rule considering Tier 3 or γM ($\gamma = 2.85$ and M=0.23) control rule considering Tier 4 would be the recommended OFL control rule for Tanner crab. Harvest rates in recent years have been well below either of these control rules.

To evaluate the short-term (30-year) and long-term (100-year) impacts of the alternatives on EBS Tanner crab, 10 harvest strategy scenarios under Tier 3 and seven harvest strategy scenarios under Tier 4 were investigated to predict the changes in stock abundance levels under various harvest rates. For Alternative 1, two harvest control rules were simulated to predict the possible effects of this alternative on stock biomass; the status quo harvest strategy and fishing at the Alternative 1 OFL control rule. For Alternatives 2 and 3, an evaluation was made of control rules under Tiers 2 to 4 assuming that the stock-recruitment relationship and base parameter values determined for Bristol Bay portion of the stock were applicable to whole EBS stock (i.e., Tier 2 and Tier 3 assumptions). Another set of evaluation of control rules under Tier 4 was also carried out assuming that Bristol Bay stock assessment parameters were not adequate to apply to the whole EBS stock.

Alternatives 2 and 3 simulations with an $F_{35\%}$ control rule (Tier 3) produced higher retained short-term and long-term yields. The status quo harvest strategy was satisfactory, with performance similar to the

Alternative 2 and 3 scenarios. Fishing under the Alternative 1 OFL control rule performed worst of all, with a very low mean number of recruits, higher overfished percentage, and much lower long-term biomass.

Alternatives 2 and 3 simulations with an γM control rule (Tier 4) also produced higher retained short-term and long-term yields. The status quo harvest strategy was satisfactory, with performance similar to the Alternative 2 and 3 scenarios with an γM control rule. Fishing under the Alternative 1 OFL control rule performed unsatisfactorily, with a very low mean number of recruits, higher overfished percentage, and much lower long-term biomass. The stock did not rebuild during the time horizon considered.

Under Alternative 1, no estimates of B_{MSY} or MSST are made for the other Tanner crab stocks. Under Alternative 2 and 3, the Eastern Aleutian Islands Tanner crab stock would be under Tier 4. For this analysis, average biomass from 1999 to 2005 was used as a B_{MSY} proxy for Eastern Aleutian Islands Tanner crab. Stock status would be below its B_{MSY} proxy but above MSST proxy. Historical comparison of stock status shows that the stock was below the MSST proxy in all years prior to 2000, with the exception of 1999. Under Alternative 3, Western Aleutian Islands Tanner crab would be under Tier 6 due to lack of available information and a default OFL would be set at zero for retained catch. Under Option A, Eastern and Western Aleutian Islands Tanner crabs would be removed from the FMP and managed by the State.

Blue King Crab

Under Alternative 1, Pribilof Islands blue king crab and St. Matthew blue king crab have been declared overfished and are under rebuilding plans. Under Alternatives 2 and 3, both of these stocks would be managed as Tier 4 stocks. As such, proxy B_{MSY} values would be estimated. Under Alternatives 2 and 3, the status of these blue king crab stocks would be similar to the status under Alternative 1.

The Alternative 1 status determination criteria for Pribilof Islands blue king crab establish a B_{MSY} of 13.2 million pounds of total mature biomass and an MSST of 6.6 million pounds. The 2006 total mature biomass estimate is 1.6 million pounds, well below the MSST for this stock. Under Alternatives 2 and 3, the Pribilof Islands blue crab estimate of B_{MSY} proxy would be 6.68 million pounds of mature male biomass, with an MSST of 3.34 million pounds. For comparison, the 2006 estimate of mature male biomass for this stock is 0.63 million pounds.

For St. Matthew blue king crab, a B_{MSY} of 22.0 million pounds of total mature biomass was established with an MSST of 11.0 million pounds. The 2006 total mature biomass estimate for this stock is 11.2 million pounds, slightly above the MSST. Under Alternatives 2 and 3, the St. Matthew blue king crab estimate of B_{MSY} proxy would be 13.92 million pounds of mature male biomass, with an MSST of 6.96 million pounds. For comparison, the 2006 estimate of mature male biomass for this stock is 7.41 million pounds.

Under Option A, St. Lawrence blue king crab would be removed from the FMP and managed by the State.

Golden King Crab

Under Alternative 1, no OFL, B_{MSY}, or MSST estimates are made for any of the golden king crab stocks. Under Alternatives 2 and 3, two golden king crab stocks (Pribilof Islands, Aleutian Islands) are preliminarily recommended for Tier 5. Under Tier 5, the OFL would be set using average catch estimated for a selected time period. For Aleutian Islands golden king crab, if average catch is used to establish an OFL for this stock, the OFL would be very close to the current total allowable catch. Under Alternative

3, St. Matthew golden king crab would be recommended for placement in Tier 6 whereby a default OFL would be set at zero. Option A would remove St. Matthew golden king crab from the FMP for exclusive management by the State.

Other Crab Stocks

Under Alternative 1, no B_{MSY} or MSST was specified for these stocks and the maximum fishing mortality threshold was based on the MSY control rule of 0.3 for Tanner crabs and 0.2 for king crabs.

Under Alternative 2, these stocks would all be under Tier 5, OFLs would be calculated for each stock based upon average catch.

Under Alternative 3, these stocks would be under Tier 6. For Tier 6 stocks, a default OFL would be set equal to zero for retained catch, unless the SSC determines a value based on the best available information. No additional status determination criteria are currently estimated for these stocks nor proposed under the revised definitions.

Option A would remove the following crab stocks from the FMP: Eastern Bering Sea grooved Tanner crab; Eastern Aleutian Islands grooved Tanner crab and Western Aleutian Islands grooved Tanner crab; Aleutian Islands scarlet king crab; Eastern Bering Sea scarlet king crab; Bering Sea triangle Tanner crab; and Eastern Aleutian Islands triangle Tanner crab. The State would manage these stocks without Federal oversight. NMFS and the Council find that the State of Alaska has is a legitimate interest in the conservation and management of these stocks for which there is either no directed fishery, a limited incidental or exploratory fishery, or the majority of catch occurs in State waters.

Prohibited Species Catch Limits

Chapter 10 analyzes the effects of the alternatives on crab caught as bycatch in the BSAI groundfish fisheries and scallop fishery. Bycatch limits are established in BSAI groundfish fisheries for red king crab, Tanner crab, and snow crab. Once these limits are exceeded, the specified area closures are triggered for the fishery. Crab species are also caught as bycatch in the Alaskan scallop fishery and bycatch limits by species are established for this fishery.

Under Alternatives 2 and 3, OFLs would restrict crab harvest levels in the near-term resulting in a projected increase in abundance. Since bycatch limits are based on overall abundance, the amount allocated for bycatch could increase. If an OFL for a crab species is exceeded, there is no inseason response for management measures in the fisheries which catch those crab species as bycatch. Should a crab stock become overfished and necessitate a rebuilding plan (or revisions to an existing rebuilding plan), regulations to reduce the bycatch of crab in groundfish and scallop fisheries would be considered at that time.

Economic and Social Effects

Chapter 11 analyzes the economic and social effects of the alternatives. The economic and social impacts are largely qualitative and deal with impacts on persons and on communities. The economic impacts of Alternatives 2 and 3 depend on the extent to which those control rules constrain the status quo harvest strategies used in establishing TACs. The immediate (5 or 6-year) simulation projections suggest that TACs under Alternatives 2 and 3 would be less than under Alternative 1. The extent of this difference depends on the degree to which actual TACs are set below the proposed OFLs. Under the Alternative 1, the MSY control rule for these fisheries has not been constraining. However, the proposed OFLs for

Alternatives 2 and 3 would be lower than those under Alternative 1, so TACs would likely have to be set lower to adjust for the lower OFLs.

In general, any decline in the TAC is likely to contribute to reduced gross revenues to harvesters, processors, and other businesses that rely on the crab fisheries. Reductions in TAC could also negatively impact communities through reduced spending in that community by processors, harvesters, crab support businesses, residents that work in the crab industry, and other residents and businesses that indirectly depended on the crab industry.

Despite these concerns, projected changes in retained catches under Alternatives 2 and 3 are generally small in the immediate, short, and long terms. In both the Bristol Bay red king crab and the snow crab fisheries declines in retained catch are projected to be less than 2%–5% in the immediate term (i.e., the next 6 years). Given these relatively small changes, economic effects of this action are likely to be limited.

Impacts of changes in TACs resulting from the proposed action will likely vary across communities depending on the degree of importance the crab fishery to the local economy. Communities with a high degree of dependency on the crab fishery will likely be affected to a larger degree than communities with low a dependency on the fishery. For example, snow crab is very important to the economies in St. Paul and St. George. Any changes in the snow crab OFL that result in a change in the snow crab total allowable catch will likely impact these communities to a much higher degree than Dutch Harbor or Kodiak, which are diversified across many fisheries.

Cumulative Effects

Chapter 12 analyzes the cumulative effects of the alternatives. The cumulative effects of crab fishing are analyzed in the Crab EIS (NMFS 2004a), including the interactive effects of any past, present, and reasonable foreseeable future external actions. That analysis is incorporated by reference. The Crab EIS concludes that for the majority of the components of the environment analyzed, the cumulative effects of the crab fisheries are insignificant based on the best available scientific information. For some environmental components analyzed, the Crab EIS determined the cumulative effects were unknown, because of a lack of sufficient information on the cumulative condition or the inability to predict effects of external future actions. No new significant information is available that would change these determinations in the Crab EIS. This action would not result in additional impacts beyond those considered in the Crab EIS and is not anticipated to change any of the cumulative effects conclusions.

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List of Acronyms and Abbreviations[1]

AAC	Alaska Administrative Code
ADF&G	Alaska Department of Fish and Game
AFA	American Fisheries Act
AFSC	Alaska Fisheries Science Center
AP	advisory panel
B	fertilized egg production index in terms of mature biomass
Board	Board of Fisheries
BSAI	Bering Sea and Aleutian Islands
CDQ	community development quota
CEQ	Council on Environmental Quality
CFR	Code of Federal Regulations
CIE	Center for Independent Experts
CL	carapace length
cm	centimeter
COBLZ	*C. opilio* Bycatch Limitation Zones
Council	North Pacific Fishery Management Council
CP	catcher/processor
CPT	Crab Plan Team
CPUE	catch per unit effort
CSA	catch survey analysis
CV	coefficient of variation
CW	carapace width
EA	environmental assessment
EAI	Eastern Aleutian Islands
EBS	Eastern Bering Sea
EEZ	Exclusive Economic Zone
EFH	essential fish habitat
EIS	environmental impact statement
ESA	Endangered Species Act
ESB	effective spawning biomass
F	fishing mortality rate
FMP(s)	fishery management plan(s)
FONSI	finding of no significant impact
FR	Federal Register
GC	general counsel
GHL	guideline harvest level
GOA	Gulf of Alaska
HAPC	habitat area of particular concern
IFQ	individual fishing quota
IPQ	individual processing quota
ITQ	individual transferable quota
LBA	length-based analysis
LLP	License Limitation Program
M	natural mortality rate
Magnuson-Stevens Act	Magnuson-Stevens Fishery Conservation and Management Act
MFMT	maximum fishing mortality threshold

[1] Appendix A contains the notations used in the equations in this EA.

MMB	mature male biomass
MSRA	Magnuson-Stevens Fishery Conservation and Management Reauthorization Act
MSST	minimum stock size threshold
MSY	maximum sustainable yield
NA (na)	data not available/applicable
NEPA	National Environmental Policy Act
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
NPFMC	North Pacific Fishery Management Council (the Council)
OFL	overfishing level
OY	optimum yield
pdf	probability density function
PQS	processor quota shares
PSC	Prohibited Species Catch
QS	quota shares
RAM	Restricted Access Management
SAFE	Stock Assessment and Fishery Evaluation
Secretary	Secretary of Commerce
SPR or S-R	spawner per recruit
SSC	Scientific and Statistical Committee
State	State of Alaska
SY	sustainable yield
TAC	total allowable catch
TMB	total mature biomass
U.S.	United States
USFWS	United States Fish and Wildlife Service
WAI	Western Aleutian Islands

1 INTRODUCTION

The king and Tanner crab fisheries in the Exclusive Economic Zone (EEZ) (3 to 200 miles offshore) of the Bering Sea and Aleutian Islands off Alaska are managed under the Fishery Management Plan for Bering Sea/Aleutian Islands King and Tanner Crabs (FMP). This FMP was developed by the North Pacific Fishery Management Council (Council) under the Magnuson-Stevens Fishery Conservation and Management Act (Magnuson-Stevens Act). The Secretary of Commerce first approved the FMP on June 2, 1989.

The FMP establishes a State/Federal cooperative management regime that defers crab fisheries management to the State of Alaska (State) with Federal oversight. State regulations are subject to the provisions of the FMP, including its goals and objectives, the Magnuson-Stevens Act, and other applicable Federal laws. The FMP defers much of the management of the BSAI crab fisheries to the State of Alaska using the following three categories of management measures:

1. Those that are fixed in the FMP and require a FMP amendment to change;
2. Those that are framework-type measures that the State can change following criteria set out in the FMP; and
3. Those measures that are neither rigidly specified nor frameworked in the FMP and are at the discretion of the State.

The proposed action is to establish overfishing levels (OFLs) that provide objective and measurable criteria for identifying when the fishery to which the FMP applies is overfished or when overfishing is occurring, in compliance with the Magnuson-Stevens Act. Section 303(a)(10) of the Magnuson-Stevens Act requires that FMPs specify objective and measurable criteria for identifying when the fishery to which the FMP applies is overfished (with an analysis of how the criteria were determined and the relationship of the criteria to the reproductive potential of the stock). The OFLs are a Category 1 measure in the FMP. As such, revisions to the OFLs require an FMP amendment.

Determinations of total allowable catches (TACs) and guideline harvest levels (GHLs) are Category 2 management measures and are deferred to the State following the criteria in the FMP. Catch levels established by the State must be in compliance with OFLs established in the FMP, to prevent stocks from being overfished or for overfishing to occur. As described in Chapter 2, NMFS annually determines if catch levels have exceeded rates determined to constitute overfishing or if stocks have reached or are approaching an overfished status. If either of these occurs, NMFS notifies the Council and the Council must immediately end overfishing and develop an FMP amendment to rebuild the stock within two years. More information on the notification and actions necessary by the Council are described in Section 1.1.

Management actions for the BSAI crab fisheries must comply with applicable Federal laws and regulations. Although several laws and regulations guide this action, the principal laws and regulations that govern this action are the Magnuson-Stevens Act and the National Environmental Policy Act (NEPA). None of the alternatives require implementing regulations and, therefore, the Regulatory Flexibility Act does not apply and review under Executive Order 12866 is not required.

1.1 National Standard 1

The Magnuson-Stevens Act national standard 1 states that "Conservation and management measures shall prevent overfishing while achieving, on a continuing basis, the optimum yield (OY) from each fishery for the U.S. fishing industry." The specification of OY and the conservation and management measures to achieve it must explicitly prevent overfishing. NMFS published national standard guidelines (50 CFR part 600) to provide comprehensive guidance for the development of FMPs and FMP amendments that comply with the Magnuson-Stevens Act national standards.

The Magnuson-Stevens Fishery Conservation and Management Reauthorization Act of 2006 (MSRA, Public Law 109-479) provided additional language to prevent overfishing by requiring that FMPs establish a mechanism for specifying annual catch limits in the plan (including a multiyear plan), implementing regulations, or annual specifications, at a level such that overfishing does not occur in the fishery, including measures to ensure accountability. The MSRA also modified the language in section 304(e)(3) of the Magnuson-Stevens Act to extend the time period for the Council and Secretary to develop and implement a rebuilding plan from one year to two years.

1.1.1 Definitions

Definitions of “overfished” and “overfishing” are provided in the national standard guidelines (50 CFR 600.310). While Section 3(29) of the Magnuson-Stevens Act defines both “overfishing” and “overfished” as a rate or level of fishing mortality that jeopardizes a fishery's capacity to produce maximum sustainable yield (MSY) on a continuing basis, the national standard guidelines provide guidance on the specification of “overfished” as a status determination different from “overfishing”. Excerpts from the national standard guidelines are provided below:

> 50 CFR 600.310(d) *Overfishing—*
>
> (1) *Definitions.*
>
> > (i) “To overfish” means to fish at a rate or level that jeopardizes the capacity of a stock or stock complex to produce MSY on a continuing basis.
> >
> > (ii) “Overfishing” occurs whenever a stock or stock complex is subjected to a rate or level of fishing mortality that jeopardizes the capacity of a stock or stock complex to produce MSY on a continuing basis.
> >
> > (iii) In the Magnuson-Stevens Act, the term “overfished” is used in two senses: first, to describe any stock or stock complex that is subjected to a rate or level of fishing mortality meeting the criterion in paragraph (d)(1)(i) of this section, and second, to describe any stock or stock complex whose size is sufficiently small that a change in management practices is required in order to achieve an appropriate level and rate of rebuilding. To avoid confusion, this section uses “overfished” in the second sense only.
>
> (2) *Specification of status determination criteria.* Each FMP must specify, to the extent possible, objective and measurable status determination criteria for each stock or stock complex covered by that FMP and provide an analysis of how the status determination criteria were chosen and how they relate to reproductive potential. Status determination criteria must be expressed in a way that enables the Council and the Secretary to monitor the stock or stock complex and determine annually whether overfishing is occurring and whether the stock or stock complex is overfished. In all cases, status determination criteria must specify both of the following:
>
> > (i) *A maximum fishing mortality threshold or reasonable proxy thereof.* The fishing mortality threshold may be expressed either as a single number or as a function of spawning biomass or other measure of productive capacity. The fishing mortality threshold must not exceed the fishing mortality rate or level associated with the relevant MSY control rule. Exceeding the fishing mortality threshold for a period of 1 year or more constitutes overfishing.
> >
> > (ii) *A minimum stock size threshold or reasonable proxy thereof.* The stock size threshold should be expressed in terms of spawning biomass or other measure of productive capacity. To the extent possible, the stock size threshold should equal whichever of the following is greater: One-half the MSY stock size, or the minimum stock size at which rebuilding to the MSY level would be expected to occur within 10 years if the stock or stock complex were exploited at the maximum fishing mortality threshold specified under paragraph (d)(2)(i) of this section. Should the actual size of the

stock or stock complex in a given year fall below this threshold, the stock or stock complex is considered overfished.

(3) *Relationship of status determination criteria to other national standards*.

(i) *National standard 2.* Status determination criteria must be based on the best scientific information available (see §600.315). When data are insufficient to estimate MSY, Councils should base status determination criteria on reasonable proxies thereof to the extent possible (also see paragraph (c)(3) of this section). In cases where scientific data are severely limited, effort should also be directed to identifying and gathering the needed data.

(ii) *National standard 3.* The requirement to manage interrelated stocks of fish as a unit or in close coordination notwithstanding (see §600.320), status determination criteria should generally be specified in terms of the level of stock aggregation for which the best scientific information is available (also see paragraph (c)(2)(iii) of this section).

(iii) *National standard 6.* Councils must build into the status determination criteria appropriate consideration of risk, taking into account uncertainties in estimating harvest, stock conditions, life history parameters, or the effects of environmental factors (see §600.335).

(4) *Relationship of status determination criteria to environmental change.* Some short-term environmental changes can alter the current size of a stock or stock complex without affecting the long-term productive capacity of the stock or stock complex. Other environmental changes affect both the current size of the stock or stock complex and the long-term productive capacity of the stock or stock complex.

(i) If environmental changes cause a stock or stock complex to fall below the minimum stock size threshold without affecting the long-term productive capacity of the stock or stock complex, fishing mortality must be constrained sufficiently to allow rebuilding within an acceptable time frame (also see paragraph (e)(4)(ii) of this section). Status determination criteria need not be respecified.

(ii) If environmental changes affect the long-term productive capacity of the stock or stock complex, one or more components of the status determination criteria must be respecified. Once status determination criteria have been respecified, fishing mortality may or may not have to be reduced, depending on the status of the stock or stock complex with respect to the new criteria.

(iii) If manmade environmental changes are partially responsible for a stock or stock complex being in an overfished condition, in addition to controlling effort, Councils should recommend restoration of habitat and other ameliorative programs, to the extent possible (see also the guidelines issued pursuant to Section 305(b) of the Magnuson-Stevens Act for Council actions concerning essential fish habitat).

1.1.2 Notification and Council action requirements

Section 304(e) of the MSA requires that, within two years of secretarial notification, the Council prepare and implement an FMP amendment to immediately end overfishing and rebuild the stock. The national standard guidelines specify the considerations necessary for approval of proposed status determination criteria as well as the notification requirements for stocks failing to meet their approved criteria and resulting Council actions required.

Section 304(e)(5) *Secretarial approval of status determination criteria.* Secretarial approval or disapproval of proposed status determination criteria will be based on consideration of whether the proposal:

(i) Has sufficient scientific merit.

(ii) Contains the elements described in paragraph (d)(2) of this section.

(iii) Provides a basis for objective measurement of the status of the stock or stock complex against the criteria.

(iv) Is operationally feasible.

(6) *Exceptions.* There are certain limited exceptions to the requirement to prevent overfishing. Harvesting one species of a mixed-stock complex at its optimum level may result in the overfishing of another stock component in the complex. A Council may decide to permit this type of overfishing only if all of the following conditions are satisfied:

(i) It is demonstrated by analysis (paragraph (f)(6) of this section) that such action will result in long-term net benefits to the Nation.

(ii) It is demonstrated by analysis that mitigating measures have been considered and that a similar level of long-term net benefits cannot be achieved by modifying fleet behavior, gear selection/configuration, or other technical characteristic in a manner such that no overfishing would occur.

(iii) The resulting rate or level of fishing mortality will not cause any species or evolutionarily significant unit thereof to require protection under the ESA.

(e) *Ending overfishing and rebuilding overfished stocks*—

(1) *Definition.* A threshold, either maximum fishing mortality or minimum stock size, is being "approached" whenever it is projected that the threshold will be breached within 2 years, based on trends in fishing effort, fishery resource size, and other appropriate factors.

(2) *Notification.* The Secretary will immediately notify a Council and request that remedial action be taken whenever the Secretary determines that:

(i) Overfishing is occurring;

(ii) A stock or stock complex is overfished;

(iii) The rate or level of fishing mortality for a stock or stock complex is approaching the maximum fishing mortality threshold;

(iv) A stock or stock complex is approaching its minimum stock size threshold; or

(v) 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.

(3) *Council action.* Within 2 years of such time as the Secretary may identify that overfishing is occurring, that a stock or stock complex is overfished, or that a threshold is being approached, or such time as a Council may be notified of the same under paragraph (e)(2) of this section, the Council must take remedial action by preparing an FMP, FMP amendment, or proposed regulations. This remedial action must be designed to accomplish all of the following purposes that apply:

(i) If overfishing is occurring, the purpose of the action is to end overfishing.

(ii) If the stock or stock complex is overfished, the purpose of the action is to rebuild the stock or stock complex to the MSY level within an appropriate time frame.

(iii) If the rate or level of fishing mortality is approaching the maximum fishing mortality threshold (from below), the purpose of the action is to prevent this threshold from being reached.

(iv) If the stock or stock complex is approaching the minimum stock size threshold (from above), the purpose of the action is to prevent this threshold from being reached.

(4) *Constraints on Council action.*

(i) In cases where overfishing is occurring, Council action must be sufficient to end overfishing.

(ii) In cases where a stock or stock complex is overfished, Council action must specify a time period for rebuilding the stock or stock complex that satisfies the requirements of Section 304(e)(4)(A) of the Magnuson-Stevens Act.

The national standard guidelines also provide guidance for rebuilding overfished stocks, including specifying the time period for rebuilding (not listed here but found under §600.310). Further interim measures may be implemented by the Secretary while remedial actions (e.g., FMP amendment or regulations) are being developed in order to prevent overfishing.

Considerations of these measures are critical in the development and implementation of the overfishing definitions as provided in this analysis for BSAI crab stocks.

1.2 Purpose and need

The purpose of the proposed action is to establish status determination criteria in compliance with the Magnuson-Stevens Act and the national standard guidelines, as described above. The current definitions were implemented under Amendment 7 to the FMP in 1998. In the environmental assessment (EA) for that amendment, the Crab Plan Team (CPT) stated its intent to review the definitions after five years or at such a time that environmental conditions have changed such that revising the definitions may be necessary. In 2003, the CPT undertook a review of the current definitions and decided that it would be prudent at that time to begin the process of crafting updated definitions which would incorporate the extensive scientific developments to date and facilitate the incorporation of new scientific information as it becomes available. The fixed format of the current definitions does not allow for incorporation of new information without amending the FMP. More information on the development of alternatives for this analysis may be found in Section 2.4.

The need for the proposed action is explained in the CPT's problem statement:

> *New overfishing definitions are necessary to reflect current scientific information and accomplish the following:*
> - *Provide an FMP framework for definition values to facilitate use of the best available scientific information as it evolves.*
> - *Provide a new tier system that accommodates varying levels of uncertainty of information and takes advantage of alternative biological reference points.*
> - *Define the status determination criteria and their application to the appropriate component of the population.*

1.3 Scope of this Environmental Assessment

This EA relies heavily on the information and analysis contained in the Bering Sea Aleutian Islands Crab Fisheries Final Environmental Impact Statement/Regulatory Impact Review/Initial Regulatory Flexibility Analysis/Social Impact Assessment (NMFS 2004a), which is available on the NMFS Alaska Region web site at http://www.fakr.noaa.gov/sustainablefisheries/crab/eis/default.htm. Throughout this analysis, that document is referred to as the "Crab EIS." Additional information concerning the crab fisheries and management under the Crab Rationalization Program (Program), and impacts of these on the human environment are contained in that document.

The Crab EIS provides the status of the environment and analyzes the impacts of the crab fisheries on the human environment. This EA tiers off of the Crab EIS to focus the analysis on the issues ripe for decision and eliminate repetitive discussions. The proposed action would establish revised overfishing definitions for the crab stocks under the FMP. This EA details the specific impacts of the proposed action.

Chapter 3 of the Crab EIS contains a complete description of the human environment, including the physical environment, habitat, crab life history, marine mammals, seabirds, crab fisheries, a management history, the harvesting sector, the processing sector, and community and social conditions. These descriptions are incorporated by reference.

In addition to the factors discussed in the Crab EIS, this action specifically concerns the annual establishment of OFLs using the tier system based status determination criteria for the crab stocks under the FMP. Relevant and recent information on each crab stock is contained in the chapter for that species.

The Council on Environmental Quality (CEQ) regulations encourage agencies preparing NEPA documents to "tier their environmental impact statements to eliminate repetitive discussions of the same issues and to focus on the actual issues ripe for decision at each level of environmental review." Specifically, 40 CFR 1502.20 states the following:

> Whenever a broad environmental impact statement has been prepared (such as a program or policy statement) and a subsequent statement or environmental assessment is then prepared on an action included within the entire program or policy (such as a site specific action) the subsequent statement or environmental assessment need only summarize the issues discussed in the broader statement and incorporate discussions from the broader statement by reference and shall concentrate on the issues specific to the subsequent action. (40 CFR 1502.20)

In 40 CFR 1508.28, the CEQ regulations further define tiering as the coverage of general matter in broader environmental impact statements with subsequent narrower statements of environmental analyses incorporating by reference the general discussion and concentrating solely on the issues specific to the statement subsequently prepared. This section of the CEQ regulations further notes that tiering is appropriate when the sequence of statements or analysis is from a program, plan, or policy environmental impact statement to a program, plan, or policy statement or analysis of lesser scope or to a site-specific statement or analysis.

This EA also relies heavily on the information and analysis contained in the Council's annual BSAI Crab Stock Assessment and Fishery Evaluation (SAFE) Reports, available from the Council web site at http://www.fakr.noaa.gov/npfmc/SAFE/SAFE.htm or http://www.fakr.noaa.gov/npfmc/membership/plan teams/ CPT/CRABSAFE06.pdf. The SAFE Reports contain the status of the crab stocks, the results of the NMFS Eastern Bering Sea trawl survey, the annual management fisheries report, stocks assessments, and an economic report.

2 Description of Alternatives

This Chapter provides (1) a description of the alternatives, (2) a comparison of the status determination criteria in the alternatives, (3) a description and comparison of two options considered for the OFL setting and review process, (4) a description and comparison of two options considered for FMP stocks, and (5) a discussion of the development of alternatives and the alternatives considered and eliminated from detailed study.

Chapter 3 provides information regarding the methodology for determining the parameters and assumptions used in the assessment modeling for applying the alternitives in the impacts analysis in Chapters 4-12.

Three alternatives and two sets of options are analyzed in this EA. Options 1 and 2 for the OFL setting and review process apply to Alternatives 2 and 3 only. Options A and B for FMP stocks apply to all alternatives.

<table>
<tr><td>Alternative 1: Status quo</td><td>N/A</td><td rowspan="3">Option A: Remove specific stocks from FMP

Or

Option B: Status quo - no removal of stocks</td></tr>
<tr><td>Alternative 2: Five-Tier System</td><td rowspan="2">Option 1: Council annually adopts OFLs in June

Or

Option 2: Council annually reviews OFLs in the fall</td></tr>
<tr><td>Alternative 3: Six-Tier System</td></tr>
</table>

2.1 Alternative 1: status quo

Alternative 1 utilizes the status determination criteria established in Amendment 7 to the FMP. The Council adopted Amendment 7 in 1998 and the Secretary approved Amendment 7 on March 3, 1999 (64 FR 11390). Amendment 7 provided fixed values in the FMP for the minimum stock size threshold (MSST), MSY, OY, and maximum fishing mortality threshold (MFMT) for the BSAI king and Tanner crab stocks, as shown in Table 2-1. The EA for Amendment 7 specified that the CPT would reevaluate the status determination criteria every five years or when environmental conditions indicate a regime shift.

The FMP establishes the criteria shown in Table 2-1 to determine the status of the stocks and whether overfishing is occurring, a stock or stock complex is overfished, a stock or stock complex is approaching its overfished level, or the rate or level of fishing mortality for a stock or stock complex is approaching the OFL.

In the Alternative 1 tier system, the OFL control rule for each crab species is based on the estimates of biomass and size frequency from the annual NMFS Eastern Bering Sea (EBS) trawl survey, the natural mortality rate set in the FMP, and retained catch. The 22 king and Tanner crab stocks managed under the FMP are classified into three tiers according to level of data availability: Tier 1–unsurveyed stocks with minimal history of effort and harvest; Tier 2–stocks with sporadic or limited years of survey data, but well documented history of catch and effort; Tier 3–stocks with annual survey data, well documented history of catch and effort, and information pertaining to productivity parameters.

For the Tier 3 stocks, the B_{MSY}, the MSST, and MSY were defined as functions of survey estimates of total (male and female) mature biomass (TMB), and the MFMT, which is a fishing mortality rate (F) set equal to an estimate of the natural mortality rate (set at M=0.2 for all species of king crab and M=0.3 for all *Chionoecetes* species). There are six Tier 3 stocks that are annually surveyed by the NMFS EBS trawl survey: Bristol Bay red king crab, Pribilof Islands red king crab, St. Matthew blue king crab, Pribilof Islands blue king crab, EBS Tanner crab, and snow crab.

Tier 1. Crab stock is not surveyed. Some catch data available.
F_{MSY} = M = 0.2 (king), 0.3 (Tanner and snow).
B_{MSY} not estimable.
MSY is estimated from a proxy of mature biomass and stock utilization rate.

Tier 2. Sporadic or limited years of survey data. Catch and effort data on each crab stock is well documented.
F_{MSY} = M = 0.2 (king), 0.3 (Tanner and snow).
B_{MSY} not estimable.
MSY is estimated from a proxy of mature biomass and stock utilization rate.

Tier 3. Data Available: historical catch, continuous inseason catch and effort data, stock assessment, growth, maturity, limited natural mortality and stock recruitment relationship information.
F_{MSY} = M = 0.2 (king), 0.3 (Tanner and snow).
B_{MSY} is the average survey biomass of mature males and females from 1983 to 1997.
MSY = B_{MSY} *F_{MSY}.

For Tier 3 stocks, NMFS determines the harvest rate that would constitute overfishing for the upcoming season by applying the MFMT to the survey abundance estimate of the TMB to derive the OFL and compares that to the TAC or GHL for that fishery. The MFMT is represented by the sustainable yield (SY) in a given year, which is the MSY control rule, determined by M, applied to the current TMB. Overfishing occurs if the harvest level exceeds the SY. This MSY control rule was defined as the Baranov catch equation applied to TMB under the assumption that TMB estimated at the time of survey is the average TMB available for the year and because the size structure, sex, and fishing season dates are optimum yield choices that can vary from stock to stock.

For Alternative 1, the MSY control rule is specified as:

$$SY = TMB*M.$$

MSY for a Tier 3 stock is defined as the average of the annually computed SY over the 15-year period, 1983-1997. MSY has been estimated for all stocks except Aleutian Islands scarlet king and EBS scarlet king crabs.

NMFS annually determines if a stock is overfished or approaching an overfished condition by comparing the estimates of TMB from the NMFS survey with the MSST (or proxies) defined in the FMP and shown in Table 2-1. MSST for a stock is defined as one-half of B_{MSY}. B_{MSY} for a stock is defined as the average annual estimated TMB for the 15-year period, 1983-1997. If the stock biomass drops below the MSST (or proxy thereof) then the stock is considered to be overfished.

Table 2-1 MSST (minimum stock size threshold), MSY, and OY in millions of pounds (metric ton, t, in parentheses), and the MFMT (maximum fishing mortality threshold) values for BSAI king and Tanner crabs.

Stock	MSST	MSY	OY range	MFMT
WAI red king	NA	1.5 (680)	0-1.5 (0 – 680)	0.2
Bristol Bay red king	44.8 (20,321)	17.9 (8,119)	0-17.9 (0 – 8,119)	0.2
EAI red king	NA	NA	NA	0.2
Pribilof Islands red king	3.3 (1,497)	1.3 (590)	0-1.3 (0 – 590)	0.2
Norton Sound red king	NA	0.5 (227)	0-0.5 (0 – 227)	0.2
Pribilof Islands blue king	6.6 (2,994)	2.6 (1,179)	0-2.6 (0 – 1,179)	0.2
St. Matthew blue king	11.0 (4,990)	4.4 (1,996)	0-4.4 (0 – 1,996)	0.2
St. Lawrence blue king	NA	0.1 (45)	0-0.1 (0 – 45)	0.2
Aleutian Islands golden king	NA	15.0 (6,804)	0-15.0 (0 – 6,804)	0.2
Pribilof Islands golden king	NA	0.3 (136)	0-0.3 (0 – 136)	0.2
Northern District golden king	NA	0.3 (136)	0-0.3 (0 – 136)	0.2
Aleutian Islands scarlet king	NA	NA	NA	0.2
EBS scarlet king	NA	NA	NA	0.2
Total king crab		**43.9 (19,913)**	**0-43.9 (0 – 19,913)**	
Eastern Aleutian Tanner	NA	0.7 (318)	0-0.7 (0 – 318)	0.3
EBS Tanner	94.8 (43,001)	56.9 (25,810)	0-56.9 (0 – 25,810)	0.3
Western Aleutian Tanner	NA	0.4 (181)	0-0.4 (0 – 181)	0.3
Total Tanner		**58.0 (26,309)**	**0-58.0 (0 – 26,309)**	
EBS snow	460.8 (209,017)	276.5 (125,420)	0-276.5 (0 – 125,420)	0.3
Total snow		**276.5 (125,420)**	**0-276.5** (0 – 125,420)	
Eastern Aleutian triangle Tanner	NA	1.0 (454)	0-1.0 (0 – 454)	0.3
EBS triangle Tanner	NA	0.3 (136)	0-0.3 (0 – 136)	0.3
Eastern Aleutian grooved Tanner	NA	1.8 (816)	0-1.8 (0 – 816)	0.3
EBS grooved Tanner	NA	1.5 (680)	0-1.5 (0 – 680)	0.3
Western Aleutian grooved Tanner	NA	0.2 (91)	0-0.2 (0 – 91)	0.3
Total other Tanner		**4.8 (2,177)**	**0-4.8 (0 – 2,177)**	

NA: Indicates that insufficient data exists to calculate value.

2.1.1 Timing of status quo OFL setting process

Under Alternative 1, stock abundance estimations, status determinations, and TAC setting for the surveyed stocks all occur in the fall, after the survey and before the start of the crab fisheries (see Table 2-2). NMFS conducts the annual trawl survey from June through mid-August. For the surveyed stocks, NMFS and ADF&G annually estimate stock abundance based on the NMFS EBS trawl survey. Surveyed stocks include snow crab, EBS Tanner crab, Bristol Bay and Pribilof Islands red king crab, and Pribilof Islands and St. Matthew blue king cab. ADF&G sets the TACs on or immediately before October 1, and the crab fisheries open on October 15. The Council and SSC review the survey results, status of the stocks, the TACs, and the SAFE report.

For stocks not covered by the NMFS annual trawl survey, ADF&G sets the TACs according to its schedule and information is provided in the SAFE.

Table 2-2 Timing of status quo process for surveyed stocks under Alternative 1.

by April	Assessment authors update assessment models.
May	CPT reviews models, assumptions, parameters, fishery data from prior year, etc.
June	SSC review of models, etc.
June-August	NMFS annual trawl survey.
August	NMFS and ADF&G produce abundance estimates from models and area-swept method using survey data.
September	NMFS determines status of stocks relative to MSSTs in FMP and calculates the OFLs. CPT review of survey results, abundance estimates, status of the stocks, and OFLs – information compiled for SAFE.
October 1	State sets the TAC for the fall fisheries based on the abundance estimates from models or area-swept estimates of survey data. TACs are set using an established harvest strategy and constrained by the OFLs.
October	The Council and SSC review the survey results, status of the stocks relative to OFLs, the TACs, and SAFE report.

2.2 Alternative 2: Five-Tier System (Preferred)

Alternative 2 would amend the FMP to include the five-tier system in Table 2-3 and an OFL setting and review process for assigning each crab stock into a tier and for setting the OFLs. The OFL setting and review process would be as described in either Option 1 or Option 2 (see Section 2.5). Additionally, the Council may choose to remove specific crab stocks from the FMP, as described in Option A (see Section 2.6).

This alternative establishes the five-tier system under which 'overfishing' and 'overfished' are annually formulated and assessed to determine the status of the crab stocks and whether (1) overfishing is occurring or the rate or level of fishing mortality for a stock or stock complex is approaching overfishing, and (2) a stock or stock complex is overfished or a stock or stock complex is approaching an overfished condition.

The proposed tier system under Alternatives 2 and 3 is structured based upon the availability of information for a given stock, and once a stock is assigned to a tier, this tier then provides the formula for calculating the OFL (Figure 2-1).

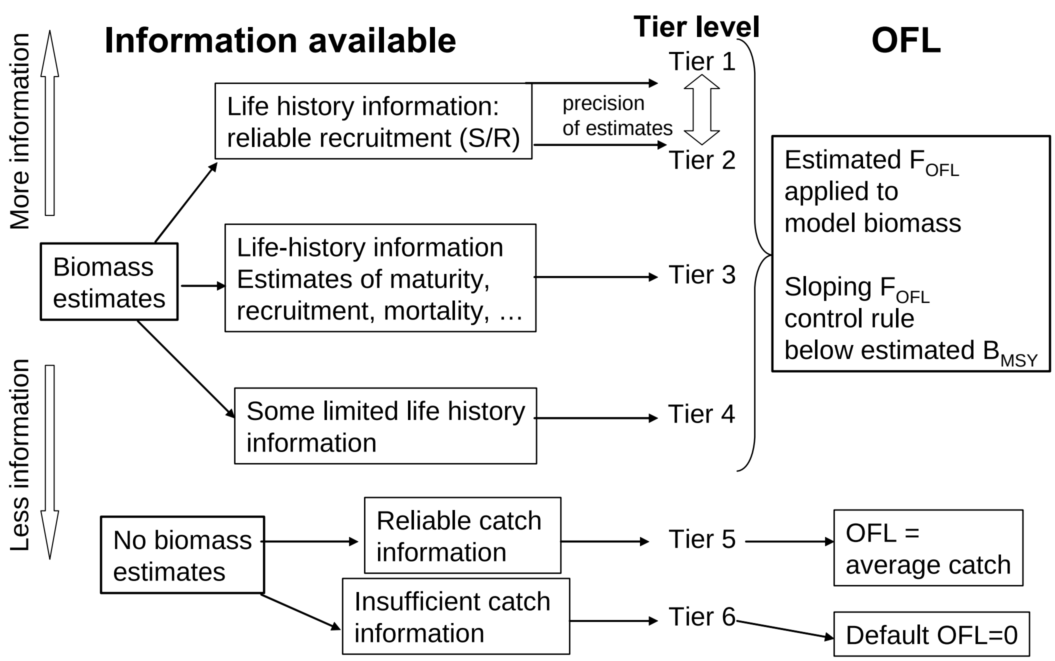

Figure 2-1 Schematic of the proposed tier system under both Alternatives 2 and 3. Tier 6 is for Alternative 3 only.

Table 2-3 Alternative 2 Five-Tier System. The tiers are listed in descending order of information availability. Appendix A contains the notations used in the equations.

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_{prox}, $B_{msy^{prox}}$	**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.

This tier system has analogs to the Council's groundfish tier system. However, in the groundfish tier system, the specified F_{ABC} is the maximum target F to ensure a buffer between the overfishing F_{OFL} and the target F, as required by the groundfish FMPs. For crab, the FMP defers the specification of the allowable harvest level to the State, with Federal oversight. The annual TAC or GHL could be set anywhere below the OFL and the State would determine the buffer between the TAC or GHL and the OFL necessary prevent exceeding the OFL.

The F_{OFL} for each stock would be annually estimated using the tier system in Table 2-3. The F_{OFL} would be applied to abundance estimates to calculate the OFL. Overfishing is defined as any amount of fishing in excess of a maximum allowable rate, the F_{OFL} control rule. The control rule defines the full selection fishing mortality rate to apply to the exploitable stock at any level of the egg production index or its mature male biomass (MMB) proxy. Annual determination of overfishing would occur by comparison of the OFL as calculated for all catch (retained and discard losses) with the total catch for the same time period. This total catch would include all fishery removals for those stocks where non-target fishery removal data are available (Tiers 1-3). Discard losses are determined by multiplying the appropriate handling mortality rate by observer estimates of bycatch discards. For those stocks where only retained catch information is available, the OFL would be estimated for the retained catch portion only, with the corresponding overfishing comparison on the retained catch only (Tiers 4 and 5).

In Tiers 1 through 4, three levels of stock status are specified and denoted by “a”, “b”, and “c” (see Table 2-3). 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). Lastly, in stock status level “c”, a threshold value (β) of B/ B_{MSY} is established below which directed fishing is prohibited. In stock status level “c,” 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. The Council will develop a rebuilding plan once a stock level falls below the MSST. The SSC would recommend whether a given item of information is “reliable” for the purpose of this definition, and may use either objective or subjective criteria in making such determinations.

For each stock in Tiers 1 through 4, the fishing mortality rate corresponding to the overfishing limit (i.e., F_{OFL}) is specified in the tier system. In Tier 5, the OFL is specified in terms of an average catch value over an historical time period, unless the SSC recommends an alternative value based on the best available scientific information.

The overfished criterion is expressed in terms of annual estimates of MMB compared to the established MSST. For stocks where MSST (or proxies) are defined, if the MMB drops below the MSST (or proxy thereof) then the stock is considered to be overfished. MSST is defined as ½ B_{MSY}. MSSTs or proxies would be set for stocks in Tiers 1-4.

2.2.1 Tiers 1 through 3

The overfishing and overfished definitions for stocks in Tiers 1-3 result from simulation modeling that captures the essential population dynamics of the stock as well as the performance of the fisheries. Annual scenarios would be run using the projection models to determine if a stock is overfished or approaching an overfished condition. The simulation modeling approach employed in the derivation of the annual OFLs captures the historical performance of the fisheries as seen in observer data from the early 1990s to present. These data allow the formulation and use of selectivity curves for the discard fisheries (directed and non-directed discard losses) as well as the directed fishery (retained catch) in the models. In formulating the OFL, which is the annual catch limit corresponding to the threshold on fishing, the calculation would account for all losses to the stock not attributable to natural morality. The OFL resulting from this approach, therefore, is the total catch limit comprised of three catch components: [1] non-directed fishery discard losses; [2] directed fishery discard losses; and [3] directed fishery retained catch. To determine the discard losses, the handling mortality rate is multiplied by bycatch discards in each fishery. Overfishing occurs if, in any year, the sum of all three catch components exceeds the OFL.

For Tiers 1 through 3, reliable estimates of B, B_{MSY}, and F_{MSY}, or their respective proxy values, are available. Tiers 1 and 2 are for stocks with a reliable estimate of the spawner/recruit relationship, thereby enabling the estimation of the limit reference points B_{MSY} and F_{MSY}.

- Tier 1 is for stocks with assessment models in which the pdf of F_{MSY} is estimated.
- Tier 2 is for stocks with assessment models in which a reliable point estimate, but not the pdf, of F_{MSY} is made.
- Tier 3 is for stocks where reliable estimates of the spawner/recruit relationship are not available, but proxies for F_{MSY} and B_{MSY} can be estimated.

For Tier 3 stocks, maturity and other essential life-history information are available to estimate proxy limit reference points. For Tier 3, a designation of the form "F_X" refers to the fishing mortality rate associated with an equilibrium level of fertilized egg production (or its proxy) per recruit equal to X% of the equilibrium level in the absence of any fishing.

For Tiers 1 through 3, an F_{MSY} control rule reduces the F_{OFL} as biomass declines by stock status level (Figure 2-2; Table 2-3). For Tiers 1-3, the coefficient α is set at a default value of 0.1 with the understanding that the SSC may recommend a different value for a specific stock or stock complex as merited by the best available scientific information. In this analysis, MMB at the time of mating of primiparous females (February 15) is used as the best available proxy for fertilized egg production. Using MMB eliminates the need for estimating uncertain parameters such as mating ratios, fertilization rates, and which males take part in mating. As research improves our estimates of key processes controlling crab reproduction, it is anticipated that alternative indices of fertilized egg production will be considered that are based on a combination of male and female biomass. Alternative 2 does not prescribe this parameter to allow modifications as information improves.

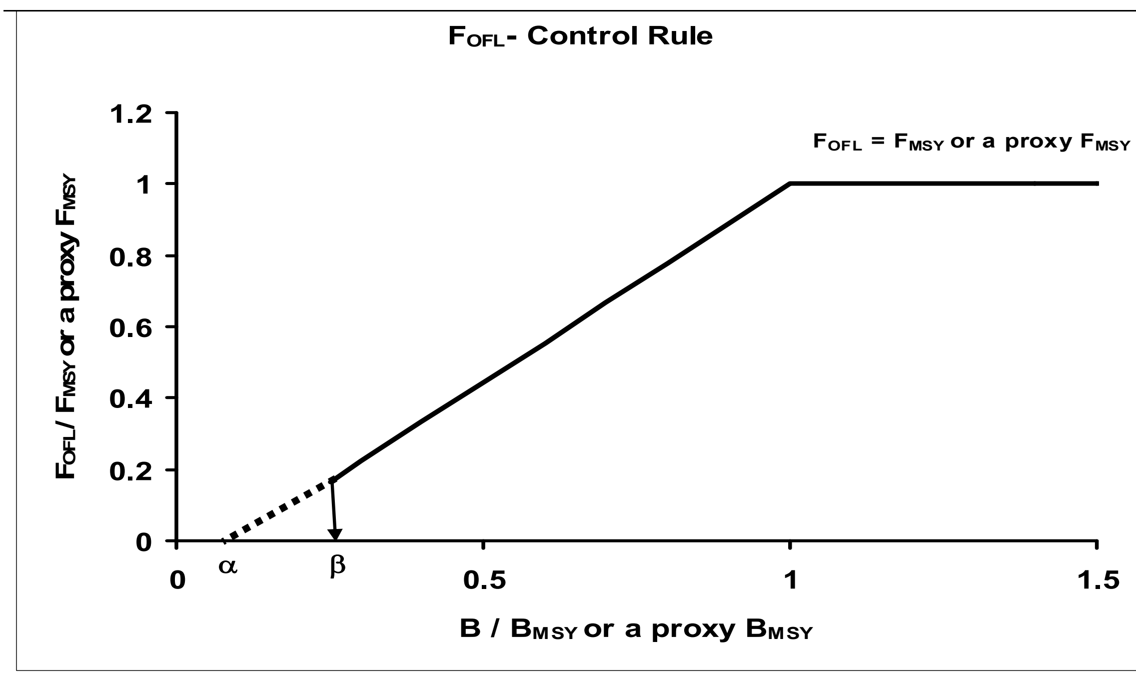

Figure 2-2 Proposed control rule for overfishing for Tiers 1 through 4 under Alternatives 2 and 3. Directed fishing mortality is 0 below β.

Table 2-4 F_{OFL} overfishing control rule reference guide.

- 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 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 $\beta \cdot B_{MSY} < B \leq B_{MSY}$.

2.2.2 Tier 4

Tier 4 is for stocks where essential life-history, recruitment information, and understanding are lacking. Therefore, it is not possible to estimate the spawner-recruit relationship. However, there is sufficient information for simulation modeling that captures the essential population dynamics of the stock as well as the performance of the fisheries. The simulation modeling approach employed in the derivation of the annual OFLs captures the historical performance of the fisheries as seen in observer data from the early 1990s to present and thus borrows information from other stocks as necessary to estimate biological parameters such as γ.

In Tier 4, a default value of natural mortality rate (M) or an M proxy, and a scalar, γ, are used in the calculation of the F_{OFL}. Explicit to Tier 4 are reliable estimates of current survey biomass and the instantaneous M. The proxy B_{MSY} is the average biomass over a specified time period, with the understanding that the Council's Scientific and Statistical Committee may recommend a different value for a specific stock or stock complex as merited by the best available scientific information. A scalar, γ, is multiplied by M to estimate the F_{OFL} for stocks at status levels a and b, and γ is allowed to be less than or greater than unity. Use of the scalar γ is intended to allow adjustments in the overfishing definitions to account for differences in biomass measures. A default value of γ is set at 1.0, with the understanding that the Council's Scientific and Statistical Committee may recommend a different value for a specific stock or stock complex as merited by the best available scientific information.

Annual scenarios would be run using the projection models, if a model is available, or survey data, if no model is available, to determine if a stock is overfished or approaching an overfished condition. In this analysis, a retained catch OFL is estimated for all Tier 4 stocks because the information necessary to determine total catch OFLs is not available. For example, bycatch information is not available for Norton Sound red king crab and adequate information to estimate bycatch selectivity is not currently available for blue king crab stocks. Therefore, in the near term, annual determination of overfishing would occur by comparing the OFL as calculated by applying Tier 4 with the retained catch for the same time period.

If the information necessary to determine total catch OFLs is not available for a Tier 4 stock, then the OFL is determined for retained catch. In the future, as information improves, data would be available for some stocks to allow the formulation and use of selectivity curves for the discard fisheries (directed and non-directed losses) as well as the directed fishery (retained catch) in the models. The resulting OFL from this approach, therefore, would be the total catch OFL.

Tier 4 stocks have MSST proxies. If the annually estimated MMB drops below the MSST proxy, then the stock is considered to be overfished.

2.2.3 Tier 5

Tier 5 stocks have no reliable estimates of biomass or M and only historical data of retained catch is available. For Tier 5 stocks, the historical performance of the fishery is used to set OFLs in terms of retained catch. The OFL represents the average retained catch from a time period determined to be representative of the production potential of the stock. The time period selected for computing the average catch, hence the OFL, would be based on the best scientific information available and provide the appropriate risk aversion for stock conservation and utilization goals. In Tier 5, the OFL is specified in terms of an average catch value over a time period determined to be representative of the production potential of the stock, unless the Scientific and Statistical Committee recommends an alternative value based on the best available scientific information.

For most Tier 5 stocks, only retained catch information is available so the OFL will be estimated for the retained catch portion only, with the corresponding overfishing comparison on the retained catch only. In the future, as information improves, the OFL calculation could include discard losses, at which point the OFL would be applied to the retained catch plus the discard losses from directed and non-directed fisheries.

2.3 Alternative 3: Six-Tier System

Alternative 3 would amend the FMP to include the six-tier system in Table 2-5 (and Figure 2-1) and an OFL setting and review process for assigning each crab stock into a tier and for setting the OFLs, as described in Option 1 or Option 2 (see Section 2.5). Additionally, the Council may choose to remove specific crab stocks from the FMP, as described in Option A (see Section 2.6).

The tier system in Alternative 3 is similar to Alternative 2 for the first four tiers, however, Tier 5 is modified and Tier 6 is added (Table 2-5, Figure 2-1).

2.3.1 Tiers 1-4

The only difference for tiers 1-4 under Alternative 3 would be how the OFL would be set for stocks in stock status level “c.” Crab stocks would be in stock status level “c” when biomass is below one half of the minimum stock size threshold (MSST). Under Alternative 3, for stocks in stock status level "c," the overfishing level would be zero and any catch in any fishery would result in overfishing.

2.3.2 Tier 5

Tier 5 stocks have no reliable estimates of biomass or M, but a reliable retained catch history exists for these stocks. Therefore, only an OFL would be set for these stocks because it is not possible to set an MSST without an estimate of biomass. For stocks belonging to Tier 5, the historical performance of the fishery is used to set OFLs in terms of catch instead of fishing mortality, as in Tiers 1-3. The OFL represents the average catch from a time period determined to be representative of the production potential of the stock. The time period selected for computing the average catch, hence the OFL, is based on the best scientific information available and provides the required risk aversion for stock conservation and utilization goals.

At this time, annual determination of overfishing would occur by comparing the OFL as calculated by applying Tier 5 with the retained catch for the same time period. For most Tier 5 stocks, only retained catch information is available so the OFL will be estimated for the retained catch portion only, with the corresponding overfishing comparison on the retained catch only. In the future, as information improves, the OFL calculation could include discard losses, at which point the OFL would be applied to the retained catch plus the discard losses from directed and non-directed fisheries.

2.3.2 Tier 6

Tier 6 is for stocks where information necessary to establish an OFL and MSST is currently unavailable. For these stocks, a reliable catch history does not exist and only exploratory fishing or incidental catch has occurred in the recent past. The problems with establishing an OFL based on catch history for these stocks include: (1) catch data come from exploratory and incidental fisheries for most stocks, (2) there are only 2 to 4 years of catch data for several stocks or hardly any catch data, (3) mean catch may be too high, or (4) mean catch may be too low.

To be precautionary when stock status is unknown, the default OFL would be set at zero for retained catch. For an individual species, the SSC may wish to recommend an OFL to allow for retained catch, in which case additional research and analysis would need to be conducted to determine the OFL. Retained catch includes retained incidental catch as well as retained catch in a directed fishery. Bycatch of Tier 6 stocks would not count against an OFL equal to zero because all bycatch is discarded.

No retention would be allowed for stocks with an OFL equal to zero. If ADF&G intends to open a fishery for a specific stock or allow retained incidental catch, the SSC would recommend an OFL for that Tier 6 stock based on the best available scientific information through the OFL setting process prior to the ADF&G GHL setting process. Stocks in Tier 6 would continue to be evaluated annually for possible upgrading to Tier 5 for OFL determination. If fishing is allowed, these stocks would be monitored for trends in fishery performance and relative abundance, such as fishing effort, CPUE, mean size of landed crab, and ratio of newshell to oldshell crab.

Annual determination of overfishing would occur by comparing the retained catch with the OFL. For stocks where OFL is equal to zero, no amount of these crabs may be retained in any fishery and any retained catch would constitute overfishing.

Table 2-5 Alternative 3 Six-Tier System. The tiers are listed in descending order of information availability. Appendix A contains the notations used in the equations.

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. $\frac{B}{B_{msy}} \le \beta$	$F_{OFL} = 0$
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. $\frac{B}{B_{msy}} \le \beta$	$F_{OFL} = 0$
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. $\frac{B}{B^{*}_{35\%}} \le \beta$	$F_{OFL} = 0$
B, M_{prox}, $B_{msy^{prox}}$	**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. $\frac{B}{B_{msy^{prox}}} \le \beta$	$F_{OFL} = 0$
Reliable catch history from a time period to be determined.	**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.
Stocks with insufficient catch history and limited scientific information.	**6**		Default OFL=0 for retained catch, unless the SSC recommends an OFL based on the best available scientific information.

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

2.4 Comparison of status determination criteria

This section provides a comparison of the status determination criteria in Alternatives 1, 2, and 3. The status determination criteria provided in Alternative 1 are fixed in the FMP and reflect the understanding of crab biology and abundance when adopted in 1998. However, since 1998, considerable work has been undertaken by ADF&G and NMFS to better understand and model the BSAI king and Tanner crab stocks. A number of the life history parameters that were unknown or controversial in 1998 have been determined to a degree of certainty. Other life history parameters that remain either unknown or controversial are the subject of ongoing research. As new information comes available, Alternatives 2 and 3 provide a mechanism to improve the status determination criteria through applying different biological reference points and adjusting the OFLs based on the level of uncertainty in the stock assessment.

Chapter 3 provides the methodologies used to apply the tier system to the 22 FMP crab stocks. Chapter 3 also provides the proposed tier assignments for the stocks under Alternatives 2 and 3. The impacts of the alternative status determination criteria are analyzed for each stock in Chapters 4 through 9.

2.4.1 Biological reference points

Biological reference points are estimated for the different species managed under this FMP. A biological reference point is a level of a fishery and/or of a stock that can be used for management. Caddy and Mahon (1995) define a reference point as a conventional value, derived from technical analysis, which represents a state of the fishery or population, and whose characteristics are believed to be useful for the management of the unit stock. Anonymous (2000) further specifies that biological reference points are quantifiable and verifiable points, expressed in terms of management and population variables, which include the amount of fishing (fishing mortality) and the condition of the fish stock (biomass). Biological reference points are defined solely using biological criteria associated with the productivity of the stock, but may be modified into management or technical reference points by incorporating social or economic criteria to define OY.

Estimation of base input parameters to determine biological reference points varies by species and by availability of information for specific stocks. Under Alternatives 2 and 3, biological parameters may be adjusted annually as information on stocks improve, or as information on specific parameters (e.g., biomass estimates, handling mortality) becomes available to suggest alternate approaches. Options 1 and 2 provide a specific review process for the CPT, SSC, and Council to scientifically review the parameters used in the models used to estimate OFLs (see Section 2.5). Unlike Alternative 1, an FMP amendment would not be required to change these biological parameters.

Table 2-6 compares the biological reference points provided in the alternatives. Additional information on biological reference points and parameters is provided in the chapter for each species.

Table 2-6 Comparison of biological reference points used in the alternatives.

Biological Reference Points	Alternative 1 (Status quo)	Alternatives 2 and 3
Maximum Sustainable Yield (MSY) or MSY proxy	average of the annually computed sustained yield (SY) over the 15-year period, 1983-1997 (SY = total mature biomass * M)	Calculated by applying F_{MSY}† or F_{MSY} proxy† in tier system to appropriate biomass estimate
MSY Biomass (B_{MSY})	average annual estimated total mature biomass for the 15-year period, 1983-1997	Mature male biomass† at MSY level
Minimum stock size threshold (MSST)	½ B_{MSY}	½ B_{MSY}
Maximum fishing mortality threshold (MFMT or F_{OFL} control rule)	MSY control rule applied to the current total mature biomass	F_{OFL} control rule calculated by applying tier system: Tiers 1 and 2 – mean of pdf of F_{MSY} and F_{MSY} Tier 3 - F_{MSY} proxy = $F_{35\%}$† Tier 4 - F_{MSY} proxy = γ† * M
MSY control rule	M	F_{OFL} control rule
Natural mortality rate (M)	0.2 for all species of king crab 0.3 for all *Chionoecetes* species	0.18† for all species of king crab 0.23† for male and 0.29† for female *Chionoecetes* species
OFL	Sustainable yield (SY) = Total mature biomass * M	Total catch OFL calculated applying F_{OFL} control rule or mean retained catch determined for a specified period
Optimum yield (OY)	OY range 0 to MSY	OY range 0 to < OFL catch

† These parameters and assumptions are frameworked in the tier system and the values used for this analysis are based on the best available scientific information. Biological parameters can change with new scientific information through the OFL setting process outlined in Options 1 and 2 (see Section 2.5).

Table 2-7 through Table 2-9 compare the application of the alternative biological reference points using 2006 data (in millions of pounds). These tables are examples of the types of information that will be summarized annually when determining the status of the stocks under the alternatives.

Table 2-7 provides the information necessary to determine whether a stock is overfished by comparing estimated biomasses with the MSSTs established for the stocks under the alternatives. Information available to determine B_{MSY} or proxy and the resulting MSST or proxy is only available for stocks in Tiers 1-4. A stock is considered overfished if the biomass is below the MSST and rebuilt when the biomass is above B_{MSY} for two consecutive years. For Alternative 1, B_{MSY} and MSST are in terms of TMB and so the annual TMB estimate is compared to these two benchmarks. For Alternatives 2 and 3, B_{MSY} and MSST are in terms of MMB and so the annual MMB estimate is compared to these two criteria. According to the table, the status of these six stocks relative the MSST is similar under all alternatives. Information is not available to establish the MSST for the remaining crab stocks. However, for Bristol Bay red king crab, EBS Tanner crab, and Pribilof Islands red king crab, the status of the stocks would change relative to B_{MSY}. Under Alternative 1, these stocks are above B_{MSY} in 2006 and under Alternatives 2 and 3, these stocks would be below B_{MSY}.

Table 2-7 Comparison of the application of alternative overfished biological reference points for the stocks in Tiers 1-4 using 2006 data (in millions of pounds).

	Alternative 1			Alternatives 2 and 3		
Stock	**B_{MSY} in TMB**	**MSST in TMB**	**B(06) inTMB**	**Proxy B_{MSY} in MMB**	**MSST in MMB**	**B(06) in MMB**
Bristol Bay red king crab	**89.6**	**44.8**	**157.2**	**77.86**	**38.93**	**65.54**
Pribilof Islands red king crab	**6.6**	**3.3**	**19**	**7.82**	**3.91**	**6.43**
Pribilof Islands blue king crab	13.2	6.63	1.6	6.68	3.34	0.63
St. Matthew blue king crab	22	11	11.2	13.92	6.96	7.41
EBS Tanner crab, Tier 3	**189.6**	**94.8**	**253.3**	**70.84**	**35.42**	**62.76**
EBS Tanner crab, Tier 4				82.26	41.13	
Snow crab	921.6	460.8	547.6	354.72	177.36	211
Norton Sound red king crab	NA	NA	NA	3.76	1.88	4.88
EAI Tanner crab	NA	NA	NA	1.62	0.81	2.87

Note: **Bold** indicates a change is status: under Alternative 1 stock is above B_{MSY} and stock is below B_{MSY} under Alternatives 2 and 3.

Table 2-8 and Table 2-9 provide the information necessary to compare the proposed OFL values under Alternatives 2 and 3, using the information available in 2006, with the Alternative 1 OFLs and the retained catch. This table provides information for determining whether overfishing is occurring for a stock. Overfishing occurs for a stock when the catch is greater than the OFL. For all stocks for which information is available, the OFL applies to total catch. For those stocks for which information is insufficient to determine discard losses, the OFL applies to the retained catch only.

In Table 2-8, for Alternatives 2 and 3, F_{OFL} control rules would be set according to the tier system (Table 2-3 and Table 2-5):

For Tier 3 stocks:

- For Tanner crab, $F_{35\%}$ is 0.8 when the MMB is above $B_{35\%}$. However, the sliding control rule was applied to reduce the F_{OFL} to 0.70 because stock status level was “b” because the 2006 MMB estimate of 62.76 was lower than the $B_{35\%}$ (70.84).
- For Bristol Bay red king crab, $F_{35\%}$ is 0.36 when the MMB is above $B_{35\%}$. However, the 2006 stock status level was “b” because the MMB estimate of 65.54 is lower than the $B_{35\%}$ (77.86), and so the sliding control rule was applied to reduce the F_{OFL} to 0.30.

For Tier 4 stocks:

- For St. Mathew blue king crab, when MMB is above proxy B_{MSY}, γ*M = 0.36, where γ = 2.0. However, the 2006 stock status level was “b” because the MMB estimate of 7.14 is lower than the proxy B_{MSY} (13.92), and so the sliding control rule was applied to reduce the actual F_{OFL} to 0.17.

- For Pribilof Islands blue king crab, the 2006 stock status level was "c", therefore under Alternative 3, the F_{OFL} was set to zero because 2006 MMB <25% MMB_{MSY}. Under Alternative 2, the OFL would be set less than or equal to F_{MSY} in the rebuilding plan revision.
- For Norton Sound red king crab, the 2006 MMB of 4.876 is greater than the proxy B_{MSY} of 3.76, so the stocks status level is "a", and therefore the F_{OFL} is 2*0.18 = 0.36
- For EAI Tanner crab, the 2006 MMB of 2.872 is greater that B_{MSY} of 1.62, so the stock status level is "a", and therefore the 2006 F_{OFL} = 2*0.23 = 0.46.

Unlike the overfished status in Table 2-7, where the alternatives performed similarly, Table 2-8 and Table 2-9 show that the alternatives perform very differently for overfishing. According to the tables, overfishing did not occur in 2006 under Alternative 1 for the stocks for which information is available. However, under Alternatives 2 and 3, overfishing would have occurred in 2006 for snow crab. However, most likely, overfishing would not have actually occurred under Alternatives 2 and 3 because the OFL level would have been set prior to the TAC setting process, so the OFL would have constrained the TAC for that fishery.

For Tier 3 stocks, annual determination of overfishing would occur by comparison of the OFL as calculated for total catch (retained and discard losses) with the total catch for the same time period. This total catch would include all fishery removals for those stocks where non-target fishery removal data are available. Discard losses are determined by multiplying the appropriate handling mortality rate by observer estimates of bycatch discards. For stocks in Tiers 4-6, when information is not available to determine discount losses, OFL would be calculated for retained catch.

Table 2-8 Comparison of the application of alternative overfishing biological reference points using 2006 data (in million pounds) for Tier 3 and Tier 4 stocks. Alternatives 2/3 OFL catch values were estimated from 2006 legal male abundance at the time of the fishery.

			Alternative 1			Alternatives 2 and 3				
Stock	**2006/07 Retained Catch**	**2006/07 Total Catch**	**2006 TMB / TMB_{MSY}**	**F_{OFL}**	**OFL (SY=M*TMB)**	**2006 MMB / MMB_{MSY}**	**Tier and Stock Status Level**	**F_{OFL}**	**OFL Retained Catch**	**OFL Total Catch**
BB red king crab	15.748	17.219	1.754**	0.200	31.440	0.842	3b	0.297	14.430	17.780
EBS snow crab	36.360	42.110	0.594	0.300	164.28	0.595	3b	0.511	23.590	29.980
EBS Tanner crab, Tier 3	2.120	5.152	1.336**	0.300	75.990	0.886	3b	0.699	13.076	18.234
EBS Tanner crab, Tier 4	2.120	5.152	1.336**	0.300	75.990	0.763	4b	0.483*	9.903	14.350
Pribilof Islands red king crab	0.000		2.879**	0.200	3.800	0.822	4b	0.289	1.464	
Pribilof Islands blue king crab	0.000		0.121	0.200	0.320	0.094	4c	0.000	0.000	
St. Matthew Island blue king crab	0.000		0.509	0.200	2.240	0.532	4b	0.173	0.595	
Norton Sound red king crab	0.453		NA	0.200	0.500(MSY)	1.298**	4a	0.360	1.119	
EAI Tanner crab	0.084		NA	0.300	0.700(MSY)	1.772**	4a	0.460	0.683	

* EBS Tanner crab maximum F_{OFL} = 2.85*M under Tier 4 control rule and for lesser known EAI Tanner crab maximum F_{OFL} = 2*M
** Fertilized egg production index (in terms of mature biomass) is above the MSY level

Table 2-9 Comparison of the application of alternative overfishing biological reference points for Tier 5 and Tier 6 stocks. Alternatives 2/3 OFL retained catch values were estimated as average catch for appropriate period during 1985-2005. The time period used for average catch estimation are given in parentheses. The catches are in millions of pounds.

		Alternative 1		Alternatives 2 and 3	
Stock	**2006/07 Retained Catch**	**F_{OFL} as MFMT**	**OFL Retained Catch (M*TMB or MSY)**	**Tier and Stock Status Level**	**OFL Retained Catch**
Dutch Harbor red king crab	0.000	0.200	NA	5	0.000 (1985-2005)
Adak red king crab	0.000	0.200	1.500(MSY)	5	0.948 (1985-1994)
Pribilof Islands golden king crab	Confidential	0.200	0.300(MSY)	5	0.174 (1993-1999)
AI golden king crab	5.260	0.200	15.000(MSY)	5	8.261 (1985-1999)
EBS grooved Tanner crab	Confidential	0.300	1.500(MSY)	5	0.352 (1993-96, 01, 03, 04)
St. Matthew Island golden king crab	0.000	0.200	0.300(MSY)	5/6	0.086 (1987-2003)
W. Aleutian Tanner crab	0.000	0.300	0.400(MSY)	5/6	0.077 (1985-1992)
St. Lawrence Island blue king crab	0.000	0.200	0.100(MSY)	5/6	0.000 (1985-2005)
Aleutian Island scarlet king crab	0.000	0.200	NA	5/6	0.013 (1992, 1994-2004)
EBS scarlet king crab	0.000	0.200	NA	5/6	0.015 (1995, 96, 01, 2003-05)
BS triangle Tanner crab	0.000	0.300	0.300(MSY)	5/6	0.038 (1995, 96, 01, 04)
EAI triangle Tanner crab	0.000	0.300	1.000(MSY)	5/6	0.295 (1995-1996)
EAI grooved Tanner crab	0.000	0.300	1.800(MSY)	5/6	0.505 (1993-1996)
WAI grooved Tanner crab	0.000	0.300	0.200(MSY)	5/6	0.075 (1994-1996)

2.4.2 Impacts of an overfished or overfishing determination

As described in section 1.1.2, if a stock is declared overfished, or overfishing is found to be occurring, the Secretary will notify the Council, and the Council must immediately end overfishing and will then have 2 years to prepare an FMP amendment to rebuild the stock.

In the case of an overfished declaration where the stock status is found to be below MSST, an FMP amendment would be prepared which would propose management measures for a rebuilding plan for the overfished stock. There have been four rebuilding plan amendments prepared for the BSAI Crab FMP following the overfishing definitions under Amendment 7 in 1998: EBS Tanner crab, snow crab, St. Matthew blue king crab, and Pribilof Islands blue king crab. Snow crab, St. Matthew blue king crab, and Pribilof Islands blue king crab remain under rebuilding plans currently, as they are not considered "rebuilt" until the stock is above B_{MSY} for two consecutive years. In 2007, EBS Tanner crab was considered rebuilt and is no longer under a rebuilding plan.

In the case of an overfishing declaration, the Council is required to "immediately take measures to end overfishing" (MSA 304(e)). Since, under Options 1 and 2, the OFL would be available prior to the State's TACs setting process, the TACs for the upcoming fishery would be constrained by the OFL and thereby prevent overfishing. However, after tabulation of all catch data and comparison of the catch to the OFL, overfishing may be determined to have occurred. Given the delegation of authority under the BSAI Crab FMP whereby TAC-setting is the State's responsibility, the Council and NMFS would advise the State to reduce their TAC in subsequent years to remain below the OFL for that stock. If the State was not able to effectively end overfishing by reducing TACs, the Council would likely develop an FMP amendment for additional management measures, including reducing crab bycatch in non-crab fisheries.

Similar management measures must also be taken if a stock is approaching an overfished condition. This is defined 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" (MSA 304(e)). If the Secretary notifies the Council of a stock approaching an overfished condition, the Council is required to take the same steps as described above in order to prevent the stock from becoming overfished.

2.4.3 Risks associated with continued use of the Alternative 1 status determination criteria

The MSST and MSY control rule in the status quo overfishing definitions (Alternative 1) provide two benchmarks to determine the status of stocks and overfishing; the MSST is the benchmark used to determine if a stock is in an overfished condition, whereas the MSY control rule is used to compute a benchmark to determine if overfishing has occurred or if a proposed TAC would constitute overfishing. MSST for each Tier 3 stock is fixed in the FMP by Amendment 7 (B_{MSY} and MSST is not defined for either the Tier 1 or Tier 2 stocks). Although not a fixed value, the MSY control rule for a stock is parameterized by the MFMT for the stock, which is fixed in the FMP by Amendment 7. MSST for a Tier 3 stock is defined as being ½ of the stock's B_{MSY}, which is defined by Amendment 7 as a fixed value for each of the Tier 3 stocks. The MSY control rule for a stock is defined as the product of the stock's estimated TMB and the fixed-value MFMT defined for the stock in the FMP by Amendment 7.

The status quo overfishing definitions have the advantage of simplicity in definition, computation, and application. MSST is defined as ½ B_{MSY}, which for Tier 3 stocks, is defined as the average annual TMB over the period 1983-1997 as estimated from results of the NMFS EBS trawl survey. If the TMB of a stock as estimated from the results of the NMFS EBS trawl survey is less than the fixed-value MSST, the stock is considered overfished. An overfished stock's progress towards rebuilding is tracked by comparing the annually estimated TMB with the fixed-value B_{MSY}; the TMB must meet or exceed B_{MSY} to be considered rebuilt. The process of comparing annual TMB estimates with fixed values requires no more analysis than is involved in estimating the TMB, an important consideration given the short time between availability of summer survey data and the opening of the fisheries in the fall.

Likewise, application of the MSY control rule to determine an overfishing level requires a simple multiplication of the TMB estimate and the MFMT. Under the status quo definitions, overfishing would occur if fishing mortality is greater than or equal to MFMT = F_{MSY}, which is fixed in the FMP as equal to an estimate of the natural mortality rate for the stock (0.2 for all king crab stocks and 0.3 for all *Chionoecetes* stocks). To determine if overfishing has occurred or if a proposed TAC would result in overfishing, the MSY control rule is applied to the stock's estimated TMB for the year of interest and the resulting sustainable yield (SY=M*TMB) value is compared with harvest or proposed TAC in question; a harvest is considered to constitute overfishing when it is equal to or greater than the SY. Again, the simplicity of this process is a benefit given the short time between availability of summer survey data and the beginning of the fall fisheries.

Although the status quo overfishing definitions have advantages of simplicity in definition, computation, and application, those definitions also carry risks in their application. Fixed values of B_{MSY}, MSST, and MFMT may not adequately reflect the realities of changing stock and environmental conditions. Additionally, there may be technical and conceptual problems in the definition and derivation of the values that are fixed in the FMP under the status quo definitions and in the status quo formulation of the MSY control rule. The B_{MSY} definition for Tier 3 stocks, for example, assumes that the average of the annual TMB for a stock during 1983-1997 is an adequate estimate of what according to the 1998 Guidelines for National Standard 1 (Optimum Yield) of the Magnuson-Stevens Act should be the long-term spawning biomass that would be achieved under an MSY control rule in which fishing mortality is constant. That assumption can be questioned regardless of the timeframe considered (i.e., regardless of whether the period 1983-1997 is the appropriate period to represent current prevailing environmental conditions). It has not been demonstrated that the TMB over the period of any Tier 3 stock was the result of application of an MSY control rule in which fishing mortality was constant. That several of the Tier 3 stocks were declared to be in overfished condition shortly after 1997 is evidence that the TMB during 1983-1997 were not the levels expected to be achieved under an MSY control rule.

Aside from technical issues that exist concerning the derivation of the status quo MSY control rule, the status quo definition of MFMT = F_{MSY} = M, and the estimated values of M under the status quo, there are issues in the application of the status quo MSY control rule. Due to problems that may be more "conceptual" than "technical," the status quo MSY control rule does not provide clear guidance for determining if overfishing is occurring or for developing harvest strategies that avoid overfishing. Although application of the status quo MSY control rule provides a sustainable yield value that a harvest or proposed TAC can be compared to, the current definitions are not clear on how all sources of fishing mortality (e.g., bycatch mortality during the directed fisheries or other fisheries) are accounted for when determining if overfishing has or could occur.

Moreover, the status quo MSY control rule does not reflect the realities of the BSAI king and Tanner crab fisheries and their management. The MSY control rule was defined in the context of the broadest and most generalized fishery practices possible (year-around fishing and constant fishing selectivity over all sizes and both sexes of mature animals) within which sex, size, and season restrictions on harvest were considered OY choices. However, since the inception of these FMP fisheries, sex restrictions (males-only harvests) have been applied; minimum-size-limit restrictions for harvesting males have been established in regulation or exist de facto due to market preferences; and, for all but a few stocks, seasonal harvest restrictions have been established. By ignoring the sex, size, and season restrictions that exist in regulation, the fishery practices that result in fishery selectivity varying by size or shell age of legal-sized males, and the potential for fishery harvests to occur during only a short period within a year, the status quo MSY control rule could allow for harvests that would clearly constitute overfishing without being formally recognized as such. Under the status quo MSY control rule, any harvest of less than 20% of a king crab stock's (or 30% of a Tanner crab stock's) mature biomass as estimated at the time of the summer stock assessment survey, when mature biomass is at or near it's annual peak, would not constitute overfishing. The MSY control rule does not consider the phase in the molting and spawning cycle during which the harvest occurs, the biomass present at the time that the harvest occurs, or the component of the mature stock that is harvested. As a result, under some conditions, the status quo MSY control rule could allow for all legal-sized or market-preferred males present in a stock to be harvested.

2.5 Options for the OFLs setting and review process

Under Alternatives 2 and 3, Options 1 and 2 (Preferred) would establish different annual processes for OFL setting and review for each stock on an annual basis.

The OFL setting and review process establishes (1) the information utilized for OFL determination; (2) the placement of stocks into tiers; (3) the estimation of stock abundance; (4) the calculation of the F_{OFL} and subsequent OFL; and (4) the comparison of each stock's status to the MSST and the catch to the OFL. The timing of the OFL setting and review process is important because it determines two key factors: (1) who the decision-maker is for establishing the OFL, and (2) what information is used in the OFL determinations. Timing also impacts the level and extent of peer review and information shared with the public.

The difference in the timing of the OFL setting and review process affects the fisheries for the surveyed stocks, Bristol Bay red king crab, snow crab, EBS Tanner crab, Pribilof Islands red and blue king crab, and St. Matthew blue king crab. These stocks would be in Tiers 1-4. Stocks in Tiers 5 and 6 are not subject to the NMFS annual trawl survey and are not directly impacted by the choice of timing of the OFL determinations. However, they would be impacted by having to conform to the annual OFL setting and review process. This would be a more frequent and involved review process than status quo.

Under both options, OFLs would be set for the upcoming crab fishing year, which runs from July 1 to June 30. The OFLs would be set prior to the State setting the TAC or GHL and would guide the TAC/GHL setting process to avoid overfishing.

Additionally, for those stocks with a total catch OFL, annual tabulation of catch by stock must be conducted after the crab fishing year for comparison to the total catch OFL. For those stocks where sufficient information is available, the OFL would apply to all catch, which includes retained catch and discard losses from crab fisheries, as well as groundfish and scallop fisheries which catch crab species as bycatch. Discard losses are determined by multiplying the appropriate handling mortality rate by the estimated by catch amounts. Retained catch data are available in the late spring shortly after the fisheries close. Bycatch from the crab fisheries is estimated using State observer program data and estimates are available by mid-August each year. Crab bycatch from the groundfish fisheries for the crab fishing year is estimated using Federal observer program data and would also be available in August. Therefore, tabulation of total catch could occur in the fall, following the crab fishing year for which the OFLs were determined, and be reported in the annual SAFE Report. NMFS would determine whether overfishing occurred in the previous year by comparing the total catch data to the OFL. Further discussion of the tabulation of annual catch and estimations of bycatch are in Chapter 3.

2.5.1 Option 1: Council annually adopts OFLs in June

Option 1 would establish a process whereby the Council would annually adopt the OFLs for each stock in June, prior to their application in the fall (Table 2-10 and Figure 2-3). The process of OFL determination and stock status determination varies depending on a stock's tier (and subsequent information availability). Each spring, the CPT would recommend to the SSC and Council, based on the work of the assessment authors, the placement of stocks into tiers (1, 2, 3 4, 5, or 6), stock status level (a, b, or c), and the resulting F_{OFL} (see the tier system in Table 2-3 and Table 2-5).

For stocks in Tiers 1-3, the F_{OFL} would be applied to model estimates of exploitable abundance to derive the OFL. The CPT would also recommend an MSST based on the stock status from the model. The information utilized in this process would be based on model simulations using previous year's survey data. The SSC and Council would review this information at the June meeting and adopt the OFLs and MSSTs.

After the summer survey, for stocks with no stock assessment model, NMFS would compare the MMB from the survey with the established MSST to determine whether the stock is overfished. For stocks in Tiers 1-4 with stock assessment models, NMFS would determine whether the stock is overfished by comparing model estimates of MMB to ½ B_{MSY} or ½ the B_{MSY} proxy value. The State would also set TACs for the fall fisheries based on the survey abundance estimates, constrained by the OFLs. Once the catch and bycatch data are available, overfishing would be determined by comparing the actual catches with the OFL. For Tier 1-3 stocks, it would be necessary to annually compile all discard losses and retained catches, and to compare that sum against the total catch OFL for that year in order to evaluate the overfishing status determination criterion for each stock. Currently, for Tier 4 stocks, information is insufficient to determine the level of discard mortality or catches by non-directed fisheries, so the OFL would be based on the retained catch. It will be necessary to annually compile all retained catches, and to compare that sum against the retained catch OFL for that year in order to evaluate overfishing for each stock

The timing of the annual fall CPT meeting and resultant SAFE report to the Council may be modified under this option for either September CPT meeting and October Council report or October CPT meeting and December Council report.

Table 2-10 Option 1 annual OFL setting and review process for Tiers 1-4.

Spring	**Tiers 1-3**: Assessment authors conduct stock assessments for each stock using data from the previous summer trawl survey and available fishery data to estimate stock biomass (as measured in MMB), as well as the biomass and fishing mortality at which MSY is achieved (B_{MSY} and F_{MSY}), or proxies for B_{MSY} and F_{MSY}. The method of stock assessment will depend on information availability. However, the assessment model will usually include information on life history, recruitment, survey biomass estimates, catchability, retained and discarded catch, as well as other sources of mortality. Chapter 3 contains additional information on the parameterization, model assumptions, and simulation methodology. **Tier 4**: Assessment authors estimate for each stock the stock biomass (as measured in MMB), as well as the biomass and fishing mortality proxies at which MSY is achieved (B_{MSY} and F_{MSY} proxies). The OFL for Tier 4 stocks is based on the most recent survey estimate of biomass and an F_{OFL} that is proportional to the best estimate of *M*.
May	CPT reviews the assessments and tier assignments and recommends the F_{OFL} based on tier system (Table 2-3 and 2-4) and the OFL and MSST. The specific rule applied to determine the F_{OFL} depends on both tier assignment (e.g., Tier 1, 2, 3, 4, 5, or 6) and the status of the stock (e.g., a, b, or c) relative to B_{MSY} (or its proxy). The OFL is expressed either in terms of total catch biomass (males and females, retained and discard losses) or retained catch, depending on information availability. The MSST is expressed in MMB.
June	Council and SSC reviews models and tier assignments and adopts OFLs and MSSTs and and stock status relative to the MSST. NMFS prepares a report of the status of the crab stocks relative to the MSSTs (or proxies). If the estimate of current stock biomass is less than the MSST, the stock is considered overfished while if the current stock biomass is above the MSST, the stock is not overfished.
June-August	NMFS annual trawl survey.
October 1	State sets TACs for the fall fisheries based on the August abundance estimates and constrained by the June OFLs.
September/October	The CPT reviews the new TACs, reviews previous year's fishery information and previous years OFLs, and compiles the SAFE report. NMFS determines whether overfishing occurred in the previous fishing year.
October/December	The Council and SSC review the TACs relative to the June OFLs, the previous year's overfishing determination, and the SAFE report.
After the fisheries close and once catch information is available	**Tiers 1-3**: Determine the total catch for the previous year, this would entail a tabulation of all retained catch and discard losses. To determine the discard losses, the handling mortality rate is multiplied by bycatch discards in each fishery. Compare the total catch to the OFL. If total catch is greater than the OFL, then overfishing occurred in the previous year. **Tier 4**: Determine the catch for the previous year and compare to the OFL. When information is insufficient to determine the level of discard mortality or catches by non-directed fisheries, the OFL would be based on the retained catch.

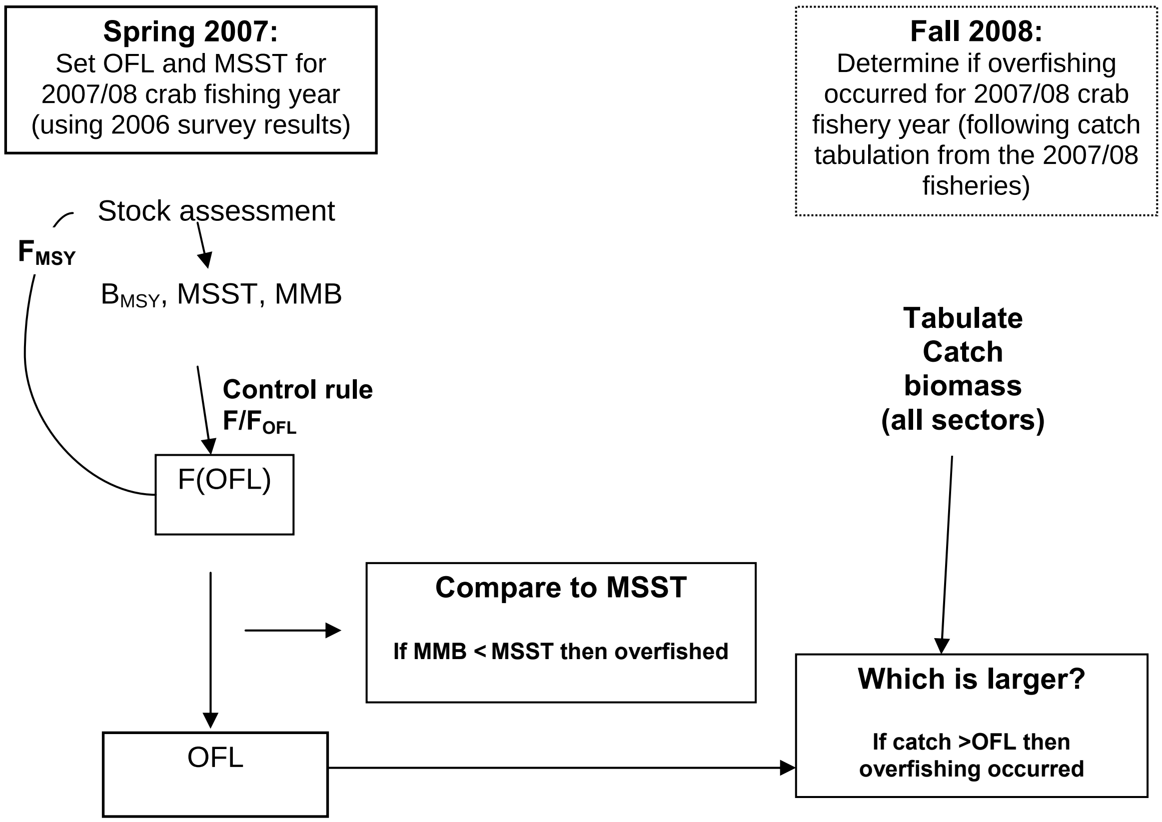

Figure 2-3 Option 1 OFL setting and review process for Tiers 1-4, using the 2007/2008 crab fishing year as an example.

2.5.2 Option 2: Council annually reviews OFLs in the fall (Preferred)

Option 2 is similar to status quo and would provide that the same abundance estimates would be used to set the OFLs, MSSTs, and TACs for each crab fishing year. The Option 2 process is described in Table 2-11 and Figure 2-4. Each spring, the CPT would review model parameter choices by the stock assessment authors and resultant tier assignments and make recommendations to the SSC. Each June, the Council and SSC would review the choice of parameters and recommend the parameters and tier assignments (i.e., 1, 2, 3, 4, 5, or 6) to be utilized in the OFL calculation simulations. The process of OFL determination and stock status determination varies depending on a stock's tier (and subsequent information availability).

The model simulations for OFL and MSST setting would be conducted after obtaining the most recent survey results from the NMFS summer trawl survey. The OFL would be set and involve the incorporation of new survey data to determine stock status level (i.e., a, b, or c) for the OFL calculation. Therefore, while the tier assignments and many of the parameters would be established following the June SSC review, OFLs would not be calculated until the survey results are available in late August. Model structure would not be changed in the interim. Following the incorporation of survey results, assessment authors would calculate the OFLs and MSSTs. NMFS would determine the status of the stocks relative to the MSSTs. The CPT would review the survey data, the OFLs, and the status of the stocks at its September meeting when it prepares the SAFE. The State would set the TACs on October 1, constrained by the OFLs. The CPT would then report the OFLs and TACs to the Council at the October Council meeting in conjunction with the presentation to the Council on the status of stocks.

Once the fisheries are closed and catch data is available, overfishing would be determined for that crab fishing year. For Tier 1-3 stocks, it would be necessary to annually compile all discard losses and retained catches, and to compare that sum against the total catch OFL for that year in order to evaluate the overfishing for each stock. Currently, for Tier 4 stocks, it would be necessary to annually compile all retained catches, and to compare that sum against the retained catch OFL for that year in order to evaluate the overfishing status determination criterion for each stock

Table 2-11 Option 2 tier and OFL setting and review process.

Spring	Assessment authors prepare stock assessment models when possible, estimate parameters, and recommend tier assignments (e.g., Tier 1, 2, 3, 4, 5, and 6) for each stock. The assessment models will depend on information availability will usually include information on life history, recruitment, survey biomass estimates, catchability, retained and discarded catch, as well as other sources of mortality. Chapter 3 contains additional information on the parameterization, model assumptions and simulation methodology.
May	CPT reviews assessment work and recommends tier assignments.
June	SSC reviews assessment work and recommends tier assignments.
June-August	NMFS annual trawl survey.
August	The determination of the OFL and MSST would depend on the stock's tier assignment. **Tiers 1-3:** Assessment authors would conduct a stock assessment using new survey data to calculate the MSST and OFL and to estimate stock biomass (as measured in MMB), as well as the biomass and fishing mortality at which MSY is achieved (B_{MSY} and F_{MSY}), or proxies for B_{MSY} and F_{MSY}. The F_{OFL} would be determined based on tier system (Table 2-3 or Table 2-4) and used to calculate the OFL. The specific rule applied to determine the F_{OFL} depends on both tier and the status of the stock (e.g. a, b, and c) relative to B_{MSY} (or its proxy). The OFL is expressed in terms of total catch biomass (males and females, retained and discard losses) for the coming year. **Tier 4**: Assessment authors would calculate the MSST and OFL using new survey data to estimate stock biomass (as measured in MMB), as well as the biomass and fishing mortality proxies at which MSY is achieved (B_{MSY} and F_{MSY} proxies). The F_{OFL} would be determined based on tier and used to calculate the OFL. The OFL for Tier 4 stocks is based on the most recent survey estimate of biomass and an F_{OFL} that is proportional to the best estimate of *M*. For Tier 4 stocks, information is insufficient to determine the level of discard mortality or catches by non-directed fisheries, the OFL will be based on the retained catch.
September	NMFS would determine the status of the stocks relative to the MSSTs. CPT reviews of OFLs, survey results, status of the stocks, compile SAFE.
October 1	State sets the TAC for the fall fisheries based on the recent survey constrained by OFLs based on same survey.
October	The Council and SSC review the status of the stocks relative to the MSST and the TACs and SAFE report.
After the fisheries close and once catch information is available	**Tiers 1-3**: Determine the total catch for the previous year, this would entail a tabulation of all retained catch and discard losses. To determine the discard losses, the handling mortality rate is multiplied by bycatch discards in each fishery. Compare the total catch to the OFL. If total catch is greater than the OFL, then overfishing occurred in the previous year. **Tier 4**: When information is insufficient to determine the level of discard mortality or catches by non-directed fisheries, the OFL will be based on the retained catch.

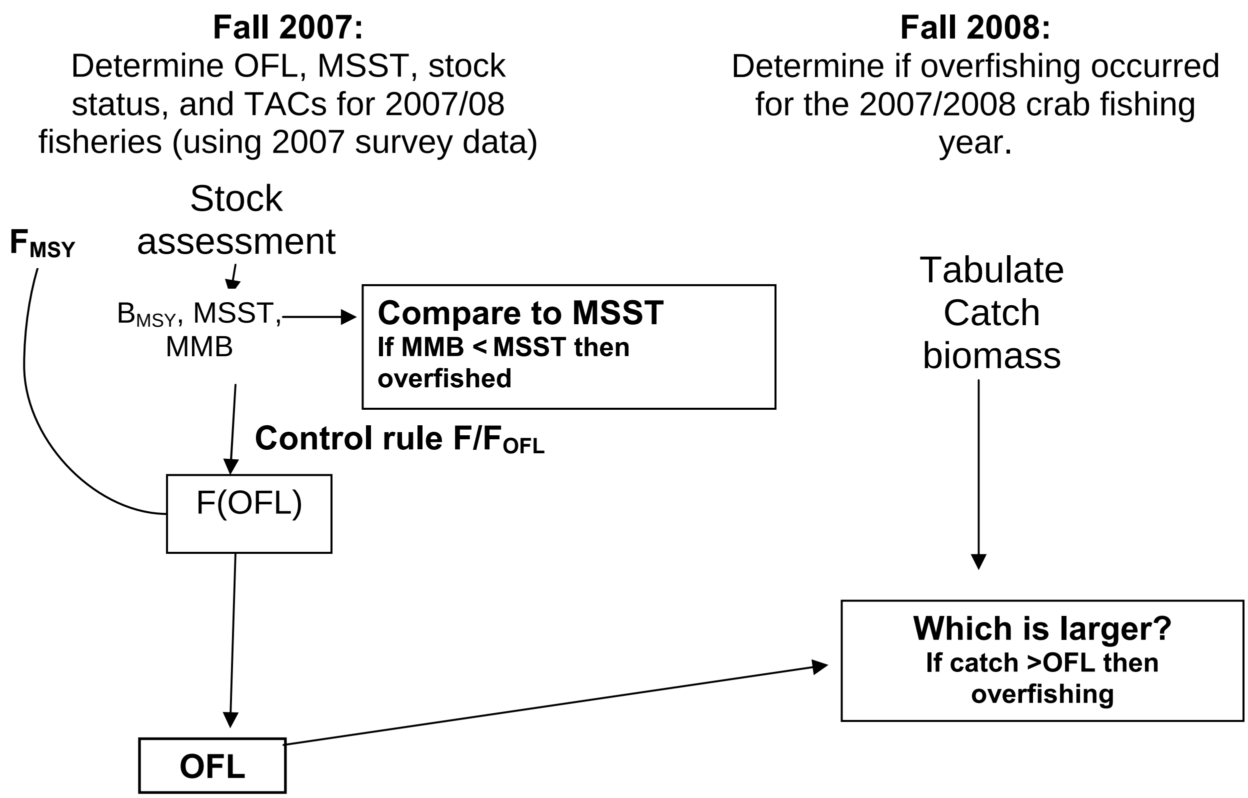

Figure 2-4 Option 2 OFL setting and review process for Tiers 1-4, using 2007/2008 crab fishing year as an example.

2.5.3 Process of stock status and OFL determination for Tier 5 and 6 stocks

Options 1 and 2 would not directly apply to stocks in Tiers 5 and 6 because they are not annually surveyed therefore the timing of the OFL calculation relative to the annual survey is not a factor. The OFL setting and review process for stock in Tiers 5 and 6 would occur at the same time as for the stocks in higher tiers. There is no reliable estimate of biomass and hence no estimate of B_{MSY} or MSST. Consequently, it is not possible to make a determination of stock status relative to an MSST or to assess whether a Tier 5 or 6 stock is overfished or not. In contrast to determining whether the stock is overfished, it is possible to determine whether overfishing occurred in the previous year.

For the Tier 5 stocks, the following process will apply for annually determining whether overfishing has occurred:

1. Use OFL calculated from the average catch for the determined time period, or other method recommended by the SSC. Currently, for purposes of analysis for Tier 5 stocks, the OFL would be based on the retained catch because information is insufficient to determine the level of discard mortality or catches by non-directed fisheries.
2. Determine the retained catch for the previous year.
3. Compare the retained catch to the OFL. If catch is greater than the OFL, then overfishing occurred in the previous year.

For the Tier 6 stocks (Alternative 3 only), the following process will apply for annually determining whether overfishing has occurred:

1. Use OFL=0, or other method recommended by the SSC. For Tier 6 stocks, the OFL will be based on the retained catch because information is insufficient to determine the level of discard mortality or catches by non-directed fisheries.
2. Determine the retained catch for the previous year.
3. Compare the retained catch to the OFL. If catch is greater than the OFL, then overfishing occurred in the previous year.

2.5.4 Comparison of the Options for the OFL Setting and Review Process

Options 1 and 2 establish different processes for OFL setting and review. This review process includes the SSC and the Council review for determining appropriate tiers and OFLs on an annual basis. The OFL setting and review process establishes the timing for: (1) the placement of stocks into tiers; (2) the information used for OFL determination; (3) the setting of the OFLs and MSSTs; and (4) the determinations of the status of the stocks relative to the OFLs and MSSTs. The timing of OFL determinations is important because it determines two key factors: (1) whether the SSC and Council can review OFL determinations prior to the establishment of TACs, and (2) what information is used in the OFL determinations. Timing also impacts the level and extent of peer review and information shared with the public. The timing of the OFL determinations are discussed in this Chapter because they similarly effect the fisheries for the stocks surveyed by the summer NMFS EBS trawl survey; i.e., Bristol Bay red king crab, snow crab, EBS Tanner crab, Pribilof Islands red and blue king crab, and St. Matthew blue king crab. Stocks not subject to the NMFS annual trawl survey, or other annual surveys used for stock assessment, are not impacted by the timing of the OFL determinations.

Under Option 1, the SSC and Council would review the final tier assignments and OFLs and MSSTs for each stock in June. OFLs and MSSTs would be determined based upon model estimates prior to the availability of data from the current summer's survey, which typically is conducted during June through early-August. Survey data through the previous summer's survey and fishery data through the most recent fishery season would be incorporated into the model used to set the OFLs and MSSTs. When the survey data from the current summer's survey becomes available in the following August, those data would be used to determine the status of the stocks relative to the pre-determined MSSTs and to set TACs in the context of the pre-determined OFLs. This option would provide time for peer review during the spring prior to the June Council meeting and would provide advanced notice of the OFLs to the industry and public prior to the announcement of TACs in October. However, Option 1 may cause problems due to the OFLs and MSSTs being determined a few months prior to availability of the current summer's survey data. That could be particularly problematic, because the abundances of crab stocks can fluctuate dramatically with no predictability. Therefore, the OFL could either be too constraining if stock abundance increases dramatically above what was predicted by the model or too liberal if stock abundance decreases dramatically below what was predicted by the model. Note that the State would use the current summer's survey data to set the TACs for the fisheries beginning in the fall. In instances when the OFL is too liberal, the State could correct for that by setting TACs based on the recent survey data to avoid overfishing. However, TACs could be unnecessarily constrained in cases when the OFL is too conservative.

Under Option 2, tier assignments would be reviewed by the SCC and Council in June, but OFLs and MSSTs would be calculated after the survey data are available in late August. The State would then set the TACs on October 1 and the Council would then review the status of the stocks, the OFLs, and the TACs in the fall. The most recent survey data would be used to estimate biomass, set the OFLs and

MSSTs, evaluate the status of stocks in relation to the status determination criteria, and to set the TACs. Hence, although Option 2 has the advantage of using the most current data for setting OFLs and MSSTs, the SSC and Council would not be able to review the OFLs and MSSTs until after the TACs have been established. This process provides limited time for peer review and public involvement.

Options 1 and 2 also affect the time available for data analysis. Potential problems with Option 2 in that regard arise from the short time period from when the survey data are available after the summer survey in mid-August to when the OFLs and MSSTs are determined, which must be prior to when the State sets the TACs on October 1. During that period, the survey data are analyzed, assessment models are run, NMFS determines the status of the stocks, the CPT meets to discuss the status of the stocks and compile the SAFE, and the State sets the TACs on October 1 for the fisheries opening October 15. Additionally, wheras under status quo this process is only conducted for the six surveyed stocks, under Alternatives 2 and 3 this process would need to be conducted annually for all FMP stocks. It is not clear that the State and NMFS have the staff available with the technical expertise necessary to apply the tier system to all FMP stocks and derive status determination criteria on an annual basis under very tight time constraints. This staffing problem would be compounded if, each fall, the previous year's catch data is tabulated and compared to the previous years OFL to determine whether overfishing occurred. Option 1 alleviates the fall analytical crunch to some extent, because the additional step of setting the OFLs and MSSTs would not need to be done. Staff resources may still be strained with Option 1, however, because OFLs and MSSTs would need to be set annually for all FMP stocks and annual catches would need to be tabulated and compared with the OFLs.

Implication of data usage under option 1

Two main issues are raised in considering Option 1 which have implications for the resulting OFL for crab stocks in the following year. The first issue relates to the observed fluctuations in area-swept estimates from one year to the next, while the second issue is related to one-year projection errors.

Area-swept estimates of biomass

Crab stocks have frequently shown fluctuations in area-swept estimates of biomass from one year to the next. Changes in biomass for each stock are shown in the figures on the status of each stock relative to overfishing in Chapters 4 though 9.

Some potential implications of using the biomass estimate from the previous summer to set the OFL, as opposed to the biomass estimate from the current summer survey, can be seen by reviewing the 1997-2006 survey biomass estimates for the annually surveyed stocks (Table 2-12).

Table 2-12 Annual survey total mature biomass (TMB, in millions of pounds) for 6 surveyed stocks 1997-2006.

Surveyed Stock	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
Bristol Bay red king crab	133.6	166.2	117.7	89.7	88	129.9	178.1	176.4	181.9	157.2
Pribilof red king crab	14	7.7	12.8	10.2	25.5	18.1	14.5	9.9	8.1	19
Pribilof blue king crab	11.7	11	9.2	7.4	7	4.5	4.1	0.5	1.6	1.6
St. Matthew blue king crab	32.7	24.1	4.8	5.2	9	4.7	12.8	7.3	5.9	11.2
EBS Tanner crab	40.6	37.6	70.1	59.1	67.7	69.4	100.8	86.8	162	253.3
EBS Snow crab	1,014.1	729.7	283.5	472.7	571	313.3	306.2	343.7	610.7	547.6

As shown in Table 2-12, the most dramatic example of a change in biomass between surveys occurred for snow crab between the 1998 and the 1999 surveys. The snow crab biomass estimate from the 1998 survey was 729.7 million pounds (330,990 t). The biomass for the 1999 survey declined to 283.5 million pounds (128,595 t). The St. Matthew blue king crab stock also showed a marked and unexpected decline between the 1998 and the 1999 surveys; the total mature biomass estimate from the 1999 survey was 20% of that estimated from the 1998 survey.

For Option 1, which relies on a one-year projection of crab abundance and biomass, the OFL for the snow crab fishery that opened in 2000 would have been based on survey data only through the 1998 survey. That projection would have resulted in 2000 OFLs double the level corresponding to the 1999 survey observations.

Relative one-year projection errors

Another important criterion for comparing the timing of OFL determinations in Options 1 and 2 is relative one-year projection errors for Option 1. Although year-to-year fluctuation of biomass estimates by the models will be somewhat less than area-swept estimates, the model projection errors can be large during some years. To examine model uncertainty, model projections were compared to observed survey estimates for St. Matthew blue king crab and Bristol Bay red king crab. Two comparisons were made. The first compares the one-year model projection for a given year to the estimate made in that year, called the terminal year assessment. The second compares the one-year model projection to the estimate for the given year made in 2006. Biomasses estimated in terminal years are used in Option 2 for determination. Biomasses estimated in 2006 are considered as baseline estimates and should be more reliable than those in terminal years because more data are available in 2006, the most recent year's assessment for this report.

Table 2-13 illustrates the relative model errors from 1997 to 2006 with the current four-stage stock assessment model for St. Mathew blue king crab. Besides the exceptional year of 1999, relative one-year projection errors ranged from -17% to 22% for legal male biomass and from -19% to 33% for MMB when compared to biomasses estimated in terminal years. This means that during the 10-year period, in any given year the one-year projection for Option 1 would have either underestimated legal male biomass by up to 17% or overestimated the biomass of legal males by up to 22% when compared biomasses estimated for Option 2. Relative errors of projected to observed biomasses estimated in 2006 were generally larger than errors based on terminal year estimates. Therefore, the one-year projection for Option 1 would have under or over estimated biomass by even greater amounts. The worst projection error (greater than 400%) occurred in 1999. As a comparison, relative errors of terminal year assessment for Option 2 are much smaller than the relative errors of one-year projection for Option 1 when compared to baseline biomass estimates (Table 2-13).

Table 2-13 Relative model errors from 1997 to 2006 with a 4-stage model for St. Matthew male blue king crab. Relative errors for biomass A vs. B is (A-B)/B*100. One-year projection is used for Option 1, and terminal year assessment is used for Option 2.

Year	% relative errors (1-yr-projection vs. terminal year assessment)		% relative errors (1-yr-projection vs. 2006 assessment) (Option 1)		% relative errors (terminal year vs. 2006 assessment) (Option 2)	
	Legals	Matures	Legals	Matures	Legals	Matures
1997	-10.88	-7.26	-2.04	-0.26	9.92	7.55
1998	-0.78	-0.85	13.75	12.42	14.64	13.38
1999	428.83	425.51	424.73	396.89	-0.78	-5.45
2000	-11.24	-9.94	-2.10	-9.10	10.29	0.94
2001	-16.81	-19.19	7.12	4.15	28.77	28.88
2002	8.68	16.02	45.03	48.11	33.44	27.66
2003	10.48	7.78	41.57	33.14	28.14	23.53
2004	22.08	33.09	30.65	37.53	7.02	3.34
2005	6.30	5.37	3.41	0.02	-2.72	-5.08
2006	-8.08	-7.18	-8.08	-7.18	0.00	0.00

Table 2-14 illustrates the relative one-year model projection errors from 1997 to 2006 for Bristol Bay red king crab. The updated model used to examine projection errors for Bristol Bay red king crab is described in Appendix B in the 2006 SAFE report (NPFMC 2006a). Constant natural mortality of 0.18 and constant molting probabilities for males over time were used in the updated model.

Compared to Bristol Bay red king crab biomasses estimated in terminal years, relative one-year projection errors ranged from -25% to 18% for mature female biomass, from -16% to 21% for MMB, and from -13% to 20% for legal male biomass. This means that during the 10-year period, in any given year the one-year projection for Option 1 would have either underestimated the legal male biomass by up to 13% or overestimated the legal male biomass by up to 20% when compared to biomasses estimated for Option 2. When compared to baseline biomass estimates (made in 2006), the maximum relative errors for mature female biomass, MMB and legal male biomass are -38%, -30% and -26% for one-year projection for Option 1, verses -29%, -19% and -20%, respectively, for Option 2 (Table 2-14).

Table 2-14 Relative model errors from 1997 to 2006 with the model for Bristol Bay red king crab. Relative errors for biomass A vs. B is (A-B)/B*100. One-year projection is used for Option 1, and terminal year assessment is used for Option 2.

Year	% relative errors (1-yr-projection vs. terminal year assessment)			% relative errors (1-yr-projection vs. 2006 assessment) (Option 1)			% relative errors (Terminal year vs. 2006 assessment) (Option 2)		
	Mature females	Mature males	Legals	Mature females	Mature males	Legals	Mature females	Mature males	Legals
1997	-13.17	-16.12	-12.55	-38.06	-29.60	-26.24	-28.66	-16.07	-15.66
1998	-13.28	-8.93	-6.58	-25.82	-15.41	-20.14	-14.46	-7.12	-14.51
1999	7.17	1.68	-4.95	-10.39	-2.63	-11.81	-16.38	-4.24	-7.21
2000	-24.95	-5.02	-4.19	-18.89	-5.41	-6.81	8.07	-0.41	-2.73
2001	17.67	20.76	19.53	-2.28	-2.03	-3.96	-16.95	-18.88	-19.65
2002	1.05	-8.64	-5.21	-17.97	-23.42	-21.70	-18.82	-16.18	-17.40
2003	-11.12	-9.56	-3.32	-13.25	-18.56	-20.03	-2.40	-9.95	-17.28
2004	2.44	-7.05	-13.29	0.62	-7.97	-17.18	-1.77	-0.98	-4.48
2005	3.89	14.43	8.62	5.15	6.65	-2.22	1.21	-6.80	-9.98
2006	7.68	-4.57	-7.43	7.68	-4.57	-7.43	0.00	0.00	0.00

2.6 Options for Removal of FMP stocks

Option A: Remove Specific Stocks from FMP (Preferred)

Option A would remove specific stocks from the FMP for which (1) there is no directed fishery; (2) harvest only occurs incidentally during fisheries targeting other crab stocks; (3) harvest only occurs in limited, exploratory fisheries; or (4) the majority of catch occurs in State waters. NMFS and the Council found that the State of Alaska has is a legitimate interest in the conservation and management of these stocks and that Federal conservation and management is not necessary. The State would have sole management authority for these species, as they do for hair crab (the hair crab fishery, which occurs in the EEZ, was removed from the FMP). Currently, the FMP defers the management of these fisheries to the State. Therefore, the State already manages these stocks and collects all of the biological information. Except for the EAI Tanner and king crab stock, NMFS or ADF&G do not survey these stocks. Harvest histories of the unsurveyed stocks are sporadic and the harvests from those stocks are managed either as incidental catch in fisheries targeting other crab stocks or as limited, exploratory fisheries. Any future exploratory fishery would be operated by ADF&G commissioner's permit, which means the State determines if and when these fisheries occur, who may participate, observer requirements, and how much is harvested. The EAI Tanner crab fishery is essentially a state-waters fishery because 93% of landings from 1985-2006 were in state-waters statistical areas.

Option A would remove the following 12 stocks from the FMP:

1. EAI Tanner crab
2. WAI Tanner crab
3. EBS grooved Tanner crab (*Chionoecetes tanneri*)
4. EAI grooved Tanner crab
5. WAI grooved Tanner crab
6. BS triangle Tanner crab (*Chionoecetes angulatus*)
7. EAI triangle Tanner crab
8. St. Matthew golden king crab
9. St. Lawrence Island blue king crab
10. AI scarlet king crab (*Lithodes couesi*)
11. EBS scarlet king crab
12. EAI red king crab (Dutch Harbor)

Section 306(a)(3) of the Magnuson-Stevens Act provides for State management authority in Federal waters off Alaska in the absence of Federal management of the species in question. Under Option A, the State of Alaska would continue existing State management for these crab stocks. The existing delegated authority is costly and burdensome for these stocks with limited fishery histories for the following reasons: (1) State personnel are required to comply with the additional Federal management processes; (2) the State needs to meet both state and Federal requirements which are often on different timeframes for management (e.g., public meetings and reports); and (3) the State can not meet the costly assessment requirements needed to develop OFLs for these stocks. Instead, conservative management of the species under exclusive State management would be less costly and less onerous.

Under this option, Federal management would be removed, including the Magnuson-Stevens Act measures, such as the limited access requirements, Essential Fish Habitat (EFH) designation, and status determination criteria. Currently, vessels that intend to participate in these fisheries need a Federal license limitation program (LLP) license with a minor species or AI Tanner crab endorsement. NMFS issued crab LLP licenses with new species endorsements to crab LLP license holders subsequent to removing the LLP requirements for fisheries under the Crab Rationalization Program. NMFS issued an AI Tanner crab endorsement to holders of crab LLP with a BSAI snow and Tanner crab endorsement and issued crab LLPs with minor species endorsements to all crab LLP license holders. Therefore, the LLP requirement does not limit access to these potential fisheries to historic or recent participants.

Although a Magnuson-Stevens Act requirement, insufficient information is available to determine EFH for grooved Tanner, triangle Tanner, and scarlet king crab (See EFH EIS, NMFS 2005). The EFH designated for golden king crab, Tanner crab, and blue king crab species would not change with the removal of WAI and EAI Tanner crab, St. Matthew golden king crab, and St. Lawrence blue king crab stocks. Additionally, these stocks would continue to benefit from the Federal habitat protection measures for the EFH for these three species.

Option B Status quo – No removal of stocks

Under this option, the current 22 stocks would remain in the FMP and, as required by the Magnuson-Stevens Act, OFLs would need to be established for all FMP stocks. As described under Alternative 1, the current status determination criteria only established an MFMT for these species based on the natural mortality rate set for king and Tanner crabs in 1999. The information necessary to establish an overfishing limit for these stocks is currently unavailable (except for AI Tanner crabs). Additionally, there may be State confidentiality issues that may restrict the reporting of status of these stocks relative to the OFLs because many of these exploratory fisheries are prosecuted by fewer that three vessels or processed by fewer than three processors.

In the future, NMFS and the State would need to ensure that these stocks comply with the new Magnuson-Stevens Act requirement for annual catch limits and accountability measures for all species under the FMP. NMFS is developing guidelines on annual catch limits and accountability measures. FMPs will have to be in compliance with these guidelines by 2010.

2.7 Development of alternatives and those considered and eliminated from detailed study

The CPT concluded in 2003 that an analysis of a new FMP amendment revising the current status determination criteria was warranted since the adoption of the 1998 overfishing definitions under Amendment 7. The plan team designated an interagency workgroup consisting of four members to devise alternative overfishing definitions for crab stocks and to periodically report to both the CPT and the SSC on their progress. Progress by the interagency workgroup has been documented in the reports from the CPT (see minutes from the CPT 9/03, 5/04, 9/04, 5/05, 9/05, 5/06, 9/06) and minutes from the SSC (see SSC minutes 5/04, 10/04, 2/05, 6/05, 10/05, 4/06, 6/06, 10/06). These reports are available on the Council website.

In February 2006, a workshop consisting of interagency and outside crab experts was convened in February 2006 to discuss various biological and model parameterization issues associated with the draft tier system and assessment models. The Workshop Report Crab Overfishing Definitions Inter-agency Workshop (NPFMC 2006c) is available on NPFMC website:

http://www.fakr.noaa.gov/npfmc/analyses/KTCAM24/OverfishingWksp.pdf

In April 2006, a review was convened with the Center for Independent Experts (CIE) to provide guidance on the development of the tier system. The CIE report, Review of Overfishing Definitions (CIE 2006), is available on NPFMC website:

http://www.fakr.noaa.gov/npfmc/analyses/KTCAM24/CIE_Overfishing406.pdf

The CPT crafted a problem statement and draft suite of alternatives at its May 2006 meeting. The alternatives to status quo use the same tier system but differ in the OFL decision making body and the timing of OFL determination.

During the three years of development, the CPT, the workgroup, and the SSC considered many alternatives to most aspects of the proposed OFLs, including alternative biological parameters, such as *M* values, alternative modeling scenarios and methods, and alternative tier systems. This section provides a summary of the alternatives that were considered but received little analysis because they were scientifically unsuitable for the crab OFLs or contrary to the national standard guidelines. A brief rational as to why these alternatives were not included in this EA is presented below.

During the process of developing alternatives consideration was given to analyzing fixed mortality values. This would be an approach similar to that utilized in the current overfishing definitions, however updated mortality information would be used to establish these new fixed values. The SSC recommended that this alternative be dropped from the analysis (see SSC minutes, February 2006) given that it was highly unlikely that fixed values would be retained under the FMP in light of the fact that the current fixed values are being revised due to their inflexibility to incorporating new scientific information. Substituting updated fixed values did not seem to represent a tenable solution nor provide meaningful analytical contrast and thus this alternative was dropped from the analysis.

A range of control rules were evaluated over the course of this analysis in conjunction with the recommended control rules for Tiers 1-4 (Figure 2-2). Chosen values for α and β alter the slope and intercept for the control rule. A sensitivity analysis was conducted which evaluated a range of values for α and β. This analysis, as well as the justification for the chosen values for α and β for these control rules, are detailed in Section 3.2.5.2 and Chapters 4 and 5.

An option was considerd for Alternative 2 that would set the OFL for tier 1-4 stocks in stock status level "c" based on the existing prohibited species catch (PSC) limits established for the Federal groundfish fisheries. For stocks in stock status level "c," the directed fishery would be closed and an OFL that accounts for all sources of fishing mortality is required by the Magnuson-Stevens Act. Assessment authors discussed this issue quite a bit to address the need to have a specific limit for F that is less than or equal to F_{MSY} at all biomass levels but that would allow for bycatch to occur below β^*B_{MSY}. A number of problems arose with setting an OFL based on the existing PSC limits: (1) while PSC limits exist for snow crab, Tanner crab, and Bristol Bay red king crab, all other crab stocks do not have trawl bycatch limits; (2) the PSC limits are minimum trawl bycatch caps, which means that as biomass goes to very low levels F could go above F_{MSY}; (3) the PSC limits close areas, not fisheries, so crab bycatch can still occure after the limit has been reached; and (4) the PSC limits do not account for crab bycatch in other crab or scallop fisheries. As a result, assessment authors could not come up with an OFL formula using the existing bycatch caps that complied with the Magnuson-Stevens Act.

The workgroup and the CPT spent a considerable amount of time debating the best method for setting OFLs for the data-poor crab stocks. The problem is that the Magnuson-Stevens Act requirement to set an OFL despite a lack of information results in an arbitrary solution for data limited stocks. In addition to the alternatives and options presented in this EA, the CPT discussed the following different ways to address data poor crab stocks:

- Do not address data-poor stocks and return to the original five-tier system from the November 2006 EA for Amendment 24.
- Modify Tier 5 to include these stocks by saying "For stocks with insufficient catch history, an OFL would only be established in the case of a directed fishery, or if bycatch increased to a level of concern."

- Add a Tier 6 that sets OFL = X% of historic catch.
- Add a Tier 6 that says "No OFL, unless the SSC recommends an OFL based on the best available scientific information."
- Add a Tier 6 that puts these stocks into a complex and sets an OFL for the complex, based either on a percent of the sum of historic catches or a number such as 100 thousand.
- Keep the status quo OFLs for these stocks and do not include them in the tier system (so the tier system would only apply to stocks that fit in Tiers 1-5 and the default OFL for the rest would be status quo).

Each of these options were considered and lliminated from detailed study because they are not scientifically viable and would have either resulted in OFLs the CPT considered arbitraty or not set an OFL and therefore not complied with the Magnuson-Stevens Act.

3 Methodology for impact analysis

This chapter contains detailed information regarding methodology for analyzing the impacts of the alternatives on the crab stocks under the FMP. Chapters 4 though 9 contain detailed information regarding the status of the 22 crab stocks managed under this FMP, the biological parameters employed in modeling the impacts of the alternatives for these stocks, and the impacts of the OFL alternatives on these stocks.

Table 3-1 provides the proposed tier assignments for the 22 FMP crab stocks for purposes of this analysis. Actual assignment to tiers under Alternatives 2 and 3 would occur annually during the OFL setting and review process in either Option 1 or 2, and would be determined by the SSC and Council, under recommendation from the CPT.

Table 3-1 Proposed tier assignments for the 22 FMP crab stocks for purposes of this EA. Stocks considered for removal from FMP under Option A are in bold.

Tier	Alternative 2	Alternative 3
1	None	None
2	None	None
3	1. Bristol Bay red king crab (*P. camtschaticus*) 2. EBS snow crab (*C. opilio*)	1. Bristol Bay red king crab 2. EBS snow crab
4	3. EBS Tanner crab (*C. bairdi*) 4. Pribilof Islands red king crab 5. Pribilof Islands blue king crab (*P. platypus*) 6. St. Matthew blue king crab 7. Norton Sound red king crab 8. **EAI Tanner crab**	3. EBS Tanner crab 4. Pribilof Islands red king crab 5. Pribilof Islands blue king crab 6. St. Matthew blue king crab 7. Norton Sound red king crab 8. **EAI Tanner crab**
5	9. **Dutch Harbor red king crab** 10. Adak red king crab 11. Pribilof Islands golden king crab (*L. aequispinus*) 12. Aleutian Islands golden king crab 13. **EBS grooved Tanner crab (*C. tanneri*)** 14. **WAI grooved Tanner crab** 15. **EAI grooved Tanner crab** 16. **St. Matthew golden king crab** 17. **WAI Tanner crab** 18. **St. Lawrence Island blue king crab** 19. **AI scarlet king crab (*L. couesi*)** 20. **EBS scarlet king crab** 21. **BS triangle Tanner crab (*C. angulatus*)** 22. **EAI triangle Tanner crab**	9. **Dutch Harbor red king crab** 10. Adak red king crab 11. Pribilof Islands golden king crab 12. Aleutian Islands golden king crab
6	NA	13. **EBS grooved Tanner crab** 14. **WAI grooved Tanner crab** 15. **EAI grooved Tanner crab** 16. **St. Matthew golden king crab** 17. **WAI Tanner crab** 18. **St. Lawrence Island blue king crab** 19. **AI scarlet king crab** 20. **EBS scarlet king crab** 21. **BS triangle Tanner crab** 22. **EAI triangle Tanner crab**

3.1 Fertilized egg production proxy – mature male biomass

The measure of spawning biomass is a framework measure in Alternatives 2 and 3. For Tiers 1-3, this analysis uses male mature biomass (MMB) at the time of mating as a proxy for egg production largely as a result of the uncertainties in modifying female mature biomass by the appropriate sex ratios and the component of mature males that participate in mating, and secondly since the directed fishery occurs on males. In future years, the stock assessment authors, CPT, SSC, and Council may determine, through the OFL setting process, a more appropriate value for biomass based on improvements in scientific information.

Female mature biomass is used as a proxy for egg production in many fisheries applications to determine SR relationships, harvest control rules and reference points. Egg production in crab stocks, however, is complicated by obligate mating in pairs, limited spatial mobility in crabs relative to fish, and a male only directed fishery. Females may not mate due to insufficient males and may extrude eggs that are unfertilized and cannot be distinguished from fertilized eggs without laboratory procedures. Mating ratios have been proposed for crab stocks that define the number of females that can be mated by each male within a mating season to modify female spawning biomass. Laboratory studies of mating have found males mating with multiple females (Powell et al. 1974, Powell and Nickerson 1965, Paul and Paul 1997, and Paul 1984); however, mating ratios in the natural environment are unknown. Females of the *Chionoecetes* sp. may mate with more than one male in the same season which contravenes the mating ratio calculation. Another complication is that female snow crab inhabiting cold water realms have been shown to be on a two-year reproduction cycle. In addition, males that molt close to the mating season, may not participate in mating, which would affect the estimation of mature males available for mating. Also, female Tanner and snow crabs can store sperm for fertilizing egg clutches in the absence of males. Spatial distribution of the fishery may affect local sex ratios at mating time.

CIE review of the proposed OFL revisions (CIE 2006) recommended the use of MMB at the time of mating as a proxy for egg production in the short term, due to the many uncertainties in mating ratios used to modified female mature biomass. Total MMB will restrict fertilized egg production when the sex ratio is at low levels due to depletion of mature males.

The CIE review suggested three definitions for Biomass in the control rules and spawner-recruit relationships:

- total MMB
- a function of total MMB
- a function of total female egg production and a "fertilization factor".

Total MMB is a much simpler measure of spawning biomass that meets the criteria of being related to egg production and affected by fishing. The annual variability of the fraction of snow crab females that are barren, and the clutch size by shell condition indicates a relationship with the levels of exploitation of males (Turnock and Rugolo 2006).

Primiparous females (first brood) may mate at different times from multiparous females (second or later brood), however, this analysis selected a date of February 15 for calculation of MMB, prior to males molting. To calculate MMB, this analysis assumes that all pot fishing occurred or will occur before February 15 during each fishing season.

The CIE review also recommended research be conducted toward estimating an egg production index that should replace the use of MMB in future reference point estimation. There are two components of information necessary to apply an egg production index in place of MMB. The first is a set of basic reproductive dynamic relationships and the second is the set of observed information collected annual from the survey. A number of components to the egg production index are currently unknown. A total female egg production index (TFEP) would incorporate a number of components including mature male numbers and/or biomass. These components include:

- number of mature females by shell condition and size
- fecundity of females by shell condition and size
- fecundity to clutch score relationship by shell condition and size
- fraction of eggs unfertilized
- quality of eggs (may effect hatching and survival of larvae),
- stored sperm (an indication of male limitation),
- number of mature males by shell condition and size,
- mature males that take part in mating by shell condition and size,
- optimum sex ratio using males that take part in mating to mature females,
- fraction of females in biennial and annual spawning cycles
- Spatial sex ratios, affected by spatial patterns in fishing mortality

Research is needed to allow estimation of TFEP and its incorporation in the control rules and reference points. Some components of the TFEP are currently available, however, not all components are available for any BSAI crab stock. Shell age is an important component for both females and males, at present only shell condition is assessed, which is not a reliable index of shell age. Research on aging of crab is also needed to complete the estimation of TFEP.

3.2 Simulation framework for evaluation of alternatives

3.2.1 A brief overview of the analytical approach

The nature of evaluation of alternatives depended on which tier a stock was assumed to fall. Size structured stochastic projection models were used to evaluate Tier 2 to 4 control rules, status quo harvest strategy, and status quo OFL control rule (see Appendix A and Siddeek and Zheng (2007) for description of model equations). Mean catch for a fixed period was used as the OFL for Tier 5, and no OFL was determined for Tier 6. Length based stock assessment results are available for Bristol Bay red king crab, snow crab, and Bristol Bay portion of the Tanner crab stocks (Zheng at al. 1995a, Zheng and Kruse 1999, Turnock and Rugolo 2006; NPFMC 2006a). The 2005/06 parameter estimates from stock assessments of these three stocks were used as base input values in the size structured projection models (Appendices B, C, and D).

For Alternative 1, both fishing at the status quo harvest strategies and the status quo OFL control rule were modeled to compute a number of performance statistics (yield, biomass, rebuilding time, percentage of time during a given fishing period the biomass was below B_{MSY}, the stock was overfished, and the fishery was closed) using a plausible set of stock-recruitment, growth, maturity, natural mortality, handling and bycatch mortality parameters. The results were compared with those estimated under Alternatives 2 and 3 tier systems. Guidelines to compute status quo harvest strategies and OFL control rule for red king crab, snow crab, and Tanner crab are given in the respective chapters for those stocks (see also Pengilly and Schmidt 1995). Note that the OFL control rule is not used for TAC determination, but considered for determining whether the TAC exceeds the OFL or not. If the TAC exceeds the OFL, then it results in overfishing.

Alternatives 2 and 3 differ only in the number of tiers to which the 22 stocks were distributed, but the analytical procedures to assess the performance statistics in each tier were the same. Tier 2 harvest control rule formula has F_{MSY} and B_{MSY} parameters, whereas Tier 3 and Tier 4 control rule formulas have their proxies. In order to assess the performance of a particular stock at all tiers, an assumption was made that reliable pieces of information were available to determine control rule parameters for all tiers (i.e., Tiers 2-4). Tier 2 control rule demands establishment of a stock-recruitment relationship for F_{MSY} and B_{MSY} estimation. Stock-recruitment relationships for the three major stocks (Bristol Bay red king crab, snow crab, and Bristol Bay portion of the Tanner crab) were established to estimate these parameters. Tier 3 control rule formulas require proxy values for F_{MSY} and B_{MSY}. The $F_{x\%}$ (spawning potential ratio) was chosen as a proxy for F_{MSY} and the corresponding $B_{x\%}$ was considered as a proxy for B_{MSY}. A deterministic size structured model was used to locate the $F_{x\%}$ by the Clark's (1991) method. This $F_{x\%}$ control rule was used to determine the performance statistics for comparison with those estimated by other tier control rules, status quo harvest strategy, and status quo OFL control rule. The F_{MSY} and B_{MSY} proxies for Tier 4 stocks were γM and an average MMB value, respectively. Since F_{MSY} and B_{MSY} for the three major stocks (Bristol Bay red king crab, snow crab, and Bristol Bay component of Tanner crab) were determined for Tier 2 control rule analysis, the ratio of F_{MSY}/M was used as the γ value with the estimated B_{MSY} value in the Tier 4 control rule formula to determine the performance statistics. The performances statistics were compared with those under different tiers, status quo harvest strategy, and status quo OFL. Tanner crab stock was analyzed under Tier 3 and Tier 4 scenarios. For calculation of performance statistics under Tier 4 control rule, an average survey MMB for the whole EAI was used as a proxy for B_{MSY} in the control rule formula and parameters for the Bristol Bay portion of the stock was used as base input values.

For stocks belonging to Tier 5, an average catch for a pre-specified period was used as the OFL to determine overfishing levels.

Short-term projections were also made under selected $F_{x\%}$ control rules, status quo harvest strategy, and status quo OFL. The 2006 abundance and catch values were used as a starting point and stochastics size structured models with the same input base parameters and stock-recruitment parameters, as used in the evaluation of alternatives, were used to estimate projected retained and total yields with 95% confidence interval, and MMB at the spawning time (February 15).

Some details of specific analytical procedures are provided in the following sections

3.2.2 Simulation procedure for evaluation of different alternatives for Bristol Bay red king crab, snow crab, and Tanner crab

The crab populations were simulated for 30 and 100 years and fishing mortalities applied according to the particular harvest control rule. Maximum numbers of recruits (R_{max}) of 29 millions for red king, 104 millions for Tanner, and 2000 millions for snow crabs were considered in the simulations. These values were averages of the top 50% stock assessment estimated number of recruits for these stocks. In the simulations, certain stock specific characteristics were recognized: terminal molt at maturity for both sexes and differential M for male and female Tanner and snow crabs (Rugolo et al. 2005 and Tamone et al. 2005). The Ricker and Beverton-Holt stock-recruitment models were used in all simulations and the approach to select plausible stock-recruitment relationships are described in the subsequent section. No process errors on growth or M were considered for any of the three stocks. Log normal biomass observation errors (σ_1 = 0.2) and truncated normal harvest implementation errors (σ_2 = 0.1) were introduced in the red king and Tanner crab simulations. The implementation errors are minimum in the crab fisheries hence a low standard deviation was used. For snow crab simulations, observation errors on biomass were simulated with autocorrelated lognormal errors applied to abundance. A coefficient of variation of 0.15 and an autocorrelation of 0.6 were used. For stochastic simulations, the recruits were generated by a stochastic S-R model with log-normal random errors (variance σ^2 and a temporal correlation ρ).

As performance statistics, mature male and female biomass values, total and retained catch, standard deviation of the retained catch, *F*, the rebuilding time, and the percent of the time the biomass (B) was below B_{MSY}, below ½ B_{MSY}, percent of time when the fishery was closed (e.g.,, when B < 25%B_{MSY}), and final year B in relation to B_{MSY} were calculated. The average values for 1000 runs using 30 or 100 fishing years of each simulation were calculated to compare different control rules. For these simulations the population was started from the biomass levels at ½ B_{MSY} and B_{MSY}, respectively. Simulations were also carried out to evaluate alternative values of α and β of the control rule. For these simulations, the population was initialized at 10% and 50% B_{MSY}, respectively.

3.2.3 Size-structured models used in Bristol Bay red king crab, snow crab, and Tanner crab simulations

The size-structured population dynamics equations used in red king crab and Tanner crab simulations are listed in Appendix A. The size-structured model developed for snow crab is described in 2006 SAFE Report (NPFMC 2006a) and the model equations are similar to those given in Appendix A. The models consist of molting probability, size transition matrix, maturity probability, size specific fishing, handling, and trawl bycatch mortality, and constant natural mortality. Molting probabilities for immature snow and Tanner crabs were fixed at 1, those for mature crabs was fixed at 0 (terminal molt). On the other hand, the molting probability for female red king crab was fixed at 1. The base input parameter values for the three stocks are listed in Appendices B (red king crab), C (Bristol Bay portion of Tanner crab), and D (snow crab).

The simulations were initiated with a fixed number of immature new-shell recruits to the modeled population, divided equally between males and females and distributed between length bins by a probability function (Figure 3-1). Full age structure was established by deterministically projecting the initial recruits through their entire life span up to a maximum age with a given set of mortality and growth parameter values. In the deterministic simulations, once the full equilibrium age structure was achieved, the projection process stopped, and the relative MMB per recruit MMB/R (relative to MMB/R at F = 0) and relative yield (relative to maximum yield) were estimated using Beverton-Holt and Ricker S-R curves for a range of steepness (*h*) values, which contained the estimated *h* from true S-R data. The relative yield curves were plotted against relative MMB per recruit to determine a $F_{x\%}$ value as a proxy for F_{MSY} following Clark's (1991) 'minimax' method, and the corresponding $B_{x\%}$ was considered as a proxy for B_{MSY} (Siddeek and Zheng 2007). For the stochastic simulations, the stock projection process was continued with recruits generated by a stochastic S-R model with log-normal random errors (variance σ^2 and a temporal correlation ρ) for a 30-year or a 100-year fishing period for estimating various performance statistics.

3.2.4 Stock-recruitment relationship

The 1985-2005 male mature biomass (MMB or in short B) and corresponding recruit data sets for handling mortality rate 0.1, 0.2, and 0.3 were used to establish the Beverton-Holt and Ricker stock-recruitment models for the Bristol Bay red king crab (Appendix A). The two S-R models fitted at the handling mortality rate of 0.2 (the plausible value) were compared using Akaike information criterion, AIC (-2*ln(MLE) + 2p, MLE=likelihood function evaluated at the maximum likelihood estimates, and p = number of estimated parameters) and Bayes information criterion, BIC (-2*ln(MLE)+p*ln(n), n = number of data pair) to select the best model. The model which gives the minimum AIC and BIC is the best model for the given data set. The AIC and BIC statistics were 56.3 and 57.8 for Ricker curve, and

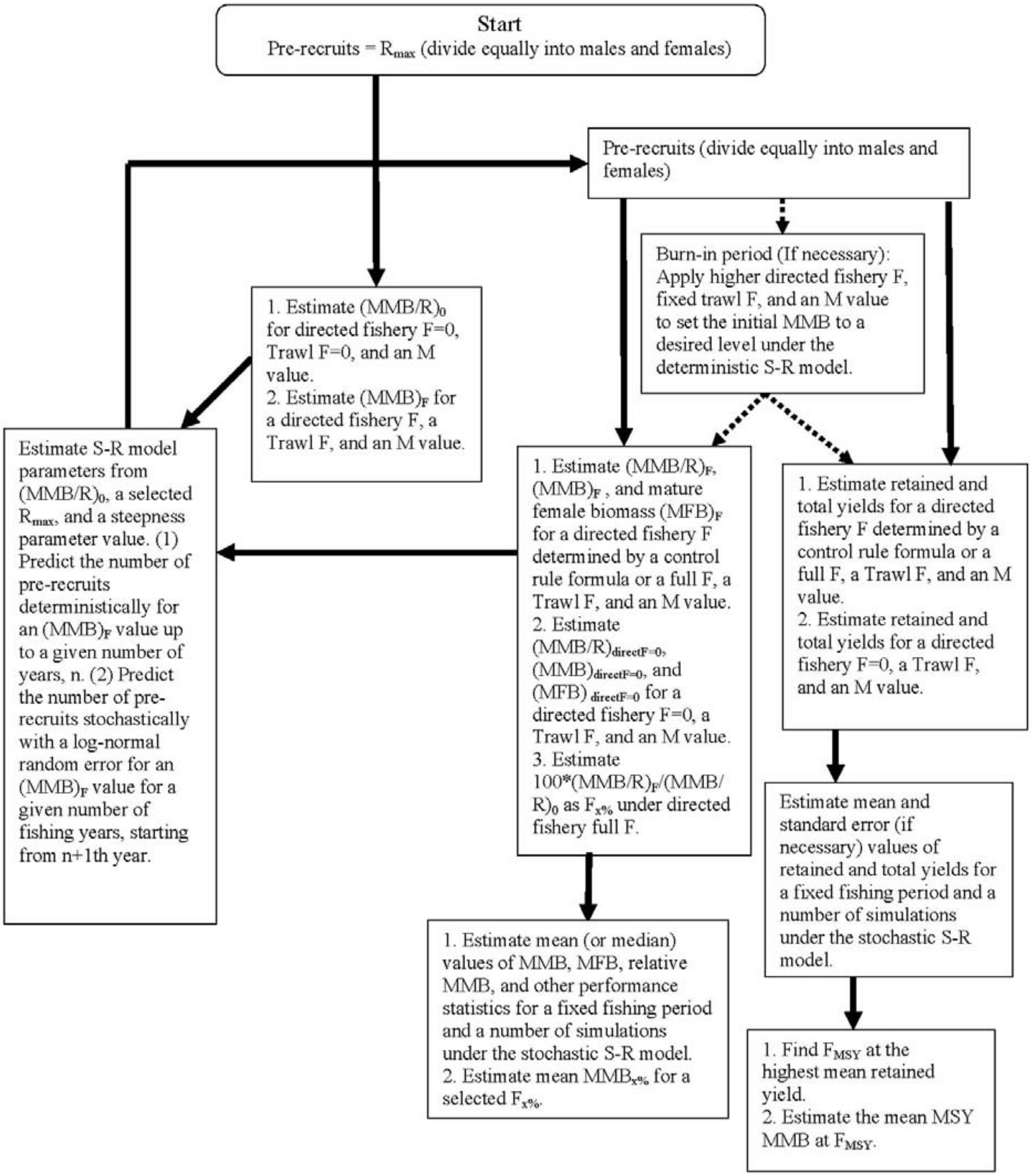

Figure 3-1 Schematic of model simulation.

57.5 and 59.0 for Beverton-Holt curve, respectively. Although the Ricker model gave the minimum AIC and BIC values the differences were not substantial (Burnham and Anderson, 2002). Nevertheless, Ricker model was selected for red king crab based on this slightly improved fit. The SAS (2004) AUTOREG procedure was used to test for autocorrelation. The Durbin-Watson statistics produced non-significant ($p>0.6$) results for presence of autocorrelation, hence the SAS Model procedure was used to fit nonlinear stock-recruitment models without autocorrelation. The estimated Beverton-Holt parameter estimate was nonsignificant, but the Ricker parameter estimate was significant. Table 3-2 provides steepness parameter estimates for the two S-R curves for different handling mortality values. The steepness parameter estimates were closer for different handling mortality values.

Steepness for the Ricker curve is defined as the fraction of R_0 (the recruitment at B_0) that occurs at a spawning biomass of 20% of B_0. Since the maximum recruitment R_{max} for the Ricker curves estimated here is closer to 20% B_0 than to B_0, the steepness parameter is greater than one. Under this definition, the steepness parameter can range from 0.2 to above 1. The steepness for the Beverton-Holt curve uses the same definition, however since the curve is asymptotic, *h* is between 0.2 and 1.0. Steepness for the Ricker curve can also be defined as the fraction of R_{max} that occurs at a spawning biomass of 20% of B_0 (This was followed in previous versions of EA). This steepness has bounds of 0 to 1.0, however, does not have the same meaning as the steepness in the Beverton-Holt curve.

Table 3-2 Stock- recruitment parameter estimates for Bristol Bay red king crab.

Handling mortality rate	Ricker S-R curve		Beverton-Holt S-R curve	
0.1	Steepness	1.64	Steepness	0.995
	Rmax	29 millions	Rmax	29 millions
0.2	Steepness	1.67	Steepness	0.99
	Rmax	29 millions	Rmax	29 millions
0.3	Steepness	1.70	Steepness	0.999
	Rmax	29 millions	Rmax	29 millions

The SAS Model procedure provided an estimate 1.2797 for the overall recruitment standard deviation σ for the given S-R data set, assuming a handling mortality rate *hm* of 0.2. Thus, for the evaluation of tier system for red king crab, the Ricker S-R model with a steepness parameter *h* value of 1.67, a R_{max} value of 29 million crabs, a handling mortality rate *hm* value of 0.2, an overall recruitment standard deviation σ of 1.2797, and an autocorrelation ρ of 0 were chosen.

The 1977-2005 MMB and corresponding recruit data sets for the handling mortality rate 0.2 was used to establish the Beverton-Holt and Ricker stock-recruitment models for the Bristol Bay component of the Tanner crab stock. The two models fitted at the handling mortality rate of 0.2 (the plausible value) were compared using AIC and BIC criteria to choose the best model. The AIC and BIC statistics were 73.4 and 75.5 for Ricker curve, and 78.7 and 80.8 for Beverton-Holt curve, respectively. The Ricker model gave the minimum AIC and BIC values and was chosen for stochastic simulations.

The SAS AUTOREG procedure was used to test for autocorrelation. The Durbin-Watson statistics produced significant ($P<0.0001$) result for presence of autocorrelation when the Ricker model was used, hence the same AUTOREG procedure was used to fit the Ricker model. On the other hand, the SAS Model procedure was used to fit the nonlinear Beverton-Holt S-R model for the same data set. The estimated Beverton-Holt parameter estimate was nonsignificant, but the Ricker parameter estimate was significant. Table 3-3 provides steepness parameter estimates for the two S-R curves.

Table 3-3 Stock- recruitment parameter estimates for the Bristol Bay component of the Tanner crab stock.

Handling mortality rate	Ricker S-R curve		Beverton-Holt S-R curve	
0.2	Steepness	2.03	Steepness	0.92
	R_{max}	104 millions	R_{max}	104 millions

The SAS AUTOREG procedure produced an overall recruitment standard deviation σ of 0.80 and an autocorrelation ρ of 0.69. For the evaluation of tier system for Tanner crab, the Ricker S-R model with a steepness parameter *h* of 1.43, a R_{max} value of 104 million crabs, a handling mortality *hm* value of 0.2, a σ of 0.80 and a ρ of 0.69 were chosen. Because EBS Tanner crab simulations were performed under Tiers 2 and 3, and Tier 4 assumptions, a middle value of the steepness parameter range considered for $F_{x\%}$ determination was used for all Tiers for comparing performance statistics under the two assumptions.

The 1978-2006 MMB and corresponding recruit data sets for handling mortality rates 0.25 and 0.50 were used to estimate stock-recruitment curves for the EBS snow crab stock. The Ricker and Beverton-Holt model parameter estimates are listed in Table 3-4.

Table 3-4 Stock- recruitment parameter estimates for EBS snow crab.

Handling mortality rate	Ricker S-R curve		Beverton-Holt S-R curve	
0.25	Steepness	0.896	Steepness	0.467
	R_{max}	2000 millions	R_0	2000 millions
0.50	Steepness	0.895	Steepness	0.494
	R_{max}	2000 millions	R_0	2000 millions

For the evaluation of tier system for snow crab, the Beverton-Holt S-R curve with a steepness parameter *h* of 0.68, a R_{max} value of 2000 million crabs, a handling mortality *hm* value of 0.50, a recruitment standard deviation σ of 0.86 and an autocorrelation ρ of 0.6 were used based on 2006 stock assessment (Turnock and Rugolo, 2006). The same set of parameters was used for simulations considering a handling mortality *hm* value of 0.25.

3.2.5 Determination of Tier 1 to 4 Control Rule Parameters

Tiers 1 to 3 control rule formulas consist of four parameters: α, β, B_{MSY} or $B_{X\%}$ and F_{OFL} (F_{MSY} or $F_{x\%}$), while the Tier 4 control rule formula consists of an additional γ parameter associated with *M* to replace F_{OFL}. The deterministic and stochastic simulation analyses were carried out to determine these parameter values first before proceeding into estimating performance statistics for different Tiers

3.2.5.1 $F_{x\%}$, $B_{x\%}$, F_{MSY}, and B_{MSY}

Stock-recruitment relationships were lacking for most BSAI crab stocks for direct estimation of F_{MSY} and B_{MSY} and qualify for Tier 1 or 2. The S-R fits to Bristol Bay red king, Bristol Bay portion of Tanner crab, and snow crab were not considered reliable for Tier 1 or 2. Therefore, reasonable ranges of S-R steepness parameter *h* were considered to determine $F_{x\%}$ and $B_{x\%}$ values as proxies for F_{MSY} (i.e., F_{OFL}) and B_{MSY} respectively in Tier 3 control rule formulas. The steepness ranges were chosen based on *h* estimates from S-R fits to Bristol Bay red king, Bristol Bay portion of Tanner crab, and snow crab stock data during low productivity periods. An *h* range of 0.66 - 1.78 for the Ricker S-R model and a corresponding *h* range of 0.53 - 0.79 for the Beverton-Holt S-R model were chosen for $F_{x\%}$ estimation by

Clark's (1991) method for the red king crab. The corresponding *h* ranges for Tanner crab $F_{x\%}$ determination were 0.66-2.2 and 0.53-0.83, respectively; and for the snow crab $F_{x\%}$ determination were 0.52-3.83 and 0.45-0.91, respectively. The $F_{x\%}$ was determined as the 'minimax' point (Clark, 1991) from relative equilibrium yield vs. relative spawning potential ratio curves.

For the red king crab and Tanner crab stocks, the $B_{x\%}$ was estimated at a selected $F_{x\%}$ value from the stochastic simulation of a 100-year fishery with a selected S-R curve and a base *h* value. The average $B_{x\%}/B_0$ ratio was used as a proxy B_{MSY}/B_0 from which the $B_{x\%}$ was determined knowing B_0. The B_0 was estimated at F = 0. When the true S-R curve with the estimated *h* value was used the same procedure provided F_{MSY} and B_{MSY} estimates.

For the snow crab stock, MMB per recruit at $F_{x\%}$ was used with the average recruitment estimated from the stock assessment models (Turnock and Rugolo 2006) to estimate $B_{x\%}$ as a proxy for B_{MSY}.

3.2.5.2 α and β

The harvest control rules involve two parameters, α and β. The α parameter in the tier formula determines the slope of the control rule line. The higher the α value the steeper the slope and hence the faster the rebuilding time of an overfished stock. The β parameter value determines the relative biomass level at which the fishery would be closed. The α and β parameters used for the Alternative 2 and 3 status determination criteria are shown in Figure 2-2.

A sensitivity analysis of the α and β parameters was investigated by considering a range of values for α (0.0, 0.05, 0.1, 0.25, 0.5) and β (0.0, 0.25, 0.5). An α value of 0.05 is used in the groundfish tier system (NPFMC 1998) whereas a β value of 0.25 is employed as a mature-stock biomass ratio (relative to MSY mature-stock biomass) to determine the fishery closure benchmark in some crab stocks. The parameters were evaluated by rebuilding analyses of a hypothetical overfished stock (10% B_{MSY} and 50% B_{MSY}) under a proxy F_{MSY} ($F_{x\%}$). A number of performance statistics were estimated from 1000 simulations of a 30-year fishery (a few years more than the maximum crab life span) with random recruitment to explore the viability of selected control rule parameter values: median rebuilding time, mean of overfished and $B<25\%B_{MSY}$ proportions, mean and coefficient of variation (CV) of mean yields during the first 10 years and the subsequent 20 years of the rebuilding time period, and the mean of the 30th year B/B_{MSY} ratio. Only red king and snow crabs were considered for these simulations. For the Bristol Bay red king crab a handling mortality rate of 0.2 and for the snow crab a handling mortality rate of 0.25 were used. The results are discussed in Chapters 4 and 5.

3.2.5.3 γ

For Tier 4 stocks, abundance estimates are available, but complete population parameters are not available for computer simulation studies and spawning biomass per recruit analyses needed for Tier 3 stocks.

An important parameter for Tier 4 is γ. The value for γ is frameworked for the FMP amendment with a default value of $\gamma = 1$. A default γ value or a range of γ values can be set for all Tier 4 stocks. In the simulation studies for this EA, the ratio of F_{MSY} to M is nearly 2.0 for Bristol Bay red king crab and 3.5 for Bristol Bay portion of the Tanner crab stock, after adjusting the shell condition selectivity. Because Tier 4 is for stocks with limited data, harvest should be more conservative than for these two stocks, which are in Tier 3. This conservation is reflected by the assumption that trawl survey catchability for legal males is equal to 1 for Tier 4 stocks, whereas the survey catchability may be estimated to be less than 1 in a model for Tier 3 stocks. For the five blue king crab and red king crab stocks, the default γ was set to be F_{MSY}/M (0.3995/0.18 ~ 2.0) based on Bristol Bay red king crab simulation results. For *Chionoecetes* species, the estimated γ from modified F_{MSY}/M (0.65574/0.23 ~2.85) was somewhat high. However, for illustrative purpose, this value was used in EBS Tanner crab simulations under Tier 4 control rule. A lower value of 2 or less was suggested for limited data stocks of *Chionoecetes* species. Stock specific gammas would be set in the annual stock assessment based on the default, values of F_{MSY} or its proxy ($F_{35\%}$) and M, or other methods appropriate to the specific stock.

3.3 OFLs for Tiers 5 and 6

Different environmental regimes can result in different levels of mean yield for a stock. For OFLs in Alternatives 2 and 3, the mean yield from the current regime was used for Tier 5 stocks. The regime shift in 1976/77 has been well documented and so the Tier 5 OFLs consider mean yields after the 1976/77 regime shift. A regime shift may have occurred in 1989, but its effect in the EBS is not very strong. The regime shift affects the crab early year classes first and then impacts catch a few years later. It takes at least 8 years from hatching to grow into legal size for most crab species. Therefore, mean yields from 1985 to 2005 were used for the Alternatives 2 and 3 Tier 5 OFLs, with some excluded years that were strongly influenced by regulatory actions. The excluded years are from 1995 to 2005 for Adak red king crab when the fishery was closed, fishing effort was less than 10% of the average, or fishing was allowed only in a small part of the fishing ground. The excluded years are from 1985 to 1992 and from 2000 to 2005 for Pribilof Islands golden king crab when the fishing effort was less than 10% of the average or the GHL was set below the previous average catch. Years from 2000 to 2005 were excluded for Aleutian Island golden king crab when the TAC was set below the previous average catch.

Under Alternative 2, all stocks not in the previous tiers would be in Tier 5, including stocks with very limited catch history. The problems with establishing an OFL based on catch history for these stocks include: (1) catch data come from exploratory and incidental fisheries for most stocks, (2) there are only 2 to 4 years of catch data for several stocks and hardly any catch data for St. Lawrence Island blue king crab, (3) mean catch for Eastern Aleutian Islands groove Tanner crab may be too high (only 4 years of data and the CPUE declined during these 4 years), and (4) mean catch for Aleutian Islands scarlet king crab and St. Matthew Island golden king crab may be too low (the maximum annual catch is more than 4.7 times of the average).

Under Alternative 3, only stocks with reliable catch histories would be in Tier 5. Alternative 3 includes a Tier 6 for stocks with insufficient catch history and limited scientific information. For Tier 6 stocks, the default OFL would be set at zero because there is no fishing for these stocks and available information is not sufficient to determine an OFL. Since OFLs are set for the retained catch only, bycatch of Tier 6 stocks in other fisheries would not be affected by an OFL of zero. Prior to the opening of a directed, incidental, or exploratory fishery for a Tier 6 stock, the OFL would be developed along with ADF&G's GHL for that fishery. The SSC would review and establish that OFL during the annual OFL setting and review process. Under any directed or exploratory fisheries, these stocks would be monitored for trends of fishing effort, CPUE, mean size of landed crab, and ratio of landed newshell to oldshell crab. Tier 6 stocks would be evaluated for upgrading to Tier 5 for OFL determination as information becomes available

3.4 Tabulation of annual catch

Under Alternatives 2 and 3, annual removals by species must be tabulated for determination of overfishing (see Section 2.4 for process of overfishing determination and impacts of determination). For purposes of this analysis, the following methodology would be employed to estimate the total removals in the BSAI crab fisheries, scallop fisheries, and Federal groundfish fisheries. The estimates of the total estimated bycatch for each stock by season would be based on data collected by onboard crab observers. These estimates would be tabulated each fall and contained in the annual SAFE report.

Estimating crab bycatch in the BSAI crab fisheries

Weight in pounds was estimated by first determining the mean weight in grams for crabs in each of three bycatch categories: legal non-retained male crabs, sublegal male crabs, and female crabs. Male crabs were identified as sublegal or legal using the cut points listed in the table below. The mean weight for each category was estimated using length frequency tables where the crab size, CW (mm) or CL (mm), was converted to grams using the established conversion equation and parameter estimates (Weight(g) = A * size(mm)^B; see table below for A and B parameter estimates). The estimated weight for each CW/CL size was multiplied by the number of crabs at that size, the products summed, and the resulting sum divided by the total number of crabs.

Mean Weight (g) = [Sum(<u>weight at size</u> * <u>number at size</u>)] / Sum(crabs)

Finally, total weights were the product of mean weight, CPUE, and total pot lifts in the fishery. The total weight in grams was then converted to pounds by dividing the gram weight by 453.6 g/lb. Missing data for a fishery that took place are represented by a zero (0). This indicates no crabs of that category were recorded by observers for that fishery and season; a dash (-) indicates no fishery took place that season. There are no size to weight conversion values for scarlet king crabs *Lithodes couesi*, female triangle Tanner crabs *Chionoecetes angulatus*, or female grooved Tanner crabs *C. tanneri* so those stocks and genders are not represented in the summaries.

Table 3-5 Size and weight relationship for BSAI crab stocks.

Species	Male size to weight conversion		Male legal cut points (mm) CW/CL > cut point => legal male crab	Female size to weight conversion[1]	
	A	B		A	B
Red king crab	0.000361	3.16	CL 138	0.022863	2.23382
Blue king crab	0.000329	3.175	St. Mat–CL 120 Prib–CL 138	0.114389	1.9192
Golden king crab	0.0002988	3.135	AI – CL 135 Prib – CL 124	0.001424	2.781
Snow crab	0.00023	3.12948	CW 78	0.000675	2.943352
Tanner crab	0.00019	3.09894	CW 139	0.003661	2.563912
Triangle Tanner crab[2]	0.0002244	3.054	CW 144	-	-
Grooved Tanner crab[2]	0.0001186	3.189	CW 127	-	-

[1] only values for mature ovigerous female crabs were used
[2] no size to weight conversion values available for female crabs

Estimating crab bycatch in the BSAI groundfish fisheries

For purposes of catch accounting in conjunction with groundfish PSC limits, crab bycatch is reported in numbers of crab. In order to estimate the weight of crab for comparison with the total catch by species to be tabulated annually, the following methodology would be employed:

> The average weight for crabs by species is derived from observer data for the groundfish fisheries. Since the observers both count and weigh crabs in their sample, both pieces of data are used to get the average weight by species for crabs sampled. This average weight is then multiplied by the catch in numbers.

Catch in numbers is reported annually in the Crab SAFE. Crab bycatch by weight will be provided on the NMFS Alaksa Region website at http://www.fakr.noaa.gov/. This information will be available to coincide with the crab fishing year over which the OFL is applied.

Estimating crab bycatch in the Bering Sea scallop fisheries

Crab bycatch in the scallop fisheries would also accrue toward the OFL for crab stocks under Alternatives 2 and 3. Tanner crab are the crab species most often taken as bycatch in scallop fisheries and make up a very small proportion of the total bycatch of Tanner crab annually (NPFMC 2007). Crab bycatch is enumerated in numbers of crab by onboard observers. A methodology similar to that utilized for groundfish will need to be undertaken to estimate the weight of crab for tabulating the total catch by species. Catch in numbers is reported annually in the Crab SAFE. The timing of catch enumeration for scallop fishery bycatch of crab would need to be revised to coincide with the crab fishing year over which the OFL is applied.

4 Red king crab *(Paralithodes camtschaticus)*

Five stocks of red king crab are managed in the BSAI area: Bristol Bay, Pribilof Islands, WAI (Adak), EAI (Dutch Harbor), and Norton Sound. This Chapter reviews the stock status and biological parameters relevant to overfishing definitions for these stocks and provides an overview of specific impacts on the stocks from the three alternatives under consideration in this analysis.

4.1 Red king crab stock status

Bristol Bay red king crab

This stock is annually surveyed by the NMFS EBS trawl survey. The 2006 estimated TMB is 157.2 million pounds (71,305 t) of TMB. This is down slightly from the estimates of the preceding 3 years (approximately 180 million pounds (81,647 t)). However, the stock remains well above MSST and B_{MSY} as currently defined (Figure 4-1). The ADF&G length-based analysis (LBA) point estimates for mature-sized males and legal males in 2006 are both slightly higher than for 2005. The LBA model for 2006 estimates that mature-sized females increased to 40.469 million crabs in 2006 from 37.848 million in 2005, continuing a trend in annually increasing abundance since 2000. Although far below the levels estimated to have existed in the late 1970s, the 2006 LBA model estimates that mature males, mature females, effective spawning biomass[2] (ESB) and legal male abundance are each at their highest levels since the early 1980s.

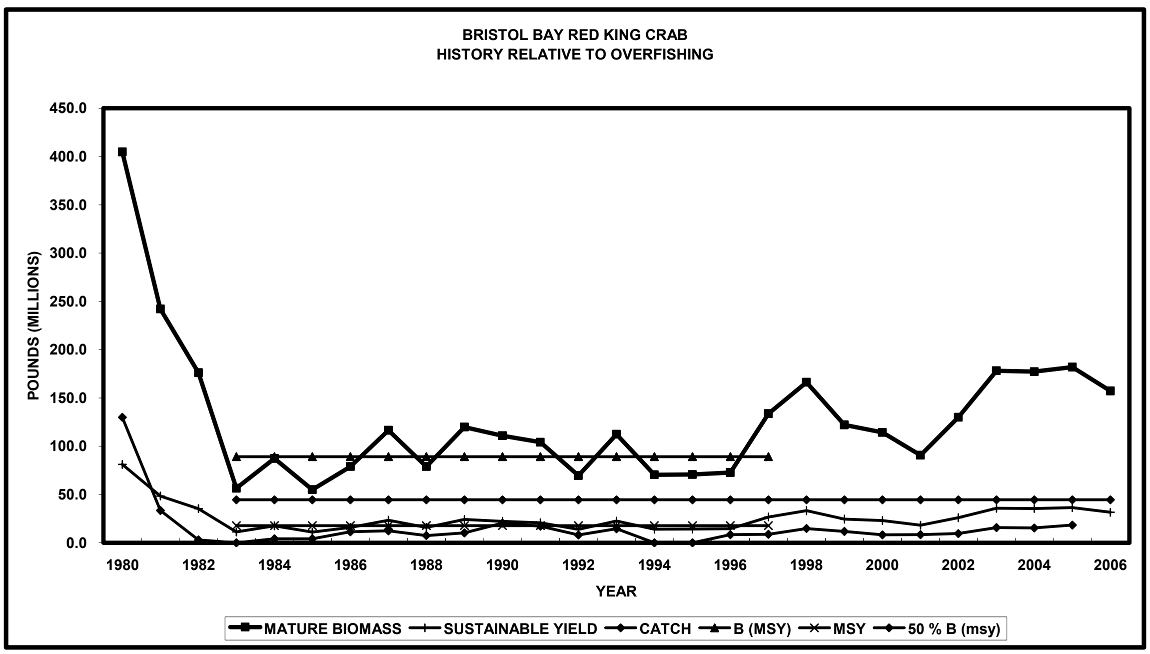

Figure 4-1 Bristol Bay Red King Crab stock status relative to overfishing

Recruitment to the stock is determined by following sex-specific size classes from the survey data and model estimates. As anticipated from the 2005 survey data, the 2006 LBA model estimated that recruits

[2] Effective Spawning Biomass is the estimated biomass of mature female crabs that the population of mature crabs successfully mates in a given year.

to the mature-sized female class in 2006 declined slightly from that of 2005. However, a mode of juvenile-sized crabs centered at approximately 72.5-mm carapace length (CL) in the 2005 male and female size-frequency distributions apparently tracked to a mode centered at approximately 87.5-mm CL in the size frequency distribution for each sex in 2006. Assuming that the 87.5-mm CL size mode continues to track into the future, it should provide good recruitment into the mature female size class (≥90-mm CL) in 2007, but would not provide strong recruitment to the mature male size class (≥120-mm CL) until 2008. Representation of juvenile crabs <70-mm CL, however, was poor for both sexes in the 2006 survey as compared to the 2002-2005 surveys (NPFMC 2006a).

Pribilof District red king crab

This stock is annually surveyed by the NMFS EBS trawl survey. Stock levels and trends for this stock are difficult to evaluate due to the low precision of abundance estimates. However, the consistency of trend in data for the previous five survey years indicated that the TMB was in decline. Estimated TMB declined annually from 25.5 million pounds (11,567 t) in 2001 to 8.1 million pounds (3,674 t) in 2005. However, TMB in 2006 rose to 19.0 million pounds (8,618 t) (Figure 4-2). ADF&G catch survey analysis (CSA)-estimated mature male abundance has shown a declining trend since 2002 through 2006.

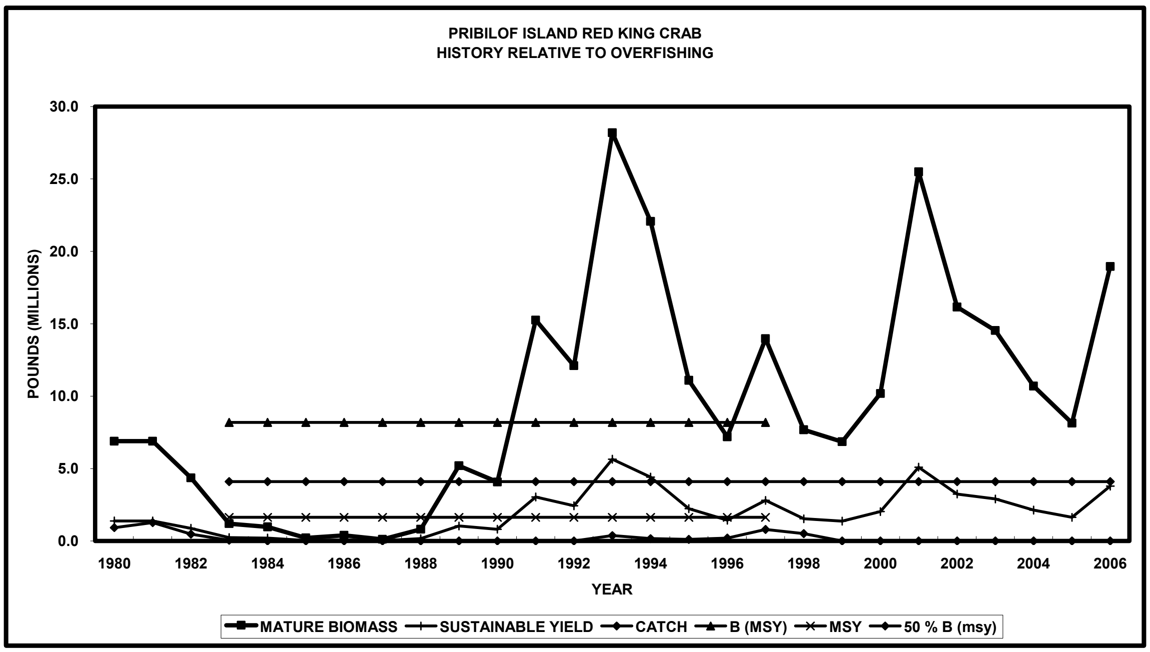

Figure 4-2 Pribilof District red king crab stock status relative to overfishing.

Mature-sized (≥120-mm CL) males captured in the 2006 trawl survey were largely legal sized (≥135-mm CL) and legal males were largely post-recruit-sized crabs ≥150-mm CL. The size-frequency distribution of males captured during the 2006 survey provides no expectation for significant recruitment to mature-sized males in 2006; after 2007, future declines in mature-size male abundance for this stock would be expected from the lack of sublegal-sized males <100-mm CL (NPFMC 2006a).

There is no harvest strategy for this stock in State regulation. The fishery has been closed since 1999 due to the poor precision of the abundance estimates, poor performance of recent fisheries, and concerns for bycatch of blue king crabs of the overfished Pribilof blue king crab stock.

Aleutian Islands red king crab: WAI (Adak or Petrel Bank) and EAI (Dutch Harbor)

This stock is not annually surveyed by NMFS. ADF&G conducts annual surveys of the EAI and triennial surveys of the WAI, the most recent of which was performed in 2004. Few red king crabs have been caught in surveys of the eastern Aleutians since 1995. The GHL for the eastern portion is based on the results of surveys, and has been closed since 1983. Historically, the GHL for the western portion has been based on the most recent fishery performance. The western portion was closed for the 1996/97 and 1997/98 seasons due to poor performance and poor signs of recruitment during the 1995/96 season. The western portion was reopened for limited exploratory fishing in some areas in 1998/99. Based on the results of the 1998/99 season, the fishery in the western portion was closed in 1999/2000.

In 1999 the CPT identified the need for standardized surveys in areas of historical production prior to reopening the fishery in the western portion; prior to that meeting, the western portion had not been surveyed since 1977. A cooperative ADF&G-Industry pot survey was performed in the Petrel Bank area under the provisions of a permit fishery in January-February and November of 2001. Results of those surveys showed high densities of legal crabs within limited portions of the surveyed area. Survey catches of females and prerecruit sized males were low. Based on results of the 2001 surveys and recommendations from ADF&G and the public, the Alaska Board of Fisheries adopted pot limits, and modified the season opening date.

A GHL of 0.5 million pounds (227 t) was set for the 2002 season in the Petrel Bank area. Because only relative abundance information is available, ADF&G monitored the fishery using inseason catch data. The management goal is to maintain a fishery CPUE of at least 10 legal crabs per pot lift. The 2002 fishery in the Petrel Bank area harvested 505,000 pounds (229 t). The fishery CPUE was 18 legal crabs per pot lift. Based on fishery performance, ADF&G announced a 0.5 million pound (227 t) GHL for the 2003 fishery and the fleet harvested 479,000 pounds (217 t). The 2003 catch rate dropped to 10 legal crabs per pot lift. The fishery was closed in 2004 and 2005. The Petrel Bank red king crab fishery will not open in 2006 due to low stock size. A pot survey was performed in November 2006 (Gish 2007) and an additional pot survey is planned for November 2007.

In order to assess red king crab in other portions of the western AI, during November 2002, a survey was conducted between 172° W longitude, and 179° W longitude (waters in the vicinity of Adak, Atka, and Amlia Islands). The survey of these waters yielded very few red king crabs and the area remains closed until further notice.

Norton Sound red king crab

This stock is not annually surveyed by NMFS. Instead, ADF&G performs a triennial trawl survey in Norton Sound[3]. Population abundance estimates from the trawl survey are evaluated by ADF&G biometricians and incorporated into a model developed by Zheng et al. (1998). The model provides estimates of the legal and sublegal male population sizes. Trawl survey and model population estimates are limited to abundances because reliable paired weight-length information is not available to estimate biomass (Soong and Banducci 2006). Estimated biomass is calculated by multiplying abundance by 3.0 pounds (1.36 kg), the average weight of legal male crabs from the summer fishery (Soong and Banducci 2006). The king crab population model estimated legal male crab abundance for the 2006 summer commercial crab fishery at 4.5 million pounds (2,041 t). This is down 27% from the 2005 model abundance estimate of 6.2 million pounds (2,812 t) for legal male crab. It should be noted that this apparent 27% decline is due to a revision of the model following the 2005 season rather than an actual loss of crab in the population. The revised model estimated the 2005 population at 4.8 million pounds

[3] With the exception of 2006 where 4 years transpired since the 2002 triennial survey.

(2,177 t) making the decline approximately 5%. Current size composition data from the 2006 winter pot study indicates that the portion of the crab population classified as recruits has decreased 9.8% since the 2005 winter survey and the post recruit male crab population has decreased 11.6%. The winter pot study also points to an above average prerecruit-1 and prerecruit-2 populations and a very small prerecruit-3 population. The prerecruit-1 crab will molt and become part of the legal population next year. These findings indicate the legal crab population has peaked and is expected to decrease in 2007 followed by an increase in 2008 and 2009.

A 10% exploitation rate on the legal population (over 4.75 inch carapace width) equates to a guideline harvest level of 454,000 pounds (206 t) of crab. The CDQ allocation for 2006 was 34,050 pounds (16 t) with the remaining 419,950 pounds (190 t) allocated to the open access fishery. This follows the harvest strategy set by the Board of Fisheries and is the highest GHL since 1982.

In 2006, a total of 224 landings were made during the open access season for a harvest of 139,131 crabs and 419,191 pounds (190 t), equating to 99.8% of the open access quota. The CDQ catch was 32,557 pounds (15 t) making the total crab harvest during the summer season 451,748 pounds (205 t).

Results from the 2006 summer trawl survey suggest that the 2008 and 2009 legal king crab populations should increase from the current population, with the 2006 pre-2 estimate at more than 80% above the 2002 estimate. Pre-2 crabs will molt over the next 2 years and contribute to the legal portion of the population in 2008 and 2009 (Soong and Banducci 2006).

4.2 Biological parameters

This section examines relevant and recent biological information necessary to understand the overfishing definitions for red king crab.

Male crabs in the Bristol Bay red king crab stock are considered functionally mature for management purposes at 120 mm CL (Zheng et al. 1995a). In the Bristol Bay red king crab stock, approximately 50% of the females that are 89 mm CL are mature and approximately 80% of the females that are 95 mm CL are mature (Otto et al. 1990). A size range of 65-200 mm CL for males and a size range of 65-165 mm CL for females were considered in the simulations. This was to include immature sizes of crabs as initial recruits to the cohorts. Appendix B provides the input base parameter values.

4.2.1 Steepness parameter estimate

The Beverton-Holt and Ricker stock-recruitment (S-R) models were fitted to the Bristol Bay red king crab stock with MMB on February 15 as the index of spawning biomass, when mature biomass is expected to be relatively low during the year. The 1985-2006 S-R data for different handling mortality (*hm*) values (0.1, 0.2, and 0.3) and the two S-R fits are depicted in Figure 4-3**.** The Ricker curves were slightly better to these data sets than the Beverton-Holt curves (see Chapter 3). Zheng et al. (1995a) also fitted Ricker S-R curves to a longer time series of data. The steepness parameter values for the Ricker curve ranged from 1.64-1.70. For illustrative purpose, a value of 1.67 based on the fit to the S-R data for *hm*=0.2 was used in the stochastic simulations.

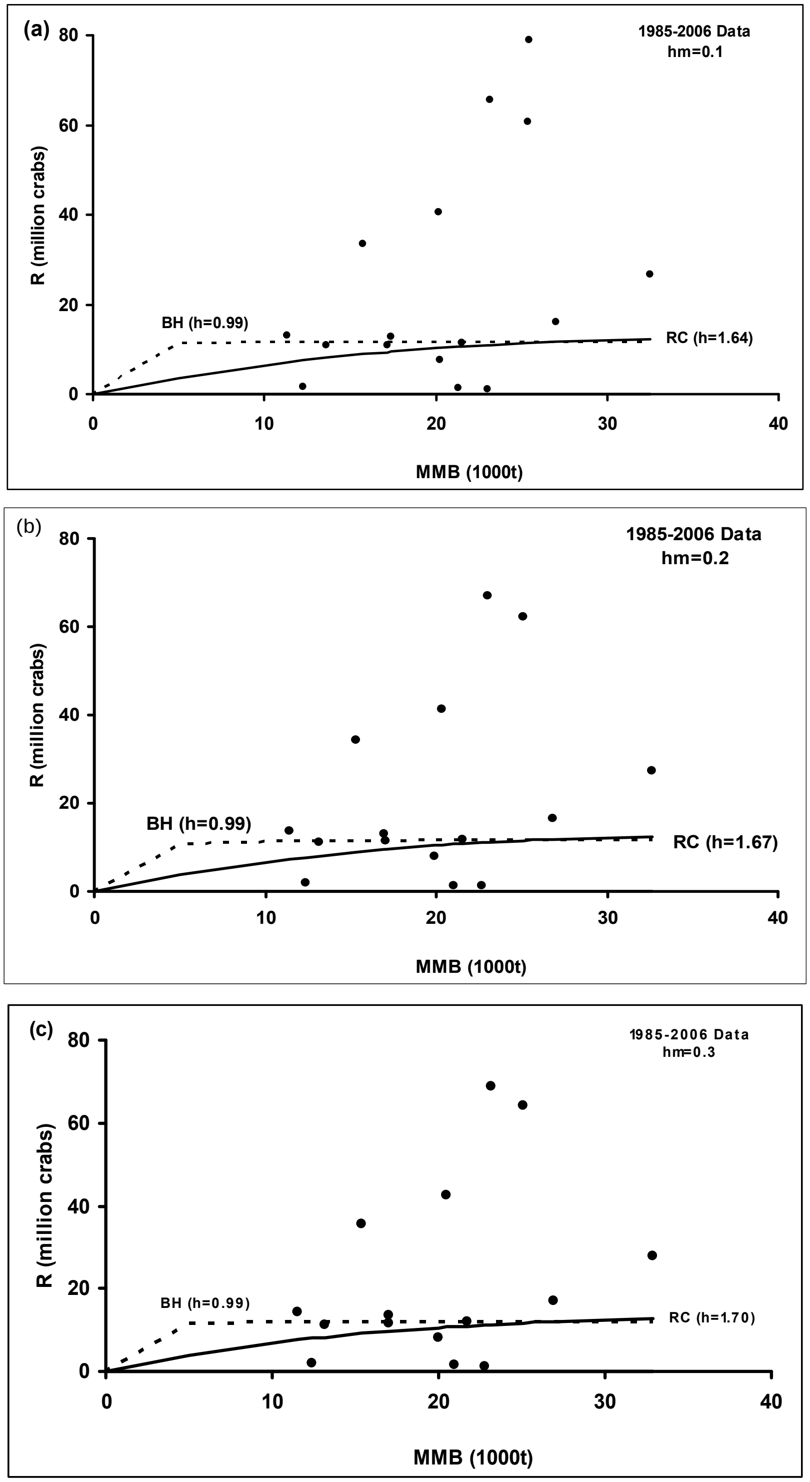

Figure 4-3 Stock-recruitment fit for the Bristol Bay red king crab 1985-2006 data assessed at M = 0.18 and handling mortality, *hm* (a) 0.1, (b) 0.2, and (c) 0.3. The steepness parameters, *h*, are given in parentheses. BH = Beverton and Holt curve, RC = Ricker curve. A 6-year lag time was used.

4.2.2 B_{MSY} and proxy B_{MSY} estimate

The simulated Bristol Bay red king crab population with a maximum number of 29 million recruits produced a B_{MSY} of 72.57 million pounds (32,916 t) of MMB and a $B_{35\%}$ of 77.86 million pounds (35,317 t) of MMB for the Ricker S-R curve with the estimated steepness parameter value of 1.67. These B_{MSY} and $B_{35\%}$ values were used in the Tier 2-4 formulas for stochastic simulations.

4.2.3 $F_{x\%}$ estimate

The $F_{x\%}$ estimates for the Bristol Bay red king crab analysis for different handling mortality values were shown in Figure 4-4. Slight changes in $F_{x\%}$ values occurred: $F_{33\%}$, $F_{34\%}$, and $F_{35\%}$ for *hm* = 0.1, 0.2, and 0.3, respectively. We considered $F_{35\%}$ as a candidate proxy F_{MSY} for detailed stochastic simulations. The corresponding F was 0.36, legal male harvest rate (at the time of the fishery) was 26%, and the mature male harvest rate (at the time of the survey, June 15) was 15%.

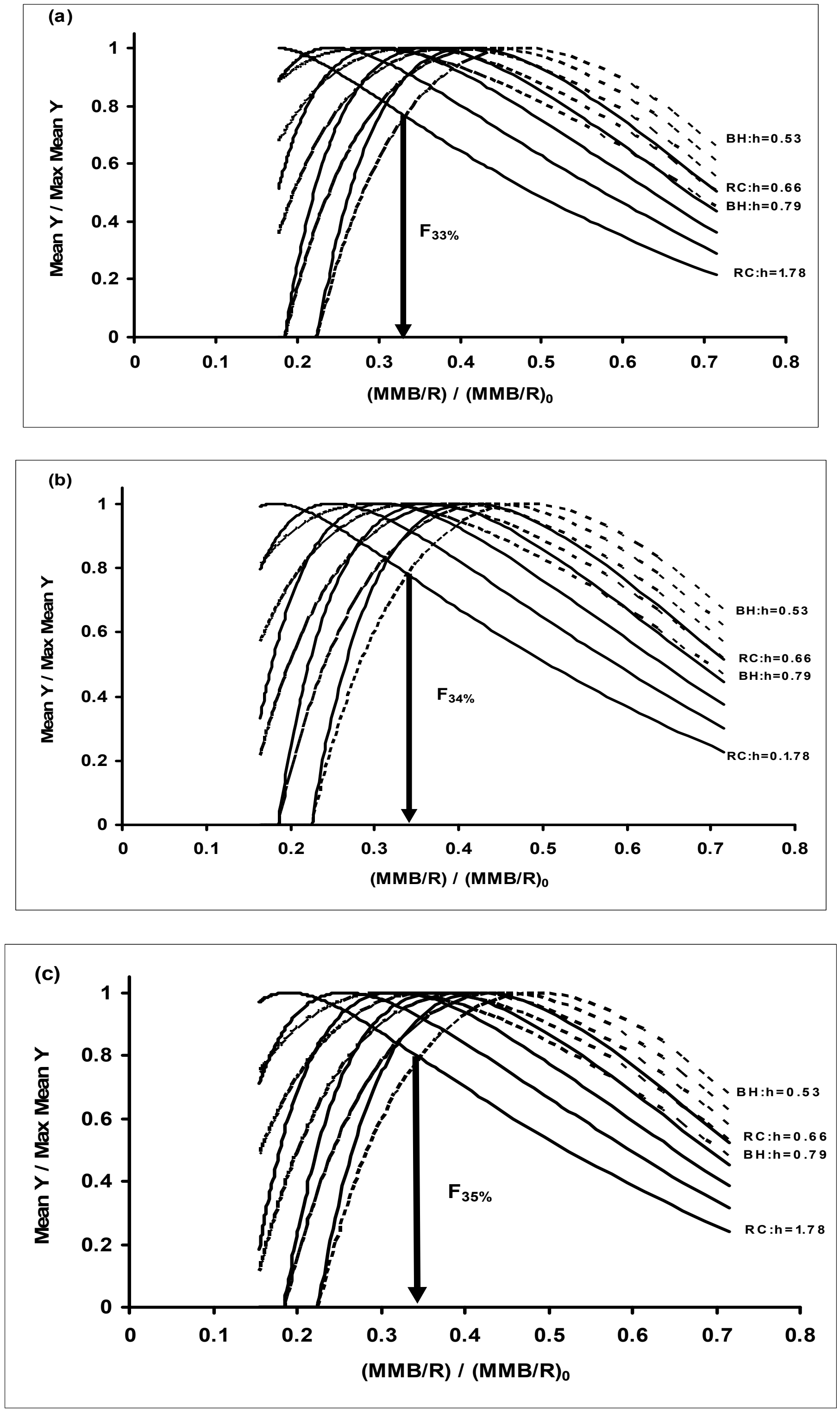

Figure 4-4 Approximate locations of spawning potential ratio ($F_{x\%}$) by equilibrium yield method for different handling mortality rates: (a) 0.1, (b) 0.2, and (c) 0.3 for red king crab. Solid lines: Ricker S-R model, dotted lines: Beverton-Holt S-R model.

4.3 Effects on Bristol Bay red king crab

4.3.1 Comparison of status determination criteria

The Alternative 1 status determination criteria for Bristol Bay red king crab establish a B_{MSY} value of 89.6 million pounds (40,642 t) of TMB, with an MSST value of 44.8 million pounds (20,321 t) (Figure 4-1). The 2006 TMB, derived from survey area-swept estimate, is above B_{MSY} at 157.2 million pounds (71,305 t).

The Alternatives 2 and 3 tier system estimates B_{MSY} differently by using MMB rather than TMB (which includes males and females), as discussed in Section 2.4.1. The Alternative 2 and 3 estimate of proxy B_{MSY} is 77.86 million pounds (35,311 t) of MMB. For comparison, the estimate of MMB for this stock in 2006 is 65.54 million pounds (29,728 t). Thus, this stock status would be below its B_{MSY} value under the Alternative 2 and 3 estimates of status determination criteria rather than above it as with Alternative 1.

The State of Alaska harvest strategy for the Bristol Bay red king crab has the following criteria (5 AAC 34.816):

Threshold levels: 8.4 million mature female crabs, 14.5 million pounds (6,577 t) of effective spawning biomass (ESB), and a minimum total allowable catch of 4.444 million pounds (2,016 t). When the threshold levels are met, the harvest rate is determined as follows:

- Mature harvest rate = 10%, if ESB is greater than14.5 million pounds (6,577 t) but less than 34.75 million pounds (15,762 t)
- Mature harvest rate = 12.5%, if ESB is at least 34.75 million pounds (15,762 t) but less than 55 million pounds (24,948 t)
- Mature harvest rate = 15%, if ESB is at least 55 million pounds (24,948 t)

In addition, the harvest is capped at 50% of available legal male abundance.

For the status quo harvest strategy, abundances are estimated at the survey time using survey selectivity, and harvest rates are applied to molting MMB at the time of the survey.

Under Alternative 1, overfishing occurs when the TAC is above the estimated SY. The Bristol Bay red king crab TAC for the 2006/2007 fishery was 15.5 million pounds (7,031 t), which is below the 2006 SY of 31.44 million pounds (14,288 t).

Annual determination of overfishing under Alternatives 2 and 3 would occur by comparison of previous year's total catch with the calculated OFL total catch using appropriate Tier 3 formula for the same time period. Total catch is equal to retained catch plus handling mortality rate times bycatch discards. Overfishing is defined as any amount of catch in excess of the OFL as prescribed through the tier system described in Section 2.2.1 and 2.3.1. For example, Figure 4-5 shows historical harvest rates in the direct fishery in conjunction with $F_{35\%}$ and $F_{40\%}$ control rules for F_{OFL} for this stock. Here harvest rates in excess of the OFL control rule (e.g. $F_{35\%}$ control rule) would constitute overfishing. This figure does not include Bristol Bay red king crab bycatch in the directed fishery or the groundfish fisheries.

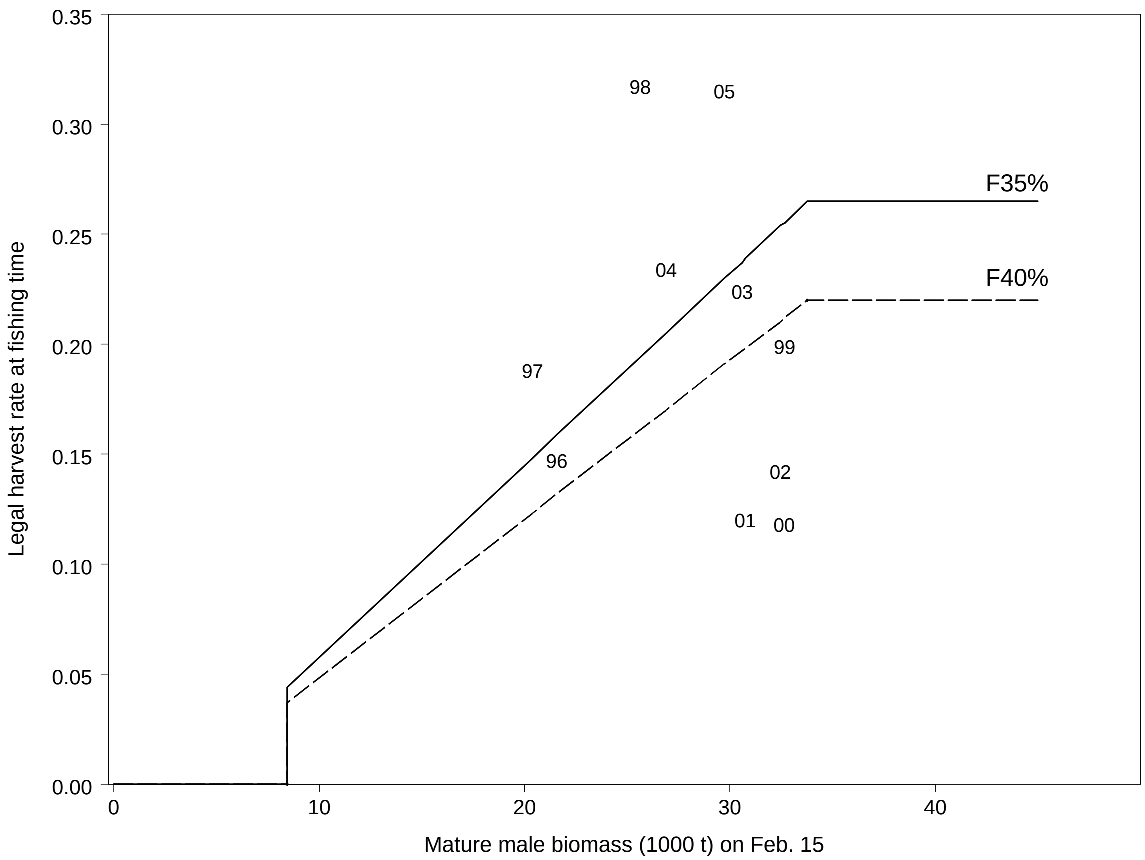

Figure 4-5 Relationships between legal harvest rate and mature male biomass on February 15 for Bristol Bay red king crab. The dotted points are legal harvest rates from 1996 to 2005. $F_{35\%}$ and $F_{40\%}$ in the figure correspond to equivalent legal harvest rates.

Under Alternatives 2 and 3, the recommended control rule for the Bristol Bay red king crab stock is $F_{35\%}$. With a recommended control rule of $F_{35\%}$, fishing rates in the directed fishery in the years 1997, 1998, 2004 and 2005 would have constituted overfishing for this stock. If $F_{40\%}$ were the recommended OFL control rule, overfishing would also have occurred in 1996 and 2003. Under Alternatives 2 and 3, harvest rates would have been constrained by the OFL control rule in those years. Total harvest rates (retained catch plus discard losses) must be below the recommended F_{OFL}, thus annual determinations would be made to ensure that the TAC is set at a level whereby the total harvest rate would be below the F_{OFL} for each stock. Figure 4-5 analyzes legal harvest rates to avoid the impacts of fishing selectivity, which varies from year to year.

The change in currency from the TMB to the MMB would affect 'overfishing' and 'overfished' determinations for the Bristol Bay red king crab during 1985-2006. Table 4-1 provides a comparison of TMB and MMB used for alternative status determination criteria for Bristol Bay red king crab. Catch Total equals the sum of retained catch plus discard losses. Discard losses were determined by multiplying the pot bycatch mortality rate of 0.2 by the estimate of discarded legal males, sublegal males, and females in the crab fisheries and multiplying the trawl bycatch mortality rate of 0.8 by trawl bycatch (NPFMC 2006a).

Under the current FMP, the historical harvest has not exceeded the OFL and TMB has been above MSST (=50%TMB_{MSY}). TMB remained above TMB_{MSY} in the late 1990s and 2000s. Therefore, the stock has not been overfished and overfishing has not occurred. On the other hand, the MMB did not exceed $B_{35\%}$ even though an increasing trend was observed during this time period.

Overfishing is shown by comparing the Alternative 2/3 OFL Total column values with Catch Total values (Table 4-1). Under Alternatives 2 and 3, the change in currency from TMB to MMB would have resulted in an overfishing determination in years 1985-1988, 1990-1993, 1997-1998, and 2005. Under Alternatives 2 and 3, the F_{OFL} is affected by the change in currency as well as biological reference points: lower MMB than $B_{35\%}$ reduces the F_{OFL} and proposed maximum F_{OFL} is much lower than the maximum legal fishing mortality resulting from 0.2 times TMB under status quo. Overall the differences in OFLs for Bristol Bay red king crab are due to the revised definition of overfishing, which considers total removals rather than retained catch, change in currency, and subsequent estimation of biological reference points.

Table 4-1 Comparison of total mature biomass (TMB) and mature male biomass (MMB) used for alternative status determination criteria for Bristol Bay red king crab. Catch Total = sum of retained catch + discard losses. Discard losses = a pot bycatch mortality rate of 0.2 multiplied by discarded legal males, sublegal males, and females in the crab fisheries + a trawl bycatch mortality rate of 0.8 multiplied by trawl by catch. Proposed FOFL is the full selection fishing mortality. OFL Retained = predicted retained catch OFL. OFL Total = sum of predicted retained catch + discard losses. The biomass and catch values are expressed in millions of pounds.

	Alternative 1					Alternatives 2 and 3				
Year	Catch Retained	Catch Total	TMB	%TMBMSY	OFL = SY	Feb 15 MMB	%B35%	Proposed FOFL	OFL Retained	OFL Total
1985	4.18	5.00	54.98	61	11.00	25.12	32*	0.09	1.03	1.65
1986	11.39	11.83	78.92	88	15.78	27.21	35*	0.10	2.25	3.11
1987	12.29	12.60	116.40	130	23.28	37.57	48*	0.15	4.40	5.56
1988	7.39	8.56	78.92	88	15.78	46.31	59	0.20	7.03	8.40
1989	10.26	10.64	119.93	134	23.99	55.38	71	0.25	10.34	11.91
1990	20.44	23.24	110.89	124	22.18	59.17	76	0.27	11.98	13.50
1991	17.38	18.98	104.08	117	20.82	50.10	64	0.22	8.39	9.54
1992	8.12	10.66	69.47	78	13.89	37.42	48*	0.15	4.53	5.45
1993	14.68	18.30	112.43	125	22.49	33.88	44*	0.14	3.72	4.66
1994	Closed	0.27	70.57	79	14.11	28.97	37*	0.11	2.64	3.46
1995	Closed	0.29	70.61	79	14.12	43.90	56	0.19	6.44	7.49
1996	8.51	9.11	72.75	81	14.55	50.86	65	0.22	8.73	9.98
1997	8.91	9.57	133.60	149	26.72	47.57	61	0.21	7.93	9.45
1998	14.95	19.38	166.23	186	33.25	44.94	58	0.19	7.05	8.87
1999	11.86	12.98	122.13	136	24.43	56.50	73	0.25	11.01	13.12
2000	8.24	9.36	114.20	127	22.84	72.01	92	0.33	17.06	19.19
2001	8.52	9.86	90.61	101	18.12	71.97	92	0.33	17.73	19.86
2002	9.67	10.89	129.85	145	25.97	67.82	87	0.31	16.38	18.62
2003	15.73	18.63	178.13	199	35.63	71.55	92	0.33	17.88	20.30
2004	15.45	16.84	177.25	198	35.45	67.46	87	0.31	15.43	17.90
2005	18.52	22.26	181.88	203	36.38	59.32	76	0.27	12.40	15.17
2006	15.75	17.22	157.19	175	31.44	65.54	84	0.30	14.43	17.78

* Overfishing [Fertilized egg production index (in terms of mature biomass) is below 50% MSY level.]

4.3.2 Sensitivity analysis of α and β

The mean 30th year MMB/MMB_{MSY} ratio and the mean next 20-yr mean yield increased as α and β values increased. The opposite was true for the mean first 10-yr mean yield. The stock exceeded MMB_{MSY} in the 30th year for all combinations of α and β values. For the (α, β) combination of (0.1, 0.25) the mean first 10-yr mean yield was higher, but the mean next 20-yr mean yield was lower than under the (α, β) combination of either (0.25, 0.25) or (0.5, 0.5). Higher (α, β) values tend to produce higher next 20-yr mean yields (i.e., medium term yield) and 30th year MMB/MMB_{MSY} ratio. Although the analysis did not provide the best (α, β) combination, nevertheless, based on the short-term higher mean retained yield and modest increase in the 30th year MMB/MMB_{MSY} ratio compared to either lower or higher values of (α, β), the (α,β) combination of (0.1, 0.25) as a default in the tier formulas was chosen for investigating different alternatives (Tables 4-2 and 4-3).

4.3.3 Evaluation of alternatives with short-term and long-term performance statistics

To evaluate the impacts of the alternatives on Bristol Bay red king crab, eleven harvest strategy scenarios were investigated to predict the changes in stock abundance levels under various harvest rates. For Alternative 1, two harvest control rules were simulated to predict the possible effects of this alternative on stock biomass; the status quo harvest strategy and fishing at the status quo OFL. For Alternative 2 and 3, an evaluation was made of Tiers 2 to 5. For analytical purposes, additional scenarios considered included a flat $F_{x\%}$, F = M, and F = 0. Performance statistics were estimated from short-term (30 years) and long-term (100 years) fishery simulations with stochastic recruitment, observation errors for biomass, and implementation errors for harvest. One thousand simulations were carried out with initial biomasses of 50% B_{MSY} and B_{MSY} to estimate the following performance statistics: median rebuilding time; mean number of recruits; total (retained+discard+trawl bycatch) yield; retained yield; mature male and female B; 30th year or 100th year B/B_{MSY} ratio; years overfished (percentage); and years of fishery closure (percentage); and mean and coefficient of variation of first 10-year and subsequent 20-year mean yields.

The performance statistic estimates for all Tiers were expressed relative to Tier 2 values, except for instances where 0 values were reported for Tier 2. In the latter case, exact values for all Tiers were provided. Tier 2 results were listed in absolute terms (Table 4-4 to Table 4-7).

The status quo harvest strategy was simulated following the harvest strategy in 5 AAC 34.816 (see section 4.3.1). The ESB was estimated using size-specific mating ratio (Zheng et al. 1995a). The abundances were estimated at the survey time using survey selectivity, and harvest rates were applied to molting mature male and legal male abundances at the time of the survey. Annual fishing mortality was approximated from harvest rates with an average fishing selectivity.

The Alternative 1 OFL harvest control rule for red king crab was simulated using the following formula:

Sustainable yield = 0.2* total survey mature biomass (male + female).

Table 4-4 lists the results of performance statistics for short-term (30 years) fishery simulations with initial MMB equal to 50% B_{MSY}. Eleven harvest strategy scenarios were investigated: Tier 2 with the F_{MSY}, Tier 3 with $F_{35\%}$ and $F_{40\%}$,Tier 4 with two times M, Tier 5 with mean catch (1985-2000 mean yield = 11.09 million pounds (5,031 t) during which the catch-per-unit-effort values were nearly constant), the status quo harvest strategy, the status quo OFL control rule, Flat F_{MSY} (i.e., no sliding fishing mortality for any level of MMB), F = M, and F = 0 harvest strategies.

Tier 2 and Tier 3 with $F_{35\%}$ control rule produced higher retained yield, lower mean rebuilding time, above MMB_{MSY} on the 30th year, as well as higher first 10-year and subsequent 20-year yields. The Tier 4 harvest strategy produced closer performance to Tier 2 with F_{MSY} and Tier 3 with $F_{35\%}$ control rules. Thus, for data poor red king crab stocks in Tier 4 with an M of 0.18, a γ value up to two is reasonable. The current State harvest strategy was satisfactory and the performance was in between Tier 3 with $F_{35\%}$ and $F_{40\%}$ (target fishing mortality candidate). Tier 5 performed worse than the status quo harvest strategy. The harvests at the status quo OFL control rule performed worst of all, with a very low mean number of recruits, higher overfished percent, and lower 30th year relative MMB. The stock rebuilt toward the end of the time horizon considered for the simulation for the status quo OFL control rule. Flat F_{MSY} and Flat $F_{35\%}$ performed worse than the sliding scale counterparts, not reaching B_{MSY} on the 30th year. Thus, a control rule that responds to changes in biomass on a sliding scale is a beneficial harvest strategy.

Table 4-5 provides the same performance statistics for the short-term (30 years) fishery when the initial MMB was set to B_{MSY}. The status quo OFL control rule resulted in the lowest mean recruitment and low 30th year relative MMB at this initial biomass level (i.e., stock depleted from the initial MSY level).

Table 4-6 and Table 4-7 list similar performance statistics as Table 4-4 and Table 4-5 respectively, but they were based on a long-term fishery (100 years). The status quo OFL control rule resulted in the lowest mean recruitment and very low 100th year relative MMB. Although mean retained yields tend to be higher under the status quo OFL control rule for the short-term fishery (Table 4-4 and Table 4-5), the retained yield dropped under the long-term fishery scenario (Table 4-6 and Table 4-7).

The F = 0 scenarios in Table 4-4 through Table 4-7 provide the non-fishery yields, which are mainly trawl bycatch yields under varying biomass levels. The rebuilding time and terminal relative MMB under other tiers can be compared with the virgin level estimates. In particular, the OFL harvest control rules produced much lower final year relative MMB than that obtained at the virgin level.

Additional evaluations of Bristol Bay red king crab simulations were done in order to examine the applicability of the Tier 5 formulation for a well studied stock. The applicability of average catch as an OFL control rule using the well studied Bristol Bay red king crab stock was investigated. The OFL was set as the mean fishery yield from 1985-2000 of 11.09 million pounds (5,030 t) and 75% of mean catch was set as the target. Then, the same performance statistics under stochastic simulations (Table 4-4 through Table 4-7) were calculated. As expected the mean retained yields were lower compared to Tier 2 estimates, but the short-term and the long-term final year biomasses were higher than the Tier 2 control rule estimates, except the short-term scenario with initial biomass set at $50\%MMB_{MSY}$. Thus, in the absence of stock assessment, setting OFL as the mean yield estimated from a carefully chosen time period could be beneficial to data poor stocks.

4.3.4 Six-year projections of stock biomass under alternative control rules

Short-term (6-year) projections of current stock biomass under six control rules were run to look at impacts on retained catch and MMB estimates of fishing under the Alternative 2 and 3 proposed control rules ($F_{40\%}$ and $F_{35\%}$) compared to the unconstrained status quo harvest strategy, the status quo harvest strategy control rule constrained by $F_{35\%}$, and fishing at the status quo OFL control rule (Table 4-8). Starting at the estimated abundance in 2006 and with estimated parameters, short-term projections using the status quo harvest strategy, fishing at the status quo OFL control rule, $F_{40\%}$, and $F_{35\%}$ harvest control rules for 2007 to 2012 were made for Bristol Bay red king crab. The 2006 catch was set according to the status quo harvest strategy for all scenarios. Recruitment was projected by a Ricker S-R curve with estimated *h*. Lognormal random errors were added to recruits and biomass. Mean values from 1000 simulations were estimated with 95% confidence interval for retained catch. The status quo harvest control rule was constrained by the $F_{35\%}$ control rule. Because of the $F_{35\%}$ control rule constrains, the status quo projected mean retained yields were, in general, lower than those for $F_{35\%}$ control rule, but the confidence intervals overlapped to a great extent. As expected, the projected mean retained yields from $F_{40\%}$ control rule were lower than those under $F_{35\%}$ control rule. The mean MMB was projected above $MMB_{35\%}$ during 2009 to 2012 for $F_{40\%}$ and status quo control rules. Fishing at the status quo OFL control rule resulted in much higher mean retained yields, and lower MMB on February 15 than those by the status quo harvest strategy, $F_{40\%}$, and $F_{35\%}$ harvest control rules.

Table 4-2 Sensitivity analysis of α and β under Tier 3 control rule with F_{35} for red king crab. Mean and median were estimated from 1000 simulations of a 30-year fishery with an initial mature male biomass of 10% MMB_{MSY} with biomass observation error and harvest implementation error. All estimates are given as proportions relative to column 2 values. CV = coefficient of variation.

Harvest Control Rule Parameters: α, β	0.0, 0.0	0.0, 0.25	0.05, 0.25	0.1, 0.25	0.25, 0.25	0.0, 0.5	0.1, 0.5	0.5, 0.5
Rebuilding time (y)[a]	24	0.92	0.92	0.92	0.88	0.88	0.88	0.83
Years overfished (%)[b]	54.25	0.93	0.92	0.90	0.86	0.84	0.83	0.80
Years MMB<25%MMB_{MSY} [c]	28.75	0.92	0.92	0.92	0.91	0.90	0.90	0.90
30th year biomass ratio (%)[d]	108	1.03	1.05	1.06	1.11	1.14	1.15	1.23
First 10-yr mean retained yield (t)	558	0.85	0.82	0.79	0.66	0.59	0.58	0.46
CV first 10-yr mean retained yield	2.23	1.32	1.36	1.41	1.64	1.86	1.91	2.32
Next 20-yr mean retained yield (t)	5337	1.12	1.12	1.13	1.15	1.22	1.22	1.21
CV next 20-yr mean retained yield	0.64	0.94	0.95	0.95	0.98	0.95	0.97	1.08

[a]Median number of years taken for MMB to reach MSY level MMB for the first time
[b]Mean percent of years in a 30-year fishery the MMB < 50% MSY level MMB
[c]Mean percent of years in a 30-year fishery the MMB < 25% MSY level MMB
[d]Mean percent of 30th year MMB relative to MSY level MMB

Table 4-3 Sensitivity analysis of α and β under Tier 3 control rule with F_{35} for red king crab. Mean and median were estimated from 1000 simulations of a 30-year fishery with an initial mature male biomass of 50% MMB_{MSY} with biomass observation error and harvest implementation error. All estimates are given as proportions relative to column 2 values. CV = coefficient of variation.

Harvest Control Rule Parameters: α, β	0.0, 0.0	0.0, 0.25	0.05, 0.25	0.1, 0.25	0.25, 0.25	0.0, 0.5	0.1, 0.5	0.5, 0.5
Rebuilding time (y)[a]	11	0.91	0.91	0.91	0.91	0.91	0.91	0.82
Years overfished (%)[b]	17.07	0.98	0.95	0.91	0.75	0.70	0.68	0.52
Years MMB<25%MMB_{MSY} [c]	0.99	0.90	0.90	0.80	0.60	0.60	0.60	0.50
30th year biomass ratio (%)[d]	113	1.00	1.01	1.02	1.04	1.04	1.05	1.11
First 10-yr mean retained yield (t)	3879	1.00	0.99	0.97	0.93	0.94	0.93	0.82
CV first 10-yr mean retained yield	0.95	1.00	1.03	1.05	1.18	1.25	1.28	1.53
Next 20-yr mean retained yield (t)	8410	1.01	1.02	1.03	1.09	1.17	1.17	1.24
CV next 20-yr mean retained yield	0.49	1.00	1.00	1.00	1.02	1.04	1.06	1.06

[a]Median number of years taken for MMB to reach MSY level MMB for the first time
[b]Mean percent of years in a 30-year fishery the MMB < 50% MSY level MMB
[c]Mean percent of years in a 30-year fishery the MMB < 25% MSY level MMB
[d]Mean percent of 30th year MMB relative to MSY level MMB

Table 4-4 Short-term rebuilding simulations under various control rules for Bristol Bay red king crab. Mean and median were estimated from 1000 simulations of a 30-year fishery with an initial mature male biomass of 50%B_{MSY} with biomass observation error and harvest implementation error. All estimates are given as proportions relative to column 2 values. B = total mature male biomass, B_{MSY} = total MSY mature male biomass, and CV = coefficient of variation.

Harvest Control Rule (CR)	Tier 2 Limit (F_{MSY} CR)	Tier 3 Limit ($F_{35\%}$ CR)	Tier 3 ($F_{40\%}$ CR)	Tier 4 (F=2*M CR)	Tier 5 Limit (Mean Catch)	Status quo Harvest CR	OFL CR	Flat F_{MSY}	Flat $F_{35\%}$	F=M CR	F=0
Mean recruit no. (millions)	24.64	1.01	1.02	1.01	0.84	1.00	0.74	0.91	0.93	1.02	0.93
Mean total yield (t)	8500	0.97	0.88	0.96	0.75	0.91	1.07	0.92	0.90	0.70	0.08
Mean retained yield (t)	7237	0.97	0.88	0.96	0.69	0.90	1.03	0.89	0.88	0.69	0.00
Mean mature male biomass (t)	31317	1.06	1.15	1.04	0.80	1.04	0.54	0.79	0.84	1.32	1.95
Mean mature female biomass (t)	38316	1.01	1.02	1.01	0.90	0.99	0.84	0.94	0.95	1.03	1.02
Mean F	0.28	0.93	0.75	0.93	1.93	0.89	2.86	1.43	1.29	0.50	0.00
Rebuilding time (y)[a]	11	0.91	0.91	0.91	1.45	1.00	2.18	1.36	1.27	0.82	0.73
Years B< B_{MSY} (%)[b]	69.91	0.95	0.87	0.96	1.13	0.95	1.30	1.16	1.12	0.74	0.45
Years overfished (%)[c]	18.42	0.84	0.67	0.90	2.41	1.04	3.42	2.05	1.84	0.49	0.29
Years fishery closed (%)[d]	1.00	0.80	0.70	0.90	4.30	1.40	29.30	6.60	5.10	0.50	0.40
30th year biomass ratio (%)[e]	108	1.06	1.18	1.05	0.86	1.14	0.41	0.76	0.82	1.39	2.15
First 10-yr mean retained yield (t)	4117	0.92	0.78	0.93	1.25	1.09	1.69	1.25	1.18	0.56	0.00
CV first 10-yr mean retained yield	0.95	1.05	1.06	1.01	0.12	0.91	0.62	0.62	0.63	1.03	0.00
Next 20-yr mean retained yield (t)	8797	0.99	0.91	0.97	0.56	0.86	0.88	0.81	0.81	0.72	0.00
CV next 20-yr mean retained yield	0.49	1.00	0.96	0.98	0.29	1.02	1.37	0.96	0.94	0.88	0.00

[a]Median number of years taken for mature male biomass to reach MSY mature male biomass for the first time
[b]Mean percent of years in a 30-year fishery the mature male biomass < MSY mature male biomass
[c]Mean percent of years in a 30-year fishery the mature male biomass < 50% MSY mature male biomass
[d]Mean percent of years in a 30-year fishery the mature male biomass < 25% MSY mature male biomass
[e]Mean percent of 30th year mature male biomass relative to MSY mature male biomass

Table 4-5 Short-term rebuilding simulations under various control rules for Bristol Bay red king crab. Mean and median were estimated from 1000 simulations of a 30-year fishery with an initial mature male biomass of B_{MSY} with biomass observation error and harvest implementation error. All estimates are given as proportions relative to column 2 values. B = total mature male biomass, B_{MSY} = total MSY mature male biomass, and CV = coefficient of variation.

Harvest Control Rule (CR)	Tier 2 Limit (F_{MSY} CR)	Tier 3 Limit ($F_{35\%}$ CR)	Tier 3 ($F_{40\%}$ CR)	Tier 4 (F=2*M CR)	Tier 5 Limit (Mean Catch)	Status quo Harvest CR	OFL CR	Flat F_{MSY}	Flat $F_{35\%}$	F=M CR	F=0
Mean recruit no. (millions)	25.52	1.01	1.01	1.00	0.97	1.01	0.77	0.95	0.97	1.01	0.89
Mean total yield (t)	10223	0.96	0.87	0.96	0.62	0.94	1.20	0.99	0.96	0.69	0.07
Mean retained yield (t)	8674	0.96	0.87	0.96	0.59	0.95	1.17	0.98	0.95	0.68	0.00
Mean mature male biomass (t)	35070	1.05	1.15	1.04	1.24	1.11	0.59	0.89	0.93	1.33	2.00
Mean mature female biomass (t)	45187	1.01	1.01	1.00	1.00	1.00	0.87	0.98	0.99	1.02	1.00
Mean F	0.32	0.91	0.75	0.91	0.72	0.81	2.69	1.25	1.13	0.50	0.00
Years B< B_{MSY} (%)[a]	60.40	0.93	0.81	0.95	0.75	0.85	1.40	1.12	1.07	0.62	0.22
Years overfished (%)[b]	12.11	0.80	0.56	0.86	0.89	0.73	4.28	1.88	1.64	0.30	0.07
Years fishery closed (%)[c]	0.48	0.60	0.40	0.80	0.40	0.80	50.21	5.80	4.20	0.20	0.20
30th year biomass ratio (%)[d]	108	1.06	1.17	1.05	1.26	1.13	0.42	0.91	0.92	1.38	2.04
First 10-yr mean retained yield (t)	8371	0.92	0.79	0.93	0.61	0.94	1.59	1.09	1.02	0.56	0.00
CV first 10-yr mean retained yield	0.51	1.06	1.10	1.02	0.16	1.27	0.67	0.86	0.88	1.10	0.00
Next 20-yr mean retained yield (t)	8825	0.98	0.91	0.97	0.58	0.95	0.97	0.93	0.92	0.74	0.00
CV next 20-yr mean retained yield	0.49	1.00	0.94	0.98	0.12	0.96	1.33	0.90	0.88	0.88	0.00

[a]Mean percent of years in a 30-year fishery the mature male biomass < MSY mature male biomass
[b]Mean percent of years in a 30-year fishery the mature male biomass < 50% MSY mature male biomass
[c]Mean percent of years in a 30-year fishery the mature male biomass < 25% MSY mature male biomass
[d]Mean percent of 30th year mature male biomass relative to MSY mature male biomass

Table 4-6 Long-term rebuilding simulations under various control rules for Bristol Bay red king crab. Mean and median were estimated from 1000 simulations of a 100-year fishery with an initial mature male biomass of 50% B_{MSY} with biomass observation error and harvest implementation error. All estimates are given as proportions relative to column 2 values. B = total mature male biomass, BMSY = total MSY mature male biomass, and CV = coefficient of variation.

Harvest Control Rule (CR)	Tier 2 Limit (F_{MSY} CR)	Tier 3 Limit ($F_{35\%}$ CR)	Tier 3 ($F_{40\%}$ CR)	Tier 4 (F=2*M CR)	Tier 5 Limit (Mean Catch)	Status quo Harvest Strategy	OFL CR	Flat F_{MSY}	Flat $F_{35\%}$	F=M CR	F=0
Mean recruit no. (millions)	25.02	1.01	1.02	1.01	0.86	1.01	0.62	0.90	0.92	1.01	0.90
Mean total yield (t)	9586	0.98	0.90	0.97	0.64	0.94	0.79	0.86	0.86	0.73	0.07
Mean retained yield (t)	8215	0.98	0.90	0.97	0.60	0.94	0.76	0.83	0.84	0.72	0.00
Mean mature male biomass (t)	33407	1.06	1.17	1.05	0.95	1.12	0.41	0.76	0.83	1.37	2.09
Mean mature female biomass (t)	40399	1.01	1.03	1.01	0.86	1.01	0.63	0.90	0.92	1.03	0.95
Mean F	0.30	0.90	0.73	0.90	1.47	0.83	2.70	1.33	1.20	0.53	0.00
Rebuilding time (y)[a]	11	0.91	0.91	0.91	1.45	1.00	2.18	1.27	1.18	0.82	0.73
Years B<B_{MSY} (%)[b]	65.06	0.93	0.83	0.95	1.02	0.86	1.43	1.21	1.15	0.64	0.25
Years overfished (%)[c]	16.08	0.81	0.60	0.87	2.23	0.79	4.58	2.40	2.07	0.35	0.14
Years fishery closed (%)[d]	0.68	0.71	0.43	0.86	7.00	0.86	65.15	11.00	7.71	0.29	0.29
100th year biomass ratio (%)[e]	105	1.07	1.18	1.06	1.11	1.14	0.33	0.93	0.95	1.40	2.15

[a]Median number of years taken for mature male biomass to reach MSY mature male biomass for the first time
[b]Mean percent of years in a 100-year fishery the mature male biomass < MSY mature male biomass
[c]Mean percent of years in a 100-year fishery the mature male biomass < 50% MSY mature male biomass
[d]Mean percent of years in a 100-year fishery the mature male biomass < 25% MSY mature male biomass
[e]Mean percent of 100th year mature male biomass relative to MSY mature male biomass

Table 4-7 Long-term rebuilding simulations under various control rules for Bristol Bay red king crab. Mean and median were estimated from 1000 simulations of a 100-year fishery with an initial mature male biomass of B_{MSY} with biomass observation error and harvest implementation error. All estimates are given as proportions relative to column 2 values. B = total mature male biomass, B_{MSY} = total MSY mature male biomass, and CV = coefficient of variation.

Harvest Control Rule (CR)	Tier 2 Limit (F_{MSY} CR)	Tier 3 Limit ($F_{35\%}$ CR)	Tier 3 ($F_{40\%}$ CR)	Tier 4 (F=2*M CR)	Tier 5 Limit (Mean Catch)	Status quo Harvest Strategy	OFL CR	Flat F_{MSY}	Flat $F_{35\%}$	F=M CR	F=0
Mean recruit no. (millions)	25.27	1.01	1.02	1.00	0.93	1.01	0.63	0.91	0.93	1.01	0.89
Mean total yield (t)	10092	0.97	0.89	0.97	0.61	0.95	0.84	0.89	0.88	0.72	0.07
Mean retained yield (t)	8639	0.98	0.89	0.97	0.58	0.95	0.82	0.87	0.86	0.72	0.00
Mean mature male biomass (t)	34498	1.06	1.17	1.05	1.20	1.14	0.43	0.80	0.86	1.37	2.10
Mean mature female biomass (t)	42389	1.01	1.02	1.01	0.96	1.01	0.66	0.92	0.94	1.03	0.95
Mean F	0.31	0.90	0.74	0.90	0.94	0.81	2.68	1.29	1.16	0.52	0.00
Years B<B_{MSY} (%)[a]	62.20	0.93	0.81	0.95	0.80	0.83	1.46	1.20	1.14	0.61	0.18
Years overfished (%)[b]	14.21	0.80	0.56	0.86	1.27	0.68	4.96	2.38	2.03	0.28	0.06
Years fishery closed (%)[c]	0.55	0.67	0.33	0.67	3.00	0.50	77.45	10.67	7.33	0.17	0.17
100th year biomass ratio (%)[d]	105	1.07	1.18	1.06	1.15	1.14	0.33	0.94	0.95	1.40	2.15

[a]Mean percent of years in a 100-year fishery the mature male biomass < MSY mature male biomass
[b]Mean percent of years in a 100-year fishery the mature male biomass < 50% MSY mature male biomass
[c]Mean percent of years in a 100-year fishery the mature male biomass < 25% MSY mature male biomass
[d]Mean percent of 100th year mature male biomass relative to MSY mature male biomass

Table 4-8 Retained catch, total catch, and mature male biomass (MMB) projections for six years from 2007 to 2012 using $F_{35\%}$, $F_{40\%}$, status quo harvest strategy, and OFL control rules (CR) for Bristol Bay red king crab. The 2006 catch was set according to status quo control rules for all scenarios. All estimates are mean values from 1000 simulations under the stochastic Ricker S-R curve. The status quo harvest strategy estimates were provided for unconstrained and $F_{35\%}$ control rule constrained scenarios. The 95% confidence limits of retained catches are given in parentheses. All values are in 1000t.

Year	Status quo Harvest CR Retained Catch	Total Catch	Feb 15 MMB	$F_{35\%}$ CR Retained Catch	Total Catch	Feb 15 MMB	$F_{40\%}$ CR Retained Catch	Total Catch	Feb 15 MMB	Status quo Harvest Strategy CR Constrained by $F_{35\%}$	Total Catch	Feb 15 MMB	Status quo OFL CR	Total Catch	Feb 15 MMB
2006	7.04	8.76	33.62	7.04	8.76	33.62	7.04	8.76	33.62	7.04	8.76	33.62	7.04	8.76	33.62
2007	8.03 (8.02, 8.04)	10.10 (10.03, 10.39)	37.90	8.11 (6.27, 8.40)	10.20	37.82	6.63 (5.09, 6.88)	8.42	39.33	7.97 (7.10, 8.03)	10.02	37.94	15.42 (15.42, 15.43)	19.15	30.12
2008	10.39 (10.22, 11.19)	13.09 (12.63, 14.78)	48.50	9.46 (8.04, 10.07)	11.97	49.40	8.07 (6.83, 8.51)	10.22	52.35	9.61 (9.59, 9.80)	12.13	49.39	14.02 (14.01, 14.06)	18.27	36.90
2009	11.81 (10.62, 16.56)	14.35 (12.52, 21.93)	57.46	12.21 (11.89, 13.35)	14.77	57.90	10.62 (10.37, 11.55)	12.85	62.34	11.53 (10.76, 13.11)	13.98	58.60	16.63 (16.21, 18.54)	20.75	40.58
2010	11.54 (8.85, 20.02)	13.61 (10.11, 25.78)	60.41	14.43 (12.70, 23.26)	16.83	57.87	12.77 (11.33, 20.10)	14.89	63.65	11.52 (9.14, 18.91)	13.56	61.49	18.34 (15.63, 31.15)	21.98	36.75
2011	10.07 (6.86, 20.33)	11.63 (7.74, 24.58)	54.04	13.76 (10.78, 27.21)	15.71	48.04	12.51 (9.99, 23.87)	14.25	54.41	10.19 (7.01, 20.40)	11.75	54.86	15.65 (11.10, 36.59)	18.53	27.23
2012	9.83 (5.03, 27.44)	11.44 (5.69, 32.99)	57.07	13.22 (7.74, 38.43)	15.26	47.99	12.33 (7.58, 35.63)	14.16	54.83	9.94 (5.14, 27.50)	11.56	57.71	14.14 (6.45, 52.04)	17.23	26.88

4.4 Effects on other red king crab stocks

The Pribilof Islands and Norton Sound are preliminarily placed into Tier 4 for purposes of this analysis. A default γ value based on the simulation study of Bristol Bay red king crab was set to 2.0 for these Tier 4 stocks. The γ value is frameworked and will be derived each year based the *M* value and estimated F_{OFL} for Bristol Bay red king crab. Dutch Harbor and Adak red king crab stocks are placed into Tier 5 under both Alternative 2 and 3.

<u>Pribilof District red king crab</u>

There is no formal harvest strategy in State regulations for Pribilof Island red king crab, but this stock has been very conservatively managed due to concern of blue king crab bycatch. The Alternative 1 status determination criteria for Pribilof Island red king crab establishes a B_{MSY} value of 6.6 million pounds (2,944 t) with an MSST of 3.3 million pounds (1,497 t) (Figure 4-6). The 2006 survey abundance estimate is above the B_{MSY} value at 19.0 million pounds (8,618 t). Under the Alternative 2 and 3 tier system, this stock would be managed under Tier 4 and B_{MSY} and MSST are provided based upon MMB. Additionally, the MFMT for determining overfishing is prescribed by the Tier 4 formula. Figure 4-6 and Table 3-1 provides estimated MMB and B_{MSY} proxy and MSST proxy (½ B_{MSY}) for the Pribilof Island red king crab stock. Average abundance from 1988 to 2006 was used for a proxy for this stock because model estimates of biomass were not available before 1988.

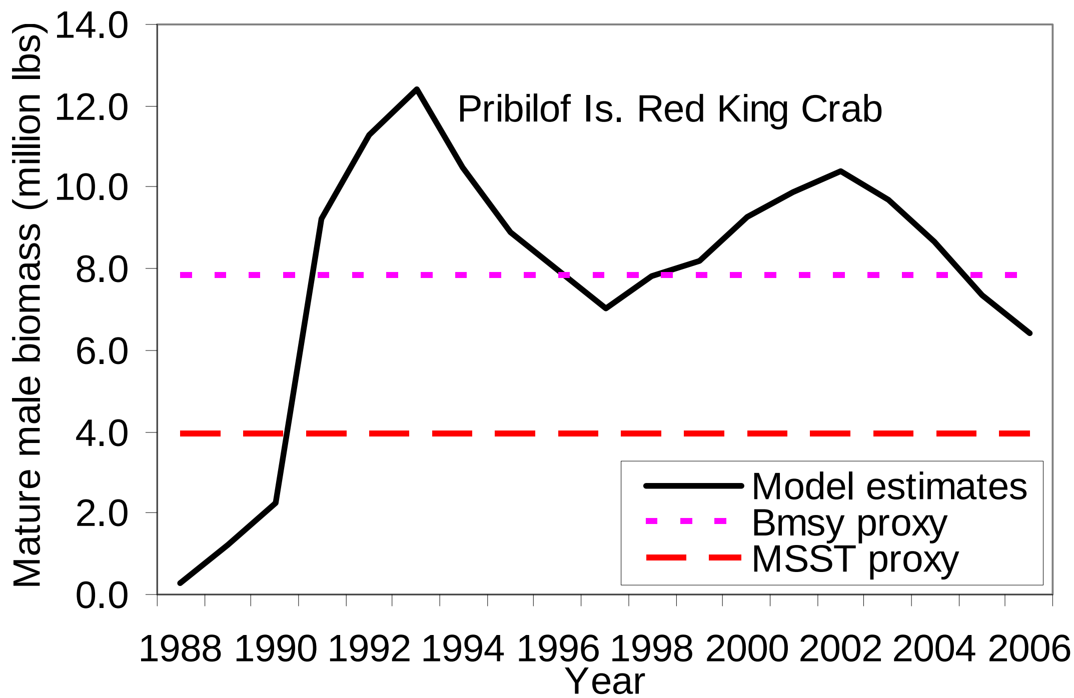

Figure 4-6 Pribilof Islands red king crab estimated mature male biomass compared to the B_{MSY} proxy and MSST proxy proposed under Alternatives 2 and 3.

Stock status for this stock under Alternatives 2 and 3, as shown in Figure 4-6, results in a different status determination than under the status quo (Alternative 1) determination. Under Alternative 1, as shown in Figure 4-2, the TMB is well above the B_{MSY} for this stock. In contrast, Figure 4-6 for Alternatives 2 and 3 indicate that this stock would be considered well below B_{MSY} proxy. The stock would still be above its

MSST proxy and thus is not considered overfished. However, under all alternatives, the stock would remain closed to directed fishing thus overfishing is not occurring on this stock.

Catch and CPUE for Pribilof Islands red king crab are provided in Figure 4-7. As discussed previously, due to conservation concerns on blue king crab, Pribilof Islands red king crab had been opened to fishing only for six years, and four of these six years were for a two-species fishery (combined GHL for both blue king and red king crabs). Thus catch and CPUE data are not very informative for this stock.

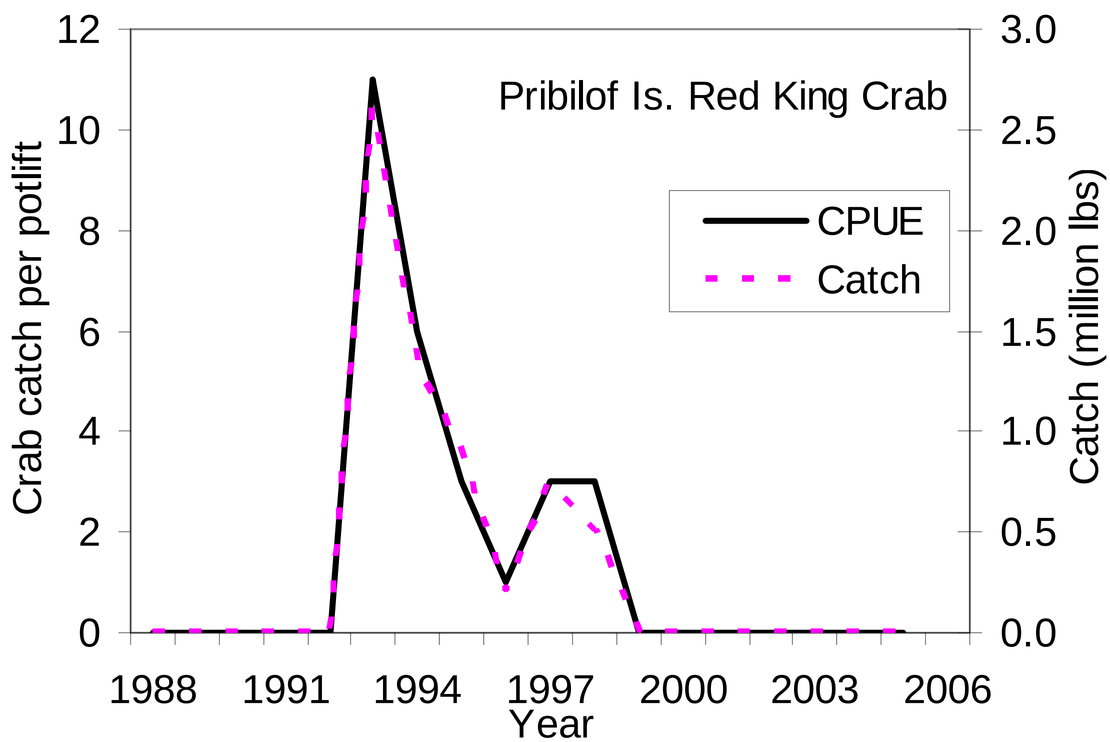

Figure 4-7 Catch and catch per potlift for Pribilof Islands red king crab.

The change in currency from the current total mature biomass to the proposed MMB does not affect the overfished definitions greatly for Pribilof Islands red king crab (Figure 4-8). After 1987, under the current definition, the stock was overfished in 1988 and 1990 whereas the stock would have been overfished in 1988, 1989 and 1990 under the proposed definition. The difference may mainly be due to survey measurement errors of total mature biomass, which was directly based on area-swept estimates. The MMB used for the Tier 4 OFL was derived from a catch-survey model. Another big difference between the current B_{MSY} and the Tier 4 B_{MSY} proxy is that the former was based on the biomass from 1983 to 1997 when the biomass was low, and the later was based on the biomass from 1988 to 2006, including all years with a high biomass. There may be a big difference between the current overfishing rates (F_{OFL}) and the proposed rate due to a change in the biological reference point for Pribilof Islands red king crab (Figure 4-8). The current F_{OFL} is applied to both mature male and female crabs whereas the Tier 4 F_{OFL} is for legal males only, and the default M for the proposed biological points is 0.18, as opposed to 0.2 used in the current definitions. For legal males, the proposed F_{OFL} is more conservative than the current overfishing rate. Overall, for this stock, the difference in F_{OFL} between the current and proposed definitions may mainly be due to a change in the biological reference point.

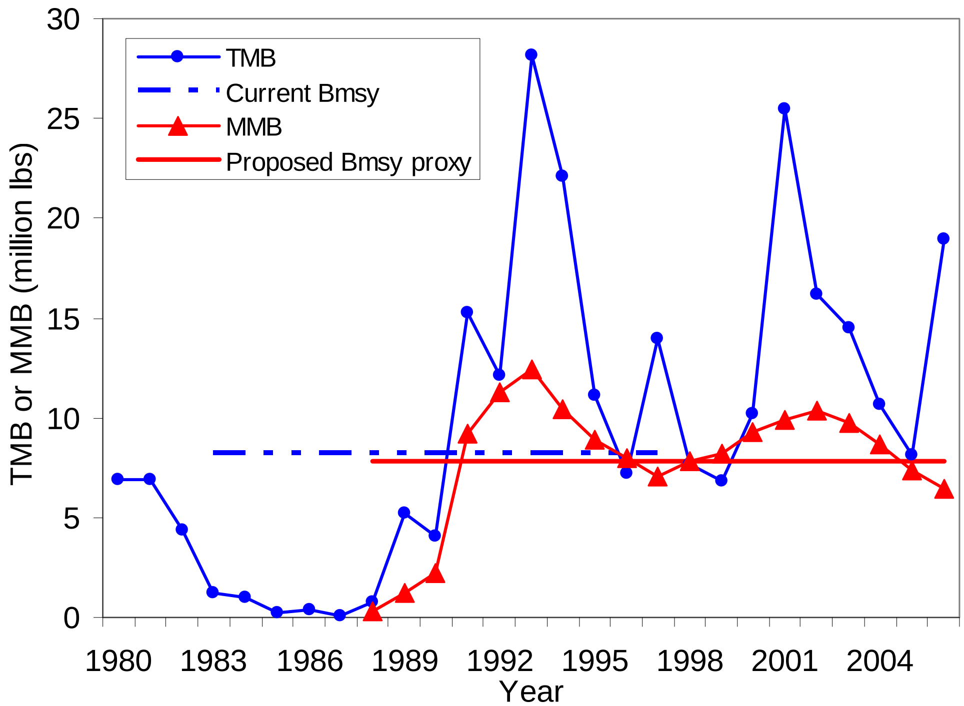

Figure 4-8 Comparison of total mature biomass and mature male biomass used for the current and proposed overfishing/overfished definitions for Pribilof Islands red king crab.

Other red king crab stocks

The other red king crab stocks include Norton Sound red king crab, Dutch Harbor (EAI) red king crab, and Adak (WAI) red king crab. Only Norton Sound red king crab supports a commercial fishery. Dutch Harbor and Adak red king crab stocks are currently closed to directed fishing due to depressed stock conditions.

For the remaining red king crab stocks, no status determination criteria were established under Alternative 1. Under Alternatives 2 and 3, Norton Sound red king crab stocks would be managed under Tier 4 while Adak (WAI) red king crab would be managed under Tier 5.

As a Tier 4 stock, both an OFL and an MSST would be determined for Norton Sound red king crab to allow managers to determine whether the stock was overfished or whether overfishing was occurring. Figure 4-9 provides estimated MMB (>93 mm CL) and B_{MSY} proxy and MSST proxy (1/2 B_{MSY}) for the Norton Sound red king crab stock. Model estimated MMB is well above the B_{MSY} proxy for this stock. The 2006 MMB estimate was 4.88, which is above the MSST of 0.81 million pounds. The current State of Alaska harvest strategy for Norton Sound red king crab has lower harvest rates than that resulted from $\gamma = 2.0$ and $M = 0.18$ when the stock abundance is above B_{MSY}. A triennial trawl survey is conducted on Norton Sound red king crab. A length-based model is used for stock assessments for Norton Sound red king crab. Catch and CPUE were extremely high during the late 1970s for this stock when the fishery just started. The CPUE after 1992 may not be comparable to those before 1993 due to changes in fishing vessels for Norton Sound red king crab (Figure 4-10).

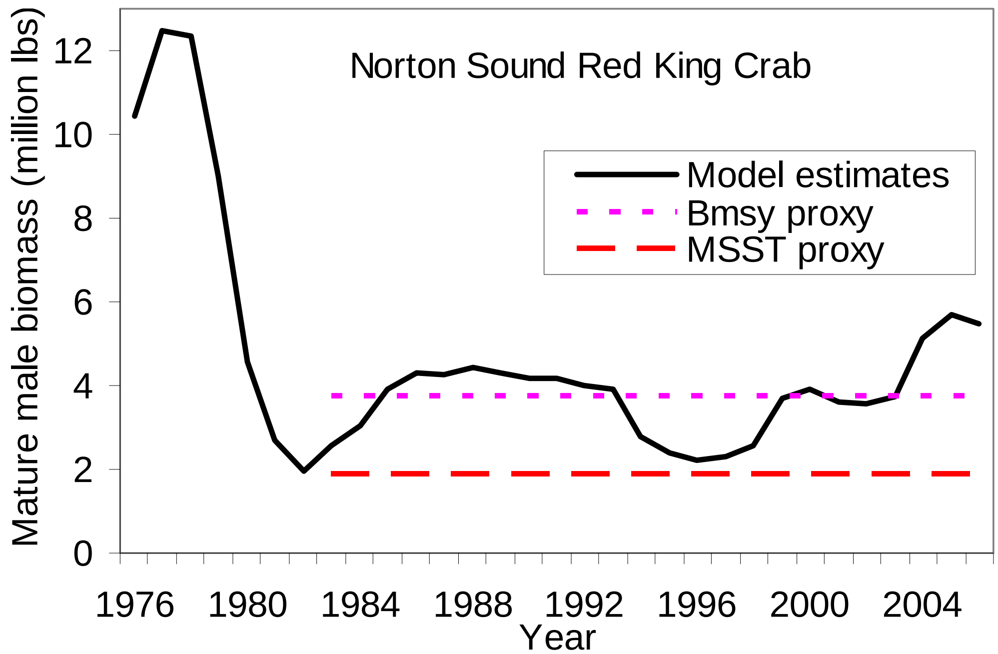

Figure 4-9 Norton Sound estimated mature male biomass compared to the B_{MSY} proxy and MSST proxy proposed under Alternatives 2 and 3.

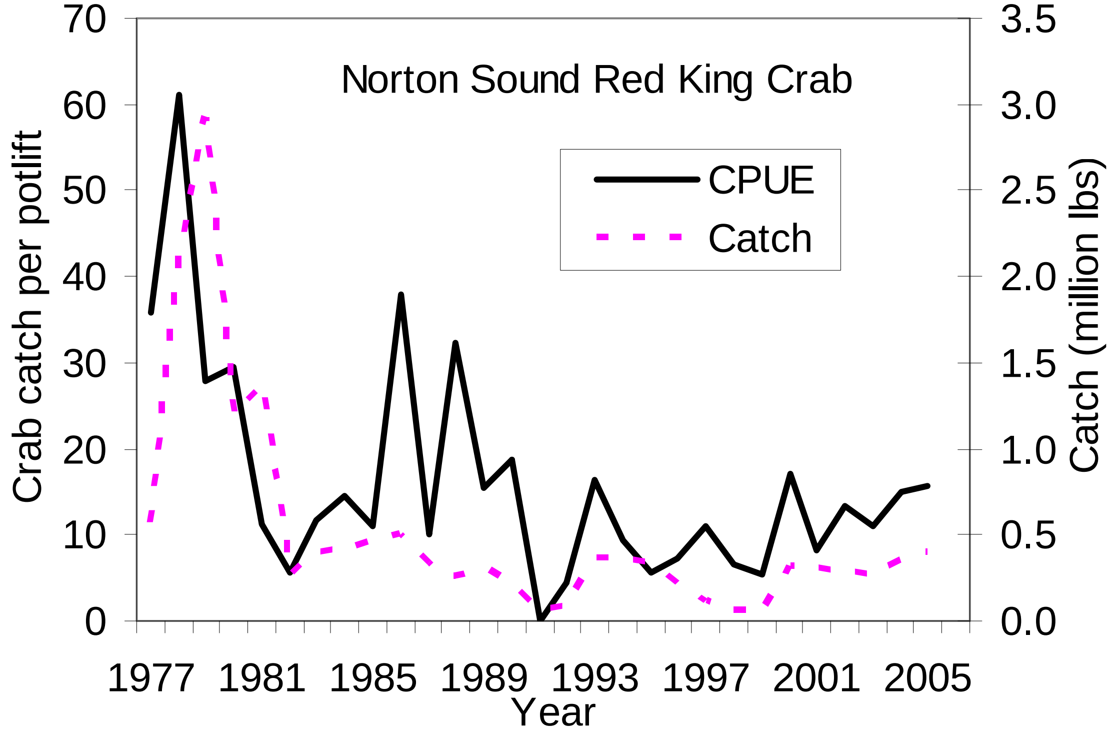

Figure 4-10 Catch and catch per pot lift for Norton Sound red king crab.

The Dutch Harbor red king crab stock has been extremely depressed during the last two decades, and the fishery has been closed since 1983. Surveys have been conducted in State waters on Dutch Harbor red king crab for most years. This stock was historically surveyed with pot gear. Beginning in the 1990s, ADF&G converted to trawl gear for surveys. These surveys were conducted on a triennial basis until 2003 when surveys have been annually conducted. Current trawl survey catches are too small to generate population indices. No models have been developed for Dutch Harbor red king crab. The new overfishing definitions would have no impact on this stock in the near future because no fishery is predicted.

Under Option A, the Dutch Harbor red king crab stock would be removed from the FMP and this stock and any potential future fishery would be exclusively managed by the State. The State conducts a survey for this stock in state waters. The effects of removing this stock from the FMP would be negligible because this action would not change its management.

Adak red king crab is preliminarily placed in Tier 5 for purposes of this analysis. No stock assessment model has been developed for this stock. The Adak red king crab stock is depressed. This stock has only been opened to fish in the very small Petrel Bank area for four years during the last 10 years. The historic average yield has been high, with the highest annual catch of 21 million pounds in 1964. However, the average yield from 1985 to 1994 is only 947,900 pounds (430 t). The years from 1995 to 2005 were excluded for Adak red king crab because the fishery was closed, fishing effort was less than 10% of the average, or fishing was allowed only in a small part of the fishing ground. The retained catch OFL would be set as 947,900 pounds (430 t), if average catch is chosen as the means to establish an OFL for this stock (Figure 4-11).

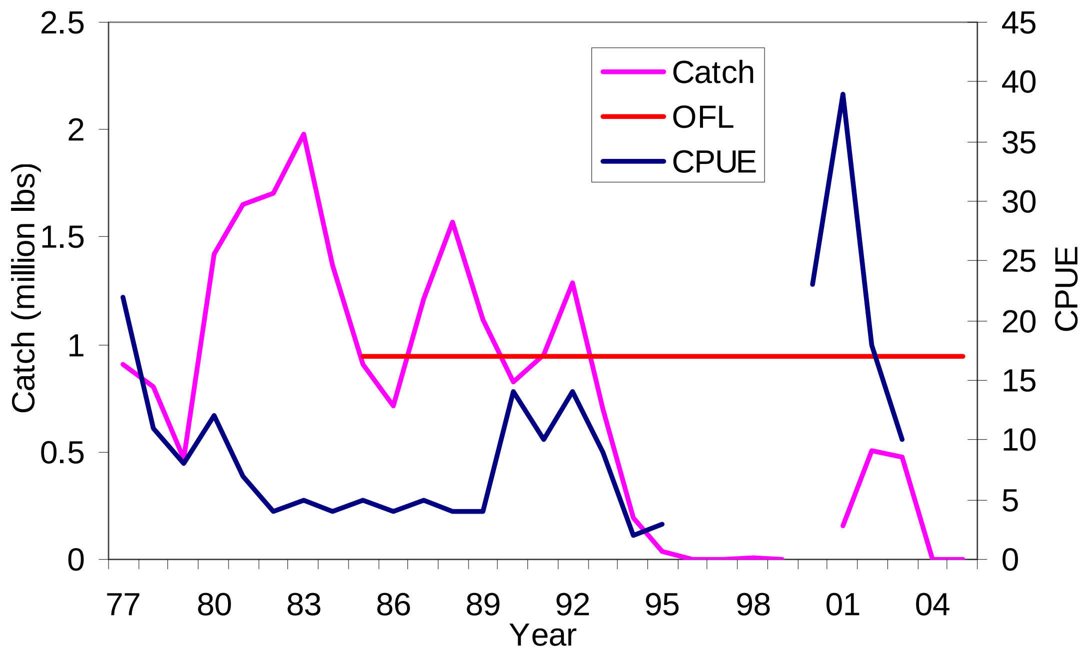

Figure 4-11 Adak red king crab historic catch compared to the suggested OFL under Alternatives 2 and 3.

5 Snow crab (*Chionoecetes opilio*)

One stock of snow crab is managed under this FMP. This Chapter reviews the stock status, biological parameters relevant to overfishing definitions for this stock, and provides an overview of specific impacts on the stock from the three alternatives under consideration in this analysis.

5.1 Snow crab stock status

This stock is annually surveyed by NMFS. The survey TMB estimate for this stock in 2006 was 547.6 million pounds (248,390 t), above MSST but slightly below the estimate for 2005 of 610.7 million pounds (277,012 t). This stock has been under a rebuilding plan since 2000, following the overfished determination in 1999. The 2006 estimated TMB remains below the rebuilt level of 921.6 million pounds (418,035 t) and maintains the trend in TMB of hovering about MSST for the last eight surveys without any apparent trend towards rebuilding (Figure 5-1). Since 1999, however, 2006 represents the first year that estimated TMB has been above MSST for 2 years in a row.

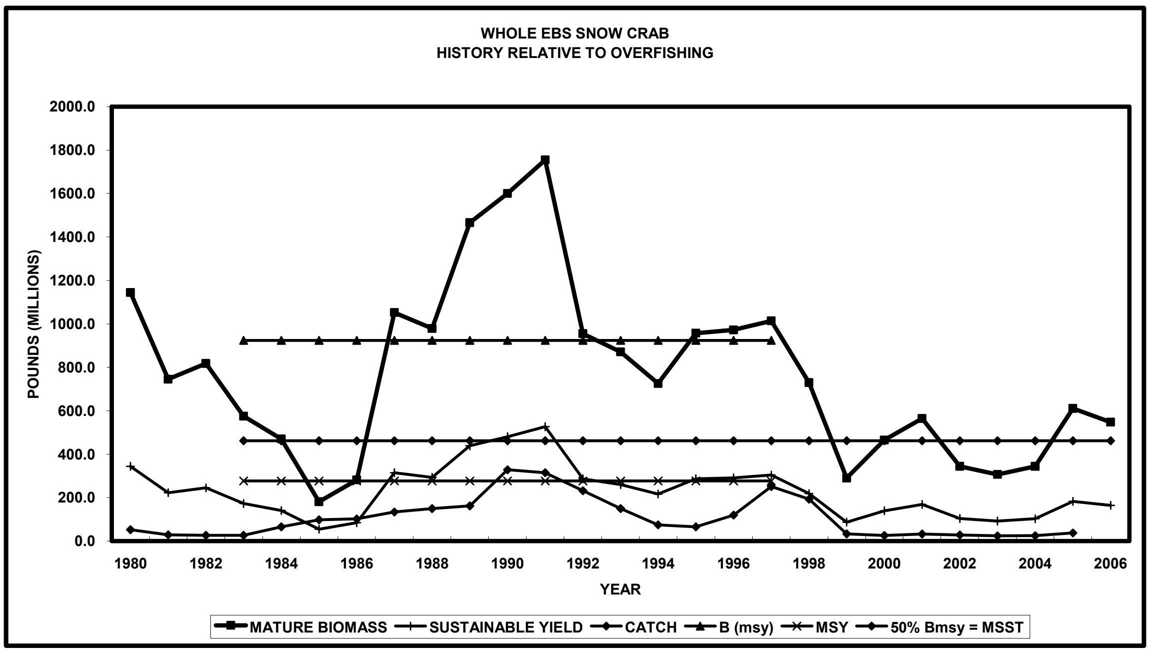

Figure 5-1 Snow crab stock status relative to overfishing.

The 2006 abundance estimates do not indicate a trend toward rebuilding (NPFMC 2006a). The 2006 area-swept abundance estimate for males ≥4-inches CW (143.89 million crabs) is by far the highest value since 1998 and twice the estimate for 2005 (72.1 million crabs). However, this area-swept estimate of abundance of males ≥4 inches in 2006 is associated with poor precision (±76.4% of the point estimate) and the doubling of abundance from 2005 is unexpected from the 2005 survey data. On the other hand, the 2006 snow crab model estimate for this value is 80.9 million crabs. The CPT supported the model biomass estimate over the area-swept abundance estimate from the survey due to the poor precision in the survey estimate.

The 2006 area-swept abundance estimate for males 78-101 mm CW (288.38 million crabs) is essentially the same as for 2005 (284.1 million crabs) and compares to annual estimates during 1999-2004 ranging from 106.2 million crabs (for 2004) to 287.7 million crabs (for 2001). Estimated abundance of males

<78-mm CW (1,106.91 million crabs) is lower than the 2005 estimate (1,911.2 million crabs); the 2006 estimate is greater than each of the annual estimates for 1997-2000, but is lower than four of the annual estimates for 2001-2005. The abundance estimate for females ≥50-mm CW in 2006 (1,045.53 million crabs) is 64% of the 2005 estimate and the abundance estimate for females <50-mm CW (669.77 million crabs) is 48% of the 2005 estimate. Since the 1999 survey, estimated abundance of females ≥50-mm CW has ranged from 510.5 million crabs (for 2002) to 1,630.8 million crabs (for 2005), whereas estimated abundance of females <50-mm CW has ranged from 180.5 million crabs (for 2002) to 1,869.2 million crabs (for 2004). Estimated mature female biomass in 2006 (214.7 million pounds or 97,387 t) is lower than in 2005 (313.1 million pounds or 142,021 t). Area-swept estimated mature male biomass in 2006 (332.9 million pounds or 151,002 t) is up slightly from the 2005 estimate (297.6 million pounds or 134,990 t), but more than half of that estimate (180.98 million pounds or 82,092 t) is attributable to males ≥4-inch CW. So, regardless of the increase in estimated abundance of males ≥4-inch CW, the 2006 standard survey area-swept estimates provide no strong evidence that the stock is currently or potentially rebuilding (NPFMC 2006a).

5.2 Effects on Snow Crab

5.2.1 Comparison of status determination criteria

Under Alternative 1, the snow crab stock was declared overfished in 1999 and has been under a rebuilding plan since then. The Alternative 1 status determination criteria for snow crab established a B_{MSY} value of 921.6 million pounds (418,035 t) of TMB, with an MSST value of 460.8 million pounds (209,018 t). The 2006 TMB estimate is 547.6 million pounds (248,390 t), above the MSST for this stock but below the B_{MSY} value. While the survey TMB under Alternative 1 estimates the stock above its MSST and hence no longer in an overfished condition, this stock remains under a rebuilding plan until the stock is above B_{MSY} for two consecutive years.

Under Alternative 1, the current F_{MSY} is 0.3 for snow crab. The OFL is the expected retained catch (SY) derived by multiplying F_{MSY} by the total survey mature biomass in the current year.

For snow crab the calculation is,

$$OFL = SY = 0.3 * TMB,$$

where SY is the retained catch (total catch less discards) and TMB = males plus females.

The snow crab TAC for the 2006/2007 fishery was 36.6 million pounds (16,602 t), which is below the 2006 SY of 164.5 million pounds (74,617 t).

In conjunction with the rebuilding plan, the harvest strategy for snow crab was modified in 2000 to allow for greater probability of rebuilding the depleted stock. The status quo harvest strategy uses fixed values of biomass reference points and harvest rates that will affect their performance depending on the estimated or true values of F_{MSY} and B_{MSY} or their proxy values. Under the status quo harvest strategy, the exploitation rate (E) is a function of TMB.

When TMB $\geq B_{MSY,}$ $E = (F_{MSY} * 0.75) = 0.225$. When TMB $< 0.25*B_{MSY}$ $E = 0$.

When the TMB is $\geq B_{MSY}$ and TMB $< 0.25*B_{MSY}$:

$$E = \frac{0.75 * Fmsy * \left[\frac{TMB}{Bmsy} - \alpha \right]}{(1-\alpha)}$$

where B_{MSY} is average survey total mature biomass from 1983 to 1997 (418,900 tons), α = -0.35, and F_{MSY}=0.3.

The maximum retained catch is determined by using the *E* determined from the control rule as an exploitation rate on MMB at the time of the survey,

- Retained Catch = *E*•MMB.

In addition to the control rule described above, there is a 58% maximum harvest rate on exploited legal male abundance. Exploited legal male abundance is defined as the estimated abundance of all new shell legal males >=4.0-in (102 mm) CW plus a percentage of the estimated abundance of old shell legal males >=4.0-in CW. The percentage to be used is determined using fishery selectivities for old shell males. For this analysis, a value of 25% was used.

Under Alternative 2 and 3, B_{MSY} for snow crab is measured in MMB only, as discussed in Section 2.4.1. This long-term B_{MSY} estimate for the stock is 354.7 million pounds (187,500 t) of MMB. An MSST value for this stock would be estimated as ½ B_{MSY} of 177.36 million pounds. The 2006 MMB estimate for 2006 is 211 million pounds (95,700 t). This is above the MSST value for this stock.

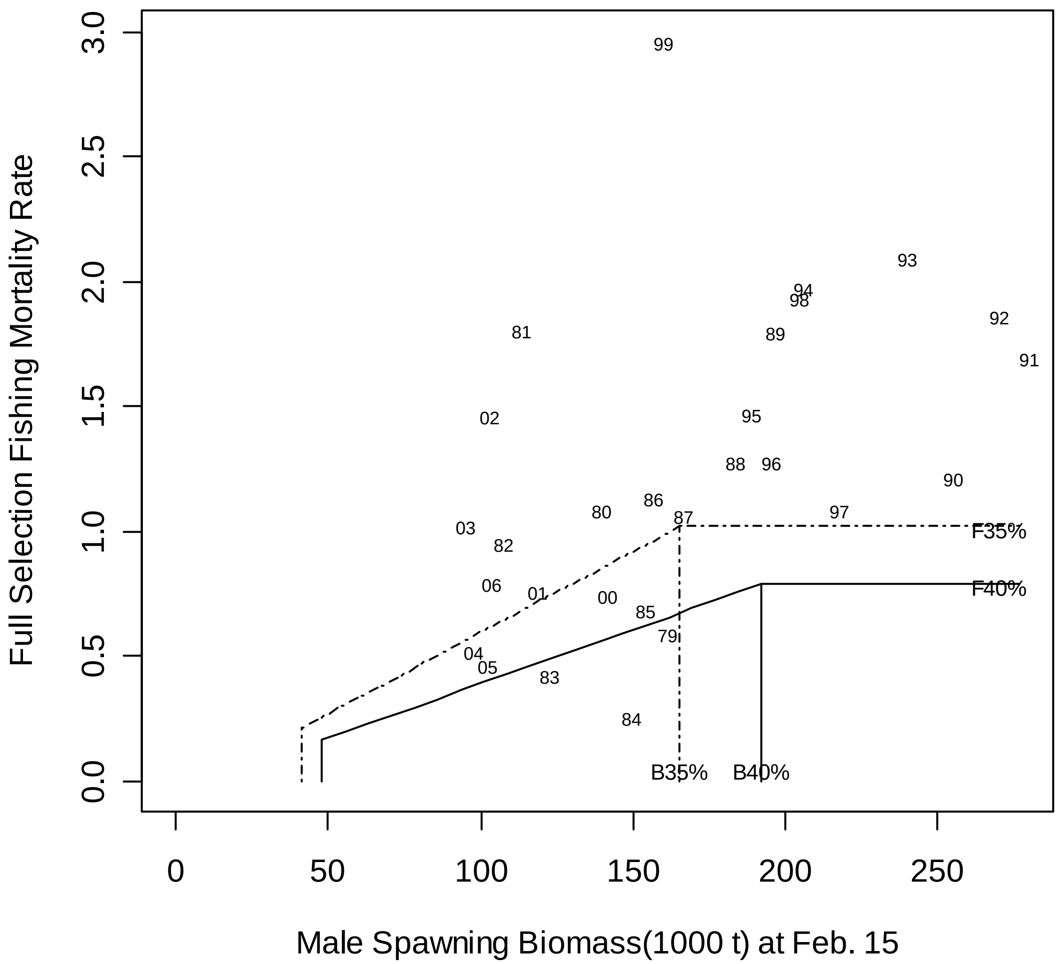

Figure 5-2 Full selection fishing mortality rate and male spawning biomass at February 15 estimated from the snow crab stock assessment model (Turnock and Rugolo 2006 Crab SAFE).

Under Alternatives 2 and 3, annual determination of overfishing would occur by comparing the estimated total catch from the previous year with the calculated OFL for the same time period. Overfishing is defined as any amount of catch in excess of the OFL as prescribed through the tier system described in Sections 2.2 and 2.3. Figure 5-2 shows the historical harvest rates and MMB in conjunction with proposed $F_{35\%}$ and $F_{40\%}$ control rules under Alternatives 2 and 3. The recommended control rule for the snow crab stock is $F_{35\%}$ (see following section for additional information and simulation studies).

Table 5-1 shows the observed catch, biomass values and OFL (catch and F) for Alternatives 1 and 2-3. Under Alternatives 2 and 3, with a recommended control rule of $F_{35\%}$, the observed catch exceeded the OFL (total catch) in the years 1981, 1986,1988-1994, 1998-1999, 2002-2003 and 2006 would have constituted overfishing for this stock. The retrospective application of the $F_{35\%}$ control rule to calculate OFL levels results in some years where the fishing mortality values indicate overfishing occurring when total catch does not due to a higher observed retained catch relative to the estimated total catch. Under Alternatives 2 and 3, harvest would have been constrained in the years where the observed total catch exceeded the retrospective OFL. However, if the $F_{35\%}$ control rule was in place historically, the actual catches and biomass values would have been different than estimated here. Harvest must be below the recommended OFL, thus annual determinations would be made to ensure that the TAC is set at a level whereby the harvest would be below the OFL for each stock.

Given that Alternatives 2 and 3 estimate new biological parameters for this stock, if either of these alternatives are adopted the rebuilding plan would need to be re-evaluated and potentially revised to reflect new information on the stock, including new estimates of stock recovery in relation to new estimates of B_{MSY}.

B_{MSY} under Alternative 1 is estimated as the average of the survey total mature biomass (males and females) from 1983 to 1997. MMB at the time of mating is used in the control rules for Alternatives 2 and 3. MMB per recruit at the time of mating is used with the average recruitment estimated from the stock assessment models to estimate $B_{35\%}$ and a proxy for B_{MSY}. The 2006 total survey mature biomass was 59% of the B_{MSY} for Alternative 1 (418,900 t). Under Alternatives 2 and 3, the 2006 MMB was 58% of $B_{35\%}$ (160,900 t). If MMB at the time of the fishery estimated from the snow crab stock assessment model were used with the status quo control rule (0.3 * biomass), the OFL in terms of retained catch averaged about 62% of the status quo OFL (0.3*TMB) (Table 5-1). MMB at the time of the fishery is used for the control rule because the values of MMB at Feb 15 have the observed catch removed and would not represent the OFL for that year. While the retained catch was not restricted in any year with the status quo OFL, the OFL using MMB at the time of the fishery was lower than the retained catch in 1990 to 1992 and 1997 to 1998. If MMB were used historically to set the OFL, a different time series of catches and biomass values may have occurred.

Table 5-1 Snow crab overfishing catch for 1981 (year of fishery) to 2006 for Alternatives 1 and 2-3. Alternative 2-3 uses the $F_{35\%}$ control rule. Total survey mature biomass (TMB 1000s tons) is the observed values. Mature male biomass (MMB) at February 15 and at the beginning of the fishery are estimated from the stock assessment model. Catch and OFL are in millions of lbs.

Fishery Year	Retained Catch	Total catch	Alternative 1			Alternative 2-3					
			TMB (Fishery year -1)	$\%B_{MSY}$	OFL Retained	MMB (Feb 15)	MMB at beginning of fishery	$\%B_{35}$	F_{OFL}	OFL Retained	OFL Total
1981	66.9	74.6	1,141.8	124	342.5	242.0	306.0	68	0.6	29.3	42.0
1982	29.3	36.3	743.6	81	223.1	229.9	257.0	65	0.57	25.5	40.5
1983	26.2	31.2	816.2	89	244.9	262.7	285.6	74	0.66	46.6	64.2
1984	26.8	29.7	574.2	62	172.3	322.3	346.1	91	0.84	72.4	89.1
1985	66.0	73.5	469.0	51	140.7	331.5	391.4	94	0.86	70.4	86.9
1986	97.9	112.2	181.1	20	54.3	337.5	425.3	95	0.88	73.0	93.9
1987	101.9	118.6	280.7	30	84.2	359.3	447.7	101	0.93	99.9	128.9
1988	135.3	154.2	1,049.4	114	314.8	397.5	513.7	112	0.93	117.7	146.5
1989	149.4	182.6	976.8	106	293.0	426.4	556.8	120	0.93	105.4	137.3
1990	161.9	206.4	1,463.0	159	438.9	553.7	689.9	156	0.93	144.5	191.0
1991	328.7	392.9	1,597.2	173	479.2	608.7	884.6	172	0.93	240.0	289.7
1992	315.3	364.8	1,751.2	190	525.4	587.2	858.7	166	0.93	212.5	249.9
1993	230.8	293.3	952.6	103	285.8	521.2	731.5	147	0.93	149.2	182.6
1994	149.8	169.2	869.0	94	260.7	445.9	577.5	126	0.93	100.5	130.7
1995	75.2	90.0	723.8	79	217.1	409.0	478.3	116	0.93	65.3	92.6
1996	65.8	86.7	954.8	104	286.4	422.2	481.6	119	0.93	58.5	88.9
1997	119.5	146.7	970.2	105	291.1	472.6	572.9	133	0.93	111.5	147.6
1998	252.1	273.2	1,012.0	110	303.6	443.3	651.9	125	0.93	158.0	187.9
1999	194.3	211.2	728.2	79	218.5	345.4	511.7	98	0.9	97.5	116.4
2000	33.2	35.2	289.5	31	86.9	304.9	334.2	86	0.79	39.2	54.8
2001	25.3	27.5	464.6	50	139.4	253.7	277.4	72	0.64	26.0	38.1
2002	32.8	39.6	563.2	61	169.0	219.6	251.2	62	0.54	14.5	22.7
2003	28.4	33.9	343.6	37	103.1	202.6	227.7	57	0.49	17.6	25.7
2004	23.8	25.7	306.7	33	92.0	208.1	228.4	59	0.5	24.9	32.8
2005	26.0	27.9	343.0	37	102.9	218.0	240.7	62	0.53	27.3	33.9
2006	37.0	42.0	609.4	66	182.8	220.0	254.1	62	0.54	23.5	29.9

5.2.2 Steepness parameter and $F_{x\%}$ estimate

MMB at February 15 and recruitment estimated from the snow crab stock assessment model were used to estimate the steepness parameters for Beverton Holt and Ricker curves (Figure 5-3). R0 for the Beverton and Holt curve and Rmax for the Ricker were fixed at 1.0 billion recruits (1/2 total recruits). Steepness for the Ricker curve was estimated at 3.4 (if defined as the fraction of R0 that occur at 20% B0). The steepness of the estimated Beverton and Holt curve was 0.467. A Beverton and Holt curve with steepness of 0.68 was used in the simulations as the midpoint between the range of estimated steepness. Recent recruitments (1989-2002 year classes) are mostly lower than recruitment in earlier years. These lower recruits may be an indication of lower productivity of the stock, which would indicate a lower steepness than the curve estimated from all the data. However, two recent recruitments are near the average level and may result in increases in the stock in the next few years (see 5 year projections).

Figure 5-4 shows the range of S-R models used to determined Fx% for different handling mortality values (0.25, 0.4, 0.5, 0.6), using Clark's method for a steepness (h) parameter range of 0.45–0.91 for the Beverton and Holt curve (h range of 0.52 to 3.83, for the same definition of steepness with the Ricker curve), which includes the range of steepness from estimated SR curves for snow crab. The Fx% value ranged from F38% to F39%. For comparison, the red king crab Fx% ranged from F33% to F35%. One proxy value for all crab species was chosen at F35%.

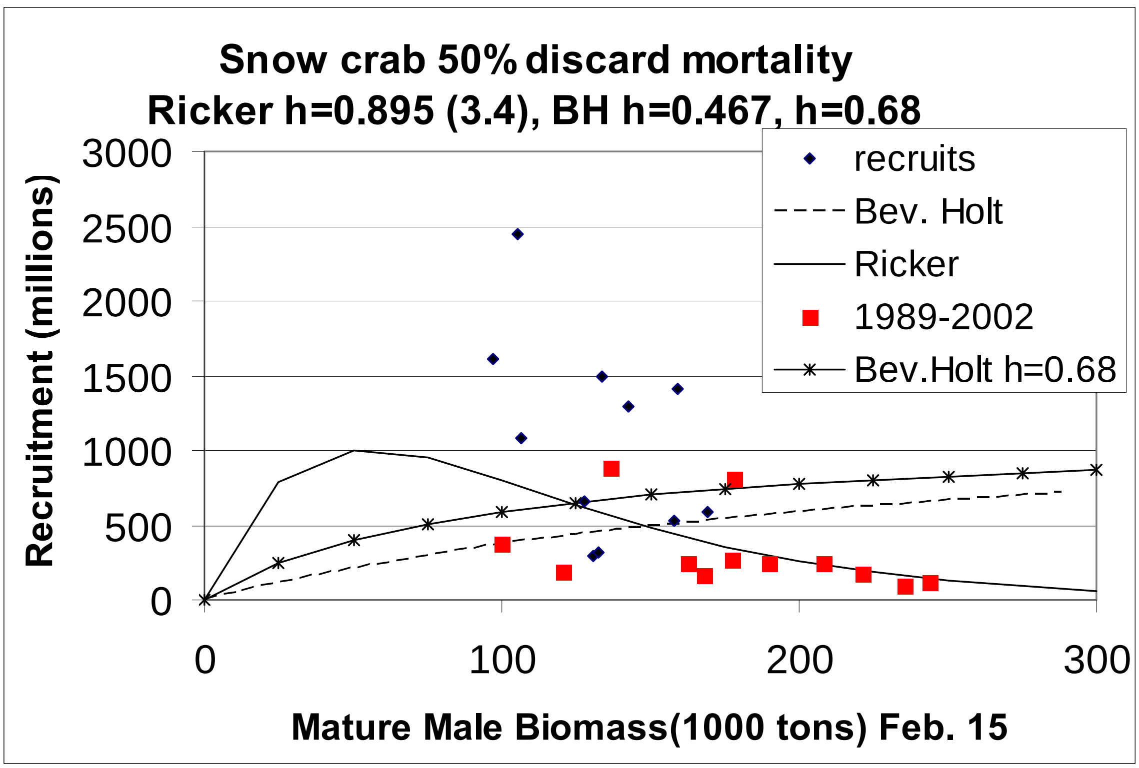

Figure 5-3 **Estimated spawner recruit curves using Mature male biomass. R0 for the Beverton and Holt curve and R_{MAX} for the Ricker were fixed at 1.0 billion recruits (1/2 total recruits). Steepness for the Ricker curve was 3.4 (if defined as the fraction of R_0 that occur at 20% B_0). The steepness of the estimated Beverton and Holt curve was 0.467. A Beverton and Holt curve with steepness of 0.68 was used in the simulations as the midpoint between the range of estimated steepness.**

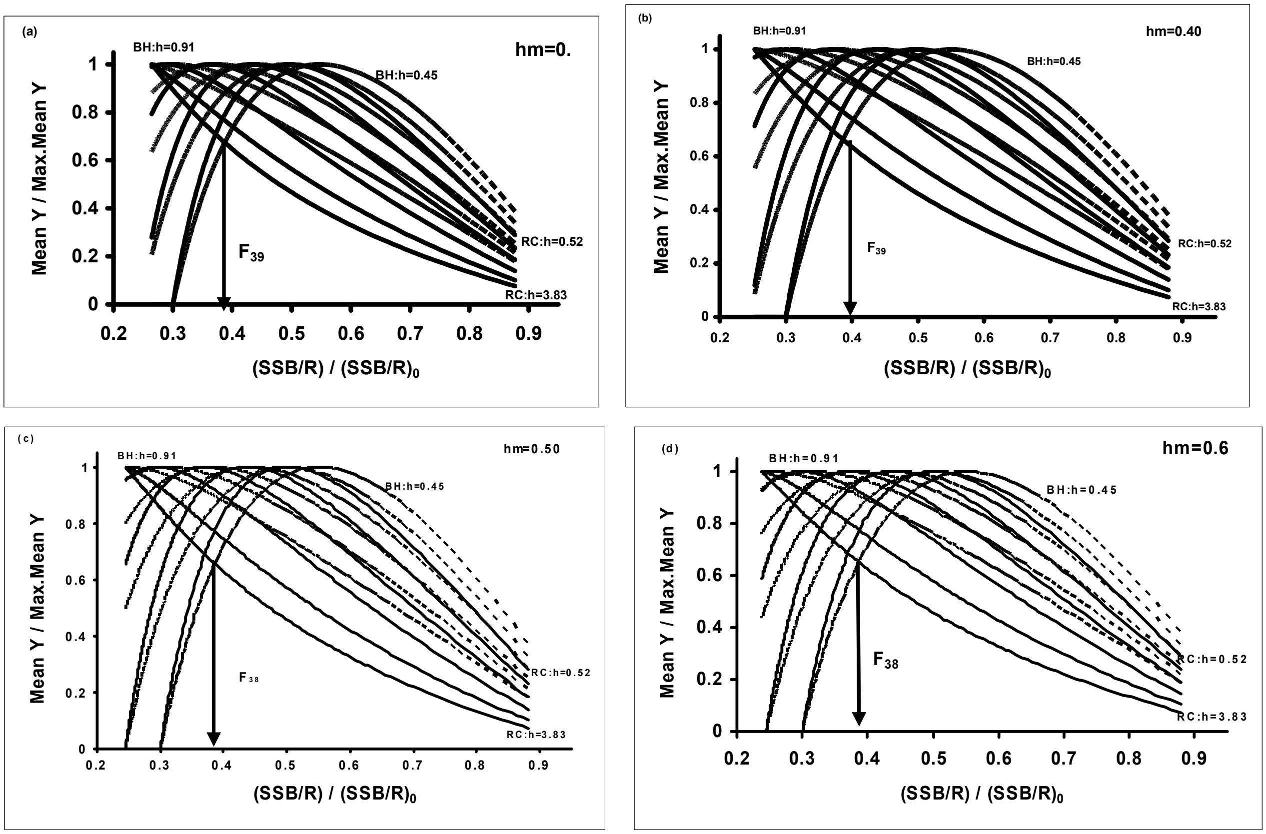

Figure 5-4 Locations of spawning potential ratio ($F_{x\%}$) by equilibrium yield method for different handling mortality rates: (a) 0.25, (b) 0.4, (c) 0.5, and (d) 0.6 for snow crab. Solid lines: Ricker S-R model (RC), dotted lines: Beverton-Holt S-R model (BH). Steepness (h) ranges for BH: 0.45-0.91 and for RC: 0.52-3.83.

5.2.3 Sensitivity analysis of α and β

Various combinations of the α (0, 0.05, 0.1, 0.25) and β (0, 0.25) parameters of the control rule were used to evaluate short-term performance and rebuilding (Figure 5-5; Table 5-2 and Table 5-3). The F_{MSY} control rule was used for all simulation runs. The rebuilding time starting at 10% B_{MSY} was 26 years for α = 0.1 and β = 0.25. Lower alpha values resulted in an increase of 1 year on the rebuilding time. With beta = 0.25, the fishery was closed about 8%–10% of the time in the first 30-year period, however, mean yields were similar between scenarios. If α = 0.25 (β = 0.25, however, not needed), rebuilding time was 25 years, fishery closures were lower than other scenarios with β = 0.25 (6%), however, mean yields were lower in the first 10 years than for all other scenarios.

There was very little difference in rebuilding times or other measures of performance between α and β values considered when rebuilding from 50% B_{MSY} (Table 5-2). The scenario with α = 0.25 resulted in 1 year less rebuilding time, and a slightly smaller mean yield in the first 10 years than the other scenarios.

The F_{MSY} control rule (α = 0.1 and β = 0.25), resulted in shorter rebuilding time (14 yr) relative to a constant F_{MSY} strategy (17 yr) when starting from 50% B_{MSY} (Table 5-2). Mean yield in the first 10 years of rebuilding was about 10% less with the sloping control rule; however, over the 30-year period mean yields were equal for the control rule and the constant F_{MSY} strategy, due to faster rebuilding with the sloping control rule. The rebuilding time for the status quo harvest strategy was 13 years, while 75% F_{MSY} CR and $F_{40\%}$ CR rebuilding times were 11 years.

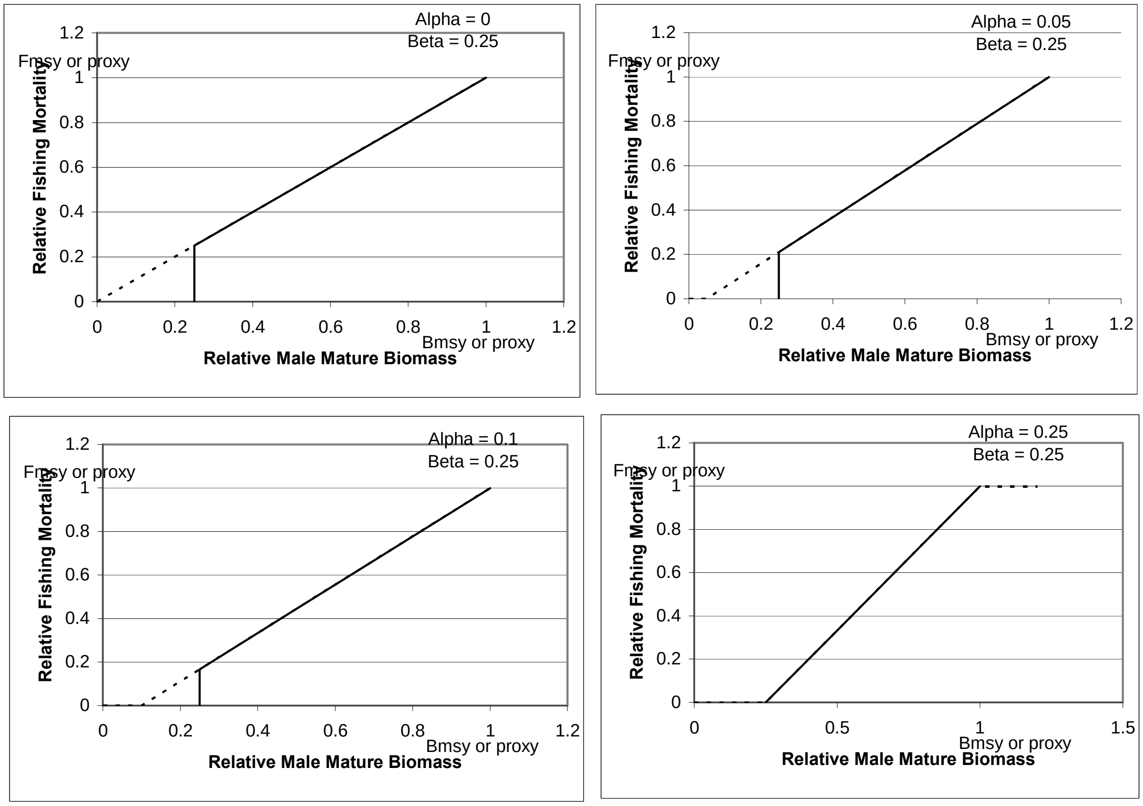

Figure 5-5 Overfishing control rules for alpha values of 0, 0.05, 0.1 and 0.25, and beta values of 0 and 0.25. Solid lines indicate control rules with beta = 0.25 (vertical line). When Beta = 0.0 the control rules extend to the alpha value on the x axis (indicated by the dotted lines).

5.2.4 Evaluation of alternatives with short-term and long-term performance statistics

The impact of fishing at the status quo OFL control rule and the status quo snow crab harvest strategy were simulated in conjunction with proposed control rules under the new tier system in Alternative 2 and 3. The harvest control rules applied to the simulated population follow the control rules in the proposed tier system as well as fishing at the status quo OFL control rule and the status quo harvest strategy. Table 5-4 through Table 5-8 provide the results of performance statistics for short-term (6 years and 30 years) and long-term (100 years) fishery simulations. Different harvest strategy scenarios were investigated to predict the changes in stock abundance levels under various harvest rates. The Alternative 2 and 3 scenarios include: Tier 2 with the F_{MSY}, Tier 2 at 75% F_{MSY}, Tier 3 with $F_{35\%}$, Tier 3 at 75% $F_{35\%}$, Tier 3 at 75% $F_{40\%}$, Tier 4 with 1.5*M, Tier 4 at M, and Tier 5 with mean constant catch. The scenario that best represents the potential OFL for snow crab under Alternatives 2 and 3 is Tier 3 with $F_{35\%}$ control rule. The Alternative 1 scenarios include the status quo harvest strategy and fishing at the status quo OFL control rule. For analytical purposes, additional scenarios considered include a default harvest strategy of a flat F_{MSY} (i.e., no sliding fishing mortality for any level of B), F = 0, and F_{MSY} control rule with the status quo harvest strategy.

Simulations for this analysis used a Beverton-Holt S-R curve with steepness h = 0.68, and R_0 = 2.0 billion recruits (male+female) for snow crab.

Projections based on alternative harvest strategies applied the proposed Tier 3 harvest control rule. Average recruitment was estimated from the most recent stock assessment model (Turnock and Rugolo 2006). Following Clark (2001) a proxy for limit reference points (F_{OFL}) were derived from SPR analysis. Based on SPR analyses, $F_{35\%}$ is considered as a proxy for F_{MSY} and B_{MSY} proxy is equal to $B_{35\%}$ (Figure 5-6). $F_{xx\%}$ is the fishing mortality rate at which the equilibrium spawning biomass per recruit is reduced to xx% of its value in the equivalent unfished stock. The time period used to estimate average recruitment will influence the B% values. The complete time period used in the snow crab stock assessment model from 1978 to 2006 was used to estimate an average recruitment.

Simulation results are presented for two model scenarios, 25% and 50% mortality on discarded crab from the directed pot fishery.

5.2.4.1 Mortality 25% on directed pot fishery discards

Short-term (30 years) and long-term (100 years) simulations were conducted using a model with 25% discard mortality from the directed pot fishery (Table 5-4 and Table 5-5). Long-term (100 years) simulation results estimated F_{MSY} at 1.0 and B_{MSY} (MMB at mating time) at 391.98 million pounds (177,800 t) (Table 5-5) using a Beverton and Holt S-R curve with steepness 0.68 and R_0 = 2.0 billion recruits. $F_{35\%}$ was estimated at 1.03, and $F_{40\%}$ = 0.78. $B_{35\%}$ (336.64 million pounds or 152,700 t) and $B_{40\%}$ (384.70 million pounds or 174,500 t) were estimated using ½ mean estimated recruitment from the stock assessment model (0.63 billion) and MMB at mating time per recruit fishing at $F_{35\%}$ (0.61 pounds or 0.000242 t) or $F_{40\%}$ (0.53 pounds or 0.000277 t). The long-term average retained catch for the F_{MSY} control rule was 119.34 million pounds (54,130 t), a little higher than the MSY (fishing at constant F_{MSY}) of 116.38 million pounds (52,790 t).

Rebuilding from 50% B_{MSY} did not occur in the first 30 years under the status quo OFL CR. Rebuilding was slightly faster and yields lower for the status quo harvest CR than the $F_{35\%}$ CR.

Under Alternative 1, fishing at the status quo OFL control rule results in mean MMB at 26% of B_{MSY}, and mean retained catch of 64.86 million pounds (29,420 t) (56% of MSY) (Table 5-5). The status quo harvest strategy is between the F_{MSY} control rule and the 75% F_{MSY} control rule. The $F_{35\%}$ control rule results in lower MMB, although similar mean yields, due to $B_{35\%}$ being lower than B_{MSY} in the control rule. A scenario was also run with the F_{MSY} control rule together with the status quo harvest strategy. The F in each year of the simulation was estimated for both strategies and the lower F applied. In some years the status quo harvest strategy was constrained by the F_{MSY} control rule, however, mean yield was very similar to the status quo harvest strategy alone, while the mean F was lower, and MMB about 10% higher.

Constant catch (Tier 5) can drive the stock to low levels if catch is greater than about 60% of MSY and there is no reliable estimate of relative stock size to gauge when to decrease catches. If a reliable index of stock size is available so that catch can be decreased as relative stock size goes down then a higher fraction of MSY could be used as constant catch. Simulations were run at a constant catch equal to the 1985-2000 average of 156 million lbs. (70,900 t). The actual catch in a particular year of the simulation may be less than the average mean catch due to low abundance of exploitable males. Mature male biomass was below 50% B_{MSY} about 80% of the time in the first 30 years, and 84% of the time in 100 year simulations.

5.2.4.2 Mortality 50% on directed pot fishery discards

Short-term (30 years) and long-term (100 years) simulations were conducted using a model with 50% discard mortality from the directed pot fishery (Table 5-6 through Table 5-8).

Rebuilding times ranged from 0.23 (directed F=0) to 1.15 of the Tier 2 result ($F_{35\%}$ and the status quo harvest strategy CR) relative to the F_{MSY} CR, except for fishing at the status quo OFL control rule, which did not rebuild the stock (Table 5-6). Fishing mortality values were lower for the 50% discard model compared to the 25% discard model and biomass was higher, however, average yields were only slightly lower. Results however are not directly comparable given the modifications necessary to the model and parameters in order to respecify discard mortality. The F_{MSY} control rule (α=0.1 and β=0.25), resulted in shorter rebuilding time relative to a constant F_{MSY} strategy (1.23 relative to F_{MSY} CR). The status quo harvest strategy CR was similar to the $F_{35\%}$ CR in rebuilding times and short-term yields.

Long-term (100 years) simulation results estimated F_{MSY} at 0.86 and B_{MSY} (MMB at mating time) at 413.36 million pounds (187,500 t) (Table 5-7) using a Beverton and Holt S-R curve with steepness 0.68 and R0 = 2.0 billion recruits. $F_{35\%}$ was estimated at 0.93, and $F_{40\%}$= 0.72. $B_{35\%}$ (354.72 million pounds or 160,900 t) and $B_{40\%}$ (405.21 million pounds or 183,800 t) were estimated using ½ mean estimated recruitment from the stock assessment model (0.656 billion) and MMB per recruit at mating time, fishing at $F_{35\%}$ (0.61 pounds or 0.000245 t) or $F_{40\%}$ (0.62 pounds or 0.00028 t). The long-term average retained catch for the F_{MSY} control rule was 114.07 million pounds (51,740 t), a little higher than the MSY (fishing at constant F_{MSY}) of 111.33 million pounds (50,500 t). Long-term average results were similar for the $F_{35\%}$ CR and the status quo harvest strategy CR, with F and retained catch slightly lower and biomass slightly higher for the status quo harvest strategy CR. When the F_{MSY} and status quo harvest strategy CR were simulated together (whichever F was lower was applied to the stock), the results were similar to the F_{MSY} CR, with slightly lower F and retained yields. Figure 5-6 shows one simulation run of 200 years, each run will have a different trajectory of recruitment, biomass, F and catch values. Values would be different when each CR is applied separately. The F_{MSY} CR constrained the catch from the status quo harvest strategy CR when stock biomass declined to lower levels. The status quo harvest strategy CR estimated F sometimes higher and sometimes lower than the F_{MSY} CR at higher stock size. The maximum F from the status quo harvest strategy CR is a little higher than F_{MSY}.

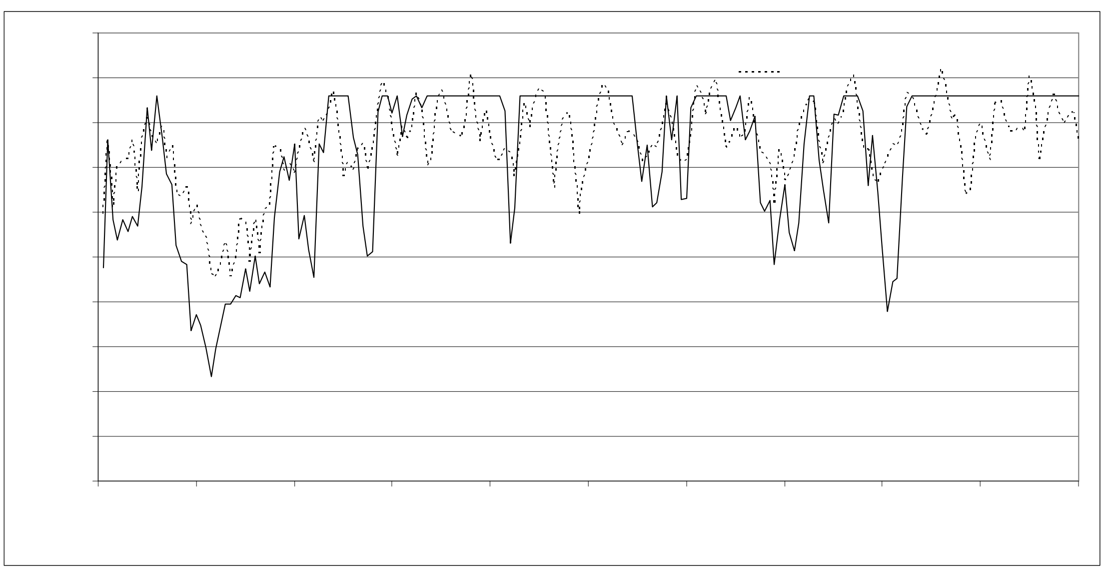

Figure 5-6 Comparison of snow crab fishing mortality estimated each year using the status quo harvest strategy CR and the F_{MSY} CR for one simulation run of 200 years, using the 50% discard mortality model

Table 5-2 Snow crab simulation for 25% discard mortality model starting at 50% B_{MSY}, using the F_{MSY} control rule for 30 year time period. Mean and medians are estimated from 1000 simulations of a 30-year fishery. Values are all relative to the first column where alpha = 0 and beta=0, except for mean fishery closures which is in percent for every column. Biomass values in first column are 1000 tons.

Harvest Control Rule Parameters: α, β	0.0,0.0	0.0, 0.25	0.05, 0.25	0.1, 0.25	0.05, 0.0	0.1, 0.0	.25,.25
Median rebuilding time (yr) from 1000 simulations of a 30-year fishery	14.00	1.00	1.00	1.00	1.00	1.00	0.93
Mean Overfished % (mature male B < 100% mature male B_{MSY})	70.33	1.00	1.00	0.99	1.00	0.99	0.98
Mean Overfished % (mature male B < 50% mature male B_{MSY})	3.29	1.00	0.91	0.78	0.91	0.78	0.47
Mean Fishery Closure %	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mean 30th Year mature male B/mature male B_{MSY} ratio	1.07	1.00	1.01	1.01	1.01	1.01	1.03
Mean First 10-yr Mean Yield	34.57	1.00	1.00	0.99	1.00	0.99	0.97
CV First 10-yr Mean Yield	0.57	1.00	1.00	1.02	1.00	1.02	1.07
Mean Next 20-yr Mean Yield	50.30	1.00	1.00	1.00	1.00	1.00	1.01
CV Next 20-yr Mean Yield	0.74	1.00	1.00	1.00	1.00	1.00	1.01

Table 5-3 Snow crab simulation for 25% discard mortality model starting at 10% B_{MSY}, using the F_{MSY} control rule for a 30-year period. Mean and medians are estimated from 1000 simulations of a 30-year fishery. Values are all relative to the first column where alpha = 0 and beta=0, except for mean fishery closures which is in percent for every column. Biomass values in first column are 1000 tons.

Harvest Control Rule Parameters: α, β	0.0, 0.0	0.0, 0.25	0.05,0.25	0.1,0.25	0.05, 0.0	0.1, 0.0	.25,.25
Median rebuilding time (yr) from 1000 simulations of a 30-year fishery	28.00	0.96	0.96	0.93	0.96	0.96	0.89
Mean % mature male B < 100% mature male B_{MSY}	88.28	1.00	0.99	0.99	0.99	0.99	0.97
Mean Overfished % (mature male B < 50% mature male B_{MSY})	48.80	0.98	0.96	0.93	0.97	0.94	0.83
Mean Fishery Closure % (mature male B < beta* mature male B_{MSY} or alpha * mature male B_{MSY})	0.00	9.95	9.24	8.50	0.00	0.03	6.32
Mean 30th Year mature male B/mature male B_{MSY} ratio	0.95	1.01	1.02	1.03	1.01	1.03	1.06
Mean First 10-yr Mean Yield	6.12	0.94	0.90	0.86	0.95	0.89	0.66
CV First 10-yr Mean Yield	0.80	1.20	1.23	1.26	1.06	1.15	1.65
Mean Next 20-yr Mean Yield	34.26	1.02	1.03	1.03	1.01	1.03	1.07
CV Next 20-yr Mean Yield	0.86	0.99	0.99	1.00	1.00	1.00	1.01

Table 5-4 25% discard mortality. Short-term rebuilding simulations for snow crab, starting from an initial mature male biomass = 50% mature male B_{MSY}. Mean and median are estimated from 1000 simulations of a 30-year fishery. All values relative to first column with Fmsy CR, except mean fishery closure with is in percent.

Harvest Control Rule	Tier 2 limit (F_{MSY} in CR)	Tier 2 target (75% F_{MSY} in CR)	Tier 3 limit (F35% in CR)	Tier 3 target (75% F for F35% in CR)	Tier 3 limit (F40% in CR)	Tier 4 limit (F=1.5*M in CR)	Tier 4 target (1.0*M in CR)	Tier 5 target (Mean Catch)	Status quo Harvest CR	Status quo OFL CR	Flat F_{MSY}	F=0	Fmsy CR with ADFG CR
Mean Recruit No. in 30-yr fishery	1.41	1.04	0.98	1.02	1.03	1.11	1.16	0.71	1.00	0.68	0.94	1.24	1.02
Mean Total Yield in 30-yr fishery	52	0.96	1.01	0.96	0.96	0.75	0.59	0.91	0.97	0.93	1.00	0.01	0.96
Mean Retained Yield in 30-yr fishery	44.65	0.96	1.01	0.96	0.96	0.75	0.58	0.90	0.97	0.91	1.00	0.00	0.96
Mean Mature Male Biomass in 30-yr fishery	168.09	1.14	0.95	1.09	1.11	1.57	1.87	0.50	1.04	0.38	0.88	2.75	1.09
Mean Mature Female Biomass in 30-yr fishery	118.63	1.03	0.98	1.01	1.02	1.09	1.12	0.78	1.00	0.75	0.96	1.18	1.01
Mean F	0.79	0.81	1.09	0.86	0.84	0.43	0.25	5.62	0.94	6.30	1.27	0.00	0.87
Median Rebuilding Time in 30-yr fishery (y)	14	0.79	1.07	0.86	0.79	0.43	0.29	NAN	0.93	NAN	1.21	0.21	0.86
Mean %times B<B_{MSY} in 30-yr fishery	69.82	0.84	1.06	0.90	0.87	0.49	0.25	1.33	0.94	1.42	1.09	0.10	0.90
Mean Overfished in 30-yr fishery% (B<50% B_{MSY})	2.63	0.43	1.76	0.78	0.52	0.16	0.00	30.52	1.61	32.43	5.09	0.00	0.88
Mean Fishery Closure in 30-yr fishery% (B<25% B_{MSY})	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.12	0.00	0.00	100.00	0.08
Mean 30th Year mature male B/mature male B_{MSY} Ratio	1.08	1.18	0.95	1.13	1.15	1.76	2.14	0.46	1.08	0.30	0.89	3.44	1.13
Mean First 10-yr Mean Yield	33.35	0.94	1.04	0.95	0.93	0.68	0.45	1.32	0.99	1.35	1.11	0.00	0.96
CV First 10-yr Mean Yield	0.63	0.90	0.94	0.92	0.98	0.76	1.08	0.53	0.89	0.79	0.79	NAN	0.93
Mean Next 20-yr Mean Yield	50.3	0.97	1.00	0.96	0.97	0.77	0.63	0.75	0.96	0.77	0.97	0.00	0.96
CV Next 20-yr Mean Yield	0.74	0.96	0.99	0.96	0.97	0.86	0.86	0.77	0.97	1.07	0.96	NAN	0.96

Table 5-5 25% discard mortality. Long-term simulations for snow crab, starting from an initial mature male biomass = 100% mature male B_{MSY}. Mean and median are estimated from 1000 simulations of a 100-yr fishery. All values relative to first column with Fmsy CR, except mean fishery closure which in percent.

Harvest Control Rule	Tier 2 limit (F_{MSY} in CR)	Tier 2 target (75% F_{MSY} in CR)	Tier 3 limit (F35% in CR)	Tier 3 target (75% F for F35% in CR)	Tier 3 limit (F40% in CR)	Tier 4 limit (F=1.5*M in CR)	Tier 4 target (1.0*M in CR)	Tier 5 target (Mean catch)	Status quo Harvest CR	Status quo OFL CR	Flat F_{MSY}	F=0	F_{MSY} CR with Status quo harvest CR
Mean Recruit No. in 100-yr fishery	1.52	1.05	0.98	1.03	1.04	1.16	1.22	0.52	1.02	0.47	0.95	1.32	1.03
Mean Total Yield in 100-yr fishery	63.19	0.98	1.00	0.98	0.99	0.82	0.69	0.58	0.98	0.55	0.97	0.01	0.98
Mean Retained Yield in 100-yr fishery	54.13	0.98	1.00	0.98	0.98	0.81	0.67	0.57	0.98	0.54	0.98	0.00	0.98
Mean Mature Male Biomass in 100-yr fishery	196.27	1.18	0.95	1.14	1.15	1.80	2.15	0.36	1.10	0.24	0.91	3.55	1.14
Mean Mature Female Biomass in 100-yr fishery	139.93	1.05	0.98	1.04	1.04	1.17	1.22	0.52	1.02	0.47	0.95	1.33	1.04
Mean F	0.86	0.79	1.07	0.85	0.83	0.41	0.27	5.27	0.88	5.79	1.16	0.00	0.85
Median Rebuilding Time in 30-yr fishery (y)	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mean %times B<Bmsy in 100-yr fishery	52.78	0.71	1.09	0.79	0.76	0.20	0.08	1.76	0.83	1.88	1.14	0.00	0.79
Mean Overfished in 100-yr fishery% (B<50% B_{MSY})	2.46	0.39	1.74	0.71	0.48	0.09	0.02	34.13	1.39	37.17	5.09	0.00	0.78
Mean Fishery Closure in 100-yr fishery% (B<25% B_{MSY})	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.11	0.00	0.00	100.00	0.06
Mean 100th Year mature male B/mature male B_{MSY} Ratio	1.1	1.18	0.95	1.15	1.15	1.80	2.16	0.36	1.10	0.24	0.91	3.56	1.15

Table 5-6 50% discard mortality. Short-term rebuilding simulations for snow crab, starting from an initial mature male biomass = 50% mat. Male B_{MSY}. Mean and median are estimated from 1000 simulations of a 30-year fishery. All values relative to first column with Fmsy CR, except mean fishery closure which in percent.

Harvest Control Rule	Tier 2 limit (F_{MSY} in CR)	Tier 2 target (75% F_{MSY} in CR)	Tier 3 limit (F35% in CR)	Tier 3 target (75% F for F35% in CR)	Tier 3 limit (F40% in CR)	Tier 4 limit (F=1.5*M in CR)	Tier 4 target (1.0*M in CR)	Tier 5 target (Mean Catch)	Status quo Harvest CR	Status quo OFL CR	Flat F_{MSY}	F=0	F_{MSY} CR with Status quo harvest CR
Mean Recruit No. in 30-yr fishery	1.43	1.03	0.98	1.01	1.02	1.06	1.14	0.60	0.98	0.62	0.95	1.23	1.01
Mean Total Yield in 30-yr fishery	52.77	0.94	1.02	0.97	0.97	0.73	0.63	0.82	1.00	0.90	1.01	0.01	0.97
Mean Retained Yield in 30-yr fishery	43.18	0.95	1.01	0.97	0.97	0.73	0.63	0.75	1.00	0.82	1.01	0.00	0.97
Mean Mature Male Biomass in 30-yr fishery	179.73	1.14	0.93	1.07	1.08	1.39	1.73	0.34	0.95	0.31	0.88	2.65	1.05
Mean Mature Female Biomass in 30-yr fishery	121.67	1.03	0.98	1.01	1.02	1.02	1.10	0.67	0.98	0.71	0.96	1.17	1.01
Mean F	0.69	0.80	1.13	0.90	0.87	0.49	0.33	6.79	1.09	7.23	1.25	0.00	0.91
Median Rebuilding Time in 30-yr fishery (y)	13	0.77	1.15	0.92	0.92	0.62	0.31	NAN	1.15	NAN	1.23	0.23	1.00
Mean %times B<B_{MSY} in 30-yr fishery	69.12	0.83	1.08	0.92	0.91	0.58	0.35	1.40	1.03	1.44	1.09	0.11	0.94
Mean Overfished in 30-yr fishery% (B<50% B_{MSY})	2.41	0.41	2.05	0.88	0.63	0.30	0.07	37.71	2.69	38.54	5.30	0.00	0.95
Mean Fishery Closure in 30-yr fishery% (B<25% B_{MSY})	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.14	0.00	0.00	100.00	0.04
Mean 30th Year mature male B/mature male B_{MSY} Ratio	1.09	1.18	0.92	1.10	1.10	1.70	1.97	0.29	0.97	0.22	0.89	3.28	1.08
Mean First 10-yr Mean Yield	32.81	0.90	1.06	0.96	0.95	0.63	0.55	0.60	1.05	1.31	1.10	0.00	0.98
CV First 10-yr Mean Yield	0.58	1.00	0.95	0.93	0.98	0.83	0.83	0.82	0.90	0.86	0.81	NAN	0.93
Mean Next 20-yr Mean Yield	48.37	0.96	1.00	0.97	0.98	0.77	0.66	0.75	0.98	0.65	0.97	0.00	0.97
CV Next 20-yr Mean Yield	0.74	0.95	0.99	0.95	0.96	0.86	0.82	0.34	0.97	1.09	0.95	NAN	0.95

Table 5-7 50% discard mortality. Long-term simulations for snow crab, starting from an initial mature male biomass = 100% mat. Male B_{MSY}. Mean and median are estimated from 1000 simulations of a 100-yr fishery. All values relative to first column with Fmsy CR, except mean fishery closure which in percent.

Harvest Control Rule	Tier 2 limit (F_{MSY} in CR)	Tier 2 target (75% F_{MSY} in CR)	Tier 3 limit (F35% in CR)	Tier 3 target (75% F for F35% in CR)	Tier 3 limit (F40% in CR)	Tier 4 limit (F=1.5*M in CR)	Tier 4 target (1.0*M in CR)	Tier 5 target (mean catch)	Status quo Harvest CR	Status quo OFL CR	Flat F_{MSY}	F=0	Fmsy CR With ADFG CR
Mean Recruit No. in 100-yr fishery	1.54	1.05	0.97	1.03	1.03	1.14	1.19	0.35	0.99	0.32	0.95	1.31	1.02
Mean Total Yield in 100-yr fishery	63.39	0.98	1.00	0.98	0.99	0.84	0.70	0.41	0.99	0.39	0.98	0.01	0.99
Mean Retained Yield in 100-yr fishery	51.74	0.98	1.00	0.98	0.99	0.84	0.70	0.38	0.99	0.36	0.98	0.00	0.99
Mean Mature Male Biomass in 100-yr fishery	207.53	1.19	0.92	1.11	1.11	1.68	2.03	0.18	0.99	0.14	0.90	3.40	1.09
Mean Mature Female Biomass in 100-yr fishery	141.98	1.05	0.97	1.03	1.03	1.15	1.20	0.35	0.99	0.33	0.95	1.31	1.02
Mean F	0.74	0.80	1.11	0.88	0.88	0.46	0.31	6.53	1.03	6.74	1.16	0.00	0.90
Median Rebuilding Time (y)	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mean %times $B<B_{MSY}$ in 100-yr fishery	52.65	0.70	1.15	0.83	0.82	0.21	0.11	1.86	1.01	1.90	1.15	0.00	0.86
Mean Overfished in 100-yr fishery% ($B<50\%\ B_{MSY}$)	2.35	0.38	2.09	0.83	0.60	0.11	0.03	40.46	2.50	41.70	5.37	0.00	0.88
Mean Fishery Closure in 100-yr fishery% ($B<25\%\ B_{MSY}$)	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.15	0.00	0.00	100.00	0.04
Mean 100th Year mature male B/mature male B_{MSY} Ratio	1.11	1.19	0.92	1.11	1.11	1.77	2.03	0.18	0.98	0.14	0.90	3.39	1.09

Table 5-8 50% discard mortality. Short-term rebuilding simulations for snow crab, starting from an initial mature male biomass = 100% mature male B_{MSY}. Mean and median are estimated from 1000 simulations of a 30-year fishery. All values relative to first column with Fmsy CR, except mean fishery closure which in percent.

Harvest Control Rule	Tier 2 limit (F_{MSY} in CR)	Tier 2 target (75% F_{MSY} in CR)	Tier 3 limit (F35% in CR)	Tier 3 target (75% F for F35% in CR)	Tier 3 limit (F40% in CR)	Tier 4 limit (F=1.5*M in CR)	Tier 4 target (1.0*M in CR)	Tier 5 limit (75% MSY Catch)	Tier 5 target (Mean Catch)	Status quo Harvest CR	Status quo OFL CR	Flat F_{MSY}	F=0	F_{MSY} CR with Status quo harvest CR
Mean Recruit No. in 30-yr fishery	1.58	1.04	0.98	1.02	1.02	1.10	1.13	1.02	0.76	0.99	0.68	0.98	1.22	1.02
Mean Total Yield in 30-yr fishery	63.31	0.94	1.02	0.97	0.97	0.76	0.62	0.75	0.95	1.00	0.97	1.01	0.01	0.97
Mean Retained Yield in 30-yr fishery	51.68	0.94	1.02	0.97	0.97	0.76	0.62	0.74	0.89	1.00	0.88	1.01	0.00	0.97
Mean Mature Male Biomass in 30-yr fishery	204.91	1.15	0.94	1.09	1.09	1.53	1.79	1.39	0.56	0.99	0.35	0.94	2.72	1.07
Mean Mature Female Biomass in 30-yr fishery	140.37	1.03	0.99	1.01	1.02	1.07	1.10	1.02	0.83	1.00	0.77	0.98	1.16	1.01
Mean F	0.75	0.79	1.12	0.88	0.88	0.45	0.31	1.48	5.25	1.03	6.63	1.15	0.00	0.91
Median Rebuilding Time in 30-yr fishery (y)	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mean %times B<Bmsy in 30-yr fishery	55.13	0.60	1.17	0.77	0.79	0.20	0.09	0.64	1.59	1.05	1.80	1.14	0.00	0.87
Mean Overfished in 30-yr fishery% (B<50% Bmsy)	1.22	0.39	2.18	0.82	0.61	0.19	0.02	12.66	51.60	2.75	65.69	5.49	0.00	0.89
Mean Fishery Closure in 30-yr fishery% (B<25% Bmsy)	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.08	0.00	0.00	100.00	0.01
Mean 30th Year mature male B/mature male Bmsy Ratio	1.11	1.19	0.93	1.11	1.11	1.66	2.00	1.48	0.44	0.99	0.24	0.92	3.32	1.09
Mean First 10-yr Mean Yield	50.66	0.90	1.04	0.94	0.95	0.67	0.51	0.78	1.15	1.01	1.25	1.03	0.00	0.96
CV First 10-yr Mean Yield	0.49	0.98	0.98	0.94	0.98	0.94	0.94	0.14	0.58	0.98	1.14	0.94	0.00	0.96
Mean Next 20-yr Mean Yield	52.19	0.96	1.00	0.98	0.98	0.81	0.67	0.71	0.77	1.00	0.71	1.00	0.00	0.98
CV Next 20-yr Mean Yield	0.72	0.96	1.00	0.96	0.97	0.86	0.83	0.26	0.78	0.99	1.11	0.96	0.00	0.96

5.2.4.3 Handling mortality impacts

The F_{MSY} control rule was used to calculate long- and short-term values for yield, biomass and other measures under different handling mortality estimates (Table 5-9 and Table 5-10). A full set of parameters, including fishery selectivities, were estimated for each discard mortality assumption from the snow crab stock assessment model (Turnock and Rugolo, 2006) for input into the projection model. Fishery selectivity curves for the retained and total catch were estimated for each handling mortality assumption as two-parameter ascending logistic curves by fitting the observed catch and size compositions by size and shell condition in the snow crab stock assessment model. The selectivities for the retained catch were estimated by multiplying an estimated two-parameter logistic retention curve by the selectivities for the total catch (retained plus discarded).

The value of F_{MSY} decreases from 1.0 using 25% handling mortality to 0.82 at 60% handling mortality, and B_{MSY} increases for 177.7 to 190.7, due to changes in fishery selectivity curves and average recruitment estimated from the stock assessment model. The long-term retained catch declines from 119.34 million pounds (54,130 t) with the 25% handling mortality scenario to 112.50 million pounds (51,030 t) using the 60% handling mortality scenario, a decline of about 5.7%. Average retained catches during the first 10 years with a starting biomass of 50% B_{MSY}, were 6.5% lower with 60% handling mortality than with 25% handling mortality. Average retained catches during the next 20 years (11th to 30th years) were similar to long-term averages, at 5.5% lower for 60% handling mortality than 25% handling mortality.

The sensitivity to incorrectly specifying the discard mortality was investigated by estimating the reference points and using the F_{MSY} CR and the $F_{35\%}$ CR for a 25% *hm* when the true *hm* was 60% (labeled 60%*hm* true, applied 25%*hm* in Table 5-9 and Table 5-10. This scenario resulted in higher fishing mortality, lower MMB and longer rebuilding time than if the correct CR was applied (60%*hm*). Mean retained yield in the first 10 years of rebuilding was lower (about 7%), however, long term yield was the same. Results for the $F_{35\%}$ CR were similar to the F_{MSY} CR.

If the true *hm* is 25% and the CR for 60% *hm* is applied, MMB is higher than the 25% *hm* scenario, rebuilding is faster by about 29% for the F_{MSY} CR, mean yield in the first 10 years is about 3% higher, and about 2% lower over the long term (100 years). Rebuilding time for the $F_{35\%}$ CR is the same as the F_{MSY} CR with 25% hm, due to $B_{35\%}$ being lower than B_{MSY} and higher fishing mortality applied using the $F_{35\%}$ CR.

Table 5-9 Long-term (100-yr) simulation for snow crab comparing the F_{MSY} control rule with 25%, 40%, 50% and 60% handling mortality (hm) starting at B_{MSY}.

Harvest Control Rule	25% hm	40% hm	50% hm	60% hm	60%hm true, applied 25%hm	25%hm true, applied 60%hm	$F_{35\%}$ 60%hm true applied 25%hm	$F_{35\%}$ 25%hmt rue applied 60%hm
F_{MSY}, B_{MSY}	1.0, 177.7	0.91, 183.9	0.86, 187.5	0.82, 190.7	0.82, 190.7	1.0, 177.7	0.82, 190.7	1.0, 177.7
Mean Recruit No. in 100-yr fishery	1.52	1.53	1.54	1.54	1.49	1.57	1.46	1.52
Mean Total Yield in 100-yr fishery	63.19	63.33	63.39	63.44	63.70	62.64	63.23	62.77
Mean Retained Yield in 100-yr fishery	54.13	52.58	51.74	51.03	51.46	53.16	51.00	53.40
Mean Mature Male Biomass in 100-yr fishery	196.27	203.42	207.53	211.21	188.66	219.50	178.24	202.15
Mean Mature Female Biomass in 100-yr fishery	139.93	141.26	141.98	142.61	137.67	144.80	134.51	140.71
Mean F	0.86	0.78	0.74	0.70	0.80	0.74	0.86	0.83
Median Rebuilding Time in 100-yr fishery (y)	0	0	0	0	0	0	0	0
Mean %times $B<B_{MSY}$ in 100-yr fishery	52.78	52.69	52.65	52.63	63.39	42.31	62.33	56.55
Mean Overfished in 100-yr fishery% ($B<50\%$ B_{MSY})	2.46	2.38	2.35	2.34	4.29	1.29	4.68	4.55
Mean Fishery Closure in 100-yr fishery% ($B<25\%$ B_{MSY})	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00
Mean 100th Year mature male B/mature male B_{MSY} Ratio	1.10	1.11	1.11	1.11	0.99	1.23	1.00	1.06

Table 5-10 Short-term (30 years) simulation for snow crab comparing the F_{MSY} control rule with 25%, 40%, 50% and 60% discard mortality starting at 50% B_{MSY}.

Harvest Control Rule	25% hm	40% hm	50% hm	60% hm	F_{MSY} 60%hm true applied 25%hm	F_{MSY} 25%hm true applied 60%hm	$F_{35\%}$ 60%hm true applied 25%hm	$F_{35\%}$ 25%hm true applied 60%hm
Mean Recruit No. in 30-yr fishery	1.41	1.42	1.43	1.44	1.36	1.48	1.33	1.44
Mean Total Yield in 30-yr fishery	52.45	52.40	52.77	52.64	51.26	53.12	51.57	54.21
Mean Retained Yield in 30-yr fishery	45.03	43.62	43.18	42.45	41.57	45.18	41.74	46.21
Mean Mature Male Biomass in 30-yr fishery	169.09	175.24	179.73	182.67	161.24	190.55	152.08	176.61
Mean Mature Female Biomass in 30-yr fishery	119.34	120.36	121.67	121.99	114.56	125.91	112.56	123.54
Mean F	0.80	0.72	0.69	0.65	0.72	0.70	0.79	0.80
Median Rebuilding Time in 30-yr fishery (y)	14.00	14.00	13.00	13.00	18.00	10.00	18.00	14.00
Mean %times B<B_{MSY} in 30-yr fishery	69.76	69.58	69.12	69.15	78.37	59.46	77.73	71.42
Mean Overfished in 30-yr fishery% (B<50% B_{MSY})	2.58	2.53	2.41	2.40	5.25	1.20	5.55	4.31
Mean Fishery Closure in 30-yr fishery% (B<25% B_{MSY})	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mean 30th Year mature male B/mature male B_{MSY} Ratio	1.08	1.09	1.09	1.09	0.97	1.21	0.98	1.04
Mean First 10-yr Mean Yield	34.27	32.91	32.81	32.03	29.80	35.59	31.11	37.87
CV First 10-yr Mean Yield	0.58	0.58	0.58	0.59	0.61	0.56	0.58	0.53
Mean Next 20-yr Mean Yield	50.41	48.97	48.37	47.66	47.46	49.97	47.05	50.38
CV Next 20-yr Mean Yield	0.74	0.74	0.74	0.73	0.75	0.72	0.74	0.72

5.2.5 Six-year projections of stock biomass under alternative control rules

Catch and MMB at time of mating for winter/spring 2007 to 2012 were projected using the simulation model and starting at the current abundance and biomass from the 2006 stock assessment model using 50% discard mortality (Table 5-11). The 2007 fishery catch was fixed for all scenarios at 37.04 million pounds (16,800 t). Fishing at the status quo OFL control rule, catch is almost 3 times the $F_{35\%}$ catch in 2008 and 50% higher in 2009. These initial high catches resulted in declining biomass to about 31% of B_{MSY} (127.87 million pounds or 58,000 t) in 2010. Due to low biomass, catches were lower in 2010 to 2012; however, the biomass stays at about 31% B_{MSY}. The mean MMB for 100 year simulations using the status quo OFL control rule was 14% of B_{MSY} (Table 5-11). Catch using the status quo harvest strategy control rule is similar to the $F_{35\%}$ control rule in 2008 and 2010 and lower in 2009. The 2011 and 2012 catch is projected to be slightly higher than $F_{35\%}$ control rule. 95% probability intervals on catch are included in Table 5-11 to show uncertainty in future catches incorporating process and sampling errors. $F_{40\%}$ control rule projects catch about 25% lower in 2008, 3.5% higher in 2009 and about 10% lower in 2010 and 2011. However, the $F_{40\%}$ control rule results in higher biomass values which would result in faster rebuilding times. A simulation run was also conducted using the $F_{35\%}$ control rule in conjunction with the status quo harvest strategy control rule. The fishing mortality for both control rules was calculated in each year of the projection and the F that was lower was applied. This simulation does not apply any buffer to the F applied to the stock relative to the F_{OFL}. The projected catches for the $F_{35\%}$ control rule with the status quo harvest strategy control rule were lower than the $F_{35\%}$ control rule and the status quo harvest strategy control rule in the first year, slightly higher than the status quo harvest strategy control rule in 2009-2010, slightly lower than the status quo harvest strategy control rule in 2011-2012. MMB was slightly higher than the status quo harvest strategy control rule in all years, and about 4% to 7% higher than the $F_{35\%}$ control rule alone.

Table 5-11 Six-year projections of total catch (1000 tons) and mature male biomass (MMB) at time of mating (after the fishery), starting from the 2006 Bering Sea snow crab population numbers using fishing at the status quo OFL, F35%, F40%, and the status quo harvest strategy control rules. The OFL in 2007 is fixed at 22,300 tons for all scenarios. 95% probability interval for total catch in parentheses.

Year of fishery	Status quo OFL retained catch	Status quo OFL MMB	$F_{35\%}$ CR Total catch	$F_{35\%}$ CR MMB	$F_{40\%}$ CR Total catch	$F_{40\%}$ CR MMB	Status quo harvest strategy CR Total catch	Status quo harvest strategy CR MMB	$F_{35\%}$ with ADFG CR Total catch	$F_{35\%}$ with ADFG CR MMB
2007	22.3	95.7	22.3	95.7	22.3	95.7	22.3	95.7	22.3	95.7
2008	102.9 (91.9, 12.8)	75.7	34.8 (21.0, 52.0)	120.2	26.2 (15.1, 40.6)	126.4	34.7 (22.1, 50.5)	120.3	32.9 (21.0, 48.1)	121.6
2009	78.6 (67.3, 89.4)	63.7	53.3 (36.2, 70.9)	136.8	45.1 (29.4, 62.4)	150.8	43.7 (26.7, 64.5)	144.4	44.3 (26.9, 65.5)	145.6
2010	40.7 (34.0, 48.7)	57.9	41.8 (28.8, 56.8)	133.8	38.0 (25.3, 53.3)	150.9	42.2 (26.9, 57.2)	141.9	42.3 (26.9, 57.5)	142.6
2011	39.8 (28.9, 62.8)	58.2	32.6 (20.3, 48.3)	128.2	30.2 18.4, 45.5)	144.8	33.7 (23.8, 43.2)	134.0	33.5 (23.1, 43.4)	134.8
2012	52.7 (22.1, 129.4)	59.7	38.4 (17.9, 80.8)	132.4	34.8 (16.4, 72.3)	149.2	40.1 (21.2, 83.5)	135.7	39.2 (19.3, 83.5)	137.1

6 Tanner crab (*Chionoecetes bairdi*)

Three stocks of *C. bairdi* Tanner crab are managed under this FMP, the EBS Tanner crab stock, the EAI Tanner crab stock, and the WAI Tanner crab stock. This Chapter reviews the stock status and biological parameters relevant to overfishing definitions for these stocks and provides an overview of specific impacts on the stock from the three alternatives under consideration in this analysis.

Although annual survey estimates are available for the entire EBS Tanner crab stock, stock assessment modeling is carried out only for the Bristol Bay portion of the stock. Therefore, overfishing definition analyses were carried under Tiers 2 and 3, and Tier 4 control rules for the EBS Tanner crab stock (analytical details are given in the subsequent sections).

6.1 Tanner crab stock status

Eastern Bering Sea Tanner crab

This stock is annually surveyed by NMFS. This stock was declared overfished in 1998 and a rebuilding plan was subsequently adopted in 1999. The 2006 TMB estimate for this stock is 253.3 million pounds (114,896 t), a significant increase above the 2005 estimate (162.0 million pounds or 73,483 t) and above the B_{MSY} for the first time since the overfished declaration of 1998 (Figure 6-1). Note that under the rebuilding plan established for this stock, this stock is considered rebuilt if total mature biomass is above the B_{MSY} level (189.6 million pounds or 86,002 t) for two consecutive years. If the stock is estimated above B_{MSY} in 2007 the stock would be considered rebuilt. For the first time since the overfished declaration, estimated TMB in the last 2 years has shown consistent sharp annual increases comparable to that seen in the mid-1980s.

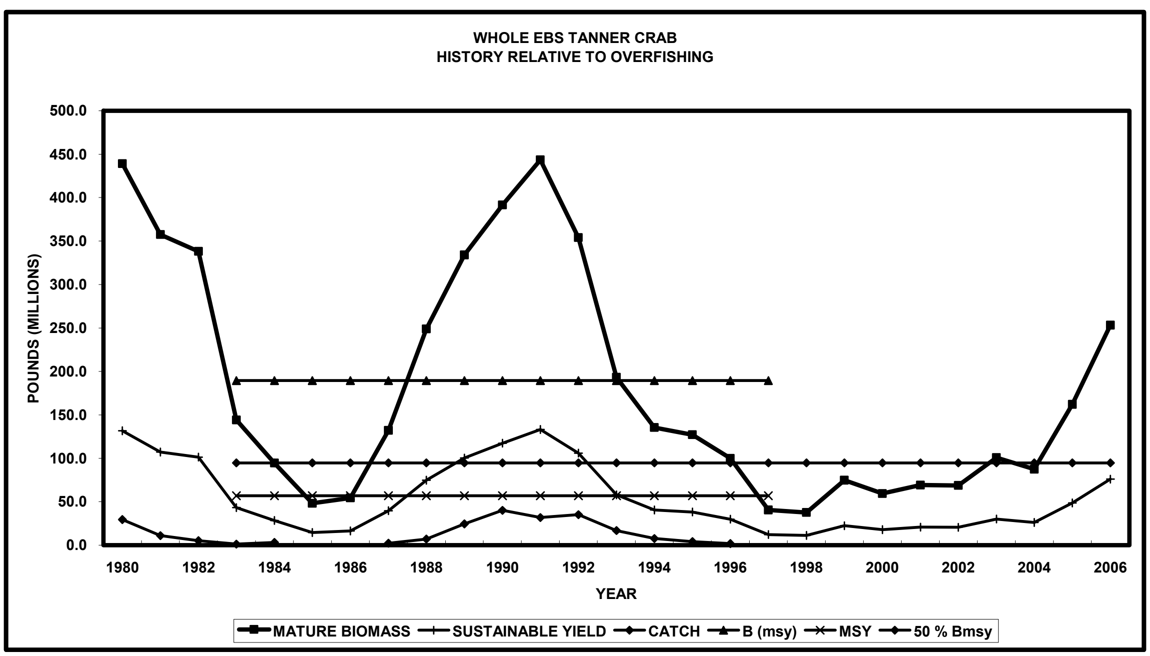

Figure 6-1 EBS Tanner crab stock status relative to overfishing

Recruitment trends are estimated by survey abundance of size categories. ADF&G's area-swept estimates for mature-sized female abundance in the Eastern Subdistrict increased by approximately 50%

between 2005 and 2006; from 42.513 million crabs in 2005 to 65.500 million crabs in 2006. Prior to the results for 2005, abundance estimates of mature-sized females have shown only minor fluctuations about depressed levels in the overall Eastern Subdistrict. Given the size frequency distribution of females in 2005, the increase in mature female abundance and biomass in 2006 is not entirely unexpected, although the level of increase is higher than was expected from the 2005 data. There is a relatively large mode at roughly 75-mm CW in the size frequency distributions for both males and females in 2006. That may provide continued recruitment into the mature size classes in the near-term future. However, unlike the size frequency distributions for the previous four years, there is very poor representation of males or females <50-mm CW in 2006 and that is not promising for continued recruitment to mature size classes in the long-term future.

The area-swept abundance estimates for mature-sized males in the Eastern Subdistrict has shown an increasing trend since 1997, with a marked increase between 2004 and 2005. Separate TACs are established for the areas east and west of 166° W longitude. During a large majority of years, most of the mature-sized males in the Eastern Subdistrict occurred in the area east of 166° W longitude. Since 2004, however, a majority of the estimated mature-sized male abundance has occurred west of 166° W longitude; in 2006 two-thirds of the estimated abundance of mature-sized males was from the area west of 166° W longitude. Old-and-older-shelled crabs dominated the legal-sized males in the Eastern Subdistrict during the 2006 survey; approximately 80% of the legal males were in old- or older-shell condition. Although, the high incidence of old- or older-shelled crab among the legal males may be due to later than usual molting associated with the cold water temperatures recorded during the 2006 summer survey, it is more likely that the old shell crabs represent males that terminally molted to maturity a year earlier. Hence, in terms of growth, low future productivity would be expected from the legal males (as well as from sublegal, mature-sized males).

EBS Tanner crab is managed east and west of 166º W longitude, with a separate TAC for each area. The calculated 2005/06 TAC for the area east was below the minimum TAC and the east fishery was not opened. In the west area, the 2005/06 TAC was 1.62 million pounds (735 t). For the 2006/07 fishery, ADF&G calculated the TAC of 1.875 million pounds (850 t) for the east, using a 10% harvest rate applied to the molting mature male abundance. West of 166° W long., the TAC of 1.094million pounds (496 t) was calculated using a 25% harvest rate applied to the exploitable legal male abundance estimate.

In the area west of 166° W long., ADF&G statistical area 695700 which lies between 169° W long. and 170° W long. and 57° N lat. and 57° 30’ N lat. was closed to commercial fishing for Tanner crab to protect the Pribilof blue king crab stock. The majority of blue king crabs captured during the 2005 and 2006 survey were found in this area. The exploitable legal male Tanner crabs that were estimated to be in this statistical area were not used in setting the 2005/05 or 2006/07 TACs.

Eastern Aleutian Islands Tanner crab

Abundance for this stock is not annually estimated by NMFS. ADF&G conducted pot surveys in the Eastern Aleutians District in 1975, 1976, 1977, 1979, 1980, 1981, 1984, 1985, 1986, and 1987 (Donaldson and Hicks 1980a, 1980b; Colgate and Hicks 1981; ADF&G 1985, 1986, 1987). Those surveys primarily targeted red king crab, but also captured Tanner crabs (Colgate and Hicks 1981). The pot surveys provided general information on relative abundance and distribution of Tanner crabs, but no estimates of Tanner crab abundance have been made from the pot survey results. The pot surveys during 1975-1987 do not provide a consistent time series in terms of area of coverage. For example, whereas 20-40% of the stations surveyed during the pot surveys of 1975-1981 were offshore ocean stations, stations sampled during the 1985 and subsequent pot surveys were almost exclusively within the state waters of bays and inlets. Trawl surveys in the Eastern Aleutians District, which have provided data for computing abundance estimates for Tanner crab within the areas surveyed, were performed by ADF&G in 1990, 1991, 1994, 1995, 1999, 2000, and 2003-2005 (Urban 1992, 1993, 1996a, 1996b; Worton 2000, 2001; Spalinger 2004, 2005, 2006). Most recently, a trawl survey in the Eastern Aleutians District was performed in 2006, but the results have not been published at this time. The trawl survey sampling has mainly concentrated on the Bering Sea side of Unalaska Island and Akutan Bay, where the majority of commercial catch has occurred since the 1970s (ADF&G 1979). Like the pot surveys, the area covered by ADF&G's Eastern Aleutian District trawl survey has varied over time, with the area surveyed generally contracting over the years; for example, 45 stations were sampled by the 1990 survey, whereas 21-24 stations were sampled by the 2004-2006 surveys. Also like the pot surveys of the mid-1980's, the trawl survey has been performed almost exclusively within the state waters of bays and inlets; only four of the 46 stations that have been sampled by the trawl survey during 1990-2006 involve tows outside of state waters and 96% of the tows were within state waters during the most recent three trawl surveys. Since the trawl survey began, the majority of the Tanner crab stock has been found in the vicinity of Akutan Island, Beaver Inlet, Unalaska Bay and Makushin/Skan Bay, whereas the trawl survey estimates of abundance in the Usof, Akun, Pumicestone, and Inanudak Bays and the area off Cape Idak have been low. In 2003, to better assess abundance in some historically important areas for Tanner crabs, ADF&G conducted a pot survey within the state waters of Unalaska Bay, Beaver Inlet, and the Akutan/Akun Islands areas through the cooperative efforts of commercial fishermen participating under a commissioner's permit (Bon and Bowers 2006).

The Eastern Aleutian District Tanner crab commercial fishery began in the 1970s and is a small fishery compared to the EBS Tanner fishery. Harvests peaked at 2.5-million pounds (1,134 t) in the 1977/1978 season (Bush et al. 2005) and, even during the only three seasons in which the harvests exceeded 1-million pounds (454 t) (the 1976/1977 through 1978/1979 seasons), the fishery was characterized as being "limited to smaller local fishing vessels fishing in local bays" (ADF&G 1980). The fishery has continued to be concentrated in nearshore waters, bays, and inlets; 93% of the total harvest during 1985-2006 occurred within statistical areas representing state waters (ADF&G Venus fish ticket system, 3 March 2007). Following the 1976/1977-1979/1980 seasons, during which the average annual harvest was 1.6-million pounds, harvests decreased in the 1980s, averaging 370-thousand pounds (168 t) for the 1980-1989 seasons. Harvests continued to decline in the 1990s, averaging 106-thousand pounds (48 t) during the 1990-1994 seasons, and the fishery was closed for the 1995 through 2002 seasons. During 2003, the State only allowed commercial fishing for vessels participating in a pot survey under the provisions of a commissioner's permit (see above), during which 15-thousand pounds (6.8 t) were retained for sale. For the 2004-2007 seasons, the State opened the fishery with GHLs of 34-thousand to 135-thousand pounds (15.4 t – 61.2 t). Since 2004, the State has restricted commercial fishing to Unalaska, Makushin/Skan, or Akutan Bays, depending on season, with separate GHLs established for separate bays if more than one bay is opened during a season.

The Eastern Aleutian District Tanner crab stock also supports a subsistence fishery (Bush et al. 2005). Based on a survey of Unalaska residents, total subsistence harvest of Tanner crab by that community in 1994 was 11 thousand crabs. From returns of subsistence permits issued in Dutch Harbor during 2000-2004, the annual subsistence harvest of Tanner crabs during those years is estimated to have increased from 1.2 thousand crabs in 2000 to 6.9 thousand in 2004, with an annual average over that period of 4.1 thousand crabs.

Abundance estimates of Eastern Aleutian District Tanner crabs from the ADF&G trawl survey are not directly comparable year-to-year due to the general contraction since 1990 in the area surveyed and, consequently, the area for which abundance estimates were made. However, using a minimum 114-mm CW as a proxy for identifying mature males, there has been an apparent increase in the abundance of mature-sized males from the early 1990s to the more recent survey years. Abundance of mature-sized males estimated from the 1990-1995 surveys averaged 0.37-million crabs, whereas abundance of mature-sized males estimated from the 1999-2005 surveys averaged 1.22-million crabs (Spalinger 2006).

Abundance of mature-sized male Tanner crabs for the area surveyed by the 2005 trawl survey (i.e., Akutan, Unalaska/Kalekta, Makushin, and Pumicestone Bays) was 1.12-million crabs, of which 478 thousand were legal males (Spalinger 2006). Those results were comparable to the 2004 trawl survey (1.17 million mature-sized males and 542 thousand legal males), which was limited to the same bays as the 2005 survey (Spalinger 2005). Stations in Makushin/Skan Bay accounted for 80% of the legal male estimate from the 2005 survey. On the basis of those results, Makushin/Skan Bay was opened to commercial fishing for the 2006 season with a GHL of 87 thousand pounds (39.5 t), representing 10% of the estimated abundance of legal males in that bay.

Western Aleutian Islands Tanner crab

No stock assessment surveys are conducted for Tanner crab in the Western Aleutian District; thus no population estimates are available. Stock status is currently unknown. Historic fisheries were managed using GHLs set from commercial catch data (ADF&G 2005). Harvest of Tanner crab from the Western Aleutian District has, in general, been incidental to the directed red king crab fishery in that area. Commercial harvest has ranged from a high of over 800,000 pounds (363 t) during the 1981/82 season to less than 8,000 pounds (3.6 t) in 1991/92 (ADF&G 2005). No commercial harvest of Tanner crab has occurred in the Western Aleutian District since 1995/96. Tanner crab abundance in the Western Aleutian District is probably limited by available habitat. Most of the historical harvest occurred within a few bays in the vicinity of Adak and Atka Islands (ADF&G 2005).

6.2 Biological Parameters

This section examines relevant and recent biological information necessary to understand the overfishing definitions.

A size range of 70-170 mm CW for both sexes was considered in the simulations. The lower limit was less than the 50% maturity lengths for the Bristol Bay portion of the Bering Sea Tanner crabs (113 mm CW for males and 83.5 mm CW for females; Zheng, unpublished). This size range was chosen to include immature sizes of crabs as initial recruits to the cohorts. Appendix C provides the input base parameter values. Terminal molt at maturity was assumed for both sexes in all simulations.

6.2.1 Steepness parameter estimate

6.2.1.1 Tier 3 assumption

The Beverton-Holt and Ricker S-R models were fitted to the Tanner crab stock in Bristol Bay with MMB as the spawner unit. Because of the lack of recent stock assessment information on this stock, the 1977-2005 data (post-regime shift) were used to determine the steepness parameter. The S-R data were generated for a handling mortality (*hm*) value of 0.2. Figure 6-2 depicts the stock-recruitment scatter plot and the S-R fits. The AIC and BIC statistics suggested that the Ricker curve was more appropriate to this data set than the Beverton-Holt curve (see Chapter 3). The middle value of the steepness parameter range selected for $F_{x\%}$ determination was 1.43. This value was used in the Ricker curve for performance statistics calculations under Tier 3 assumption for the entire EBS Tanner crab stock by stochastic simulations. Performance statistics under Tier 2 control rule using the same stock-recruitment relationship were also estimated for comparison.

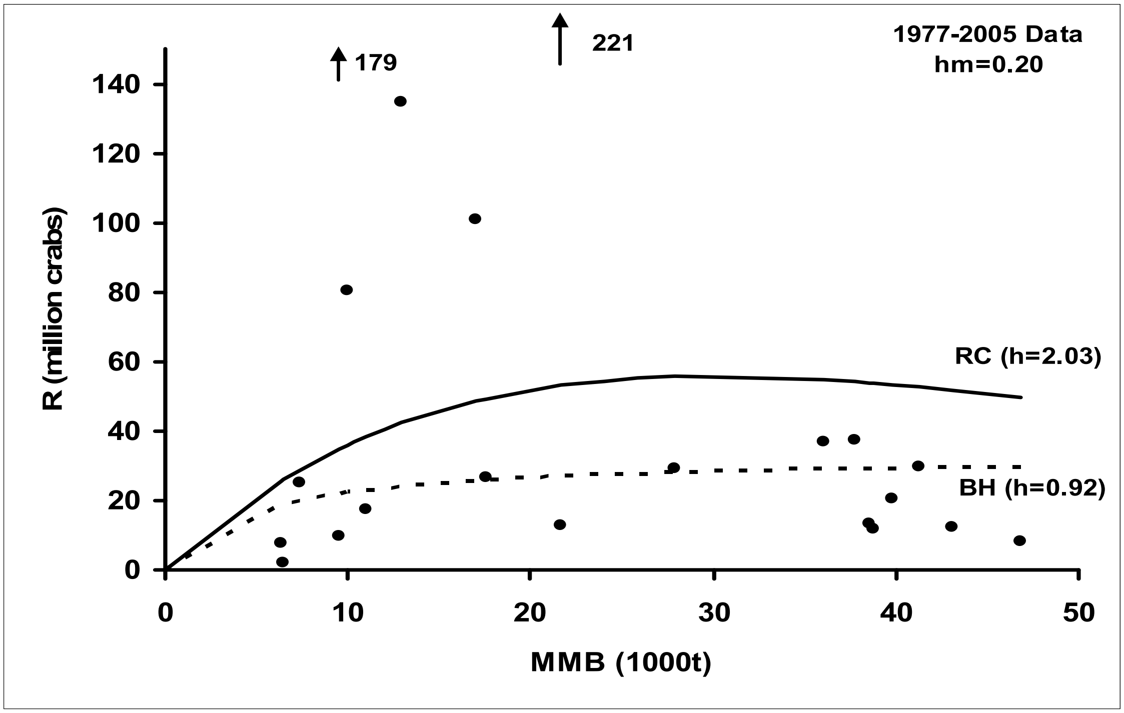

Figure 6-2 Stock-recruitment fit for the Bristol Bay portion of the Tanner crab 1977-2005 data assessed at male M=0.23 and female M=0.29 and handling mortality, hm=0.2. The steepness parameter (h) values are given in parentheses. BH=Beverton and Holt curve, RC=Ricker curve.

6.2.1.2 Tier 4 assumption

The same steepness parameter value used for Tier 3 analyses, 1.43, was used in the Ricker curve for performance statistics calculations under Tier 4 assumption for the entire EBS Tanner crab stock by stochastic simulations.

Appendix C provides the base input parameter values for the Bristol Bay portion of the Tanner crab stock for model simulations under Tier 3 and Tier 4 assumptions.

6.2.2 B_{MSY} and proxy B_{MSY} estimate

6.2.2.1 Tier 3 assumption

The simulated population with a maximum number of 104 million recruits produced a B_{MSY} of 68.22 million pounds (30,943 t) of MMB and $B_{35\%}$ of 70.84 million pounds (32,134 t) of MMB (proxy B_{MSY}) for the Ricker S-R curve with the estimated steepness parameter value of 1.43. These B_{MSY} and proxy B_{MSY} values were used in the Tier 2-4 formulas for stochastic simulations.

6.2.2.2 Tier 4 assumption

The average of the 1983-2006 NMFS survey estimates of eastern Bering Sea MMB (unadjusted) was considered as the proxy B_{MSY} (82.26 million pounds, 37,312 t, of MMB) to use in a set of tier formulas for stochastic simulations. This period was chosen to consider a set of mature biomasses appeared after the regime shift.

6.2.3 Proxy F_{MSY} estimate

6.2.3.1 Tier 3 assumption

The proxy F_{MSY} for Tier 3 formula is $F_{x\%}$. The $F_{x\%}$ estimate for a handling mortality rate of 0.2 is shown in Figure 6-3. Although the estimated $F_{x\%}$ value was $F_{32\%}$, a conservative $F_{35\%}$ was selected for detailed stochastic simulations in common with other crab analyses reported in this document. The corresponding F was 0.80, the legal male harvest rate (at the time of the fishery) was 36%, and the mature male harvest rate (at the time of survey, June 15) was 16%.

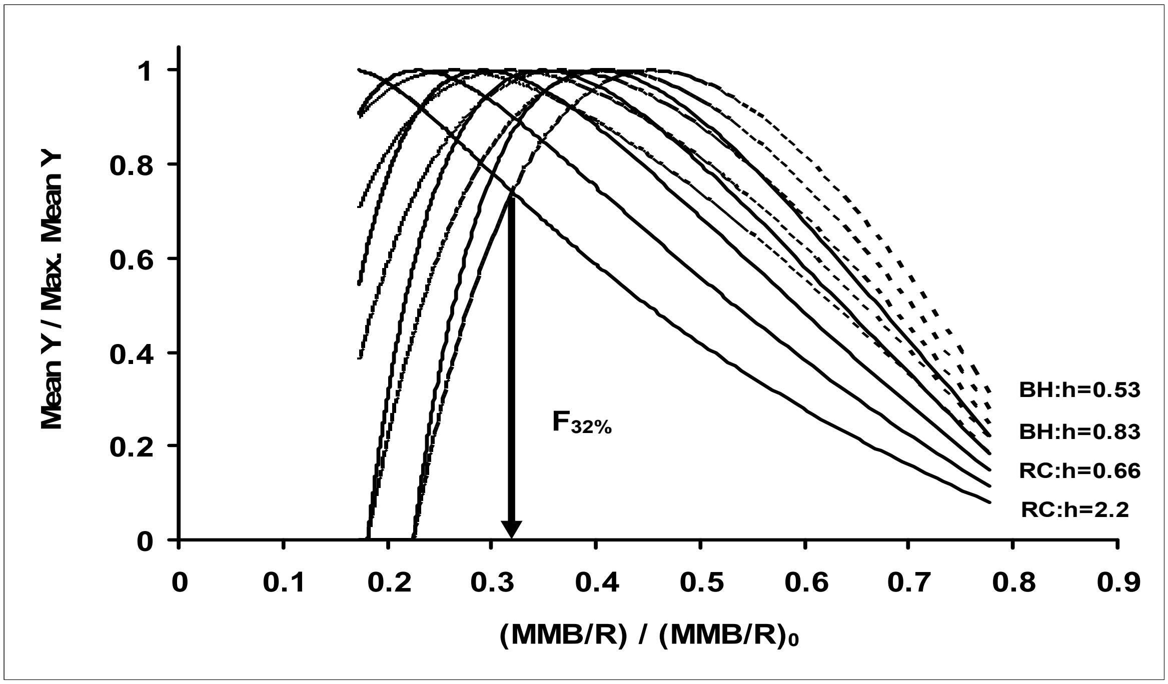

Figure 6-3 Approximate location of spawning potential ratio ($F_{x\%}$) by equilibrium yield method for a handling mortality rate of 0.2 for the Bristol Bay portion of the Tanner crab stock. Solid lines = Ricker S-R model (RC), dotted lines = Beverton-Holt S-R model (BH).

6.2.3.2 Tier 4 assumption

The proxy F_{MSY} for Tier 4 formula is γM. The γ was estimated from a modified F_{MSY} estimate and M. The modification was made, in this instant, because of uncertainty in the newshell and oldshell male selectivity values obtained from assessment models developed in the late 1990s (Zheng and Kruse 1999). The modified F_{MSY} was estimated assuming the newshell selectivity applicable to both newshell and oldshell crabs. The modified F_{MSY}/M ratio (0.6557/0.23) was approximately 2.85, which appears somewhat high. However, for illustrative purpose, analysts selected this γ value to estimate the proxy F_{MSY} (γM). The γM was used in a set of tier formulas for stochastic simulations.

6.3 Effects on EBS Tanner Crab

6.3.1 Comparison of status determination criteria

Under Alternative 1, the EBS Tanner crab stock was declared overfished in 1998 and has been under a rebuilding plan since then. The Alternative 1 status determination criteria for EBS Tanner crab establish a B_{MSY} value of 189.6 million pounds (86,002 t) of TMB with an MSST value of 94.8 million pounds (43,001 t) of TMB. The 2006 TMB from the survey area-swept estimate was 253.3 million pounds (114,896 t), above the B_{MSY} for this stock. In order to be considered rebuilt, this stock must be above its estimated B_{MSY} two consecutive years. 2006 represents the first time the TMB was above the B_{MSY} for this stock since NMFS declared the stock overfished in 1998.

In conjunction with the rebuilding plan, the harvest strategy was modified to allow for greater probability of rebuilding the depleted stock. The State of Alaska harvest strategy for the EBS Tanner crab has the following criteria (5 AAC 35.508):

- Threshold level: 21 million pounds (9,526 t) of mature female (>79 mm CW) biomass (FSSB). When the threshold level is met, the harvest rate is determined as follows:
- Mature harvest rate on molting mature male (100% new-shell and 15% old-shell >112-mm CW) abundance = 10%, if FSSB is greater than 21 million pounds (9,526 t) but less than 45 million pounds (20,412 t)
- Mature harvest rate on molting mature male abundance = 20%, if FSSB is at least 45 million pounds (20,412 t)

In addition, the harvest is capped at 50% of exploitable legal male (100% new-shell and 32% old-shell >138-mm CW) abundance.

The OFL control rule for Tanner crab is the following:

Sustainable yield = 0.3* TMB (male + female).

Under Alternative 1, overfishing occurs when the TAC is above the estimated SY. The Tanner crab TAC for the 2006/2007 fishery was approximately 3 million pounds (1,361 t), which is below the 2006 SY of 75.99 million pounds (34,469 t).

Under the Alternative 2 and 3 status determination criteria, B_{MSY} for Tanner crab is measured in MMB, as discussed in Section 2.4.1. The long-term B_{MSY} estimate for the stock, assuming that the Bristol Bay stock assessment parameters were valid for the entire EBS stock, would be 68.22 million pounds (30.943 t) of MMB. For comparison, the 2006 MMB for the stock is 62.76 million pounds (28,470 t). This stock would be below its B_{MSY}, unlike under Alternative 1.

Given that new biological parameters for this stock would be re-estimated under Alternatives 2 and 3, the rebuilding plan would need to be re-evaluated and potentially revised to reflect new information on the stock, including new estimates of stock recovery in relation to new estimates of B_{MSY}.

Under Alternatives 2 and 3, annual determination of overfishing would occur by comparing the previous year's total catch with the previously calculated OFL for the same time period. Overfishing is defined as any amount of catch in excess of the OFL as prescribed through the tier system described in Sections 2.2.1 and 2.3.1. $F_{35\%}$ is the recommended OFL control rule under Tier 3 assumption. Figure 6-4 shows the relationship between legal F and MMB for both the $F_{35\%}$ and $F_{40\%}$ control rules under Tier 3 assumption for the EBS Tanner crab. Harvest rates in recent years have been well below both control rules depicted.

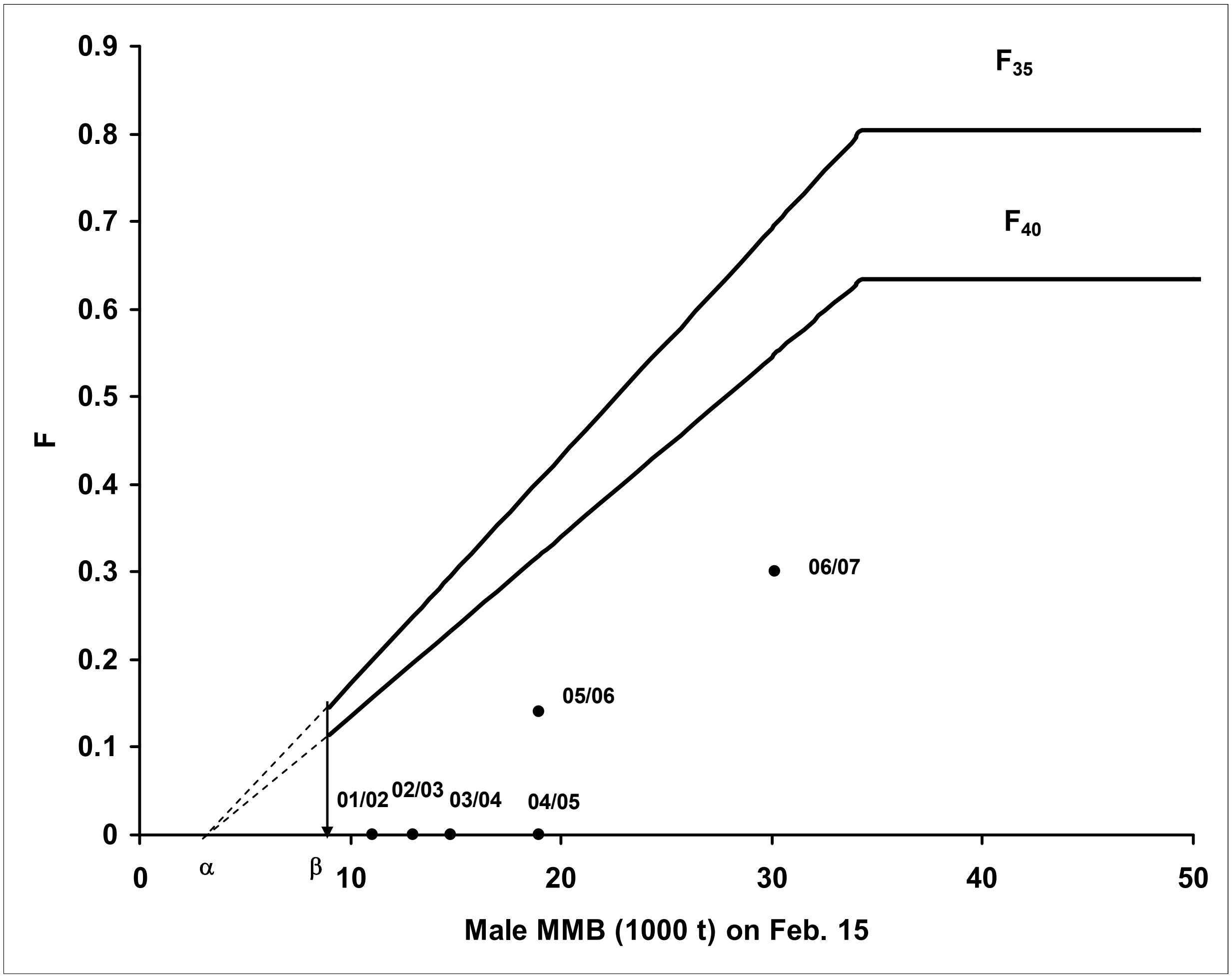

Figure 6-4 Relationship between legal male F and mature male biomass (MMB) on February 15 for EBS Tanner crab. The MMB estimates were based on Bristol Bay stock parameters. $F_{35\%}$ and $F_{40\%}$ control rules are included. The filled circles are F values for respective fishing seasons, 2001/2002 – 2005/2006.

6.3.2 Evaluation of Alternatives with short-term and long-term performance statistics

6.3.2.1 Tier 3 assumption

To evaluate the impacts of the alternatives on EBS Tanner crab, assuming Bristol Bay stock assessment parameters were valid for the whole EBS stock, eleven harvest strategy scenarios were investigated to predict the changes in stock abundance levels under various harvest rates. For Alternative 1, two harvest control rules were simulated to predict the possible effects of this alternative on stock biomass; the status quo harvest strategy and fishing at the status quo OFL. For Alternatives 2 and 3, an evaluation was made of Tier 2 to 5 control rules. For analytical purposes, additional scenarios considered included a flat F_{MSY} (i.e., constant F_{MSY}), flat $F_{35\%}$, F = M, and F = 0 control rules.

The status quo harvest strategy was simulated following the criteria in 5 AAC 35.508. Fishing at the Alternative 1 OFL control rule for Tanner crab was simulated using the following formula:
Sustainable yield = 0.3* total survey mature biomass (male + female).

Table 6-1 lists the results of performance statistics for short-term (30 years) fishery simulations with initial MMB equal to 50% B_{MSY}. Eleven control rule scenarios were investigated: Tier 2 with the F_{MSY}, Tier 3 with $F_{35\%}$ and $F_{40\%}$, Tier 4 with 2.85 timesM, Tier 5 with mean ctach, the status quo harvest strategy, fishing at the status quo OFL control rule, Flat F_{MSY}, Flat $F_{35\%}$, F = M, and F = 0 control rules. For the status quo OFL control rule and the status quo harvest strategy, the abundances were estimated at the survey time using survey selectivity, and harvest rates were applied to molting MMB estimates at the time of the survey.

Tier 2 with F_{MSY} and Tier 3 with $F_{35\%}$ produced higher mean retained yield and resulted in higher biomass relative to B_{MSY} on the 30th year, as well as higher first 10-year and subsequent 20-year mean retained yields. The Tier 4 harvest strategy produced in between Tier 3 with $F_{35\%}$ and with $F_{40\%}$ performance. Thus, for Tanner crab with a male M of 0.23, a γ value as high as 2.85 is reasonable. Tier 5 control rule produced mixed results, higher 30th year relative MMB, but lower long-term yield . The status quo harvest strategy was satisfactory, with performance slightly lower, but 30th year relative MMB much higher to $F_{40\%}$. However, the simulation procedure for application of the status quo harvest strategy was an approximation to the actual procedure being followed by the State. The status quo OFL control rule produced low mean number of recruits, much higher overfished and fishery closure percents, and much lower 30th year relative MMB compared to those for Tier 2 control rule. The stock did not rebuild during this time period under the status quo OFL control rule. Flat F_{MSY} and Flat $F_{35\%}$ performed unsatisfactorily compared to the sliding scale counterparts with higher overfished and fishery closure percents, and lower 30 th year relative MMB.

Table 6-2 provides the same performance statistics for the short-term (30 years) fishery when the initial MMB was set to B_{MSY}. The performance statistics patterns were similar, compared to those under 50% B_{MSY} initial biomass. The OFL control rule produced very low mean recruitment and very low 30th year relative MMBcompared to those under Tier 2 control rule while the initial MMB was set to B_{MSY}.

Table 6-2 provides the same performance statistics for the long-term (100 years) fishery when the initial biomass was set to 50% B_{MSY}. The retained yield under Tier 3 control rule with $F_{35\%}$ was much closer to that of Tier 2 control rule with F_{MSY}. The long-term projection of biomass exceeded the B_{MSY} level more than under Tier 2 control rule, suggesting that $F_{35\%}$ was a good choice as a proxy for F_{MSY}. The Tier 4 control rule with 2.85M performed well except it produced slightly lower retained yield compared to the F_{MSY} level. Thus a γ value up to 2.85 is reasonable for data poor Tanner crab stocks. Tier 5 control rule produced higher 100th year relative MMB, but lower long-term retained yield and higher fishery closer percent compared to the Tier 2 control rule.

Table 6-3 provides the same performance statistics for the long-term (100 years) fishery when the initial MMB was set to B_{MSY}. The performance statistics patterns were similar, but the mean yields were higher compared to those under 50% B_{MSY} initial biomass. The status quo OFL control rule produced very low mean recruitment and very low 100th year relative MMB compared to those under Tier 2 control rule at this initial biomass level.

The F = 0 scenarios in Table 6-1 through Table 6-4provide the trawl fishery yields under varying biomass levels. The rebuilding time and terminal relative MMB under other tiers can be compared with the virgin level estimates. In particular, the OFL harvest control rules produced much lower final (30th or 100th) year relative MMB than that obtained at the virgin level.

6.3.2.2 Tier 4 assumption

To evaluate the impacts of the alternatives on EBS Tanner crab, when stock-recruitment and biological parameters necessary for Tier 2 and Tier 3 analyses were not available (i.e., the Bristol Bay assessment parameters were not strictly applicable to the whole EBS Tanner crab stock), Tier 4 approach was made to investigate alternatives for EBS Tanner crab stock. Eight control rule scenarios were investigated to predict the changes in stock abundance levels under various harvest rates. For Alternative 1, two harvest control rules were simulated to predict the possible effects of this alternative on stock biomass; the status quo harvest strategy and fishing at the status quo OFL. For Alternatives 2 and 3, evaluations were made of Tier 4 control rule with γM, where $\gamma = 2.85$, and of Tier 5 control rule with mean catch. For analytical purposes, additional scenarios considered included a flat γM (i.e., constant γM), $F = 2M$, $F = M$, and $F = 0$ control rules.

The status quo harvest strategy was simulated following the criteria in 5 AAC 35.508. Fishing at the Alternative 1 OFL control rule for Tanner crab was simulated using the following formula:

Sustainable yield = 0.3* total survey mature biomass (male + female).

For the status quo OFL control rule and the status quo harvest strategy, the abundances were estimated at the survey time using survey selectivity, and harvest rates were applied to molting MMB estimates at the time of the survey.

Table 6-5 lists the results of performance statistics for short-term (30 years) fishery simulations with initial MMB equal to 50% B_{MSY}. The status quo harvest strategy produced slightly lower mean retained yield, equal rebuilding time, slightly higher overfished proportion, higher fishery closure proportion, and much higher MMB relative to B_{MSY} on the 30th year than the Tier 4 control rule with γM. The Tier 5 control rule produced lower retained yield, higher fishery closure percent, and higher 30th year relative MMB. The status quo OFL control rule produced low mean number of recruits, much higher overfished and fishery closure percents, and much lower 30th year relative MMB compared to those for Tier 4 control rule with γM. The stock did not rebuild during this time period under the status quo OFL control rule. Flat γM performed satisfactorily on yields, but unsatisfactorily on other performance statistics (rebuilding, overfishing, fishery closure, final year MMB ratio) than the other sliding scale control rules.

Table 6-6 provides the same performance statistics for the short-term (30 years) fishery when the initial MMB was set to B_{MSY}. The performance statistics patterns were similar, but the mean yields were higher compared to those under 50% B_{MSY} initial biomass. The OFL control rule produced low mean recruitment and low 30th year relative MMBcompared to those under Tier 4 control rule while the initial MMB was set to B_{MSY}.

Table 6-7 provides the same performance statistics for the long-term (100 years) fishery when the initial biomass was set to 50% B_{MSY}. The mean retained yield under status quo control rule was little lower than that of the Tier 4 control rule with γM. The long-term projection of MMB exceeded the B_{MSY} level for all control rules except the flat Tier 4 and status quo OFL control rules. The status quo OFL control rule produced the lowest 100th year relative MMB and the stock did not rebuild.

Table 6-8 provides the same performance statistics for the long-term (100 years) fishery when the initial MMB was set to B_{MSY}. The performance statistics patterns were similar, but the mean yields were higher compared to those under 50% B_{MSY} initial MMB. The performance of the status quo OFL control rule was again unsatisfactory at this initial biomass level.

The F = 0 scenarios in Table 6-5 through Table 6-8 provide the trawl fishery yieldsunder varying biomass levels. The rebuilding time and terminal relative MMB under other tiers can be compared with the virgin level estimates. In particular, the OFL harvest control rules produced much lower final (30^{th} or 100^{th}) year relative MMB than that obtained at the virgin level.

Table 6-1 Short-term rebuilding simulations for various control rules for EBS Tanner crab under Tier 3 scenario. Mean and median were estimated from 1000 simulations of a 30-year fishery with an initial mature male biomass of 50% B_{MSY} with biomass observation error and harvest implementation error. All estimates are given as proportions relative to column 2 values. B = total mature male biomass, B_{MSY} = total MSY mature male biomass, CV = coefficient of variation, and NR = not rebuilt.

Harvest Control Rule (CR)	Tier 2 Limit (F_{MSY} CR)	Tier 3 Limit $F_{35\%}$ CR)	Tier 3 ($F_{40\%}$ CR)	Tier 4 (F=2.85*M CR)	Tier 5 Limit (Mean Catch)	Status quo Harvest CR	Status quo OFL CR	Flat F_{MSY}	Flat F_{35}	F=M CR	F=0
Mean recruit no. (millions)	86.58	1.01	1.03	1.02	0.97	1.03	0.53	0.89	0.90	1.05	1.01
Mean total yield (t)	12001	0.99	0.92	0.93	0.62	0.88	1.01	0.96	0.95	0.61	0.24
Mean retained yield (t)	7535	0.99	0.91	0.92	0.50	0.85	0.84	0.93	0.92	0.51	0.00
Mean mature male biomass (t)	28731	1.03	1.14	1.11	1.25	1.30	0.34	0.78	0.81	1.56	2.02
Mean mature female biomass (t)	34284	1.01	1.04	1.03	1.00	1.13	0.56	0.90	0.91	1.10	1.11
Mean F	0.61	0.95	0.79	0.82	0.74	0.74	5.28	1.38	1.31	0.33	0.00
Rebuilding time (y)[a]	10	1.00	0.90	0.90	0.90	0.80	NR	1.70	1.60	0.70	0.60
Years B<B_{msy} (%)[b]	68.73	0.97	0.86	0.89	0.82	0.74	1.44	1.20	1.17	0.55	0.38
Years overfished (%)[c]	14.76	0.91	0.69	0.75	1.26	0.68	5.91	2.36	2.21	0.35	0.25
Years fishery closed (%)[d]	0.27	0.67	0.67	0.67	7.67	0.67	152.00	10.33	8.67	0.33	0.33
30th year biomass ratio (%)[e]	104	1.04	1.16	1.13	1.50	1.45	0.20	0.77	0.80	1.70	2.22
First 10-yr mean retained yield (t)	5475	0.97	0.85	0.88	0.68	0.85	1.53	1.12	1.10	0.43	0.00
CV first 10-yr mean retained yield	0.73	1.01	1.01	1.00	0.21	0.73	0.60	0.71	0.71	1.00	0.00
Next 20-yr mean retained yield (t)	8565	0.99	0.93	0.93	0.45	0.85	0.62	0.87	0.87	0.54	0.00
CV next 20-yr mean retained yield	0.41	0.98	0.95	0.95	0.22	0.80	1.27	1.02	1.00	0.80	0.00

[a]Median number of years taken for mature male biomass to reach MSY mature male biomass for the first time
[b]Mean percent of years in a 30-year fishery the mature male biomass < MSY mature male biomass
[c]Mean percent of years in a 30-year fishery the mature male biomass < 50% MSY mature male biomass
[d]Mean percent of years in a 30-year fishery the mature male biomass < 25% MSY mature male biomass
[e]Mean percent of 30th year mature male biomass relative to MSY mature male biomass

Table 6-2 Short-term rebuilding simulations under various control rules for EBS Tanner crab under Tier 3 scenario. Mean and median were estimated from 1000 simulations of a 30-year fishery with an initial mature male biomass of B_{MSY} with biomass observation error and harvest implementation error. All estimates are given as proportions relative to column 2 values. B = total mature male biomass, B_{MSY} = total MSY mature male biomass, and CV = coefficient of variation.

Harvest Control Rule (CR)	Tier 2 Limit (F_{msy} CR)	Tier 3 Limit ($F_{35\%}$ CR)	Tier 3 ($F_{40\%}$ CR)	Tier 4 (F=2.85 *M CR)	Tier 5 Limit (Mean Catch)	Status quo Harvest CR	Status quo OFL CR	Flat F_{msy}	Flat F_{35}	F=M CR	F=0
Mean recruit no. (millions)	91.28	1.01	1.02	1.02	1.01	1.03	0.64	0.95	0.96	1.03	0.97
Mean total yield (t)	14503	0.99	0.91	0.93	0.54	0.86	1.19	1.00	0.99	0.59	0.23
Mean retained yield (t)	9091	0.98	0.90	0.92	0.42	0.84	1.02	0.99	0.97	0.50	0.00
Mean mature male biomass (t)	32690	1.03	1.14	1.11	1.54	1.38	0.42	0.89	0.92	1.57	2.03
Mean mature female biomass (t)	39976	1.01	1.03	1.03	1.06	1.14	0.65	0.96	0.97	1.08	1.07
Mean F	0.70	0.94	0.77	0.81	0.39	0.64	4.60	1.20	1.14	0.31	0.00
Years $B<B_{msy}$ (%)[a]	58.0	0.95	0.81	0.84	0.48	0.55	1.66	1.14	1.11	0.39	0.19
Years overfished (%)[b]	6.83	0.85	0.54	0.62	0.40	0.28	9.78	2.28	2.07	0.12	0.07
Years fishery closed (%)[c]	0.05	0	0	0	0.2	0	28.2	0.8	0.6	0	0
30th year biomass ratio (%)[d]	104	1.04	1.17	1.14	1.65	1.47	0.24	0.94	0.95	1.69	2.18
First 10-yr mean retained yield (t)	9218	0.97	0.86	0.88	0.41	0.77	1.55	1.05	1.02	0.43	0.00
CV first 10-yr mean retained yield	0.52	1.02	1.02	1.02	0.23	0.92	0.69	0.88	0.88	1.04	0.00
Next 20-yr mean retained yield (t)	9028	0.99	0.92	0.93	0.42	0.88	0.75	0.95	0.95	0.53	0.00
CV next 20-yr mean retained yield	0.39	1.00	0.95	0.95	0.21	0.79	1.23	0.97	0.95	0.79	0.00

aMean percent of years in a 30-year fishery the mature male biomass < MSY mature male biomass
[b]Mean percent of years in a 30-year fishery the mature male biomass < 50% MSY mature male biomass
[c]Mean percent of years in a 30-year fishery the mature male biomass < 25% MSY mature male biomass
[d]Mean percent of 30th year mature male biomass relative to MSY mature male biomass

Table 6-3 Long-term rebuilding simulations under various control rules for EBS Tanner crab under Tier 3 scenario. Mean and median were estimated from 1000 simulations of a 100-year fishery with an initial mature male biomass of 50% B_{MSY} with biomass observation error and harvest implementation error. All estimates are given as proportions relative to column 2 values. B = total mature male biomass, and B_{MSY} = total MSY mature male biomass.

Harvest Control Rule (CR)	Tier 2 Limit (F_{msy} CR)	Tier 3 Limit ($F_{35\%}$ CR)	Tier 3 ($F_{40\%}$ CR)	Tier 4 (F=2.85CR)	Tier 5 Limit (Mean Catch)	Status quo Harvest CR	Status quo OFL CR	Flat F_{msy}	Flat F_{35}	F=M CR	F=0
Mean recruit no. (millions)	89.16	1.01	1.03	1.02	0.99	1.04	0.32	0.89	0.91	1.04	0.98
Mean total yield (t)	13341	0.99	0.93	0.94	0.57	0.90	0.52	0.92	0.92	0.62	0.24
Mean retained yield (t)	8409	0.99	0.92	0.93	0.45	0.88	0.43	0.89	0.90	0.53	0.00
Mean mature male biomass (t)	31058	1.03	1.15	1.13	1.49	1.41	0.18	0.78	0.82	1.64	2.14
Mean mature female biomass (t)	36942	1.01	1.05	1.04	1.04	1.16	0.30	0.88	0.90	1.10	1.08
Mean F	0.65	0.95	0.80	0.83	0.52	0.69	4.95	1.29	1.23	0.32	0.00
Rebuilding time (y)[a]	10	0.90	0.90	0.90	0.90	0.80	NR	1.70	1.60	0.70	0.60
Years B<B_{msy} (%)[b]	62.78	0.96	0.81	0.85	0.60	0.58	1.59	1.23	1.20	0.40	0.22
Years overfished (%)[c]	10.52	0.86	0.58	0.66	0.90	0.43	9.06	2.91	2.64	0.19	0.13
Years fishery closed (%)[d]	0.12	0.00	0.00	0.00	14.00	0.00	762.00	33.00	26.00	0.00	0.00
100th year biomass ratio (%)[e]	104	1.04	1.16	1.13	1.61	1.46	0.07	0.94	0.95	1.67	2.19

[a]Median number of years taken for mature male biomass to reach MSY mature male biomass for the first time
[b]Mean percent of years in a 100-year fishery the mature male biomass < MSY mature male biomass
[c]Mean percent of years in a 100-year fishery the mature male biomass < 50% MSY mature male biomass
[d]Mean percent of years in a 100-year fishery the mature male biomass < 25% MSY mature male biomass
[e]Mean percent of 100th year mature male biomass relative to MSY mature male biomass

Table 6-4 Long-term rebuilding simulations under various control rules for EBS Tanner crab under Tier 3 scenario. Mean and median were estimated from 1000 simulations of a 100-year fishery with an initial mature male biomass of B_{MSY} with biomass observation error and harvest implementation error. All estimates are given as proportions relative to column 2 values. B = total mature male biomass, and B_{MSY} = total MSY mature male biomass.

Harvest Control Rule (CR)	Tier 2 Limit (F_{msy} CR)	Tier 3 Limit ($F_{35\%}$ CR)	Tier 3 ($F_{40\%}$ CR)	Tier 4 (F=2.85*M CR)	Tier 5 Limit (Mean Catch)	Status quo Harvest CR	Status quo OFL CR	Flat F_{msy}	Flat F_{35}	F=M CR	F=0
Mean recruit no. (millions)	90.55	1.01	1.03	1.02	1.00	1.04	0.37	0.91	0.93	1.03	0.97
Mean total yield (t)	14085	0.99	0.93	0.94	0.55	0.89	0.64	0.94	0.94	0.62	0.23
Mean retained yield (t)	8871	0.99	0.92	0.93	0.43	0.87	0.53	0.92	0.92	0.53	0.00
Mean mature male biomass (t)	32235	1.03	1.15	1.13	1.59	1.43	0.22	0.82	0.86	1.64	2.13
Mean mature female biomass (t)	38633	1.01	1.04	1.04	1.06	1.16	0.36	0.91	0.92	1.10	1.07
Mean F	0.68	0.96	0.79	0.82	0.40	0.66	4.74	1.24	1.18	0.32	0.00
Years $B<B_{msy}$ (%)[a]	59.44	0.95	0.80	0.83	0.46	0.52	1.66	1.22	1.18	0.35	0.15
Years overfished (%)[b]	8.25	0.85	0.52	0.61	0.48	0.27	10.76	2.94	2.62	0.10	0.06
Years fishery closed (%)[c]	0.07	0.00	0.00	0.00	4.00	0.00	689.00	23.00	18.00	0.00	0.00
100th year biomass ratio (%)[d]	104	1.04	1.16	1.13	1.62	1.46	0.08	0.94	0.95	1.67	2.19

[a]Mean percent of years in a 100-year fishery the mature male biomass < MSY mature male biomass
[b]Mean percent of years in a 100-year fishery the mature male biomass < 50% MSY mature male biomass
[c]Mean percent of years in a 100-year fishery the mature male biomass < 25% MSY mature male biomass
[d]Mean percent of 100th year mature male biomass relative to MSY mature male biomass

Table 6-5 Short-term rebuilding simulations for various control rules for EBS Tanner crab under Tier 4 scenario. Mean and median were estimated from 1000 simulations of a 30-year fishery with an initial mature male biomass of 50% B_{MSY} with biomass observation error. All estimates are given as proportions relative to column 2 values. B = total mature male biomass, B_{MSY} = total MSY mature male biomass, CV = coefficient of variation, and NR = not rebuilt.

Harvest Control Rule (CR)	Tier 4 (F=γ*M CR) γ=2.85	Tier 5 Limit (Mean Catch)	Status quo Harvest CR	Status quo OFL CR	Flat F=γ*M	F=2M CR	F=M CR	F=0
Mean recruit no. (millions)	89.96	0.93	0.99	0.51	0.92	1.01	1.01	0.97
Mean total yield (t)	11115	0.67	0.95	1.09	0.98	0.88	0.65	0.26
Mean retained yield (t)	6901	0.55	0.93	0.91	0.97	0.85	0.54	0.00
Mean mature male biomass (t)	33587	1.07	1.11	0.29	0.79	1.13	1.36	1.73
Mean mature female biomass (t)	35914	0.96	1.08	0.54	0.91	1.03	1.05	1.06
Mean F	0.46	0.98	0.98	7.00	1.43	0.74	0.39	0.00
Rebuilding time (y)[a]	11	1.18	1.00	NR	1.73	0.82	0.73	0.64
Years B<B_{msy} (%)[b]	69.97	0.94	0.89	1.42	1.18	0.87	0.69	0.49
Years overfished (%)[c]	18.80	1.53	1.01	4.96	2.04	0.78	0.56	0.43
Years fishery closed (%)[d]	0.52	8.60	1.60	115.00	6.80	0.80	0.60	0.40
30th year biomass ratio (%)[e]	103	1.25	1.21	0.17	0.81	1.16	1.44	1.85
First 10-yr mean retained yield (t)	4556	0.81	1.02	1.83	1.20	0.80	0.48	0.00
CV first 10-yr mean retained yield	0.81	0.19	0.65	0.54	0.65	0.99	0.99	0.00
Next 20-yr mean retained yield (t)	8073	0.48	0.90	0.65	0.90	0.86	0.56	0.00
CV next 20-yr mean retained yield	0.40	0.23	0.83	1.30	0.98	0.93	0.85	0.00

[a]Median number of years taken for mature male biomass to reach MSY mature male biomass for the first time
[b]Mean percent of years in a 30-year fishery the mature male biomass < MSY mature male biomass
[c]Mean percent of years in a 30-year fishery the mature male biomass < 50% MSY mature male biomass
[d]Mean percent of years in a 30-year fishery the mature male biomass < 25% MSY mature male biomass
[e]Mean percent of 30th year mature male biomass relative to MSY mature male biomass

Table 6-6 Short-term rebuilding simulations for various control rules for EBS Tanner crab under Tier 4 scenario. Mean and median were estimated from 1000 simulations of a 30-year fishery with an initial mature male biomass of B_{MSY} with biomass observation error. All estimates are given as proportions relative to column 2 values. B = total mature male biomass, B_{MSY} = total MSY mature male biomass, CV = coefficient of variation, and NR = not rebuilt.

Harvest Control Rule (CR)	Tier 4 (F=γ*M CR) γ=2.85	Tier 5 Limit (Mean Catch)	Status quo Harvest CR	Status quo OFL CR	Flat F=γ*M	F=2M CR	F=M CR	F=0
Mean recruit no. (millions)	94.02	0.98	1.00	0.62	0.96	1.01	1.00	0.94
Mean total yield (t)	13266	0.59	0.94	1.30	1.02	0.87	0.64	0.25
Mean retained yield (t)	8245	0.46	0.93	1.13	1.01	0.85	0.54	0.00
Mean mature male biomass (t)	37938	1.32	1.19	0.36	0.89	1.13	1.37	1.75
Mean mature female biomass (t)	41551	1.02	1.10	0.63	0.97	1.02	1.04	1.03
Mean F	0.52	0.52	0.87	6.19	1.27	0.75	0.40	0.00
Years B<B_{msy} (%)[a]	62.12	0.68	0.78	1.58	1.14	0.83	0.59	0.35
Years overfished (%)[b]	8.03	0.69	0.63	9.61	2.11	0.60	0.26	0.13
Years fishery closed (%)[c]	0.08	4.00	1.00	382.00	7.00	1.00	1.00	1.00
30th year biomass ratio (%)[d]	103	1.38	1.23	0.20	0.95	1.16	1.44	1.83
First 10-yr mean retained yield (t)	7820	0.48	0.91	1.83	1.08	0.81	0.49	0.00
CV first 10-yr mean retained yield	0.57	0.21	0.84	0.63	0.84	1.02	1.02	0.00
Next 20-yr mean retained yield (t)	8458	0.45	0.93	0.80	0.98	0.86	0.56	0.00
CV next 20-yr mean retained yield	0.38	0.21	0.82	1.26	0.95	0.95	0.84	0.00

[a]Mean percent of years in a 30-year fishery the mature male biomass < MSY mature male biomass
[b]Mean percent of years in a 30-year fishery the mature male biomass < 50% MSY mature male biomass
[c]Mean percent of years in a 30-year fishery the mature male biomass < 25% MSY mature male biomass
[d]Mean percent of 30th year mature male biomass relative to MSY mature male biomass

Table 6-7 Long-term rebuilding simulations for various control rules for EBS Tanner crab under Tier 4 scenario. Mean and median were estimated from 1000 simulations of a 100-year fishery with an initial mature male biomass of 50% B_{MSY} with biomass observation error. All estimates are given as proportions relative to column 2 values. B = total mature male biomass, B_{MSY} = total MSY mature male biomass, CV = coefficient of variation, and NR = not rebuilt.

Harvest Control Rule (CR)	Tier 4 (F=γ*M CR) γ=2.85	Tier 5 Limit (Mean Catch)	Status quo Harvest CR	Status quo OFL CR	Flat F=γ*M	F=2M CR	F=M CR	F=0
Mean recruit no. (millions)	92.58	0.95	1.00	0.30	0.93	1.01	1.00	0.94
Mean total yield (t)	12566	0.60	0.95	0.56	0.96	0.89	0.66	0.25
Mean retained yield (t)	7862	0.48	0.94	0.46	0.95	0.86	0.56	0.00
Mean mature male biomass (t)	36768	1.26	1.19	0.15	0.81	1.15	1.41	1.80
Mean mature female biomass (t)	39034	0.98	1.10	0.29	0.92	1.03	1.05	1.02
Mean F	0.50	0.68	0.90	6.44	1.32	0.76	0.40	0.00
Rebuilding time (y)[a]	11	1.18	1.00	NR	1.55	0.91	0.73	0.64
Years $B<B_{msy}$ (%)[b]	63.89	0.76	0.79	1.56	1.19	0.83	0.58	0.34
Years overfished (%)[c]	12.12	1.23	0.79	8.05	2.39	0.66	0.37	0.25
Years fishery closed (%)[d]	0.21	12.00	1.50	411.50	12.00	0.50	0.50	0.50
100th year biomass ratio (%)[e]	102	1.36	1.24	0.06	0.96	1.16	1.43	1.85

[a]Median number of years taken for mature male biomass to reach MSY mature male biomass for the first time
[b]Mean percent of years in a 100-year fishery the mature male biomass < MSY mature male biomass
[c]Mean percent of years in a 100-year fishery the mature male biomass < 50% MSY mature male biomass
[d]Mean percent of years in a 100-year fishery the mature male biomass < 25% MSY mature male biomass
[e]Mean percent of 100th year mature male biomass relative to MSY mature male biomass

Table 6-8 Long-term rebuilding simulations for various control rules for EBS Tanner crab under Tier 4 scenario. Mean and median were estimated from 1000 simulations of a 100-year fishery with an initial mature male biomass of B_{MSY} with biomass observation error. All estimates are given as proportions relative to column 2 values. B = total mature male biomass, B_{MSY} = total MSY mature male biomass, CV = coefficient of variation, and NR = not rebuilt.

Harvest Control Rule (CR)	Tier 4 (F=γ*M CR) γ=2.85	Tier 5 Limit (Mean Catch)	Status quo Harvest CR	Status quo OFL CR	Flat F=γ*M	F=2M CR	F=M CR	F=0
Mean recruit no. (millions)	93.77	0.97	1.00	0.36	0.95	1.01	1.00	0.93
Mean total yield (t)	13202	0.59	0.95	0.68	0.98	0.88	0.65	0.25
Mean retained yield (t)	8260	0.46	0.94	0.57	0.97	0.86	0.56	0.00
Mean mature male biomass (t)	38051	1.35	1.21	0.19	0.85	1.15	1.41	1.81
Mean mature female biomass (t)	40695	1.01	1.10	0.34	0.94	1.03	1.04	1.01
Mean F	0.52	0.52	0.87	6.19	1.27	0.75	0.40	0.00
Years B<B_{msy} (%)[a]	61.43	0.65	0.75	1.62	1.18	0.81	0.54	0.29
Years overfished (%)[b]	8.96	0.79	0.60	10.23	2.44	0.57	0.23	0.12
Years fishery closed (%)[c]	0.10	7.00	1.00	750.00	15.00	1.00	1.00	1.00
100th year biomass ratio (%)[d]	102	1.36	1.24	0.07	0.96	1.16	1.43	1.85

[a]Mean percent of years in a 100-year fishery the mature male biomass < MSY mature male biomass
[b]Mean percent of years in a 100-year fishery the mature male biomass < 50% MSY mature male biomass
[c]Mean percent of years in a 100-year fishery the mature male biomass < 25% MSY mature male biomass
[d]Mean percent of 100th year mature male biomass relative to MSY mature male biomass

6.4 Effects on Aleutian Islands Tanner crabs

Under the Alternative 2 and 3 tier system, EAI Tanner crab stock would be under Tier 4 because B_{MSY} proxy estimates are available (Figure 6-5 and Figure 6-6). For this analysis, average mature biomass (>114 mm CW) from 1990 to 2006 was used as a proxy for EAI Tanner crab. No survey data are available for this stock during the other years. The current stock status is above its B_{MSY} proxy. Historical comparison of stock status shows that the stock was below the MSST proxy in 1990, 1994 and 1995.

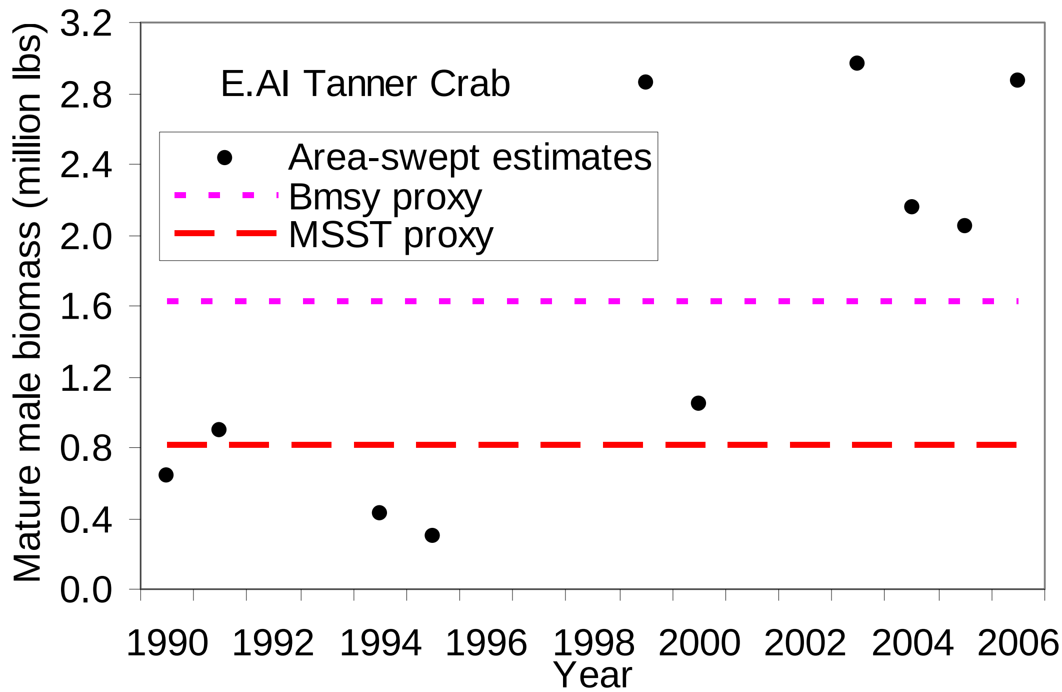

Figure 6-5 EAI Tanner crab estimated mature male biomass compared to the B_{MSY} proxy and MSST proxy proposed in Tier 4 under Alternatives 2 and 3.

No other survey data from which abundance can be directly estimated are available. Historical comparison of stock status shows that the stock was below the MSST proxy in all years prior to 1999 for which trawl survey data are available. In examining Figure 6-5, it should be noted that the area surveyed by the ADF&G trawl survey (and the area for which abundance estimates are made) has contracted during 1990-2005. It should also be noted that areas sampled by the ADF&G trawl survey have been almost exclusively inside of state waters, consistent with the historic distribution of the fishery.

Under Alternative 2, WAI Tanner crab is suggested for management as a Tier 5 stock. Based on fishing effort data, the appropriate period for catch average may be 1985 to 1992 because these are the years the fishery occurred. The average yield during that period is 76,700 pounds. If the OFL was established for this stock based upon the use of average yield over this time period, the OFL would be 76,700 pounds.

Under Alternative 3, WAI Tanner crab is suggested for management as a Tier 6 stock due to lack of available information. No stock assessment surveys are conducted for WAI Tanner crab; thus no population estimates are available and stock status is currently unknown. For WAI Tanner crab, bycatch data are available from the directed red king crab fishery. No catch has occurred since 1997. Under Tier 6, a default OFL would be set at zero for retained catch of WAI Tanner crabs.

Under Option A, the AI Tanner crab stocks would be removed from the FMP and exclusively managed by the State. The EAI Tanner crab fisheries are essentially state-waters fisheries because 93% of landings from 1985 to 2006 were in state-waters statistical areas. The State has closed the WAI Tanner crab fishery since the 1996/97 season because of insufficient information to develop a GHL or to establish that a harvestable surplus exists. The effects of removing these stocks from the FMP on the stocks themselves would be negligible because this action would not change their management. The State provides all of the management functions for these fisheries.

ADF&G is proposing a regulatory harvest strategy for the Eastern Aleutian District Tanner crab fishery to the Alaska Board of Fisheries for consideration at their March 2008 meeting. ADF&G is also proposing a regulation establishing the Akutan, Unalaska/Kaletka Bay, Makushin/Skan Bay, and General Sections within the Eastern Aleutian District as a companion to the harvest strategy proposal. The harvest strategy to be proposed for regulation is that which has been used to manage the fishery since 2004. Under that harvest strategy, GHLs for individual surveyed bays have been established on the basis of preseason estimates of the "mature male abundance" (MMA = abundance of males >114-mm CW), "molting mature male abundance" (MMMA = 100% of newshell and 15% of oldshell males >114-mm CW) for the bay. The proposed harvest strategy would establish a threshold for opening the commercial fishery in a section, defined as 50% of the average MMA in the section for the period 1990-2000. When the current estimate of MMA in the section is below the MMA threshold level, the bay is closed to commercial fishing. When the current estimate of MMA in the section is above the MMA threshold level but below the average MMA for the period 1990-2000, the section is open to commercial fishing with a GHL computed using a 10% harvest rate on the MMMA in the section and a maximum 30% harvest rate on legal-sized males. When the current estimate of MMA in the section exceeds the average MMA for the period 1990-2000, the section is open to commercial fishing with a GHL computed using a 20% harvest rate on the MMMA in the section and a maximum 30% harvest rate on legal-sized males. Under the proposed harvest strategy, a minimum computed GHL of 35,000 is necessary to open a section to commercial fishing to assure manageability of the fishery under pot limits currently in regulation for the Eastern Aleutians District (maximum of 300 pots for the entire fleet with no more than 50 pots per vessel; 5 AAC 35.525 (c) (5)).

Harvest of Tanner crabs from the Western Aleutian District has, in general, been incidental to the directed red king crab fishery in that area. Commercial harvests have ranged from a high of 839 thousand pounds (381 t) during the 1981/82 season to 8 thousand pounds in the 1991/1992 season, with the most of the harvest from the state waters within a few bays in the vicinity of Adak and Atka Islands (Bush et al. 2005). No landings were reported from the 1993/94 and 1994/95 seasons and the State has closed the fishery since the 1996/97 season because of insufficient information to develop a GHL or to establish that a harvestable surplus exists (Bush et al. 2005).

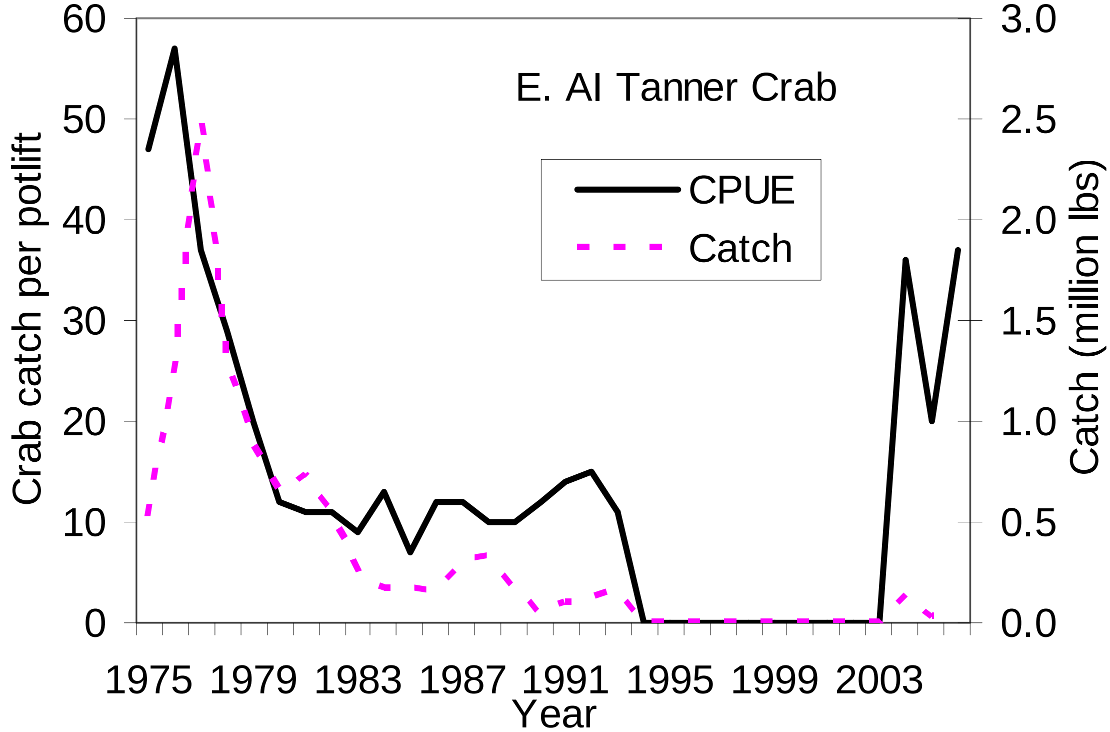

Figure 6-6 Catch and catch per pot lift for eastern Aleutian Islands Tanner crab.

7 Blue King Crab (*Paralithodes platypus*)

Three stocks of blue king crab are managed under this FMP, the Pribilof Islands stock, the St. Matthew Islands stock, and the St. Lawrence stock. Of these, both the St. Matthew blue king crab and Pribilof Islands blue king crab stocks are under rebuilding plans following overfished determinations in 1999 and 2002, respectively. This Chapter reviews the stock status and biological parameters relevant to overfishing definitions for these stocks and provides an overview of specific impacts on the stocks from the three alternatives under consideration in this analysis.

7.1 Blue king crab stock status

This section examines relevant and recent biological information necessary to understand the status of the blue king crab stocks and the overfishing definitions.

Pribilof Islands blue king crab

This stock is annually surveyed by NMFS. Based on survey biomass estimates, the stock remains in "overfished" condition for the fifth year in a row. A rebuilding plan was implemented for this stock in 2002 following an overfished declaration in 2001. The rebuilding plan does not allow for any harvest until the stock is fully rebuilt. This depressed stock continues to show declines with little indications for recovery in the near future. Estimated TMB for 2006 is 1.6-million pounds, the same as in 2005 and at the second lowest on record (Figure 7-1). The ADF&G CSA estimates for abundance of mature males, legal males, and mature females in 2006 are the lowest estimated for the period 1975-2006. A continued decline in mature male and female abundance should be expected for at least the next two years. Although relatively high numbers of small crab (< 70 mm-CL) were caught, mainly at one haul, during the 2005 trawl survey, there is very little representation of juvenile crabs in the 2006 survey (NPFMC 2006a).

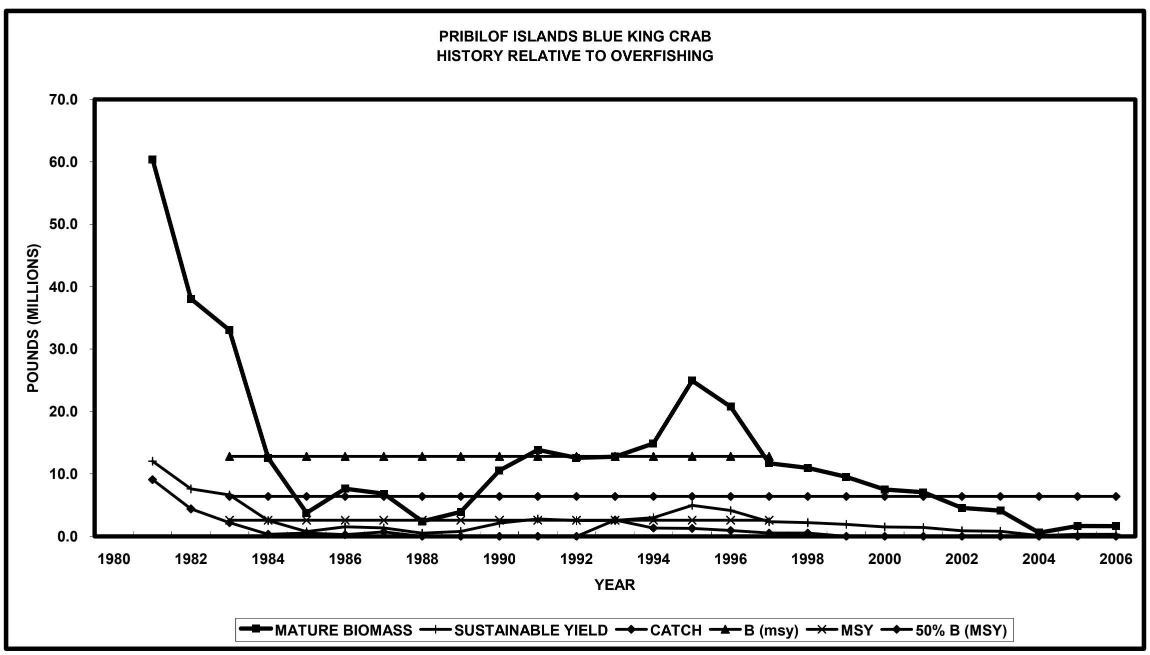

Figure 7-1 Pribilof Islands blue king crab stock status relative to overfishing.

This fishery has been closed since 1999. Because estimated TMB in 2005 was less than the B_{MSY} of 13.2 million pounds (5,987 t), this fishery was closed for the 2006/2007 season under the status quo harvest strategy. Also, the 2006 TMB was less than B_{MSY} and the fishery will remain closed for the 2007/2008 season under the State harvest strategy.

St. Matthew blue king crab

This stock is annually surveyed by NMFS. TMB in 2006 was estimated to be 11.2 million pounds (5,080 t), at its second highest level since the overfished declaration of 1999. A rebuilding plan was implemented for this stock in 2000. The series of annually estimated TMB since 1999 shows at best a slow rate of stock recovery and TMB in 2006 is at approximately ½ the "rebuilt" level of 22.0 million pounds (9,979 t) (Figure 7-2).

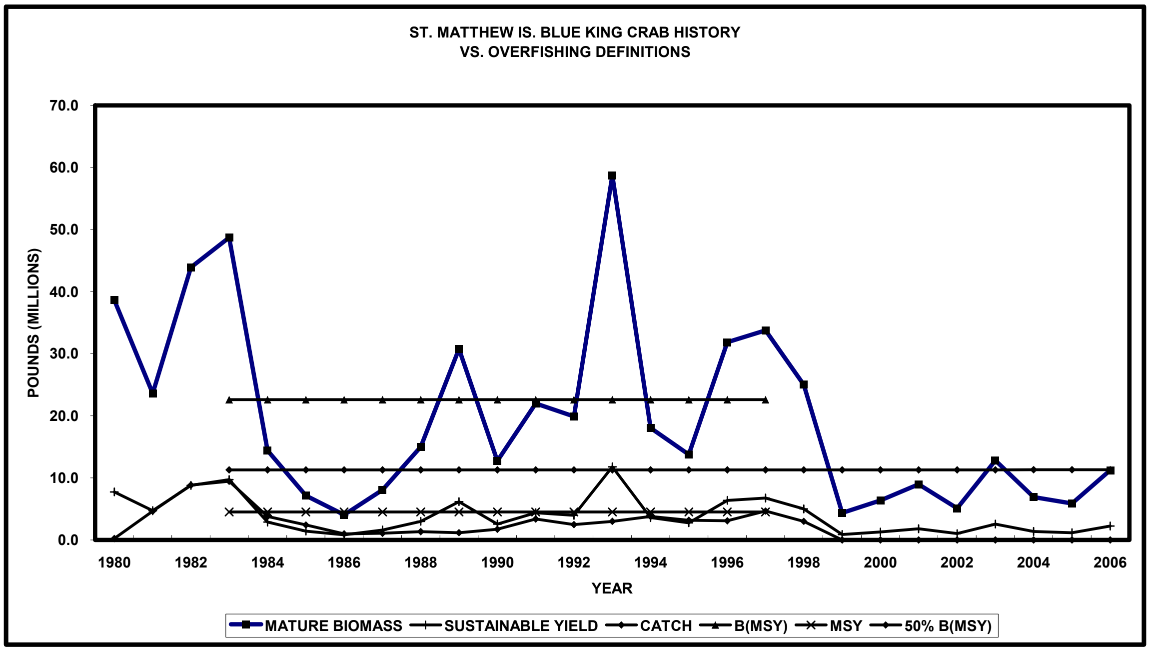

Figure 7-2 St. Matthew blue king crab stock status relative to overfishing.

From all indications, this stock continues to remain at a depressed level, comparable to that of the mid-1980s. Unlike the mid-1980s, however, the stock is in a prolonged period (now in its seventh year) of depressed status. There are some promising indications for the stock in this year's survey data, however. Although low relative to pre-1999 levels, NMFS area-swept estimates of sublegal, mature-sized males (105- to 119-mm CL) and legal-sized males (≥120-mm CL) in 2006 are, at 0.74 million and 1.38 million crabs, both more than twice the estimates for 2005 (0.3 million and 0.6 million crabs, respectively). The current ADF&G CSA estimate of the mature-sized male abundance shows the first signs of improvement since the marked stock decline observed between the 1998 and 1999 surveys. The mode of small crab (approximately 65- to 70-mm CL) observed in 2003, apparently followed into 2004 (mode near 80- to 85-mm CL) and again into 2005 (mode between 90- to 95-mm CL). In 2006, that mode has apparently provided some recruitment into the mature size class. Males 80- to 104-mm CL that appeared in this year's survey may also provide recruitment in the next 2-3 years (NPFMC 2006a).

Abundance estimates are heavily influenced by the catch in relatively few tows and precision of estimates is generally poor. Bottom temperatures in the survey stations southwest of St. Matthew Island that are important for providing catches of male blue king crab during the trawl survey were much colder in 2006 than in recent years. Bottom temperatures may affect the distribution of blue king crab within the surveyed area and that could affect the susceptibility of crabs to be caught during the survey. Additionally, it's important to note that, although poorly estimated, female blue king crabs are showing no indications of increasing in abundance; NMFS area-swept estimates of female size classes remain low and have declined from an estimate of 1.0-million females in 2003 to 0.4 million female crabs in 2006.

TMB would need to increase nearly double to 22.0 million pounds from the 2006 estimate for the stock to be considered "rebuilt." Data from the 2006 survey do not provide any expectations for such an increase in the near-term future; the estimates from 1999 through 2006 indicate at best only a weakly increasing trend in TMB. The fishery has been closed since 1999.

St. Lawrence blue king crab

This stock is not annually surveyed by NMFS. Little is known about stock status of blue king crab in the St. Lawrence Island region. Commercial harvests in the St. Lawrence have only been reported in four years. The largest of these four was a harvest of 52,557 pounds (24 t) in 1983. This was caught primarily near the southeast shore of St. Lawrence Island (Kohler and Soong 2005). In 1984, regulations were adopted which closed all waters within 10 miles of all inhabited islands in the St. Lawrence Section (St. Lawrence Island, Little Diomede, and King Island). Since that time the other three harvests on record are 984 pounds (0.4 t) in 1989, 53 pounds (0.02 t) in 1992, and 7,913 pounds (3.6 t) in 1995 (Kohler and Soong 2005). This stock is not surveyed and while commercial harvest and sale of blue king crab from near shore during winter are permitted under regulations, there are no reports to ADF&G of commercial sales in recent years (Kohler and Soong 2005).

7.2 Effects on Blue King Crab

Under Alternative 1, both the St. Matthew stock and the Pribilof stock are currently under rebuilding plans following overfished declarations in 1999 and 2002, respectively. These stocks TMB dropped below their MSST, prompting NMFS to declare that the stocks were overfished. The Pribilof District blue king crab fishery has been closed since 1999, and other crab management measures and bycatch closure zones have been enacted. Rebuilding plans for both stocks were implemented with extensive analyses provided in the EA for those amendments regarding the rebuilding strategy and estimated time to stock recovery. See NPFMC 2000 (St. Matthew) and NPFMC 2003 (Pribilof Islands) for more information on the rebuilding plans and subsequent analysis of these stocks. Both stocks will not be rebuilt until biomass is above B_{MSY} for two consecutive years.

The Alternative 1 status determination criteria for Pribilof blue king crab establish a B_{MSY} value of 13.2 million pounds (5,987 t) with an MSST value of 6.6 million pounds (2,994 t). The 2006 estimated TMB from the survey area-swept estimate is 1.6 million pounds (726 t), well below the MSST for this stock (Figure 7-1). The Pribilof stocks remains overfished with no indication of stock recovery.

For St. Matthew blue king crab under Alternative 1, a B_{MSY} of 22 million pounds (9,979 t) was established with an MSST of 11 million pounds (4,990 t). The 2006 estimated TMB for this stock, as measured by the survey area-swept method, is 11.2 million pounds (5,080 t), just slightly above the MSST for this stock (Figure 7-2). With a survey estimate just above MSST, the St. Matthew stock is no longer considered overfished.

Under Alternative 1, the harvest strategy was adopted as part of the rebuilding plan for Pribilof blue king crab in Amendment 17 to the FMP. Note that under rationalization, a TAC and IFQs will only be issued for Pribilof king crab (i.e., for the pooled Pribilof red king crab and Pribilof blue king crab).

The status quo harvest strategy has three components for computing the blue king crab component of the Pribilof king crab TAC (5 AAC 34.918).

- Minimum stock conditions for a fishery opening: The fishery will open only if the estimated TMB is at least 13.2 million pounds (5,987 t) for two consecutive years.
- A rule for computing the TAC if the stock meets minimum conditions for an opening:
  The minimum of:
  - 10% of the estimated abundance of mature males at the time of the survey times the average weight of legal males; or
  - 20% of the estimated abundance of legal males at the time of the survey times the average weight of legal males.
- A minimum TAC for a fishery opening: 0.556 million pounds (252 t).

Under Alternative 1, the status quo harvest strategy for St. Matthew blue king crab was adopted as part of the rebuilding plan in Amendment 15 to the FMP. The harvest strategy has four components for determining the TAC (5 AAC 34.917):

- A threshold of 2.9 million pounds (1,315 t) of MMB,
- An exploitation rate on mature male abundance that is a function of MMB,
- A 40% cap on the harvest of legal males, and
- A minimum 2.778 million pounds (1,260 t) TAC for a fishery opening.

MMB for blue king crabs is defined for management purposes as the biomass of males ≥105-mm CL. When MMB is below the 2.9 million pounds (1,315 t) threshold of the status quo harvest strategy, the stock is closed to commercial fishing. When the stock is above that threshold, an exploitation rate on mature male abundance (defined for management purposes as the abundance of all males ≥105-mm CL) is determined as a function of MMB. The exploitation rate on mature male abundance increases linearly from 10% when MMB = 2.9 million pounds (1,315 t) to 20% when MMB = 11.6 million pounds (5,262 t). When the MMB is >11.6 million pounds (5,262 t), the exploitation rate on mature male abundance remains at 20%. Application of the mature male exploitation rate to mature male abundance determines the targeted number of legal-sized males for commercial harvest. Minimum legal size is 5.5-in CW, but 120-mm CL is used as a proxy for the size limit in stock assessment computations. To protect from excessive harvest of the legal-sized component of the mature male stock, the targeted number of legal-sized males for commercial harvest is capped at 40% of the estimated legal-sized male abundance.

Under the tier system in Alternatives 2 and 3, both of these stocks would be managed as Tier 4 stocks. As such, proxy B_{MSY} values may be estimated. Figure 7-3 provides estimated MMB and B_{MSY} proxy and MSST proxy (½ B_{MSY}) for the Pribilof District blue king crab stock. Estimated MMB, B_{MSY} proxy, and MSST proxy (½ B_{MSY}) for the St. Matthew blue king crab stock are shown in Figure 7-5. For illustration purposes, average abundance from 1983 to 1998 was used as a proxy for two blue king crab stocks. The two blue king crab stocks have been extremely depressed since 1999, so the estimated abundance after 1998 was not used for the average. Catch and CPUE for Pribilof District blue king crab and St. Matthew blue king crab were high before 1983, corresponding to the high population abundance (Figure 7-4, Figure 7-6).

For St. Mathew blue king crab, when MMB is above proxy B_{MSY}, γ*M = 0.36, where γ = 2.0. However, the 2006 stock status level was "b" because the MMB estimate of 7.14 is lower than the proxy B_{MSY} (13.92), and so the sliding control rule was applied to reduce the actual F_{OFL} to 0.17.

For Pribilof Islands blue king crab, the 2006 stock status level was "c", therefore under Alternative 3, the F_{OFL} was set to zero because 2006 MMB <25% MMB_{MSY}. Under Alternative 2, the F_{OFL} would be set less than or equal to F_{MSY} in the rebuilding plan revision.

Based on estimated F_{OFL}, OFL catch can be estimated annually. OFL catch can be expressed as retained catch or total catch. Total catch includes retained catch and bycatch multiplied by the handling mortality rate for that fishery. Bycatch data for St. Matthew Island and Pribilof Islands blue king crab stocks have been collected since the early 1990s. However, observer coverage was very limited during the first few years, and the directed fisheries for both stocks have been closed since 1999. More bycatch data than currently available are needed to reliably estimate bycatch selectivity. Therefore, OFL catch is expressed in term of retained catch in this report for these two blue king crab stocks.

The current stock productivity is extremely low and the fisheries have been closed since 1999 for these two stocks. The new overfishing definitions, no matter how conservative, would not have any impact on these two stocks in the near future because the fisheries are closed for the foreseeable future.

Given that both stocks are under rebuilding plans and new biological parameters for these stocks are proposed under Alternatives 2 and 3, their rebuilding plans would need to be re-evaluated and potentially revised to reflect new information on the stock, including new estimates of stock recovery in relation to the new specification of B_{MSY}.

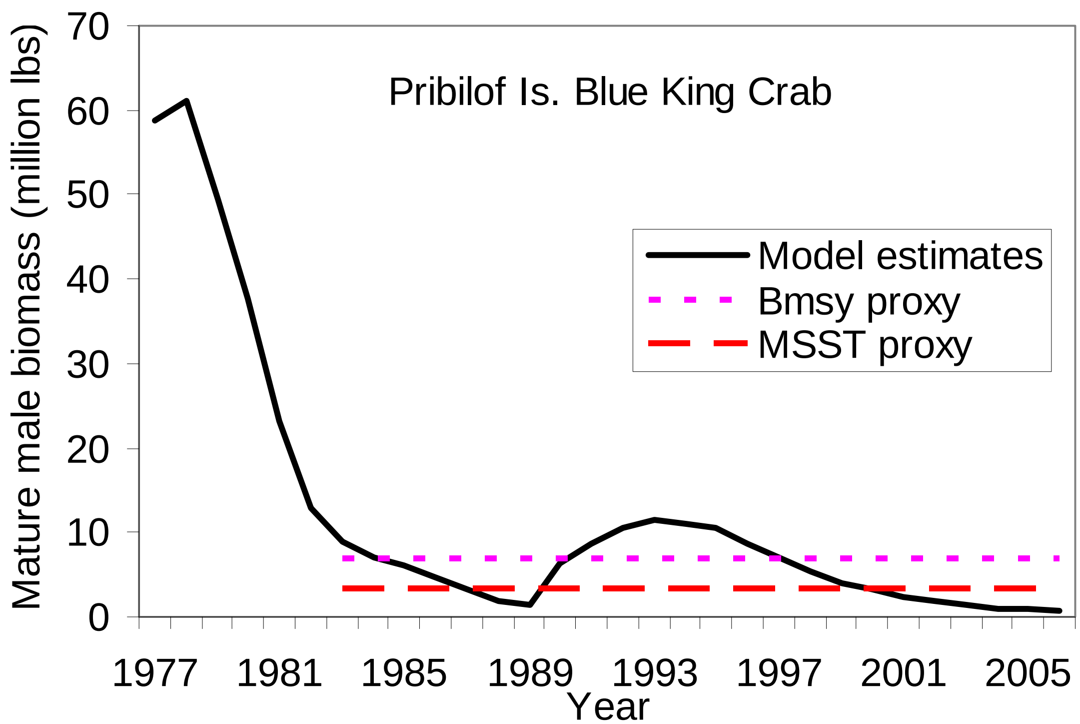

Figure 7-3 Pribilof Islands blue king crab estimated mature male biomass compared to the B_{MSY} proxy and MSST proxy proposed under Alternatives 2 and 3.

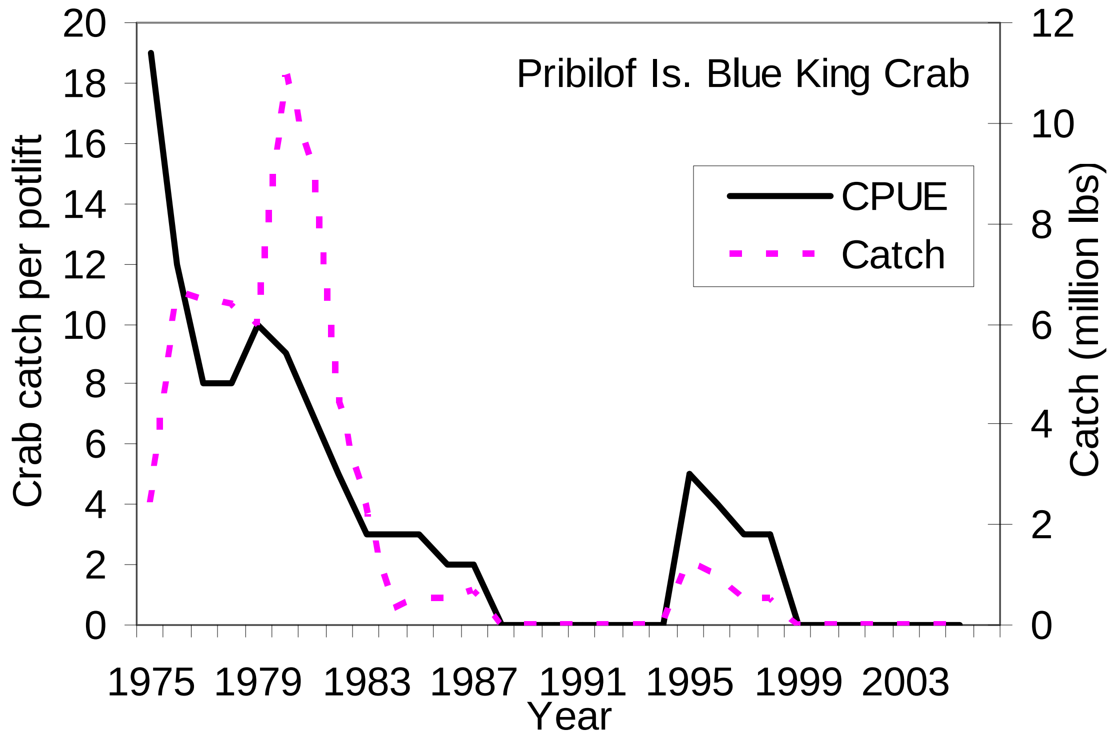

Figure 7-4 Catch and catch per pot lift for Pribilof District blue king crab.

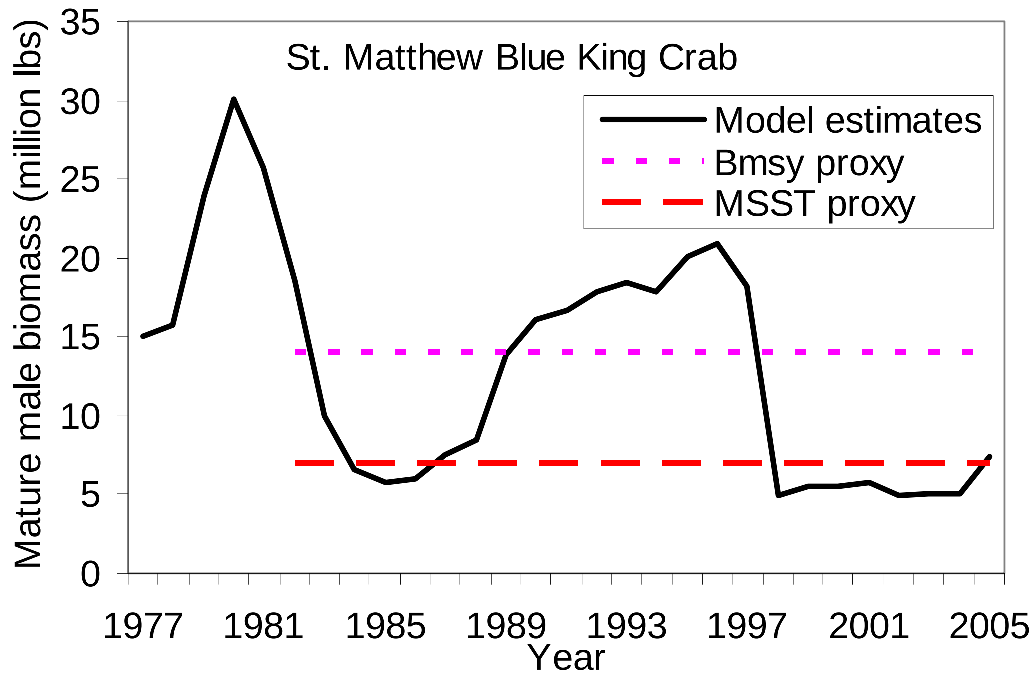

Figure 7-5 St. Matthew blue king crab estimated mature male biomass compared to the B_{MSY} proxy and MSST proxy proposed under Alternatives 2 and 3.

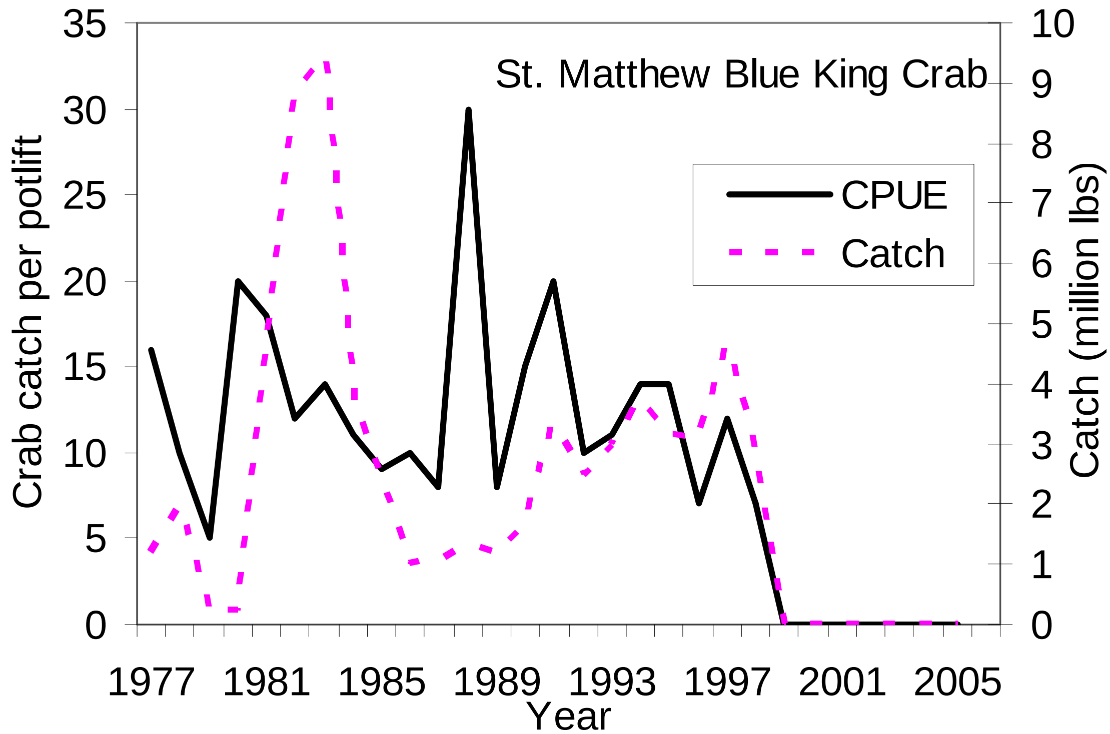

Figure 7-6 Catch and catch per pot-lift for St. Matthew Island blue king crab.

The change in currency from the current TMB to the proposed MMB affects the overfished definitions slightly for both Pribilof Islands and St. Matthew Island blue king crab stocks (Figures 7-7 and 7-8). Looking back historically for when the measure of stock biomass (TMB under Alternative 1 and MMB under Alternatives 2 and 3) is below the MSST, the years differ slightly under the alternatives based upon the change in currency. This is primarily due to the TMB estimated from the survey compared to model estimated MMB and a difference in the application of the F rates to the appropriate portion of the population for each. For instance, during 1983-2006, under the current definitions, the overfished years (TMB < MSST) were 1985, 1988, 1989, and 2002-2006 for Pribilof Islands blue king crab and 1985-1987 and 1999-2006 for St. Matthew blue king crab. During the same period, the stocks were overfished (MMB < proposed MSST(MMB)) in 1988-1989 and 2000-2006 for Pribilof Islands blue king crab and 1985-1987 and 1999-2005 for St. Matthew blue king crab under Alternatives 2 and 3. The difference may mainly be due to survey measurement errors of TMB, which was directly based on area-swept estimates. The MMB used in the proposed definitions was derived from a catch-survey model. There may be a big difference between the current overfishing rates (F_{OFL}) and the proposed rate due to both a change in the biological reference point for these two blue king crab stocks (i.e a change in the default value for natural mortality from 0.2 to 0.18) as well as the application to the appropriate portion of the population under Alternatives 2 and 3 compared to Alternative 1. The current F_{OFL} is applied to both mature male and female crabs whereas the proposed F_{OFL} is for legal males only. The default M under Alternatives 2 and 3 is also more conservative (M = 0.18) as compared with the fixed value (M = 0.2) employed under the current definitions. The impact of these two changes indicated that for legal males, the Alternative 2 and 3 F_{OFL} should be more conservative than the Alternative 1 overfishing rate for these two blue king crab stocks.

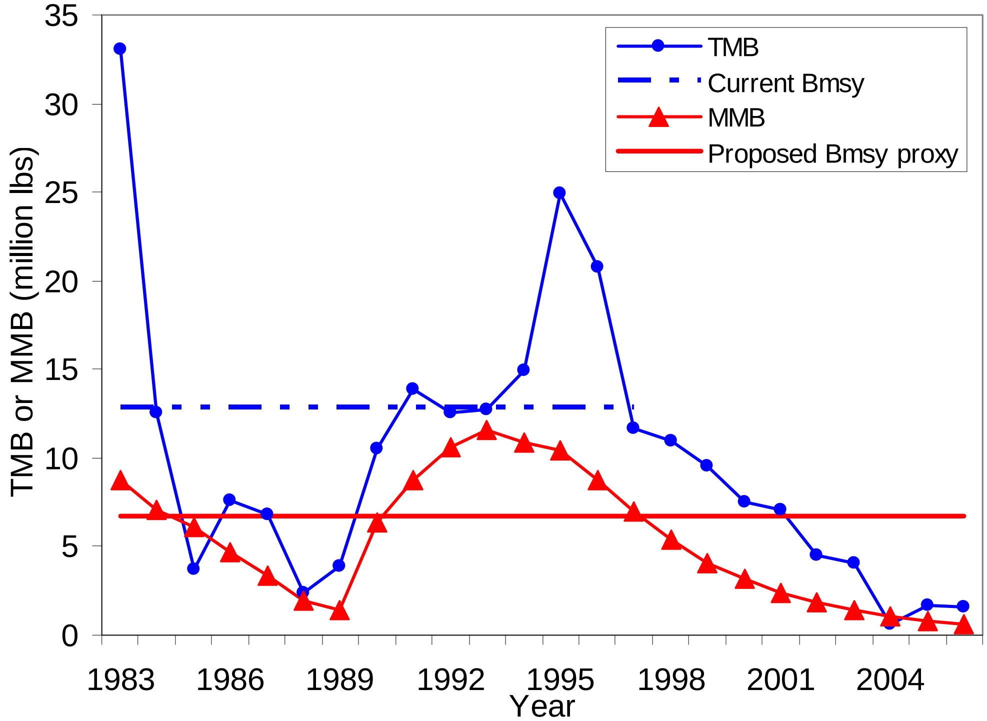

Figure 7-7 **Comparison of total mature biomass and mature male biomass used for the current and proposed overfishing/overfished definitions for Pribilof Islands blue king crab.**

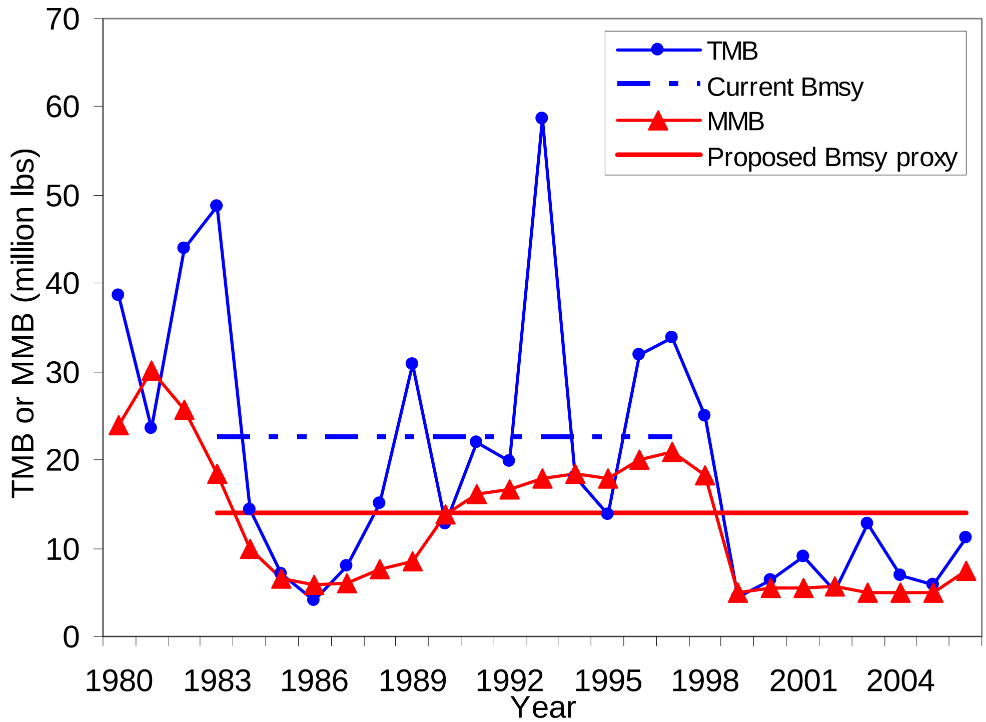

Figure 7-8 **Comparison of total mature biomass and mature male biomass used for the current and proposed overfishing/overfished definitions for St. Matthew Island blue king crab.**

The St. Lawrence blue king crab stock does not have a current estimate of B_{MSY}. Under Alternative 2, all stocks not in the previous tiers would be in Tier 5, including St. Lawrence blue king crab. The problem with establishing an OFL based on catch history for this stock that there is hardly any catch data.

Under Alternatives 3, the St. Lawrence blue king crab stock would be managed under Tier 6 and the OFL would be set at zero for retained catch for this stock due to lack of information. There is currently no fishery for this stock. However, there is some interest by CDQ groups to do some exploratory fishing on this stock. An OFL would need to be established in the OFL setting and review process for a fishery to occur.

Under Option A, the St. Lawrence blue king crab stock would be removed from the FMP and this stock and any potential future fishery would be exclusively managed by the State. The effects of removing this stock from the FMP would be negligible because this action would not change its management.

8 Golden king crab (*Lithodes aequispinus*)

There are three stocks of golden king crab managed under this FMP, the Aleutian Islands golden king crab stock, the Pribilof Islands golden king crab stock, and the Northern District golden king crab stock. This Chapter reviews the stock status, biological parameters relevant to overfishing definitions for these stocks, and provides an overview of specific impacts on the stocks from the three alternatives under consideration in this analysis.

8.1 Golden king crab stock status

This section examines relevant and recent biological information necessary to understand the status of the golden king crab stocks and the overfishing definitions.

Aleutian Islands golden king crab

This stock is not annually surveyed by NMFS. Triennial pot surveys are conducted for a portion of the Aleutian Islands golden king crab stock. The fishery is evaluated based on a combination of fishery-dependent data (observer data and commercial CPUE as well as size composition, shell condition, fecundity, catch rates by size and sex). Currently, work is being completed on a catch-survey model that uses data from the commercial fishery and triennial surveys. Once completed, this model should provide managers with additional information to assess stock status and harvest rate. Prior to the 1996/97 season, the Aleutian Islands king crab fisheries were managed as two distinct areas: the Dutch Harbor Area (east of 171° W. longitude) and the Adak Area (west of 171° W. longitude). In 1996, the Alaska Board of Fisheries (Board) noted that the management boundary at 171° W. longitude apparently bisected a single stock of golden king crab. At that meeting, the Board combined the Dutch Harbor and Adak Areas into a single management area. The Board also directed ADF&G to conservatively manage golden king crab, east and west of 174° W. longitude, as two distinct stocks. Prior to combining the two management areas, the Dutch Harbor Area had been managed on the basis of fishery performance with the historic average landings providing an informal harvest guideline. The Adak Area was formerly managed under a size-sex-season (3-S) policy. It is possible that a harvest rate strategy could be developed for this stock in the future if a model is developed and utilized for biomass estimation.

In the Aleutian Islands east of 174° W. longitude, the total number of crab per pot captured over the last eight seasons appears stable, although the legal-male catch rates have increased and the catch rates for sublegal and female crab have decreased. Legal male CPUE, based on fish ticket data, was 25 crabs per pot for the 2005/06 fishery, which is the highest on record and a 39% increase from the 2004/05 CPUE of 18 crabs per pot lift. The increase in CPUE is likely due to many factors including, but not limited to increased soak times, fewer pots being utilized, and fewer vessels participating. Escape mechanisms in golden king crab pots are very effective in allowing smaller golden king crabs to escape, especially with the longer soak times relative to other king crab fisheries.

With the implementation of the Crab Rationalization Program during the 2005/06 season observer coverage changed. Catcher-only vessels are required to carry an observer for 50% of the total golden king crab harvest by each vessel during each of three trimesters (August 15 to November 15, November 16 to February 15, and February 16 to May 15). Catcher-processor vessels are required to carry an observer for 100% of the harvest.

Sublegal male and female golden king crab also occur over a wider depth range than legal crab and may not be equally represented in the commercial catch. Recently, sublegal male CPUE has decreased and there are no indications that legal male CPUE will remain at the current high level if sublegal male CPUE is viewed as an index of possible future recruitment. Commercial fishery catch data does not provide adequate information to accurately predict future recruitment. Harvest level decisions are difficult to discern based solely on CPUE. A review of observer size frequency data and CPUE data are used in a qualitative measure to assess the effects of the current constant-catch harvest strategy. The constant-catch harvest strategy assumes that fishing mortality changes annually with the changes in exploitable biomass, however those changes are currently not measured in these golden king crab stocks. Based on a review of available data ADF&G set the 2006/07 TAC at 3.0 million pounds (1,361 t) for the area east of 174° W. longitude.

To establish the 2006/07 TACs, fishery data, observer data, and tag recovery information were used in reviewing stock status, previously established GHLs, and TACs. Fishery data, through the 2005/06 season, were examined for CPUE and geographic harvest trends. Observer data from the 1998/99 to 2005/06 seasons were examined for size composition of retained and discarded crabs, shell-age of male and female crabs, stock composition and reproductive condition of female crabs.

In the Aleutian Islands west of 174° W. longitude TAC remained at the same level as the previous year, 2.7 million pounds (1,225 t). Fishery catch statistics have not markedly changed since the GHL was developed in 1996/97. The size frequency of the retained catch continues to be stable though there appear to be fewer of the smaller pre-recruits. CPUE of pre-recruit and female crabs are also relatively stable in the catch. Most commercial fishing effort occurs at depths less than 200 fathoms. Deeper than 200 fathoms, the abundance of small male and female crab is generally greater than legal males. Recent fishery data from the western Aleutian Islands implies that the stock in that area is stable, catches of sublegal males have been steady and there are no indications of a strong recruitment episode.

Pribilof golden king crab

The golden king crab population in the Bering Sea (both Pribilof District and Northern District) is not surveyed and there is no estimate available of its abundance. There are no plans to survey this population nor has a harvest strategy been developed. The population size is believed to be limited by the available habitat in the Bering Sea for this species (NMFS 2004a). In the Pribilof District, golden king crabs have only been caught in a few deep canyons. Historic harvests have occurred in the area to the south of the Pribilof Islands (NMFS 2004a).

Northern District golden king crab

As with golden king crab in the Pribilof District, the golden king crab population in the Northern District is not surveyed and no estimate of population abundance is available. Since the 1982/83 season, harvest has only been documented for seven seasons (NMFS 2004a). Most of the harvest has occurred west of St. Matthew Island and no harvest has occurred since 1996 (NMFS 2004a).

8.2 Effects on Golden King Crab

Under Alternative 1, no estimates of B_{MSY} or MSST are made for any of the golden king crab stocks.

Under Alternatives 2 and 3, two golden king crab stocks are preliminarily recommended for Tier 5 (Pribilof Islands, Aleutian Islands). Under Tier 5, no estimates of MSST are made and the OFL would use a fishing mortality estimated based on average catch. Improved biomass estimates for the Aleutian Islands golden king crab stock are likely in the future as a stock assessment model using fishery data as well as triennial pot data will be utilized to provide estimates of stock status and harvest rate (Siddeek et al. 2005).

Under Alternative 3, St. Matthew golden king crab is recommended for placement in Tier 6, whereby OFL would be set to a default value of zero, unless the SSC recommends an alternative value based on the best scientific information.

Aleutian Islands Golden King Crab

The AI golden king crab fishery has been conducted since 1981. The State has set the TAC at 5.7 million pounds (2,586 t) since 1999. The current trend for the CPUE is up, and the CPUE in 2005/2006 has been the highest since the fishery started in 1981. The highest annual catch was about 15 million pounds (6,804 t) in 1986. Average yield from 1985 to 2005 is 7.527 million pounds (3,414 t).

Under Alternative 1, the AI golden king crab stock is managed as a Tier 2 stock with sporadic or limited years of survey data available. B_{MSY} is not estimable for this stock and no OFL is determined for this stock.

Under Alternatives 2 and 3, the AI golden king crab stock is preliminarily placed into Tier 5 for purposes of this analysis. Considering the catches after 1999 were strictly based on the TAC of 5.7 million pounds, the average catch of 8.261 million pounds (3,747 t) from 1985 to 1999 is used to establish an OFL for this stock (Figure 8-1). Years from 2000 to 2005 were excluded for Aleutian Island golden king crab because the TAC was set below the previous average catch. The historical catches in 1982, 1983, and 1985-1989 exceeded this OFL. This OFL would not constrain the current TAC and would provide potential for future increases in TAC if the stock abundance continues to increase. The CPUE for this stock increased sharply during recent years.

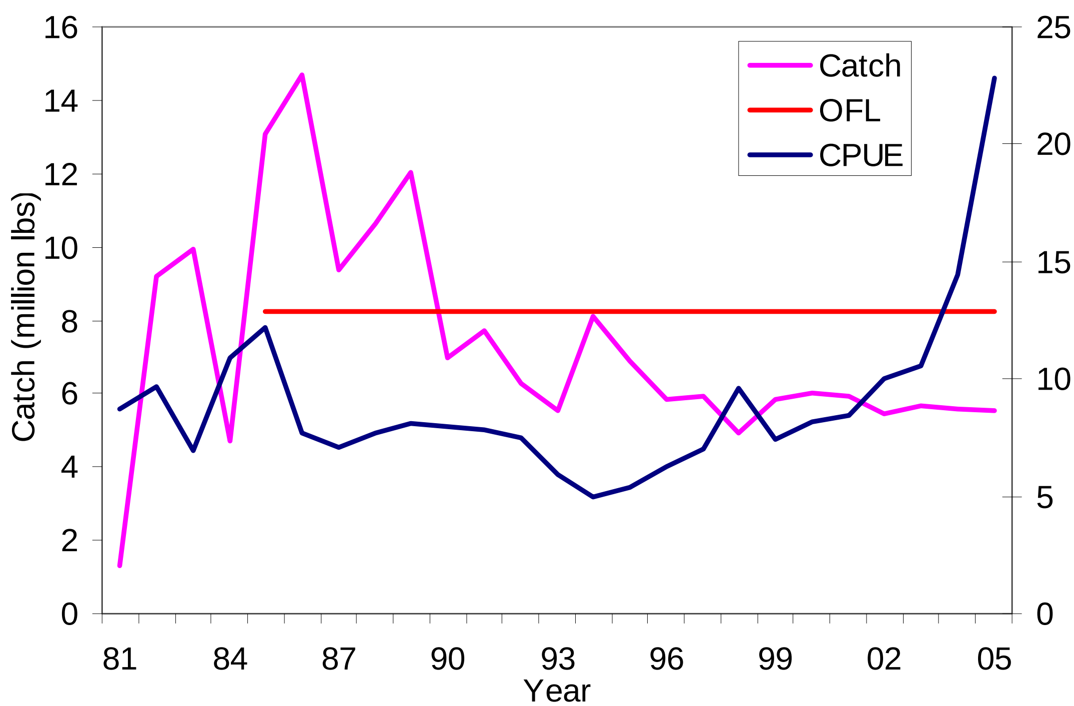

Figure 8-1 Aleutian Islands golden king crab historic catch compared to proposed OFL under Alternatives 2 and 3.

No golden king crab stocks would be in Tier 4 currently. However, a model has been developed for this stock (Siddeek et al 2005), and once the model is used for annual stock assessments and a proxy M value and means of determining a γ value are available, this stock could move into a higher tier.

Pribilof Islands Golden King Crab

For the Pribilof Islands golden king crab stock, fishing effort is sporadic before 1993 and CPUE has fluctuated quite a bit over time. The current GHL is 150,000 pounds (68 t), but due to economic factors, the GHL has not been taken in some years. Under Alternative 1, the Pribilof Islands golden king crab stock is managed as a Tier 1 stock with no survey data available. B_{MSY} is not estimable for this stock and no OFL is determined for this stock.

Under Alternative 2 and 3, the Pribilof Islands golden king crab stock would be placed into Tier 5. Based on fishing effort data, the appropriate period for catch average may be 1993 to 1999. The catches after 1999 were primarily based on the GHL, and the catches after 2002 were confidential. The average yield during 1993- 1999 is 174,200 pounds (79 t). The catches from 1985 to 1992 and from 2000 to 2005 were excluded for Pribilof Islands golden king crab because the fishing effort was less than 10% of the average or the GHL was set below the previous average catch. If the OFL was established for this stock based upon the use of average yield over this time period, the OFL would be 174,200 pounds (79 t, see Figure 8-2). This OFL would be slightly higher than the current GHL of 150,000 pounds (68 t).

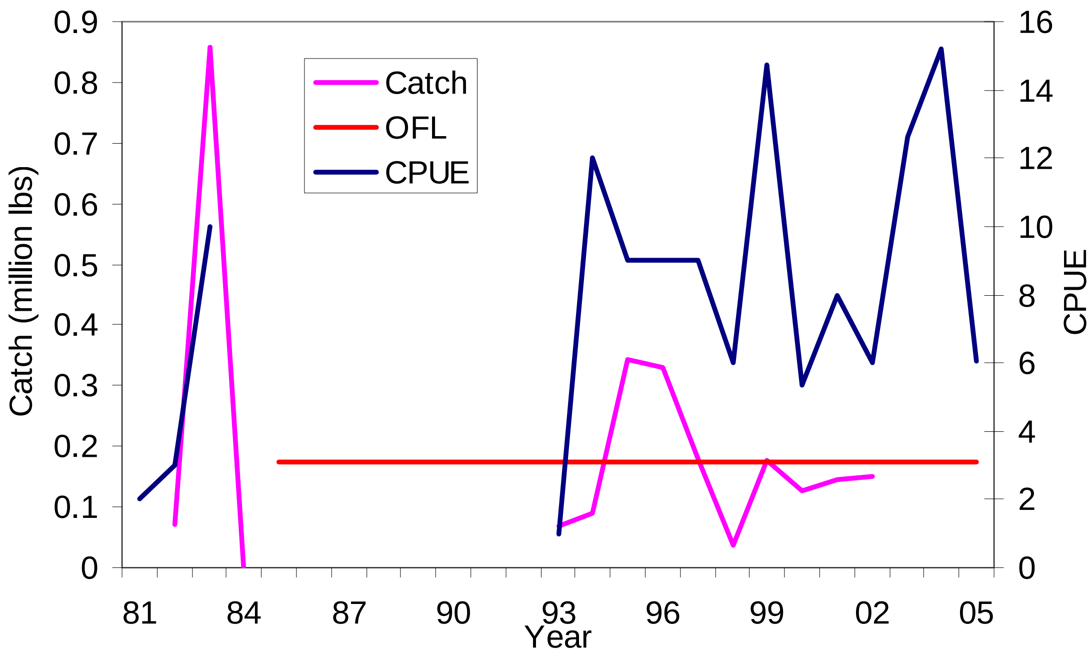

Figure 8-2 Pribilof Islands golden king crab historic catch compared to proposed OFL under Alternatives 2 and 3. Catches after 2002 are confidential.

St. Matthew Golden King Crab

There has been limited fishing effort on the St. Matthew golden king crab stock in the last 10 years. The State annually sets a GHL for this stock, however, no one has participated in this fishery since 2003.

Under Alternative 2, this stock would be in Tier 5. Based on fishing effort data, the appropriate period for catch average may be 1987 to 2003, using the following seven years: 1987-1989, 1992, 1994, 2001, and 2003. The average yield during 1987- 2003 is 86,400 pounds. If the OFL was established for this stock based upon the use of average yield over this time period, the OFL would be 86,400 pounds (39 t). However, use of the average catch may not be an appropriate measure for this stock due to the sporadic nature of this fishery, variable catches, and the fact that the State set previous harvest levels higher than currently allowed. As a result, the maximum annual catch is more than 4.7 times the average catch.

Under Alternative 3, this stock would be placed in Tier 6, whereby OFL would be set at zero for retained catch, unless the SSC approves an alternative value based on the best scientific information through the OFL setting and review process. Under this alternative, the fishery would be closed until a non-zero OFL was established for this stock. Bycatch discards of St. Matthew golden king crab in other fisheries would not count towards the directed fishery OFL.

Under Option A, this stock would be removed from the FMP and managed exclusively by the State. The effects of removing this stock from the FMP on the stock itself would be negligible because this action would not change current management.

9 Other Crab Stocks

The FMP also covers scarlet king crab (*L. couesi*), triangle Tanner crab (*C. angulatus*), and grooved Tanner crab (*C. tanneri*) fisheries. Stock status for these species is largely unknown. This Chapter reviews the stock status, biological parameters relevant to overfishing definitions for these stocks, and provides an overview of specific impacts on the stocks from the three alternatives under consideration in this analysis.

9.1 Stock status

Scarlet king crab

Two stocks of scarlet king crab are managed under this FMP, AI scarlet king crab and EBS scarlet king crab. No surveys are conducted, nor are any estimates of population abundance made for scarlet king crabs in the Aleutian Islands; consequently, stock status and distribution are not well known. There is little stock assessment data and the stock appears small and geographically limited to deep-water areas. Scarlet king crabs are associated with steep rocky outcrops and narrow ledges (NMFS 2004a). Mature scarlet king crabs are caught incidentally in the golden king crab and grooved Tanner crab fisheries (NMFS 2004a). Scarlet king crab males larger than or equal to five and one-half inches in CW may be taken as incidental harvest up to 20% of the fishery under the conditions of a commissioner's permit. Currently, ADF&G does not register vessels to fish directly for scarlet king crabs in the Bering Sea because stock size appears low. Retention of scarlet king crabs captured incidentally during fisheries that target other deepwater crab species will be permitted at low levels. Observer coverage on each vessel registered for the king crab fisheries of the Aleutian Islands has provided biological information that will be used by ADF&G to develop future management measures for scarlet king crab (ADF&G 2005).

Triangle Tanner crab

Two stocks of triangle Tanner crab are managed under this FMP, EAI triangle Tanner crab and EBS triangle Tanner crab. Surveys of population abundance are not conducted for triangle Tanner crabs; thus the status of this stock is unknown. This species occurs on the continental slope in waters > 300 m. and has been reported as deep as 2,974 m. in the eastern Bering Sea (NMFS 2004a). Historically, triangle Tanner crabs were taken as incidental harvest in the grooved Tanner crab fishery. Because of the paucity of population level data for this species and the history of the fishery, additional fishing for triangle Tanner crabs in the Eastern Aleutian District is limited to incidental harvest during the grooved Tanner crab fishery. Vessels registered to fish for grooved Tanner crabs are permitted to harvest triangle Tanner crabs at up to 50% of the weight of the target species. This harvest level is consistent with the historic development of the fishery.

Grooved Tanner crab

Three stocks of grooved Tanner crab are managed under this FMP, EAI grooved Tanner, WAI grooved Tanner and EBS grooved Tanner crab stocks. Little information is available on the biology of this species. It occurs in deep water and is not common at depths <300 m. (NMFS 2004a). No stock assessment surveys are performed on any of the three stocks and population levels are unknown. Fishery data from the mid 1990s is the primary source of information regarding abundance and stock status.

Prior to 1988, grooved Tanner crabs were landed only occasionally in the BSAI as incidental catch in the Aleutian Islands golden king crab fishery. A special permit fishery for deep water Tanner crabs (including grooved Tanner crabs) was established in 1988 and in that year two vessels obtained permits to fish for EBS grooved Tanner crabs. No commercial landings of grooved Tanner crabs were reported from the BSAI from 1989 through 1991, however, in 1992 only two vessels landed grooved Tanner crabs as incidental catch in the golden king crab fishery. In 1993, seven vessels directed effort on grooved Tanner crabs and reported landings from the EBS and EAI. Exploratory fishery participation, effort, harvest, and value in the BSAI grooved Tanner crab fisheries increased steadily from 1993 through 1995, when 15 vessels landed 2-million pounds.

Catch per unit of effort from the EAI stock declined from 15 legal crabs per pot lift in 1993 to two in 1996 and catches decreased from over 850,000 pounds (386 t) in 1995 to 106,000 pounds (48 t) in 1996. In addition, fishing effort was concentrated in three statistical areas immediately to the south of Unalaska Island. Based on the available information, the Bering Sea grooved Tanner crab stock was heavily exploited in the mid-1990s and catch rates decreased to a level where the commercial fishery was no longer economically viable. Since then, the stock has been managed more conservatively and appears to have stabilized or recovered slightly (ADF&G 2005).

Participation, effort, and landings declined in 1996 to the extent that the EBS and EAI 1996 harvests were roughly 10% of the 1995 levels. During 1997-1999 there were no landings of BSAI grooved Tanner crabs and since 2000 fishery effort and catch has been sporadic and low relative to 1993-1995.

ADF&G manages the grooved Tanner crab fisheries as a special-permit fishery under provisions of **5 AAC 35.511** that allow for exploration and development of the fishery without the benefit of a stock assessment survey. Grooved Tanner crab may be harvested only under the conditions of a permit issued by ADF&G. Under **5 AAC 35.511**, conditions may be placed on the permits by ADF&G to: restrict the depths fished; establish season dates; establish areas of operation by statistical areas or district; establish minimum size for retained crabs; require presence of an onboard observer; require logbook reporting of operations; and specify the type, size, and configuration of the pots fished. Given low catch and effort during 1988-1992 no restrictions other than area or district registration were placed on the permits until 1993, when a minimum size limit of 5 inches (127 mm) carapace width (including spines) was established in issued permits. Beginning in 1994, requirements to carry observers were put on the permits. Since 1997 specifications for escape mechanisms for the pots were also placed on the permits. Also, since 1997, ADF&G has managed both the EBS and EAI stocks to assure that the harvests do not exceed 200,000 pounds (91 t). Although exploratory fishing for WAI grooved Tanner crab was allowed under a maximum harvest level of 100,000 pounds (45 t) from 1997 through 1999, the WAI stock has been closed to commercial fishing since 2000.

Given poor fishery performance and declining harvests of the mid 1990s, ADF&G re-evaluated deepwater Tanner crab guideline harvest levels in 2000. A GHL range of 50,000 (23 t) to 200,000 (91 t) pounds was established for the Eastern Aleutian District. The GHL was set as a range to provide greater flexibility for inseason management and to better inform the public of ADF&G's management goals for the fishery. The fishery is managed so that the upper end of the GHL range is reached only when catch rates similar to, or greater than those documented prior to the harvest declines of the mid 1990s are observed. In addition to new GHL requirements, ADF&G specified that four 4.5-inch escape rings be placed on the lower third of each pot and required that pots be fished over multiple depth strata. Observers required on all vessels registered for the fishery collect biological and fishery data.

9.2 Effects on Other Crab Stocks

Information is insufficient to define B_{MSY} for these crab stocks. Only limited information is available for these stocks from historic fisheries.

Crabs stocks with no directed fisheries that were landed only as incidental catch during fisheries targeting other species of crabs include: AI scarlet crab, EBS scarlet crab, and BS triangle Tanner crab. For AI scarlet king crab, bycatch data are available from the historic fisheries that targeted AI golden king crab. For EBS scarlet king crab and BS triangle Tanner crab, bycatch data are available from the historic directed EBS grooved Tanner crab fishery.

Four of the other crab stocks have been harvested only sporadically in exploratory fisheries: EAI triangle Tanner crab, EAI grooved Tanner crab, WAI grooved Tanner crab, and EBS grooved Tanner crab. Landings of EAI triangle Tanner crab and EAI grooved Tanner crabs have occurred during only one year (2001) out of the last 10 years. For WAI grooved Tanner crab, there has been no fishing effort during the last 10 years. Consequently, of the scarlet king crab, triangle Tanner crab, and grooved Tanner crabs stocks covered by this FMP, only the EBS grooved Tanner crab stock may have a catch history sufficient for use to define overfishing levels.

Under Alternative 1, these stocks are all currently managed as Tier 1 stocks with some catch data available for some stocks. No MSST was specified for these stocks and the MFMT was based on the MSY control rule of 0.3 for Tanner crabs and 0.2 for king crabs.

Under Alternative 2, all stocks in this section are recommended for Tier 5 consideration for purposes of this analysis, including stocks with very limited catch history. Tier 5 OFLs would be calculated for purposes of this analysis based upon average catch in years with fishing effort 10% or higher of the mean fishing effort. Only using data with fishing effort 10% or higher of the average effort filters out years that do not represent normal fishing effort. As such, only retained catch would count against these OFLs. Table 9-1 provides the estimated OFLs for Alternative 2, including the years used to set the OFLs.

Table 9-1 Estimated OFLs (in pounds) for other crab stocks in Tier 5 under Alternative 2. OFLs based on mean catches from appropriate period during 1985-2005. Only used data with fishing efforts 10% or higher of the average efforts.

Stock	OFL	Years used	Number of years
EBS grooved Tanner crab	351,900	93-96, 01, 03, 04	7
AI scarlet king crab	13,400	92, 94-04	12
EBS scarlet king crab	14,800	95, 96, 01, 03-05	6
BS triangle Tanner crab	37,700	95, 96, 01, 04	4
EAI triangle Tanner crab	295,300	95, 96	2
EAI grooved Tanner crab	504,800	93-96	4
WAI grooved Tanner crab	74,600	94-96	3

The problems with establishing an OFL based on catch history for these stocks include: (1) catch data come from exploratory and incidental fisheries for most stocks, (2) there are only 2 to 4 years of catch data for several stocks, and (3) mean catch for some species may be either too high (grooved Tanner crab) or too low (Aleutian Islands scarlet king crab). Table 9-2 provides the retained catch data for these crab stocks for the period from 1992 to 2005 used to determine the years used for OFL calculation under Alternative 2. Catch data before 1992 is extremely limited. The mean catch for EAI grooved Tanner crab used to set the OFL of 504,800 pounds may be too high (only 4 years of data and the CPUE declined during these 4 years). In contrast, the State established a GHL range of 50,000 (23 t) to 200,000 (91 t) pounds for grooved Tanner crab in the Eastern Aleutian District. For EBS grooved Tanner crab, there has been sporadic fishing effort during the last 10 years and limited information is available for this stock.

The mean catch for EBS grooved Tanner crab used to set the OFL of 351,900 pounds may be too high when compared to the State's harvest limit of 200,000 (91 t) pounds. Additionally, AI scarlet king crab OFL of 13,400 may be too low (the maximum annual catch of 63,000 is more than 4.7 times of the average).

Table 9-2 Retained catch (in pounds) for the other crab stocks in the years considered for OFL determination under Alternative 2.

Year	EBS grooved Tanner crab	AI scarlet king crab	EBS scarlet king crab	BS triangle Tanner crab	EAI triangle Tanner crab	EAI grooved Tanner crab	WAI grooved Tanner crab
1992	*	*	0	0	0	0	*
1993	658,796	0	0	0	0	*	0
1994	322,444	25,107	0	0	0	773,083	*
1995	984,648	62,997	26,684	40,991	*	882,667	145,795
1996	95,795	45,000	*	*	*	108,953	*
1997	0	6,720	0	0	0	0	0
1998	0	*	0	0	0	0	0
1999	0	*	0	0	0	0	0
2000	*	*	*	*	0	0	0
2001	*	*	*	*	0	*	0
2002	0	*	0	0	1,081	0	0
2003	*	*	*	*	0	0	0
2004	*	*	*	*	0	0	0
2005	*	*	*	0	0	0	0

* Catch is confidential.

Under Alternatives 3, all stocks in this section are recommended for Tier 6 consideration for purposes of this analysis. For Tier 6 stocks, a default OFL would be set at zero for the retained catch, unless the SSC recommends an alternative value based on the best available scientific information. No additional status determination criteria are currently estimated for these stocks nor proposed under the revised definitions.

Option A would remove all of the crab stocks in this Chapter from the FMP. These stocks would continue to be managed by the State, as detailed in Section 9.1. The effects of removing these stocks from the FMP on the stocks themselves would be negligible because this action would not change their management.

10 Effects on Prohibited Species catch limits

Crab species caught as bycatch are treated as prohibited species in BSAI groundfish fisheries. Regulations for prohibited species are defined in 50 CFR 672.21. Crab bycatch in groundfish fisheries are enumerated by on-board observers and then returned to the sea. Bycatch limits are established in BSAI groundfish fisheries for the following species: red king crab, Tanner crab, snow crab. Limits are specified by target fishery. Once these limits are reached as described below, the specified area closures are triggered for the fishery. Crab species are also caught as bycatch in the Alaskan Scallop fishery. Limits are species specific for this fishery. Bycatch of crab species by fishery (directed crab, groundfish trawl, groundfish fixed gear, scallop) is summarized in the annual Crab SAFE report (NPFMC 2006a).

10.1 Snow crab PSC limits

Bycatch limits for snow crab in groundfish trawl fisheries were established under Amendment 40 to the BSAI groundfish FMP, which became effective in 1998. Snow crab PSC limits are apportioned among fisheries in anticipation of their bycatch needs for the year. A PSC limit is established for snow crab in a defined area that fluctuates with abundance except at high and low stock sizes. The PSC cap is established at 0.1133% of the total Bering Sea snow crab abundance (as indicated by the NMFS trawl survey or other approved abundance estimate as with the 2006 use of the assessment model estimate of trawl survey biomass, see BSAI Crab SAFE (NPFMC 2006a) for more information), with a minimum PSC of 4.5 million snow crabs and a maximum PSC of 13 million snow crabs. Snow crab taken within the "*C. opilio* Bycatch Limitation Zone" (COBLZ) accrue towards the PSC limits established for individual trawl fisheries (Figure 10-1). Upon attainment of a snow crab PSC limit apportioned to a particular trawl target fishery, that fishery is prohibited from fishing within the COBLZ. In 1998 the bycatch limit for snow crab was further reduced by an additional 150,000 crabs as part of Amendment 57.

The total snow crab limit in 2006 was established as 5,761,674 crabs. Table 10-1 provides the 2006 groundfish fisheries snow crab bycatch and associated fishery-specific limits within the COBLZ (data from NMFS Catch Accounting).

Table 10-1 Bycatch (in numbers of crabs) of EBS snow crabs in the COBLZ.

Fishery	**Limit**	**Total Catch**
Pacific cod	184,402	77,155
Rockfish	62,356	0
Rock sole, flathead sole, other flatfish	810,091	119,553
Pollock, Atka Mackerel, other species	106,591	2,245
Yellowfin sole	4,103,752	750,420
Greenland turbot, Arrowtooth, Sablefish	62,356	3,872
Opilio crab PSQ (CDQ fishery)	432,126	2,746
Total	**5,761,674**	**955,991**

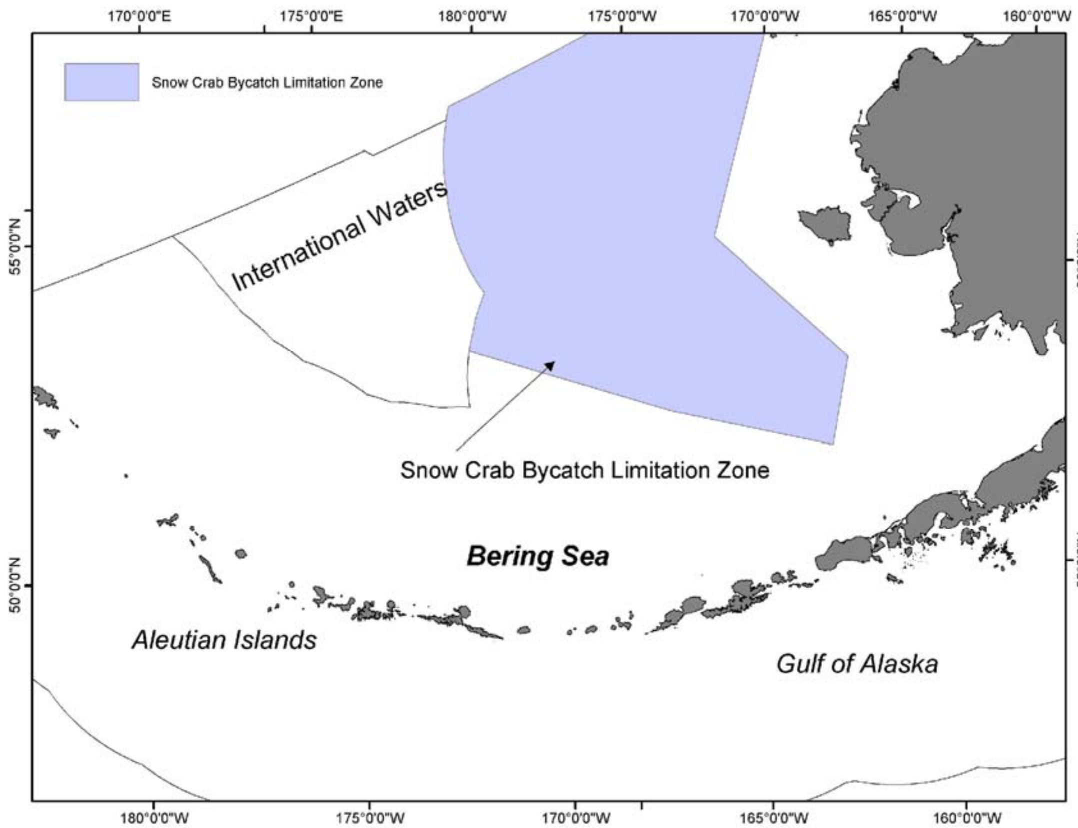

Figure 10-1 ***C. opilio*** **Bycatch Limitation Zone (COBLZ)**

Under Amendment 80 to the BSAI Groundfish FMP, the current bycatch limits as established by Amendment 40 (and modified by Amendment 57) for snow crab were modified. Under Amendment 80, once annually calculated according to the formula noted above (0.1133% of the total snow crab abundance), 61.44% of the cap will be allocated to the head and gut (H&G) sector of the trawl fleet. To accommodate the potential PSC savings the sector will likely enjoy from development of cooperatives, the calculated allocation (61.44%) to the H&G sector would be reduced by 20%, which will be phased in at 5% per year over a four-year period starting in the second year of the program. The remaining sectors of the trawl fleet will be limited to their sideboard amounts. The overall effect of this adjustment (and the limitation by the American Fisheries Act (AFA) sector to their sideboards) will be a reduction in the total limit (and overall catch) for snow crab in the COBLZ. Additional information can be found in the EA/RIR/IRFA for Amendment 80.

10.2 Red King Crab PSC limits

PSC limits are based on the abundance of Bristol Bay red king crab as shown in the adjacent box. In 1999, red king crab bycatch was reduced by an additional 3,000 crabs. In years when the abundance of red king crab in Bristol Bay is below the threshold of 8.4 million mature crabs, a PSC limit of 35,000 red king crabs is established in Zone 1 (Figure 10-2). In years when the stock is above the threshold but below 55 million

PSC limits for Zone 1 red king crab.

Abundance	PSC Limit
Below threshold or 14.5 million lbs of effective spawning biomass (ESB)	33,000 crabs
Above threshold, but below 55 million lbs of ESB	97,000 crabs
Above 55 million lbs of ESB	197,000 crabs

pounds of effective spawning biomass, a PSC limit of 97,000 red king crabs is established. A 197,000 PSC limit is established in years when the Bristol Bay red king crab stock is rebuilt (above threshold and above 55 million pounds of effective spawning biomass). Based on the 2005 estimate of effective spawning biomass (68 million pounds), the PSC limit for 2006 was 197,000 red king crabs. The regulations also specify that up to 35% of the PSC apportioned to the rock sole fishery can be used in the 56º–56º10'N-strip of the Red King Crab Savings Area. The red king crab cap has generally been allocated among the pollock/mackerel/other species, Pacific cod, rock sole, and yellowfin sole fisheries. Once a fishery reaches its red king crab PSC limit, Zone 1 is closed to that fishery for the remainder of the year, unless further allocated by season.

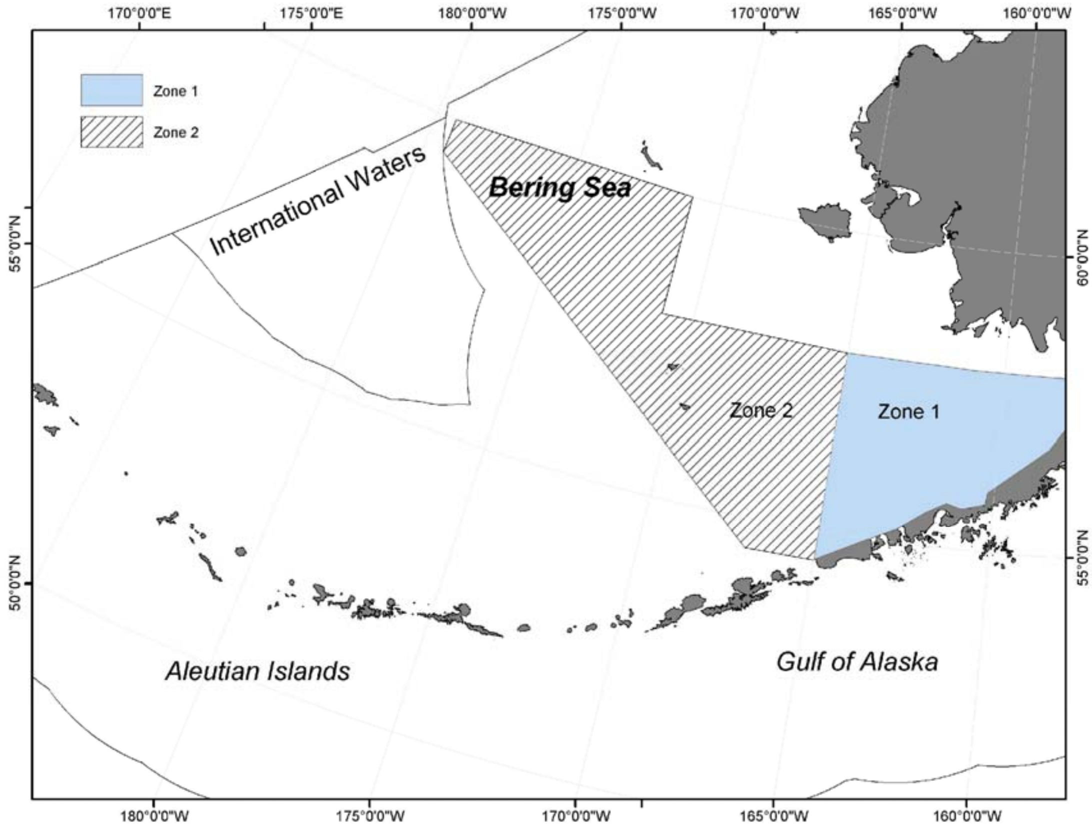

Figure 10-2 Zones 1 and 2 for red king crab and Tanner crab

10.3 Tanner crab PSC limits

PSC limits are also established for Tanner crab under Amendment 41 to the BSAI FMP. These limits are established in Zones 1 and 2 (Figure 10-2) based on total abundance (shown in adjacent box) of Tanner crab as indicated by the NMFS trawl survey. Based on 2005 abundance (763 million crabs), and an additional reduction implemented in 1999, the PSC limit for Tanner in 2006 was 980,000 crabs (1,000,000 minus 20,000) in Zone 1 and 2,970,000 crabs (3,000,000 minus 30,000) in Zone 2.

PSC limits for Tanner crab.

Zone	Abundance	PSC Limit
Zone 1	0-150 million crabs	0.5% of abundance
	150-270 million crabs	750,000
	270-400 million crabs	850,000
	over 400 million crabs	1,000,000
Zone 2	0-175 million crabs	1.2% of abundance
	175-290 million crabs	2,100,000
	290-400 million crabs	2,550,000
	over 400 million crabs	3,000,000

10.4 Scallop fishery crab bycatch limits

Crab bycatch limits (CBLs) are established for three crab species in the Alaskan Scallop fishery. CBLs are established for red king crab, Tanner crab, and snow crab according to Table 10-2 below.

Table 10-2 Scallop Fishery Crab Bycatch Limits (CBLs)

Registration Area	Red king crab	Tanner crab	Snow crab
Bering Sea (Q)	500[a]	3-tier system	3-tier system
Dutch (O)	0.5% or 1.0 %[b]	0.5% or 1.0 %[b]	NA
Adak (R)	50[c]	10,000[c]	NA

[a] fixed number of crabs
[b] percent of overall survey abundance
[c] bycatch limit set to allow fleet to explore and harvest scallops

In the Dutch Harbor Registration Area, the CBLs are set at 0.5% or 1.0% of the total crab stock abundance estimate based on the most recent survey data. In registration areas or districts where red king crab or Tanner crab abundance is sufficient to support a commercial crab fishery, the cap is set at 1.0% of the most recent red king crab or Tanner crab abundance estimate. In registration areas or districts where the red king crab or Tanner crab abundance is insufficient to support a commercial fishery, the CBL is set at 0.5% of the most recent red king crab or Tanner crab abundance estimate. Bycatch caps are expressed in numbers of crabs and include all sizes of crabs caught in the scallop fishery.

CBLs in the Bering Sea (registration Area Q) have evolved from fixed numbers in 1993 to a three tier approach used in the current fishery.

In 1998, consistent with the Tanner crab rebuilding plan in the Bering Sea, crab bycatch limits were modified. The current three tier approach was established using the bycatch limits established in Amendment 1 of the FMP, 300,000 snow crabs and 260,000 Tanner crabs. The three Tiers include (1) Tanner crab spawning biomass above MSST; bycatch limit is set at 260,000 crabs, (2) Tanner crab spawning biomass below MSST; bycatch limit is set at 130,000 crabs, and (3) Tanner crab spawning biomass is below MSST and the commercial fishing season is closed; Tanner crab limit is set at 65,000 crabs.

A similar three tier approach was taken with the snow crab bycatch caps. The three Tiers include (1) snow crab spawning biomass above the MSST; bycatch limit is set at 300,000 crabs, (2) snow crab spawning biomass below MSST; bycatch limit is set at 150,000 crabs, and (3) snow crab spawning biomass below MSST and the commercial fishing season is closed; the snow crab limit is set at 75,000 crabs.

Closures based on the fleet reaching crab bycatch limits have decreased over the years since inception of CBLs in 1993, possibly due to decreased crab abundance (Barnhart and Rosenkranz 2003). During the 1993/94 season four statewide areas were closed due to crab bycatch. Since the 2000/01 season two areas have been closed due to crab bycatch (NMFS 2005).

10.5 Effects of alternatives on Prohibited Species catch limits

The proposed action would establish alternative biomass-based OFLs for management of crab species. If these OFLs restrict current harvest levels for crab, it is possible that this would likewise affect the stair-step regulations implementing the PSC limits for the groundfish fisheries and the CBLs for the scallop fishery.

PSC limits in the groundfish fisheries are based on stock abundance. If abundance is projected to increase over time for snow crab under the new OFLs, then the amount allocated for PSC would increase. If the abundance is projected to decrease under the alternatives, the snow crab PSC allocation would decline. PSC limits for red king crab and Tanner crab are also stair-stepped based on the abundance. Only the lowest stair step is controlled by percent of abundance, thus declines in overall abundance would have a greater effect on the lower limit for those species.

For the scallop CBLs, any projected increase or decline in the biomass of crab would likewise affect the amount of crab available for by catch in the scallop fishery. Scallop fishing has been closed in the past for reaching their CBL by area, thus a decrease in the CBLs could have an impact on the scallop fishery. Additional information is available in the 2007 Scallop Stock Assessment and Fishery Evaluation (SAFE) report (NPFMC 2007).

Alternatives 2 and 3 include different methods for setting OFLs for tier 1-4 stocks in stock status level "c." Crab stocks would be in stock status level "c" when biomass is below one half of the MSST. A stock is declared overfished when it falls below the MSST and the Council is required to develop a rebuilding plan for that stock. Under Alternative 3, for stocks in stock status level "c," the overfishing level would be zero and any catch in any fishery would result in overfishing. This could create problems for fisheries that catch that stock as bycatch and for catch of that stock in research surveys. With Alternative 3, stocks in stock status level "c" would experience overfishing while under a rebuilding plan without the benefit of having the rebuilding plan determine the appropriate OFL for that stock under prevailing conditions that may allow some bycatch or research mortality.

Under Alternative 2, when a stock is in stock status level "c," the directed fishery would be closed and an F_{OFL} less than or equal to F_{MSY} would be set in the development of a rebuilding plan. This alternative would (1) only close the directed fishery when stock size is at level "c," (2) address bycatch mortality buy setting an OFL for that stock under prevailing conditions in the rebuilding plan for that stock, and (3) comply with the National Standard guidelines. The National Standard guidelines require that an overfishing level less than or equal F_{MSY} be specified to account for all sources of fishing mortality, including bycatch. F_{MSY} is the fishing mortality rate expected to result in a long-term average catch approximating maximum sustainable yield.

If an OFL for a crab species is exceeded in a given year, an overfishing determination will be found at the end of the crab fishing year, and a corresponding reduction in the harvest will be taken the following year so as to avoid a subsequent overfishing determination (see section 2.4 for more details). Amendment 24 does not provide an in-season mechanism for determining if overfishing is occurring or a response for management measures in the directed crab fisheries. Overfishing is prevented by setting the OFLs prior to the State setting the TAC for the up coming crab fishing year. The TAC is constrained by the OFLs. The State is not mandated to close directed crab fisheries for exceeding the OFL in-season. This is distinctly different from Federal groundfish fisheries management.

However, regardless of having an overfishing determination the following season, there are currently no corresponding management measures which occur in the groundfish or scallop fisheries to further limit crab bycatch. Crab catch in these fisheries is solely regulated by the bycatch limits as described in sections 10.1 – 10.4. Under all alternatives, regulations to reduce the bycatch of crab in groundfish and scallop fisheries would be considered when a crab stock becomes overfished and necessitates a rebuilding plan (or revisions to an existing rebuilding plan). Or, if the Council determines measure are necessary to end overfishing. In order for there to be any further feedback management mechanism in either the groundfish fisheries or scallop fisheries in the case that the catch of a particular crab stock exceeded its OFL, the respective BSAI groundfish FMP and Scallop FMP would need to be amended. Should a crab stock become overfished and necessitate the creation of a rebuilding plan (or revisions to an existing rebuilding plan), regulations on the bycatch of crab in groundfish and scallop fisheries would be considered again at that time and additional regulations under those FMPs may be considered in a new (or revised) rebuilding plan.

11 Economic and Social Effects

This section summarizes the effects of the alternatives on the social and economic environment. The economic and social impacts differ in fundamental ways from other resource components examined in this EA. Effects on the social and economic environment deal with impacts on persons and on communities, while other impacts deal with the natural environment. Significance findings for social and economic impacts would not affect a finding of no significant impact (FONSI); see 40 *CFR* 1508.14.

This section provides the social and economic analysis of the three alternatives: (1) Status Quo/No Action, (2) new tier system with five tiers and (3) new tier system with six tiers. The proposed action also includes two sets of options. Options 1 and 2 establish different annual processes for tier and OFL setting and review. Option 1 would establish a process whereby the Council would annually adopt the tier assignments and OFLs for each stock in June, prior to their application in the fall. Option 2 would establish a process whereby the Council and SSC would review the models and tier system framework, tier levels, and model parameterization in June. Option A would remove specific stocks from the FMP for which there is no directed fishery, a limited exploratory fishery, or the majority of catch occurs in State waters. Under Option B, the current 22 crab stocks would remain in the FMP and, as required by the Magnuson-Stevens Act, OFLs would need to be established for all FMP stocks.

Assessing the social and economic effects of the alternatives involves some degree of speculation. In general, the effects arise from the actions of individual participants in the crab fisheries under the incentives created by the different alternatives. Predicting these individual actions and their effects is constrained by incomplete information concerning the crab fisheries, including the absence of complete economic information and well-tested models that predict behavior under different institutional structures. In addition, exogenous factors, such as stock fluctuations, market dynamics, and macro conditions in the global economy will influence the responses of the participants under each of the alternatives.

As a result, the economic and social analysis of the alternatives under consideration is limited to qualitative descriptions of potential impacts rather than quantitative estimates because of uncertainty in crab stock abundance and prices. Because of the nature of the proposed action and the indeterminacy of prices, the discussion that follows considers the impact of the changes in fishing under OFL control rules independent of any price changes. In all cases, price increases would mitigate negative economic impacts of an alternative to fishery participants; price declines would exacerbate negative impacts to fishery participants.

11.1 Existing Crab Management[4]

In August 2005, fishing began under the Crab Rationalization Program (Program), developed by the Council. The Program established a quota share system for allocating the harvest in the Bristol Bay red king crab, St. Matthew blue king crab, Pribilof Islands red and blue king crab, Bering Sea snow crab, Bering Sea east Tanner crab, Bering Sea west Tanner crab, EAI golden king crab, WAI golden king crab, and WAI red king crab fisheries. The 2005/2006 commercial crab fishing season was the first to be prosecuted under the new management regime.

Prior to the implementation of the Program, the BSAI crab fisheries were prosecuted as a limited access, derby fishery, under which the participants raced for crab after the opening, with the fishery closing once managers estimated that the GHL was fully taken. The ADF&G managed the competitive general fisheries by establishing GHLs prior to the season, monitoring the harvest during the season, estimating

[4] A large part of the crab management background section originates from Barnard and Pengilly (2006).

the date and time that the harvest would attain the GHL, and closing the general fishery at that estimated date and time. After closure of the general fishery, the CDQ fishery for the season would open and participating vessels were allowed to fish until the CDQ allocation was harvested or until the regulatory season closing date.

Under the Program, ADF&G establishes a TAC for each fishery according to State regulations and NMFS distributes 10% of the TAC to the CDQ groups and the remaining 90% of the TAC to quota share (QS) holders as individual fishing quotas (IFQs). NMFS also allocates individual processing quota (IPQ) representing 90% of the IFQ TAC to processor quota share (PQS) holders.

The Program contains several provisions intended to protect the interests of communities that depend on the fisheries. Many of the measures, including the underlying dual share structure, are intended by the Council to provide community protections absent in a more traditional harvester only IFQ program. Allocation of processing shares for 90% of the TAC is intended to support communities' historic participation by tying quota to community based processing. This community link is intended to provide stability to not only the processing sector but also to support industries in the communities[5].

To maintain the historic regional distribution of landings in the crab fisheries, the Council chose to regionalize harvest and processing shares. QS, Class A IFQ (which requires delivery to a processor holding unused IPQs) and processor shares are regionally designated based on the location of the activity that gave rise to the allocation. Crabs harvested with regionally designated IFQ are required to be delivered to a processor in the designated region. Likewise, a processor with regionally designated shares is required to accept delivery of and process crab in the designated region. Communities in the Pribilof Islands and the community of Adak are the prime beneficiaries of this regionalization. Table 11-1 provides PQS by region and community.

[5] This paragraph and the following three paragraphs originate from Fina (2004).

Table 11-1 Crab rationalization PQS by region and community

Fishery	Region	Community of Right of First Refusal	Number of PQS holders	Percent of PQS pool
Bristol Bay red king crab	North	St. Paul	2	2.6
	South	Akutan	1	19.9
		False Pass	1	3.7
		King Cove	1	12.8
		Kodiak	3	3.8
		None	3	2.7
		Port Moller	3	3.5
		Unalaska	11	51.1
		Total		97.4
Bering Sea snow crab	North	None	3	1.0
		St. George	2	9.7
		St. Paul	6	36.3
		Total		47.0
	South	Akutan	1	9.7
		King Cove	1	6.3
		Kodiak	4	0.1
		None	4	1.8
		Unalaska	12	35.0
		Total		53.0
EAI Golden King crab	South	Akutan	1	1.0
		None	1	0.9
		Unalaska	7	98.1
Pribilof Island red and blue king crab	North	None	1	0.3
		St. Paul	5	67.3
		Total		67.5
	South	Akutan	1	1.2
		King Cove	1	3.8
		Kodiak	4	2.9
		Unalaska	5	24.6
		Total		32.5
St. Matthews blue king crab	North	None	5	64.6
		St. Paul	4	13.8
		Total	9	78.3
	South	Akutan	1	2.7
		King Cove	1	1.3
		Kodiak	1	0.0
		Unalaska	6	17.6
		Total		21.7
WAI golden king crab	Undesignated	NA	9	50.0
	West	NA	10	50.0
WAI red king crab	South	NA	10	100.0

Source: RAM PQS database.

The Program also includes geographic landing requirements and transfer restrictions linking PQS and IPQ to specific fishery dependent coastal communities with a history of participation in these fisheries. There are nine Eligible Crab Communities: Adak, Akutan, Unalaska/Dutch Harbor, False Pass, King Cove, Kodiak, Port Moller, Saint George, and Saint Paul. Of these, all but Adak have a “Right of First Refusal” on proposed sales of PQS for use outside of the community. All nine are protected by “Cooling-off,” a two year limit on the amount of IPQ that may be used outside of the community or borough boundary in which the IPQ was derived. Four crab fisheries are exempt from the cooling off provision: Eastern Tanner crab, Western Tanner crab, WAI red king crab, and WAI golden king crab. The two-year “cooling off period” expired July 1, 2007.

Exceptions to the right of first refusal allow a company to consolidate operations among several commonly owned plants to achieve intra-company efficiencies and to lease shares temporarily outside of a community. To exercise a right of first refusal at the time of a proposed transfer, a community group would be required to meet all of the terms and conditions of that transfer. The exceptions to the right of first refusal limit its effectiveness for ensuring shares remain in the community of origin.

Under the Program, ADF&G no longer manages the rationalized fisheries inseason; harvesters may harvest their IFQ at any time within the fishery seasons established in State regulations. Federal regulations also established other provisions for implementing the Program, including those for allocating processor shares to processors, those for governing the consolidation of QS and IFQ by vessels through leasing or purchasing of IFQs, and those for governing the formation of vessel cooperatives to coordinate harvest of allocations.

Crab pots are the legal gear for the BSAI commercial crab fisheries and only males meeting or exceeding the minimum size limits can be harvested. Females and sublegal males are also caught as bycatch but harvesters are required to immediately return these crabs to the sea. Table 11-2 provides season open dates for BSAI crab fisheries.

Table 11-2 Season opening dates for BSAI crab species

Crab Species	Season Open Dates
Snow crab	October 15
AI golden king crab	August 15
St. Matthew/Pribilof Islands king crab	October 15
Bristol Bay red king crab	October 15
Bering Sea Tanner Crab	October 15
Norton Sound king crab	July 1

11.2 Participation and Harvests

This section provides brief a summary of BSAI crab fishery vessel participation and season length from the 2001 to 2005/2006 season. The Program, which was implemented in August 2005, has reduced the number of vessels participating in the BSAI crab fisheries and has slowed the pace of the BSAI crab fisheries. Table 11-3 depicts the changes in participation and season length. For example, prior to the 2005/2006, the season length for the Bristol Bay red king crab season was 3 to 5 days. In contrast, during the 2005/2006 season, the Bristol Bay red king crab season lengthened to 93 days. At the same time the number of participating vessels declined from 251 in 2004 to 89 during the 2005/2006 season. For the Bering Sea snow crab fishery, the season lengthened to 229 days from 6 days the previous year and the number of vessels declined from 169 in 2005 season to 78 for the 2005/2006 season. For the WAI and EAI golden king crab, the number of vessels participating in the fishery declined and the season length increased from 141 days for the WAI to 273 days and from 14 days in the EAI to 273 days. Fishing was closed for Pribilof blue king crab, Pribilof red king crab, St. Matthew blue king crab, and Adak red king crab. The Bering Sea Tanner crab fishery was opened for fishing for the first time since 1996.

Table 11-3 Number of vessels and season length in days by BSAI crab species

Fishery	Season	Number of Vessels	Season Length
WAI Golden King	2001-2002	9	227.0
	2002-2003	6	205.0
	2003-2004	6	175.0
	2004-2005	6	141.0
	2005-2006	3	273.0
Adak Red King	1995-2005	FISHERY CLOSED	
Bristol Bay Red King	2001-2001	230	3.3
	2002-2002	242	2.8
	2003-2003	252	5.1
	2004-2004	251	3.3
	2005-2005	89	93.0
Bering Sea Snow Crab	2001-2001	207	30.0
	2002-2002	191	24.0
	2003-2003	192	9.0
	2004-2004	189	8.0
	2005-2005	169	6.0
	2005-2006	78	229.0
Bering Sea Tanner Crab	1997-2004	FISHERY CLOSED	
	2005-2006	43	168.0
EAI Golden King	2001-2002	19	26.0
	2002-2003	19	23.0
	2003-2004	18	24.0
	2004-2005	19	14.0
	2005-2006	7	273.0
Pribilof Blue King	1999-2005	FISHERY CLOSED	
Pribiliof Red King	1999-2005	FISHERY CLOSED	
St. Matthew Blue King	1999-2005	FISHERY CLOSED	

Source: 2006 Crab SAFE

11.3 Processor Participation

This section presents processor participation by BSAI crab and other groundfish species. For each species, the number of processors participating and wholesale revenues are presented in Table 11-4 and Table 11-5. For the Tanner crab fisheries, the number of processors and first wholesale revenues may include GOA Tanner crab information given that the data does not differentiate GOA/BSAI delivers. Crab processor data for Dutch Harbor and Kodiak are provided in the community profiles presented in Sections 11.6.2 and 11.6.5. Processor data for Akutan, King Cove, St. Paul, and Adak are not reported to prevent release of confidential information.

Table 11-4 The number of unique crab processors aggregated across Dutch Harbor, Akutan, King Cove, Kodiak, St. Paul, and Adak communities from 2000 to 2005

	Year					
Species	2000	2001	2002	2003	2004	2005
Crab, Bairdi	-	Fishery Closed	Fisher Closed	Fishery Closed	Fishery Closed	13*
Crab, Golden King	8	7	5	7	6	6
Crab, Opilio	14	14	17	15	17	14
Crab, Red King	12	13	15	18	16	11

Data Source: ADFG Commercial Operator Annual Report Summary
*Data only available by species, not by fishery.

Table 11-5 Value (in dollars) of crab processed aggregated across Dutch Harbor, Akutan, King Cove, Kodiak, St. Paul, and Adak processors by species from 2000 to 2005

	Year					
Species	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**
Crab, Bairdi		$0	$0	$0	$0	$60,403,833*
Crab, Golden King	$26,139,816	$27,002,265	$21,059,192	$27,603,224	$21,138,595	$12,392,228
Crab, Opilio	$70,920,022	$42,957,017	$69,431,163	$70,922,518	$69,891,523	$58,943,785
Crab, Red King	$38,795,745	$49,434,366	$71,023,874	$87,238,762	$80,698,679	$91,612,958
Total	**$135,855,583**	**$121,416,493**	**$162,603,766**	**$187,584,525**	**$174,613,712**	**$168,989,354**

Data Source: ADFG Commercial Operator Annual Report Summary
*Data only available by species, not by fishery.

11.4 Estimated Ex-vessel Prices

This section provides a brief summary of the annual harvest, ex-vessel price, and value from 2001 to 2005 by BSAI crab fishery. Information on harvest, ex-vessel price, and value from 1995 to 2000 are located in the Crab EIS.

Table 11-6 provides annual harvest, ex-vessel price, and value information by crab fishery from 2001 to 2006 where available. Observations from this table shows that Bering Sea snow crab had the highest harvest, but the Bristol Bay red king crab fishery has consistently had the highest ex-vessel price and value over the 2001 to 2005 period. Harvest of Bristol Bay red king has increased over the last five seasons from 7.8 million pounds (3,538 t) during the 2001 season to 16.5 million pounds (7,484 t) in the 2005 season. Average ex-vessel price for the fishery has fluctuated between $4.24 a pound in 2005 season to over $6 a pound in 2002. Value of the Bristol Bay red king crab fishery during the 2001 to 2005 seasons has ranged from $38 million in 2001 to $73 million in 2003. In recent years, the value of the fishery has ranged from $66 to $70 million. For Bering Sea snow crab, the harvest has fluctuated between the 22 million pounds (9,979 t) in 2004 to 33 million pounds (14,969 t) in the 2005/2006 season. Average ex-vessel prices ranged from nearly $1.50 a pound to a little over $2 a pound between 2001 and 2005. During the 2005/2006 season, ex-vessel prices dropped dramatically to $0.84 a pound. The value of the Bering Sea snow crab fishery has consistently been in the $40 million range during the 2002 to 2005 period, but the value of the fishery dropped to $28 million during the most recent season (2005/2006). Harvest in the AI golden king crab fishery has consistently been in the 5 to 6 million-pound range annually over the past five years, with approximately 2.7 million pounds (1,225 t) harvested in the WAI and 2.9 million pounds (1,315 t) harvested in the EAI. In the 2005/2006 season, the harvest declined slightly from the previous year. Average ex-vessel price has ranged from $3 to $3.50 over the past several years and the value has ranged from $8 to $10 million during this same period. However, in the 2005/2006 fishing season, the average ex-vessel price and value of the fishery declined. In the WAI, the ex-vessel priced declined from $3.09 to $2.05 and the value dropped from $8.16 million to $4.89 million. In the EAI the average ex-vessel price declined from $3.18 from the previous season to $2.53 and the value dropped from $9.05 million to $6.50 million. Finally, the Bering Sea Tanner crab fishery was opened for the first time during the 2005/2006 season since being closed in 1997. Forty-three vessels harvested 791,000 pounds (359 t) at a value of $0.9 million. The average ex-vessel price for that season was $1.28. The remaining BSAI crab fisheries were closed to fishing.

Table 11-6 Ex-vessel price, total value and total landed pounds by crab fishery from 2001 to 2006

Fishery	Season	Total Landed Pounds	Total Value[a]	Ex-vessel Price[b]
WAI Golden King	2001-2002	2,740,054	$7.87	$2.93
	2002-2003	2,640,604	$9.13	$3.50
	2003-2004	2,688,773	$10.11	$3.83
	2004-2005	2,688,234	$8.16	$3.09
	2005-2006	2,384,567	$4.89	$2.05
Adak Red King	1995-2005	FISHERY CLOSED		
	2002-2003	505,642	$3.29	$6.51
	2003-2004	479,113	$2.45	$5.14
Bristol Bay Red King	2001-2001	7,786,446	$37.50	$4.81
	2002-2002	8,856,828	$54.20	$6.14
	2003-2003	14,529,124	$72.70	$5.08
	2004-2004	14,112,438	$65.70	$4.71
	2005-2005	16,478,458	$69.50	$4.24
Bering Sea Snow Crab	2001-2001	23,382,046	$32.12	$1.53
	2002-2002	30,233,494	$44.20	$1.49
	2003-2003	26,198,024	$46.98	$1.83
	2004-2004	22,170,150	$44.99	$2.05
	2005-2005	23,036,287	$41.47	$1.80
	2005-2006	33,256,146	$27.66	$0.84
Bering Sea Tanner Crab	1997-2004	FISHERY CLOSED		
	2005-2006	791,315	$0.90	$1.28
EAI Golden King	2001-2002	3,178,652	$10.26	$3.30
	2002-2003	2,821,851	$9.13	$3.30
	2003-2004	2,977,055	$10.05	$3.46
	2004-2005	2,886,817	$9.05	$3.18
	2005-2006	2,567,781	$6.50	$2.53
Pribilof Blue King	1999-2005	FISHERY CLOSED		
Pribilof Red King	1999-2005	FISHERY CLOSED		
St. Matthew Blue King	1999-2005	FISHERY CLOSED		

Source: 2006 Crab SAFE
[a]Millions of dollars
[b]Average price per pound

11.5 Product Market and Prices

The information in this section is intended to provide some background concerning the role of the US producers in the current world market and a historical description of the markets for crab. A brief summary of crab production and prices is provided in the Crab EIS. The information in the Crab EIS is intended to provide some background concerning the role of the US producers in the current world market and a historical description of the markets for crab.

The 2005 and 2006 BSAI Crab SAFEs included a summary of recent research on the Alaska snow and king crab market by Dr. Joshua Greenberg and Dr. Mark Herrmann from the University of Alaska Fairbanks. The study examined influences of the snow and king crab world market and the relationship between Alaska snow and king crab landings and the world demand for these crabs. Using these influences and interrelationships, the authors developed a model to study the effects supply and demand on the Alaska snow and king crab markets. The study showed that Alaska is no longer the largest supplier of snow crab or king crab. Both snow and king crab world market prices are not responsive to changes in Alaska snow and king crab harvests. As noted in the study, this implies that the Alaska crab industry cannot rely on increases in crab prices to reduce the impacts of declining crab harvests. For snow crab, the increased harvest from Canada and the emergence of Greenland and Russia snow crab harvests has softened the Alaska snow crab market. For king crab, the introduction of Russian king crab in the Barents Sea in recent years and North Pacific for the past decade has had a major impact on the Alaska king crab market price.

11.6 Existing Community Conditions

In this section, seven Alaska communities with direct links to the BSAI crab fishery are summarized. These communities are Unalaska, Akutan, King Cove, St. Paul, St. George, Adak, and Kodiak. These communities vary in their geographic relation to the fishery; their historical relationship to the fishery; and the nature of their contemporary engagement with the fishery through local harvesting, processing, and support sector activity or ownership. Each of these factors influences the direction and magnitude of potential social impacts associated with the proposed action.

11.6.1 Community Variability

BSAI crab communities are spread over a wide geographic range. St. Paul and St. George are located on the Pribilof Islands while Unalaska, Akutan, and Adak are located on the Aleutian Chain on the Bering Sea. King Cove and Kodiak Island, respectively, are located on the Gulf of Alaska.

These communities have very different histories with respect to the Bering Sea and AI crab fisheries. Early in the development of these fisheries, Kodiak was the center of crab processing. Somewhat later, Unalaska/Dutch Harbor emerged as the center of both processing and fishery support activity, a position it has held since the crab boom years of the late 1970s. King Cove, a community with a substantial fisheries based economy for the better part of the century, has emerged as a multispecies dependent community wherein crab plays a major role. The community of Akutan, located on Akutan Island east of Unalaska/Dutch Harbor in the Aleutians, is also a major Bering Sea crab port. Akutan has one of the largest commercial shore plants in the region, but has very limited direct harvest participation and support service sector involvement. St. Paul has quite a different historical relationship to local commercial natural resources utilization than either Unalaska or King Cove. St. Paul was founded upon and for decades was sustained by a commercial harvest of marine mammals rather than fishery resources. Further, St. Paul faces fishery development challenges not seen in other crab ports. Despite being adjacent to waters where a great deal of crab harvest activity takes place, St. Paul has seen little onshore commercial fisheries related development, due to a lack of adequate harbor facilities and infrastructure as well as logistical challenges inherent in a location that is relatively remote from major transportation routes and the environmental constraints of more extreme weather and ice conditions resulting from its northerly location.

Adak has yet a different historical relationship to the fishery. Like St. Paul, historically Adak did not have a commercial fisheries based economy. While some commercial fishing related activity has taken place over the years, Adak was first and foremost a military community until very recently. This has meant that the recently re-emerged civilian community is essentially attempting to build a fisheries based local economy from scratch. Kodiak, which early in the development of the Bering Sea crab fishery was at its economic center, has becomes less of a factor in this respect in more recent years due to this development of crab harvesting, processing, and fishery support capacity elsewhere. These varying historical relationships with the fisheries have served to shape the contemporary involvement with the BSAI crab fisheries and will influence the way that social impacts resulting from this action will affect the different communities.

Limited information concerning the geographic distribution of processing in the crab fisheries can be released because relatively few processors participate in the fishery in any location. In the years preceding implementation of the Program, only data from the Bristol Bay red king crab and the Bering Sea snow crab fisheries can be released (see Table 11-7). In addition, activity on floating processors may be associated with a particular community, but is not attributed to community in these records. Dutch Harbor processors received slightly less than a majority of the landings in both fisheries. Discerning the landings of any other community in isolation is difficult because of aggregations required by confidentiality rules.

Table 11-7. Distribution of processing in the Bristol Bay red king crab and snow crab (*C. opilio*) fisheries (2001-2005).

Fishery	Year	Communities	Number of processors	Pounds processed*	Percent of processed pounds
Bristol Bay red king crab	2001	Adak, Akutan, King Cove, Floaters	6	2,663,437	34.7
		Dutch Harbor	5	3,902,545	50.8
		Catcher processors	6	312,939	4.1
		Kodiak	6	798,932	10.4
	2002	Akutan, King Cove, Floaters	6	3,372,188	38.5
		Dutch Harbor	6	4,276,910	48.8
		Catcher processors	8	300,425	3.4
		Kodiak, St. Paul	4	820,497	9.4
	2003	Akutan, King Cove, Sand Point, Floaters	10	5,207,419	36.6
		Dutch Harbor	7	7,131,382	50.1
		Catcher processors	8	680,080	4.8
		Kodiak, St. Paul	5	1,218,494	8.6
	2004	Akutan, St. Paul, King Cove, Floaters	7	5,932,888	42.7
		Dutch Harbor	6	6,504,531	46.8
		Catcher processors	8	602,749	4.3
		Kodiak	4	848,879	6.1
Bering Sea *C. opilio*	2001	Akutan, King Cove, Kodiak	3	1,889,513	8.2
		Dutch Harbor	5	7,916,618	34.5
		Catcher processors	7	3,099,567	13.5
		St. Paul, Floaters	8	10,034,268	43.7
	2002	Dutch Harbor, King Cove, Kodiak	9	13,646,381	46.1
		Catcher processors	8	1,671,036	5.6
		St. Paul, Floaters	8	14,292,205	48.3
	2003	Akutan, King Cove, Kodiak	3	2,162,245	8.5
		Dutch Harbor	6	10,308,648	40.6
		Catcher processors	5	803,452	3.2
		St. Paul, Floaters	8	12,135,777	47.8
	2004	Akutan, King Cove, Kodiak	4	2,287,481	10.4
		Dutch Harbor	6	8,714,351	39.7
		Catcher processors	6	664,660	3.0
		St. Paul, Floaters	8	10,273,001	46.8
	2005	Akutan, King Cove, Kodiak	3	2,206,008	9.7
		Dutch Harbor	6	9,759,358	43.1
		Catcher processors	6	648,967	2.9
		St. Paul, Floaters	5	10,041,444	44.3

*Excludes deadloss.

Source: ADF&G fish ticket data

The distribution of landings under the Program is difficult to predict. In the first two seasons of the Program (2005-2006 and 2006-2007) a ‘cooling off’ provision required most landings made with processor shares to be made in the community of the historic processing that led to the processor share allocation. That limitation was removed in the third season of the program. After the third year, most processor shares will still be subject to a right of first refusal that is triggered by the sale of the shares for use outside of the community of origin. The distribution of rights of first refusal is a reasonable starting point for predicting landings in the fisheries (see Table 11-1). Several exceptions to the right allow shares to be moved from a community without triggering the right. In addition, even if rights are triggered, it is possible that the community entity holding the right may be unwilling or unable to exercise its right to purchase the shares. Consequently, the distribution of rights of first refusal should be viewed only as a starting point for assessing the distribution of landings, which could change substantially over time.

Changes in the TAC of the BSAI crab as a result of revising crab overfishing definitions could have both direct and indirect economic impacts for any or all of the communities with historic participation in the crab fisheries. Although the magnitude of these impacts cannot be quantified, it is safe to say that the impacts of this action would not be uniform in distribution. Regional and community protection measures from rationalization, proximity to fishing grounds, differing natures of resident and nonresident fleets that make local and non-local deliveries, locally owned or locally sited processing plant capacity and capability differences, availability and variety of support facilities offered, and intermediate and final markets served would effect the distribution across the major BSAI crab fishing ports.

11.6.2 Unalaska

Commercial fishing and seafood processing play a significant role in the economic success of Unalaska. The community is home to the greatest concentration of processing and catcher vessel activity than any other Alaska community (EDAW, 2005). As a result, commercial fishing and seafood processing provide a significant number of jobs and income to the community. For example, the four largest employers in Unalaska are UniSea, Inc., Westward Seafoods, Alyeska Seafoods, Inc., and Royal Aleutian Seafoods, Inc.

Table 11-8 summarizes Commercial Operators Annual Report (COAR) processing data by year for the period 2000 through 2005, by species. This information may be used to gauge the community processing sector dependency on particular fisheries. As shown, pollock accounts for nearly 70% of the total wholesale value processed in Dutch Harbor in 2005. The second largest contributor to total wholesale value processed in Dutch Harbor is crab at nearly 20%. Of the crab species, red king crab provided the largest contribution at $51 million in the 2005 followed by snow crab at $33 million.

Dutch Harbor based processors received a substantial share of the processor share allocations in most crab fisheries under the Program. These shares are subject to rights of first refusal of the Dutch Harbor community entity. These shares are unlikely to migrate out of the community because crab processing at most facilities plays an important part in an integrated operation that serves several fisheries.

Dutch Harbor is also home to a residential fleet, but it is much smaller than the fleets of some other fishing communities within the same region. The local fleet tends to target cod, halibut, and crab fisheries on a small scale. In recent years participation in the BSAI crab fisheries by the Unalaska small boat fleet has diminished. Several of the crab fisheries in the surrounding area have closed, thus participation has diminished significantly. The Tanner crab fishery has been closed since 1994 and king crab since the early 1980s. In 2004, the Eastern Aleutian District local Tanner crab fishery reopened after a decade of closure. Several vessels that participate in that fishery are owned by Unalaska residents, but the restriction of 300 pots may limit the number of vessels that participate in the fishery (EDAW 2005).

Unlike many of the crab ports in the region, Unalaska also has extensive support services for the Bering Sea fisheries. The support services provided in Unalaska can support all range of services for any vessel class in the pollock, crab, and other groundfish fisheries. As a result, the support services are heavily dependent upon the success of the groundfish and crab fisheries. To some extent, the fleet services also contribute to the diversification of the Unalaska economy which insulates the community from negative changes in individual fisheries.

Table 11-8 Processing summary for Unalaska/Dutch Harbor, 2000-2005

	2000	2001	2002	2003	2004	2005
Species	**Number of Processors**					
Cod, Pacific	11	7	7	7	6	7
Crab, Bairdi				1	2	3
Crab, Golden King	5	3	3	3	3	5
Crab, Opilio	5	7	8	8	8	6
Crab, Red King	3	5	9	9	7	4
Halibut, Sablefish, and Other Groundfish	9	10	10	10	10	8
Pollock, walleye	4	5	4	4	4	4
Salmon and Herring	1	2	2	2	3	1
	Pounds Purchased					
Cod, Pacific	57,457,806	45,428,613	53,620,560	55,791,013	66,000,750	61,998,817
Crab, Bairdi	-	-	-	*	*	*
Crab, Golden King	4,907,953	*	*	*	*	3,272,765
Crab, Opilio	10,828,377	9,908,446	13,068,040	12,428,315	10,799,182	12,227,462
Crab, Red King	*	3,376,258	4,103,656	7,012,706	6,200,986	7,907,256
Halibut, Sablefish, and Other Groundfish	15,542,080	9,258,909	10,384,614	8,736,311	8,338,294	8,644,335
Pollock, walleye	614,006,201	767,967,412	818,424,456	825,449,453	811,212,331	812,404,032
Salmon and Herring	*	*	*	*	*	*
Total	**705,039,659**	**841,705,961**	**905,798,555**	**913,220,510**	**906,306,639**	**907,030,323**
	Ex-vessel Value					
Cod, Pacific	$17,192,672	$11,014,115	$11,155,935	$15,664,700	$15,341,475	$16,168,938
Crab, Bairdi	-	-	-	*	*	*
Crab, Golden King	$16,597,605	*	*	*	*	$9,106,107
Crab, Opilio	$19,996,719	$15,247,811	$18,036,649	$23,041,113	$22,356,119	$22,176,159
Crab, Red King	*	$16,602,295	$25,675,396	$36,111,810	$29,286,339	$35,889,896
Halibut, Sablefish, and Other Groundfish	$20,082,125	$13,866,890	$17,751,673	$19,216,461	$18,234,625	$18,014,568
Pollock, walleye	$75,734,720	$85,111,759	$96,406,260	$91,058,625	$88,519,966	$102,221,682
Salmon and Herring	*	*	*	*	*	*
Total	**$160,714,732**	**$156,181,349**	**$180,315,293**	**$196,946,917**	**$183,273,020**	**$203,867,090**
	Wholesale Value					
Cod, Pacific	$36,894,677	$26,755,214	$39,818,572	$41,426,284	$37,350,851	$44,032,802
Crab, Bairdi	-	-	-	*	*	*
Crab, Golden King	$21,279,999	*	*	*	*	$11,452,928
Crab, Opilio	$31,395,515	$24,570,523	$30,516,665	$38,560,268	$35,055,004	$33,221,295
Crab, Red King	*	$29,229,264	$40,034,688	$52,340,470	$46,717,154	$51,799,927
Halibut, Sablefish, and Other Groundfish	$26,147,381	$19,333,823	$20,587,667	$22,602,613	$21,935,668	$20,466,546
Pollock, walleye	$219,889,562	$237,721,421	$253,253,485	$268,674,713	$273,768,020	$340,242,214
Salmon and Herring	*	*	*	*	*	*
Total	**$355,926,180**	**$361,548,654**	**$399,070,990**	**$442,297,638**	**$430,261,461**	**$501,586,252**

Source: ADFG Commercial Operator Annual Report Summary
* Indicates the data are confidential and cannot be released
Note - data only available by crab species, not by fishery

In summary, the community of Unalaska is more economical diversified compared to other crab ports in the region, but is still heavily dependent on the groundfish and crab fisheries in the North Pacific. As noted above, the pollock fishery is the most important fishery resource for the community, contributing nearly 70% of the total value of processed groundfish followed by crab at 20% of the total value of processed product.

11.6.3 King Cove

Once heavily dependent upon salmon, the community of King Cove is now more diversified, processing groundfish and crab from the GOA and BSAI. The community is home to several large crab vessels, and is also home to Peter Pan Seafoods, the only shore based processor located in the community. The plant processes salmon, crab, halibut, and groundfish. Approximately 80% of King Cove's work force is employed full time in the commercial fishing industry (EDAW 2005). This likely underestimates the dependency of the local economy on the importance of commercial fishing in the community.

Unlike Dutch Harbor, detailed production figures cannot be disclosed because of confidentiality restrictions. In general, King Cove is more dependent upon Pacific cod than pollock, which contrasts with Unalaska and Akutan. For several years now, the amount of crab and the total value of the crab processed in King Cove have been declining, while groundfish has increased. The decline in crab production was due primarily to a decline in quotas related to reduced stocks. In addition, AFA sideboards caps on BSAI crab have also limited the amount of crab that can be processed in King Cove. Under the Program, crab processing has remained an important component of the diversified processing undertaken at the shore plant in King Cove.

The local residential fleet primarily participates in the salmon fishery, with some participation in the Pacific cod fishery. With regard to crab, King Cove is home to one large crab vessel and three smaller crab vessels, although the smaller vessels have not been active in recent years. The community is also home to several crab vessels that are owned by non-residents. It is reported that one non-resident owner keeps four Bering Sea crab vessels in King Cove. Two of those vessels are skippered and crewed by King Cove residents, while the other two vessels have outside skippers but King Cove crews (EDAW 2005). In addition, a number of crab vessels spend time in King Cove before and after the crab season. Thus, while only one locally owned vessel fishes in the crab fishery, the community is still heavily dependent upon the BSAI and GOA crab fishing for employment and income.

Rapid fleet contraction under the Program, particularly in the Bristol Bay red king crab and Bering Sea *C. opilio* fisheries, has affected King Cove. Between 10 and 15 crew jobs are estimated to have been lost in each of these two fisheries. Fleet contraction is also believed to have caused a drop in demand for harbor and moorage services and goods and services from fishery support businesses in King Cove. Attribution of these effects on the change in crab management is difficult, since data isolating spending of crab vessels and fishery participants from spending associated with other fishery and non-fishery activities are not available (Lowe, et al. 2006).

11.6.4 Akutan

Similar to King Cove and Unalaska, the economy of Akutan is heavily dependent upon the groundfish and crab fisheries in the BSAI and GOA. The community is home to a one of the largest shore based seafood processing plants in the area and is also home to a floating processor. The community also provides some limited support services to the fishing community. In addition, unique from the King Cove and Unalaska, Akutan is a Community Development Quota (CDQ) community.

The vast majority of catch landed in Akutan comes from vessels based outside of the community. Most of those vessels focus primarily on pollock, Pacific cod, and crab. The large shore plant is operated by Trident Seafoods. The shore processor is a multi-species plant, processing primarily pollock, Pacific cod, and crab. Given that the plant is an AFA-qualified plant with its own pollock co-op, pollock is the primary species in terms of labor requirements and economic value. However, the shore plant also accounts for a significant amount of the regional crab processing and also provides for a significant amount of the processing value at the plant (EDAW 2005). As with plants in Dutch Harbor and King Cove, crab has remained an important part of a diverse operation at the shore plant in Akutan since implementation of the Program.

A small number of Akutan residents do participate in the groundfish and crab fishing industry as crew members. Two residents work the IFQ black cod fishery and six individuals work the king and snow crab fisheries.

The community is also an eligible CDQ community, which benefits from the allocation of BSAI groundfish and crab TAC to the CDQ program. APICDA, which represents the community of Akutan and 5 other communities, has participated in the crab fishery through purchasing partial ownership in two crab harvest vessels, the Golden Dawn and the Farwest Leader (EDAW 2005). In addition, APICDA also has significant investments in both harvesting and processing sectors of the BSAI fisheries.

11.6.5 Kodiak

Although the economy of Kodiak is more diversified compared to King Cove and Akutan, fishing is a significant player in the community. Excluding the USCG, four of the top 10 employers in Kodiak in 2003 were fish processors.

Table 11-9 summarizes COAR processing data by year for the period 2000 through 2005 by species. This information may be used to gauge the community processing sector dependency on particular fisheries. As shown, salmon and herring account for 42% of the total wholesale value during 2005. Halibut, sablefish, and other groundfish contributed 22% of the total wholesale value, while Tanner crab contributed less than 5% of the total wholesale value.

Table 11-9 Processing summary for Kodiak for 2000 through 2005, by species

Species	2000	2001	2002	2003	2004	2005
	Number of Processors					
Cod, Pacific (gray)	8	9	8	10	9	9
Crab, Bairdi	-	5	5	5	5	6
Crab, Golden King	1	1	1	1	1	-
Crab, Opilio	2	2	3	1	2	1
Crab, Red King	5	5	4	4	3	3
Halibut, Sablefish, and Other Groundfish	11	12	11	12	13	14
Pollock, walleye	5	4	6	7	5	8
Salmon and Herring	12	13	10	13	15	16
Total	**44**	**51**	**48**	**53**	**53**	**57**
	Pounds Purchased					
Cod, Pacific (gray)	31,519,141	28,379,657	86,619,105	42,370,985	52,660,721	53,584,873
Crab, Bairdi	-	268,019	266,609	507,337	508,330	1,770,035
Crab, Golden King	*	*	*	*	*	-
Crab, Opilio	*	*	*	*	*	*
Crab, Red King	275,176	738,218	771,264	824,603	*	*
Halibut, Sablefish, and Other Groundfish	24,679,163	26,331,218	28,262,083	24,315,491	27,460,885	34,969,964
Pollock, walleye	55,533,862	53,949,109	32,991,917	44,634,584	56,827,314	99,243,809
Salmon and Herring	61,771,741	99,011,913	94,714,040	84,029,762	117,331,042	131,255,688
Total	**174,372,165**	**209,049,127**	**244,296,166**	**196,756,858**	**255,880,607**	**321,723,467**
	Ex-vessel value					
Cod, Pacific (gray)	$11,382,752	$8,262,789	$26,216,227	$13,516,150	$14,912,342	$16,793,138
Crab, Bairdi	-	$616,443	$586,124	$1,255,864	$1,246,151	$3,065,256
Crab, Golden King	*	*	*	*	*	-
Crab, Opilio	*	*	*	*	*	*
Crab, Red King	$1,373,176	$3,721,510	$5,031,912	$4,421,954	*	*
Halibut, Sablefish, and Other Groundfish	$31,154,509	$36,060,563	$31,103,602	$39,231,268	$34,423,105	$37,000,503
Pollock, walleye	$8,398,926	$7,495,671	$3,770,330	$4,159,263	$6,230,264	$13,798,461
Salmon and Herring	$23,104,107	$24,011,951	$15,003,504	$20,053,441	$25,524,100	$29,218,735
Total	**$76,579,804**	**$80,766,641**	**$82,732,088**	**$82,795,913**	**$87,051,755**	**$103,717,480**
	First Wholesale Value					
Cod, Pacific (gray)	$33,416,687	$30,077,297	$30,733,963	$27,960,142	$37,673,044	$34,578,915
Crab, Bairdi	-	$1,604,992	$1,089,537	$1,763,075	$2,376,366	$4,590,225
Crab, Golden King	*	*	*	*	*	-
Crab, Opilio	*	*	*	*	*	*
Crab, Red King	$4,622,485	$4,360,596	$5,522,146	$5,022,925	*	*
Halibut, Sablefish, and Other Groundfish	$38,759,670	$33,641,718	$34,332,331	$41,647,909	$44,636,580	$50,048,701
Pollock, walleye	$33,277,884	$31,246,185	$17,841,809	$17,561,818	$25,257,581	$38,923,478
Salmon and Herring	$64,626,776	$62,248,712	$40,469,486	$66,889,456	$77,442,018	$96,424,568
Total	**$177,617,969**	**$164,021,143**	**$131,518,164**	**$161,073,478**	**$192,942,411**	**$228,939,336**

Source: ADFG Commercial Operator Annual Report Summary
* Indicates the data are confidential and cannot be released

Unlike Unalaska, King Cove, and Akutan, Kodiak is home to an extensive resident fishing fleet. The total number of vessels is less than 600, with less than 300 that actively fished in 2002. Total estimated gross revenue of Kodiak permit holders was $111 million for 2002.

Kodiak is also home to numerous shore based processors. Species that typically contribute more than 10% of the total value are Pacific cod, pollock, and salmon. The processors located in Kodiak provide a large amount of diversity in size, volume, and species processed. The products produced by the shore plants range from large quantity canning of salmon to fresh and fresh-frozen products.

Finally, Kodiak provides a wide range of support service business that caters in whole or in part to the commercial fishing industry. As a result, the support services are heavily dependent upon the success of the different fisheries. To some extent, the fleet services also contribute to the diversification of the Kodiak economy which insulates the community from negative changes in individual fisheries.

The rapid fleet contraction under the Program is also thought to have affected Kodiak. Kodiak crew are estimated to have lost 125 positions in the Bristol Bay red king crab and approximately 60 positions in the Bering Sea snow crab fishery in the first year of the Program. A study of the effects of the Program on Kodiak during the Program's first year found anecdotal evidence suggesting declines in spending at some businesses, but evidence of a broad decline in total local spending could not be identified. The study cautioned that effects may lag, so these findings should be viewed as preliminary (Knapp 2006).

11.6.6 St. Paul

Unlike King Cove, Akutan, Unalaska, or Kodiak, St. Paul is primarily dependent upon the processing of snow crab harvested in the North Pacific. According to ownership data, all crab deliveries to the Pribilof Islands are made by non-resident vessels. Since 1992, the local shoreplant on St. Paul has been the primary processor for crab. As noted above, a number of floating processors have also frequented the area. Icicle, Norquest, Trident, and Stellar Seafoods own floaters that have recently processed crab in the Pribilof Islands. Other processors also have used floaters to process crab in and around St. Paul over the years. Further description of the processing activity in the Pribilof Islands area cannot be included in the profile due to data confidentiality restrictions.

During 1991 to 2000, snow crab accounted for 74% to 100% of the relevant BSAI crab processing in the northern region. During this same period, the northern region accounted for approximately 31% of the total processing value of the fishery. For the period 1995-1999, the northern region accounted for 43% of the total processing value of the fishery. The sharp decline in the GHL from 1999 to 2000 resulted in a drop in the harvest and drop in the percentage of the total snow crab processed in the northern region, from 49% in 1999 to 18% in 2000. Overall, the decline in snow crab stocks during that period had a disproportional effect on the community of St. Paul compared to other communities that process snow crab.

The shift away from St. Paul to other communities during this downturn in snow crab stock is estimated to be due to the slow down in fishing pressure during that period. Data from interviews with harvesters suggest that shorter seasons (and/or lower harvest levels), among other factors, have resulted in a higher proportion of crab being taken further from the grounds (away from St. Paul) for processing.

St. Paul is a primary beneficiary of the North/South regional distribution of shares in the Program. This limitation on landings should ensure that a substantial portion of the processing in the Bering Sea *C. opilio* fishery is undertaken in St. Paul. In the long run, it is possible that St. George could obtain a greater share of North landings, but most participants currently prefer St. Paul's harbor facilities to those available in St. George.

11.6.7 St. George

As with St. Paul, St. George has depended primarily on processing of crab from the Bering Sea *C. opilio* fishery. Processing of crab in St. George has been exclusively by floating processors. Snopac Seafoods, the most consistent processor in the community, has a bunkhouse that it uses for housing non-resident processing workers, who work on their floating platform. St. George is also home to Puffin Seafoods, a small fish handling facility that purchases halibut from the local fleet. These landings are typically tendered to St. Paul for processing at its shore plant. Like Akutan, St. George is an eligible CDQ community represented by APICDA. Puffin Seafoods has been in business since 1998 and is a joint venture between APICDA Joint Ventures and St. George Fishermen's Association.

Approximately 10 commercial fishing permits are issued to residents of St. George and approximately 10 residents own vessels. Residents are engaged exclusively in the fixed gear fisheries, primarily for halibut.

Since 2000, little or no crab processing has taken place in St. George. Prior to the Program, the loss of processing activity is primarily attributable to the decline in crab stocks. Under the Program, no processing has returned to St. George. Processing shares were subject to the 'cooling off' provision requiring the processing of landings with those shares to be undertaken in St. George. Yet, harbor breakwater damage caused by a storm has prevented deliveries to the community during the first two years of the Program. Whether the community can attract crab landings in the future depends in large part on its ability to provide a harbor perceived to be safe by participants.

11.6.8 Adak

The community of Adak, until recently, had no direct or indirect ties to commercial fishing because the island was home to a Naval Air Station since the 1940s. However, the U.S. Navy closed the air station several years ago, leaving the island to the local residents. As a result, the Aleut Corporation is trying to transform the island into a commercial fishing center in the Western Aleutians area of the Bering Sea.

Most commercial fishing deliveries to Adak are to a single processing plant from larger vessels from outside the area since the community has a very limited small boat residential fleet. Of the species processed, cod, halibut, and black cod are the primary species. In the past, the plant has processed golden king crab, but due to AFA crab caps, the plant is not planning on processing this species. The community has also seen some crab and cod activity related to other companies, but these companies are not physically located in the community. Further description of the processing activity in the Adak area cannot be included in the profile due to data confidentiality restrictions.

Finally, Adak is in the process of developing support services capabilities for the commercial fishing fleet. Currently, the community is the main marine refueling station for commercial shipping vessels transiting the North Pacific. The port facilities in Adak can also support a wide variety of large vessels. At-sea processors have used the port for transfer of product in addition to a supply stop.

A few aspects of the Program are structured specifically to support Adak. First, 10% of the TAC in the WAI golden king crab fishery is allocated to a community entity representing Adak. This allocation is intended to support fishery development (including both harvesting and processing) in the community. Adak is also an intended beneficiary of a regional designation on one-half of the shares in the WAI golden king crab fishery, which require crab harvested with those shares to be processed west of 174º West longitude. Currently, Adak is the only community in the West region with a shore-based processing plant. Processing of the West region allocation in Adak is not a certainty, since the rules in the fishery permit processing of those landings on floating processors.

11.6.9 Norton Sound communities

Norton Sound red king crab fishery is operated under a ''superexclusive'' permit program intended to protect the interests of local, small-vessel participants. This fishery is not included in the Crab Rationalization Program.

Approximately 93% of the registered Norton Sound red king crab fishermen are from Norton Sound communities: Nome, Unalakleet, Shaktoolik, Elim, Golovin, White Mountain, and Kotlik. For the Nome permit holders and other nearby villages (Golovin and White Mountain) red king crab is the primary source of income from fishing and a few permit holders also fish for halibut. The Shaktoolik and

Unalakleet permit holders harvest crab and salmon, and this year Elim has a commercial salmon fishery after a six year absence. The Kotlik permit holder may have a permit for the Yukon River salmon fishery.

Most crabs are delivered to the processing plant in Nome, Norton Sound Seafoods, which opened in 2002. In the 2007 summer red king crab fishery, approximately 89% of the crab harvested was sold to Norton Sound Seafoods. Previous to 2002, crab was processed at a floating processor. A tender makes periodic runs to the adjacent Golovin Subdistrict and returns the catch to the Nome plant. Norton Sound Seafoods is owned by a CDQ group, Norton Sound Economic Development Corporation (NSEDC). Beginning in the 2001 season, the NSEDC board voted to prohibit Norton Sound Seafoods from purchasing crab from permit holders who reside outside of Norton Sound. Those permit holders, and some permit holders in Shaktoolik and Unalakleet, send their catch via jet to Aquatech in Anchorage for processing. A small percentage of the catch is sold by permit holders to area residents and local restaurants.

11.7 Effects of Alternatives

Two methods are employed in order to estimate the direct economic impacts of Alternative 1 and the proposed OFLs under Alternatives 2 and 3. The first is a comparison of the proposed OFLs for the 2006/2007 fishing season using the information available by stocks (2006 MMB where applicable) with the actual retained catch from the 2006/2007 fishing season for those stocks under Alternative 1. The second method is employed for those stocks where projection modeling is possible, Bristol Bay red king crab stock and the EBS snow crab stock. For these stocks, a short-term projection of retained yield under two control rules (unconstrained state harvest strategy and an $F_{35\%}$ constrained harvest strategy) are compared for an estimate of future yield constraint. For the remaining crab stocks, a qualitative discussion of impacts is presented.

For all stocks, to avoid overfishing, TACs must be established below OFLs. Setting TACs at or near the OFL creates some risk that the OFL could be exceeded, resulting in overfishing. Therefore, a buffer between the OFL would need to be incorporated into the setting of the TAC. Depending on the size of the buffer, there could be some potential for a decline in the gross revenue for harvesters and processors in this fishery from lower TACs.

11.7.1 Comparison of catch under Alternatives 2 and 3 with actual catch under Alternative 1 (2006/07)

As a means of summarizing the potential impact of revised OFLs on current harvests by species, proposed OFLs for the 2006 stock biomass are calculated to compare against actual catch levels from the 2006/2007 fishery. Table 11-10 below shows each stock, its 2006/07 catch level under Alternative 1, as applicable, and the proposed OFL under Alternative 2 or 3. OFL values for the surveyed/population model developed stocks (Bristol Bay red king crab, snow crab, EBS Tanner crab, Pribilof Islands red and blue king crabs, St. Mathew blue king crab, and Norton Sound red king crab) were estimated from 2006 legal male abundances whereas OFL values for the other crab stocks were estimated as average catch an appropriate time period as noted in Table 2-10. For EBS Tanner crab OFL retained catch estimation, a γ value of 2.85 was used, but for other data poor Tanner crab stocks (e.g., EAI Tanner crab) a γ value of 2 was used.

Table 11-10 Stock, 2006/07 retained catch under Alternative 1, as applicable, and proposed OFL under Alternative 2 or 3. All values are in million pounds.

	Alternative 1	Alternative 2 and 3	
Stock	2006/07 Catch (Retained)	OFL (retained catch)	OFL (total catch)
BB red king crab	15.748	14.430	17.780
EBS snow crab	36.360	23.590	29.980
EBS Tanner, Tier 3	2.120	13.076	18.234
EBS Tanner, Tier 4	2.120	9.903	14.350
Pribilof Is. red king crab	0	1.464	NA
Pribilof Is. blue king crab	0	0	NA
St. Matthew blue king crab	0	0.595	NA
Norton Sound red king crab	0.453	1.119	NA
EAI Tanner crab	0.084	0.683	NA
Dutch Harbor red king crab	0	0	NA
Adak red king crab	0	0.948	NA
Pribilof Is. golden king crab	0	0.174	NA
AI golden king crab	5.260	8.261	NA
EBS grooved Tanner crab	0	0.352	NA
St. Matthew golden king crab	0	0.086	NA
WAI Tanner crab	0	0.077	NA
St. Lawrence Is. blue king crab	0	0	NA
AI scarlet king crab	0	0.013	NA
EBS scarlet king crab	0	0.015	NA
BS triangle Tanner crab	0	0.038	NA
EAI triangle Tanner crab	0	0.295	NA
EAI grooved Tanner crab	0	0.505	NA
WAI grooved Tanner crab	0	0.075	NA

In comparing the 2006/2007 retained catch with the OFL (retained catch), those stocks where the catch is greater than the proposed OFL for the same time period are the following: Bristol Bay red king crab and snow crab. An estimate of potential reduction in revenue for each of those stocks is tabulated in Table 11-11. For the remaining stocks, either catch information is insufficient to determine an OFL, catch is confidential thus complicating a determination of overfishing, or catch in 06/07 was below the proposed OFL and no impact on harvest is estimated (Table 11-11). The table suggests that a decline of approximately 8.5% of the retained catch in the Bristol Bay red king crab fishery and approximately 35% in the snow crab fishery would have been necessary to avoid overfishing for those stocks in 2006/07. As the primary fishery for most participants in the BSAI crab fisheries, it is useful to consider this reduction across the two fisheries. Collectively, the reduction represents a decrease of almost $27 million in ex-vessel revenues (or slightly more than 20% of the revenues in the two fisheries combined).

Table 11-11 Potential reduction in retained catch and ex-vessel gross revenue under Alternatives 2 or 3 compared to Alternative 1. Retained catch in millions of pounds.

Stock	Retained Catch 2006/07 fishery	OFL catch (retained)	Difference	2006/07 Ex-vessel value($/pound)	Potential reduction in ex vessel gross revenue (million $)
Bristol Bay red king crab	15.75	14.43	1.32	$3.90	$5.15
EBS snow crab	36.36	23.59	12.77	$1.70	$21.71

11.7.2 Comparison of short-term retained yield projections - Bristol Bay red king crab and Snow crab

Prior to fully judging the economic effect of the action, it is important to consider the both immediate effects beyond the first year and longer term effects on retained catches. Short-term (5 or 6-year) scenarios were evaluated in order to estimate the immediate impacts of management under the Alternatives. This analysis utilizes the yield results comparing short-term simulations of fishing under the proposed $F_{35\%}$ OFL control rule in conjunction with the State's harvest strategy with fishing at the current State harvest strategy (as an estimate of future TAC-setting). The impact of the proposed OFL control rule on future harvests is evaluated here using short-term simulations of the maximum allowable retained yield under the control rule beginning at the current stock biomass for Bristol Bay red king crab and snow crab. Projections of the retained yield under the status quo harvest strategy in conjunction with the maximum retained catch permitted under the harvest strategy constrained by the proposed OFL control rule gives an indication of the potential for the harvest strategy to be constrained by the proposed OFL, in which case the TAC would be adjusted downward accordingly. In order to avoid overfishing, TACs must be established below OFLs.

The economic impacts of the proposed OFL control rules depend upon the extent to which those control rules constrain the existing harvest strategies used in establishing TACs. Longer–term scenarios (30-year and 100-year) to evaluate the flexibility of the control rules under various stock rebuilding scenarios were described in Chapters 4, 5, and 6. These scenarios show indications of longer-term yields and progress towards rebuilding but are not intended to provide a simulation of long-term stock status, merely to show that the control rules are equally responsive and effective at stock rebuilding regardless of whether a stock is declining or increasing in biomass at the time of application. As described previously (Section 3.2) these scenarios were run to ensure that the control rule formulation is appropriate for crab stocks.

In each of the species noted below, the short-term simulation projections suggest that TACs under Alternative 2 and 3 would be less than under Alternative 1. The extent of this difference depends on the degree to which actual TACs are set below the proposed OFLs. Under Alternative 1, the MSY control rule for these fisheries has not been constraining. However, the proposed OFLs for Alternative 2 and 3 would be lower than those under Alternative 1 in some years, so TACs would have to be set lower to remain below the lower OFLs (and prevent overfishing).

Setting TACs at or near the OFL creates some risk that the OFL could be exceeded, resulting in overfishing. Therefore, a buffer between the OFL might be incorporated when setting the TAC. In general, the Program has reduced the potential for overharvest of the TAC. However, the risk of overharvest is increased when discard rates are high (which could occur, if high grading is observed). In the first year of the Program, discards of red king crab exceeded those expected during TAC setting. If these discard practices persist, a larger buffer between the OFL and TAC might needed to protect stocks.

As described previously, for those stocks for which sufficient catch data are available, the OFL will apply to all catch (including bycatch in other fisheries). Thus bycatch of crab species in other directed crab fisheries, as well as directed groundfish and scallop fisheries, accrues towards the OFL and must be annually tabulated to determine overfishing. In order to avoid exceeding the OFL, any buffer that is established between TAC and OFL must also consider the bycatch needs in these fisheries.

11.7.2.1 Bristol Bay Red King Crab

As shown in Table 11-12, catch in 2006/07 fishery was 1.32 million pounds greater than the proposed OFL for the same stock biomass under Alternative 2 or 3. This would indicate that as a minimum estimate (i.e. should TAC be set = OFL in that year), TAC would have be decreased by this amount to be below OFL in that year. The amount of potential harvest reduction would have been at least 1.32 million pounds, and greater if a buffer was established to meet minimum bycatch needs in other fisheries (as is recommended to avoid exceeding the OFL). A potential reduction in harvest of 1.32 million pounds would be equivalent to an ex-vessel value of $5.15 million in that year (Table 11-12). This gives an estimate of the immediate impact of revised OFLs for this stock in terms of reduction in harvest.

An estimate of immediate term harvest projections shows the potential for further TAC reduction in the next few years, in conjunction with longer term stock rebuilding and higher harvest in years to come. Table 11-12 provides projected annual maximum retained catch from 2007 to 2012 using the existing status quo harvest strategy and the status quo harvest strategy as constrained by the $F_{35\%}$ harvest control rules in the Bristol Bay red king crab fisheries. The projected retained catch under this constrained harvest control rule is an indication of the maximum retained catch that would be possible. Actual TACs would be below this but the exact buffer between projected OFL and TAC is unknown. For Bristol Bay red king crab, the $F_{35\%}$ control rule as a constraint on the status quo harvest strategy is lower than the unconstrained state harvest control rule alone in 2007–2010.

Differences between retained catches under the status quo and the revised OFL alternatives are less than 3 percent in all but a single case. In the third year of management under the revised OFL alternatives, retained catches would be approximately 8% (or approximately 750,000 pounds) less than under the existing rule. At the 2006-2007 ex vessel price, this catch would generate almost $3 million in ex vessel gross revenues. In the last two years of the six year simulation, retained catches under the revised control rule exceed those of the status quo by between 1% and 2%. The combined decline of ex vessel retained catch under the revised OFL alternatives compared to the status quo for the 6 years of the simulation is approximately 900,000 pounds (or slightly less than 1.5% of total catch under status quo for the period).

Table 11-12 Projected retained catch for Bristol Bay red king crab using existing harvest strategies and $F_{40\%}$ and $F_{35\%}$ harvest control rules from 2007 to 2012.

Year	Bristol Bay Red King Crab Projected Retained Catch in 1000s of tons (95% confidence intervals)	
	State Harvest CR	State Harvest CR + $F_{35\%}$ constraint
2006	7.04	7.04
2007	8.03 (8.02, 8.04)	7.97 (7.10, 8.03)
2008	10.39 (10.22, 11.19)	9.61 (9.59, 9.80)
2009	11.81 (10.62, 16.56)	11.53 (10.76, 13.11)
2010	11.54 (8.85, 20.02)	11.52 (9.14, 18.91)
2011	10.07 (6.86, 20.33)	10.19 (7.01, 20.40)
2012	9.83 (5.03, 27.44)	9.94 (5.14, 27.50)

Although not a result of this action, the projected decline in Bristol Bay red king crab TAC from the TAC in recent years (which has averaged approximately 15 million pounds in the first two years of the rationalization program) will reduce gross revenues to harvesters and processors in the fishery and contribute to fleet consolidation. The magnitude of the social and economic impacts cannot be determined in this analysis, but loss of one-third of the catch in the immediate term will likely translate into a loss of approximately one-third of the revenues to both sectors. Whether fleet consolidation will be proportional to loss of catch is not known.

The decline in the Bristol Bay red king crab TAC from current levels will impact the communities which historically processed this species (specifically Dutch Harbor which holds a right of first refusal on 51.1% of the Bristol Bay red king crab PQS pool, Akutan which holds rights of first refusal on 19.9% of the pool, and King Cove which holds a right of first refusal on 12.8% of pool. Communities with rights of first refusal on small shares of the PQS could also be impacted by changes in the Bristol Bay red king crab TAC, and, in some cases, could experience greater effects than communities like Dutch Harbor or Akutan. The degree to which the community is affected by TAC changes depends on the contribution the fishery makes to the local economy. For communities like Kodiak, the red king crab fishery plays a relatively small role in the diversified local economy. However, in King Cove, which is less diversified, the Bristol Bay red king crab fishery plays a more prominent role, so it would be affected to a higher degree by changes in the Bristol Bay red king crab TACs.

11.7.2.2 Snow Crab

As shown in Table 11-13, catch in 2006/07 fishery was 12.77 million pounds greater than the proposed OFL for the same stock biomass under alternative 2 or 3. This would indicate that as a minimum estimate (i.e., should TAC be set = OFL in that year), TAC would have be decreased by this amount to be below OFL in that year. The amount of potential harvest reduction would have been at least 12.77 million pounds, and greater if a buffer was established to meet minimum bycatch needs in other fisheries. A potential reduction in harvest of 12.77 million pounds would be equivalent to an ex-vessel value of 21.71 million dollars in that year (Table 11-13). This gives an estimate of the immediate impact of revised OFLs for this stock in terms of reduction in harvest.

An estimate of future short-term harvest projection shows the potential for further TAC reduction in the next few years, in conjunction with longer term stock rebuilding and higher harvest in years to come.

Table 11-13 provides a comparison of projected annual maximum retained catch from 2007 to 2012 using the existing status quo harvest strategy and the status quo harvest strategy as constrained by the $F_{35\%}$ harvest control rules in the snow crab fishery. Similar to the Bristol Bay red king crab, the projected retained catch under the constrained state harvest control rule is an indication of the maximum retained catch that would be possible. Actual TACs would be below this but the exact buffer between projected OFL and TAC is unknown. For snow crab, the $F_{35\%}$ control rule as a constraint on the status quo harvest strategy is lower than the unconstrained state harvest control rule alone in 2008, 2011 and 2012.

The results of the simulation of retained catches in the snow crab fishery are similar to those in the Bristol Bay red king crab fishery. In the first year of the simulation, retained catch under the revised OFL alternatives are approximately 5% (or 1.8 million pounds) lower than under the status quo. At the 2006-2007 ex-vessel price, this catch would generate approximately $3 million. Retained catches are slightly higher (less than 2%) under the revised OFL than under status quo in the second and third year of the simulation. In the fourth and fifth years, the status quo would provide slightly higher retained catches (less than 2.5%) than under the revised OFL. The combined decline of ex-vessel retained catch under the revised OFL alternatives compared to the status quo for the 5 years of the simulation is approximately 2.2 million pounds (or slightly more than 1.1% of total catch under status quo for the period). Both short run (30 year) and long run (100 year) projections show very similar retained catch levels under the status quo and the revised OFL alternatives, suggesting little impact of the action on either harvesters or processors beyond the first few years after implementation.

Table 11-13 Projected retained catch for snow crab using existing harvest strategies and $F_{40\%}$ and $F_{35\%}$ harvest control rules from 2007 to 2012. Shading represents projected constrained harvests.

	Snow Crab Projected Retained Catch in 100s of tons (95% confidence limits)	
Year	Status quo Harvest CR	Status quo Harvest CR + $F_{35\%}$ constraint
2006		
2007	22.3	22.3
2008	34.7 (22.1, 50.5)	32.9 (21.0, 48.1)
2009	43.7 (26.7, 64.5)	44.3 (26.9, 65.5)
2010	42.2 (26.9, 57.2)	42.3 (26.9, 57.5)
2011	33.7 (23.8, 43.2)	33.5 (23.1, 43.4)
2012	40.1 (21.2, 83.5)	39.2 (19.3, 83.5)

Under all of the alternatives, the declines in catches in the EBS snow crab fishery from recent catches are projected to be smaller than in the Bristol Bay red king crab fishery. As a result, the effects on revenues of harvesters and processors may be expected to be less. In addition, less fleet consolidation may occur than in the Bristol Bay red king crab fishery, which is likely to experience a substantial decline in its TAC.

Reductions in TAC could also negatively affect communities through reduced spending in that community by harvesters and processors, and residents who work in the snow crab industry, and residents and businesses that indirectly rely on the snow crab industry. Simulation results, however, suggest that any decline in TAC will be relatively small and short-term.

The impacts of TAC declines will vary across communities depending on the degree of importance the snow crab fishery plays is in the local economy. Communities with a high degree of dependency on the snow crab fishery will likely be affected to a greater higher degree than communities with low dependency on the fishery. Table 11-1 presents the distribution of rights of first refusal on PQS for snow crab by community, which is the starting point for the geographic distribution of snow crab deliveries.

For communities like St. Paul, and St. George, the snow crab fishery has been an important component of the local economy. Changes in the snow crab OFL that result in a change in the snow crab TAC will likely impact these communities to a much higher degree than Dutch Harbor or Kodiak which are more diversified across many different fisheries.

11.7.3 Tanner Crab

Any declines in Tanner crab TACs are likely to contribute to reduced gross revenues to harvesters, processors, and other businesses that rely on the Tanner crab fisheries. The immediate effects of declines in the Tanner crab TACs is likely to be limited, since the TACs in these fisheries are relatively small in recent years. In addition, the TACs have not been fully harvested suggesting that small declines in the TACs in the immediate future may not have noticeable effects. Historically, Tanner crab in the Bering Sea was important to harvesters, processors, and crab dependent communities. If this action were to effect (either increase or decrease) TACs in the longer term, those TAC changes would affect participants and communities that rely on these fisheries.

Under the proposed OFLs as shown in Table 11-109, a Tier 4 OFL for Tanner crab would not be constraining on the current TAC. Projections of short-term future yield constrained by the proposed OFLs compared with the state harvest strategy are not possible at this time for this stock, thus it is not possible to indicate if the TAC will be constrained in the future by a revised OFL under Alternative 2 or 3.

11.7.4 Other Crab Stocks

Norton Sound red king crab

The Norton Sound red king crab stock is preliminarily placed in Tier 4. This stock is currently open to fishing. Under Alternative 2 or 3, the model estimate of MMB for the Norton Sounds red king crab stock (Figure 4-6) is well above the B_{MSY} proxy for this stock, thus there is no indication that the fishery will be constrained by Alternative 2 or 3. The Norton Sound red king crab fishery, which is excluded from the Program, is operated under a vessel registration intended to protect the interests of local, small-vessel participants. Although there is no indication the fishery will be constrained under Alternative 2 or 3, if there is a change in the TAC as a result of this proposed action, the impacts will likely be limited exclusively to the participants and communities that participate in this fishery in and around the Norton Sound area. The proposed OFL for this stock is not constraining on the current TAC (Table 11-109).

Dutch Harbor red king crab

The Dutch Harbor red king crab fishery has been extremely depressed during the last two decades, and the fishery has been closed since 1983. The stock is preliminarily placed into Tier 5 for purposes of this analysis. No OFL can be calculated at this time. The new overfishing definitions will likely not have any impact on this stock in the near future because no fishery is predicted; therefore the proposed action is estimated to have no economic and social impact for this stock.

Adak red king crab

Adak red king crab is preliminarily placed in Tier 5 under Alternative 2 or 3. The stock has only been opened to fish in the Petrel Bank area for 4 years during the last 10 years. The historic average yield has been high, with the highest annual catch of 21 million pounds in 1964. However, the average yield from 1985 to 1994 is only 947,900 pounds (430 t). The OFL could be set as 947,900 pounds (430 t), if average catch for this time period is chosen as the means to establish an OFL for this stock. This stock could be promoted to Tier 4 if routine surveys are conducted.

Overall, it is unlikely the fishery would be constrained if Alternative 2 or 3 were selected. If CPUE increased in the future, TACs could be constraining by the proposed redefining of the OFL. In those cases, depending on the size of the buffer between the OFL and TAC, there is the potential for a decline in the gross revenue for harvesters and processors in this fishery from lower TACs. Under the Program, most PQS in this fishery is allocated to processors located in Dutch Harbor. As a large, diversified fisheries economy, the impact of any TAC changes on that community are expected to be small.

Pribilof Island red king crab

Under the Alternative 2 or 3 this stock would be managed under Tier 4 and B_{MSY} and MSST are provided based upon MMB. Additionally, the MFMT for determining overfishing is prescribed by the Tier 4 formula. Figure 4-6 and Table 3-5 provides estimated MMB and B_{MSY} proxy and MSST proxy (½ B_{MSY}) for the Pribilof Island red king crab stock. Average abundance from 1988 to 2006 was used for a proxy for this stock because model estimates of biomass were not available before 1988. An OFL of 1.46 million pounds could be established for this stock. This OFL would apply to the retained catch only as there is insufficient data available to establish all bycatch removals of this stock in all fisheries.

The Pribilof Island red king crab stock remains closed due to concerns with reliability of biomass estimates for the red king crab stock as well as the potential for bycatch of blue king crabs. There is no separate harvest strategy for the Pribilof Island red king crab stock (separate from the blue king crab stock). There has been some interest from the public in recent years for the Board of Fisheries to consider adopting a separate harvest strategy for this stock such that it may open on its own, given that stock status estimates (under Alternative 1) indicate that this stock is above its estimated $B_{MSY.}$ However, estimates of stock status in relation to B_{MSY} under Alternative 2 or 3 (Figure 4-6) show the stock below the B_{MSY} and declining. Should Alternative 2 or 3 be adopted, it is unlikely that this stock will open to directed fishing. Based on past catch history, the fishery was important to the St. Paul economy and its closed status has likely negatively impacted the St. Paul economy to some degree. Since it is likely this fishery will remain closed to directed fishing under this alternative, the St. Paul economy must continue to function without the revenue this fishery could bring to the local economy.

St. Matthew blue king crab and Pribilof Islands blue king crab

St. Matthew blue king crab and Pribilof Islands blue king crab stocks are both suggested for Tier 4 management under Alternative 2 or 3. Both stocks remain under rebuilding plans and are closed to fishing. Under this alternative, maximum estimated F_{OFL} rates are F = 0.36. As both stocks are currently closed to fishing (F=0), there is no constraint imposed by the calculated OFLs for these stocks. However, if either stock were to open in the future, the retained catch would need to be below the calculated OFL for this fishery. This could impose a harvest constraint on the current harvest strategy for these stocks. For these stocks, information may be insufficient to determine an OFL which is to be applied to the total catch, thus the OFL would apply here for the retained catch only. For Pribilof Island blue king crab, the MMB is below the 25% threshold and thus the OFL is set equal to 0. Any retained catch of this stock would constitute overfishing.

Revised estimates of stock status under Alternative 2 or 3 remain similar to estimates under Alternative 1. Should Alternative 2 or 3 be adopted, rebuilding plans for both stocks may need to be re-evaluated and potentially revised given new estimates of stock recovery in relation to overfishing. Table 11-1 shows the distribution of rights of first refusal on PQS for St. Matthew and Pribilof Island blue king crab by community. As noted in the table, the St. Matthew and Pribilof Island blue king crab fishery, when open, are crucial to St. Paul economy. Any changes in the blue king crab OFL that result in a change in the TAC will likely impact St. Paul.

Aleutian Island golden king crab

The golden king crab stock is recommended for management under Tier 5. Since 1998/1999 season, the State has set the AI golden king crab harvest level at 5.7 million pounds (2,586 t); 3.0 million pounds (1,361 t) of which is apportioned to the area east of 174° W. longitude, and 2.7 million pounds (1,225 t) is apportioned to the area west of 174° W longitude. During this time, an average of 19 vessels participated in this fishery.

Considering the catches after 1999 were strictly based on the TAC of 5.7 million pounds, the average catch of 8.261 million pounds (3,747 t) from 1985 to 1999 is used here (Tier 5) to establish an OFL for this stock (Figure 8-1). This would not constrain the current TAC and would provide a small room for future increases in TAC if the stock abundance continues to increase. This OFL would apply only to the retained portion of the catch as information is insufficient to determine a total catch OFL at this time. The CPUE for this stock has increased sharply during recent years. This stock could be moved to a different tier once the model under development (Siddeek et al. 2005) is used for annual stock assessment. Golden king crab may be able to sustain higher harvest rates than red and blue king crabs (see section 8.2 for additional information on harvest rate adjustments relative to movement to different tier status).

Table 11-1 shows the distribution of rights of first refusal on PQS for the EAI golden king crab fishery. The Western fishery is not subject to rights of first refusal. For EAI golden king crab, a Dutch Harbor community entity holds rights of first on 98% of the PQS. Any changes in the OFL for this species that results in a change in the TAC will likely impact Dutch Harbor. In the WAI golden king crab fishery, 50% of the PQS is designated as west shares to be delivered west of 174º W, regardless of historic landing locations in the fishery. The remaining 50% of the PQS has neither regional designation nor regional delivery requirements. Communities most impacted by changes in the TAC for these stocks will be Adak and Dutch Harbor. Effects on Dutch Harbor are likely to be less significant to the community, as its economy depends on a variety of fisheries, many of which are substantially larger in value than the Aleutian golden king crab fisheries.

Pribilof Island golden king crab

Pribilof golden king crab are found in commercial concentrations in only a few deep canyons in the Bering Sea and have never sustained a large harvests when compared to other Bering Sea king crab fisheries. The Pribilof golden king crab is excluded from the Program.

Under Alternative 2 or 3 the Pribilof Islands golden king crab stock would be placed into Tier 5. Based on fishing effort data, the appropriate period for catch average may be 1993 to 1999. The catches after 1999 were primarily based on the TAC, and the catches after 2002 were confidential. The average yield during 1993- 1999 is 174,200 pounds (79 t). If the OFL was established for this stock based upon the use of average yield over this time period, the OFL would be 174,200 pounds (79 t, see Figure 8-2). This OFL would apply only to the retained portion of the catch as information is insufficient to determine a total catch OFL at this time. The current GHL of 150,000 pounds (68 t) has not been fully harvested in recent years.

Eastern Aleutian Islands Tanner crab

The EAI Tanner crab stock is suggested for management under Tier 4. Stock status for EAI Tanner crab would be below its B_{MSY} proxy but above MSST proxy. Historical comparison of stock status shows that the stock was below the MSST proxy in all years prior to 2000, with the exception of 1999 (Figure 6-5). This fishery is primarily a state-water fishery given that 93% of the landings from 1985-2006 were in state-waters statistical areas. This fishery is not anticipated to constrained by proposed OFLs. As shown in Table 11-10, catch in 2006/07 fishery was 0.084 million pounds, which is 7,300 pounds greater than the proposed OFL for the same stock biomass under Alternative 2 or 3. This would indicate that as a minimum estimate (i.e. should TAC be set = OFL in that year), TAC would have be decreased by this amount to be below OFL in that year. The amount of potential harvest reduction would have been at least 7,300 pounds, and greater if a buffer was established to meet minimum bycatch needs in other fisheries. A potential reduction in harvest of 7,300 pounds, using the ex-vessel price for 2006 of $1.60/pound would be equivalent to an ex-vessel value of 10,000 dollars in that year (Table 11-10). This gives an estimate of the immediate impact of revised OFLs for this stock in terms of reduction in harvest.

This fishery is primarily a State water fishery, this stock is one of the twelve species that would be removed from the Federal FMP if the Council were to select Option A. The State would have sole management authority for this species, as they do for hair crab (the hair crab fishery, which occurs in the EEZ, was removed from the FMP). Currently, the FMP defers the management of these fisheries to the State. Therefore, the State already manages these stocks and collects all of the biological information. Based on this information, the economic and social effects of removing this species from the Federal FMP would be minimal.

Western Aleutian Islands Tanner crab

WAI Tanner crab is suggested for management under Tier 5 in Alternative 2 and Tier 6 under Alternative 3. For Tier 5, the appropriate period for average catch may be 1985 to 1992. The average yield during this period is 76,700 pounds. If the OFL were established based upon this time period, then the OFL would be 76,700 pounds. This OFL would apply only to the retained catch as information is insufficient to calculate a total catch OFL for this stock at this time. Under Alternative 3 the default OFL would be set equal to 0 and no retention of this stock would be possible without being considered overfishing. This stock is also considered for removal from the Federal FMP under Option A.

Other Tanner and King Crab Stocks

The remaining stocks are all placed in Tier 5 (Alternative 2) or Tier 6 (Alternative 3) for purposes of analysis under this alternative. However, catch information for these stocks is very limited. Tier 5 OFLs would be calculated based upon average catch in years with fishing effort 10% or higher of the mean fishing effort. Only using data with fishing effort 10% or higher of the average effort filters out years that do not represent normal fishing effort (Table 11-14).

The problems with establishing an OFL based on catch history for these stocks include: (1) catch data come from exploratory and incidental fisheries for most stocks, (2) there are only 2 to 4 years of catch data for several stocks, and (3) mean catch for some species may be either too high (grooved Tanner crab) or too low (AI scarlet king crab). The mean catch for EAI grooved Tanner crab used to set the OFL of 504,800 pounds may be too high (only 4 years of data and the CPUE declined during these 4 years). In contrast, the State established a GHL range of 50,000 (23 t) to 200,000 (91 t) pounds for grooved Tanner crab in the Eastern Aleutian District. For EBS grooved Tanner crab, there has been sporadic fishing effort during the last 10 years and limited information is available for this stock. The mean catch for EBS grooved Tanner crab used to set the OFL of 351,900 pounds may be too high when compared to the State's harvest limit of 200,000 (91 t) pounds. Additionally, AI scarlet king crab OFL of 13,400 may be too low (the maximum annual catch of 63,000 is more than 4.7 times of the average). All of the OFLs listed in Table 11-14 are for the retained catch only as information is insufficient at this time to determine a total catch OFL. Under Alternative 3 all of these stocks would be placed in Tier 6 and the OFL for the retained catch would be set equal to 0. No retention may occur on stocks for which OFL = 0.

Table 11-14 Estimated OFLs (in pounds) for other crab stocks in Tier 5 under Alternative 2. OFLs based on mean catches from appropriate period during 1985-2005. Data utilized includes only those with with fishing effort 10% or higher of the average effort.

Stock	OFL
EBS grooved Tanner crab	351,900
AI scarlet king crab	13,400
EBS scarlet king crab	14,800
BS triangle Tanner crab	37,700
EAI triangle Tanner crab	295,300
EAI grooved Tanner crab	504,800
WAI grooved Tanner crab	74,600

In addition, the stocks listed below are under consideration for removal from the Federal FMP under Option A. These stocks have no directed fishery or are limited to an exploratory fishery or incidental harvest. As noted above, Option A would remove specific stocks from the Federal FMP for which there is no directed fishery, a limited exploratory fishery, or the majority of catch occurs in State waters. Many of the stocks have not had a directed fishery. Some stocks have had sporadic historical fisheries that were predominantly prosecuted in State waters. Any future exploratory fishery would be operated by commissioner's permit, which means the State determines if and when these fisheries occur, who may participate, observer requirements, and how much is harvested. Based on this information, the economic and social effects would be minimal.

- EAI Tanner crab
- WAI Tanner crab
- WAI grooved Tanner crab
- EAI grooved Tanner crab
- EBS grooved Tanner crab
- EAI triangle Tanner crab
- BS triangle Tanner crab
- AI scarlet king crab
- EBS scarlet king crab
- St. Matthew golden king crab
- St. Lawrence Islands blue king crab
- Dutch Harbor red king crab

12 Cumulative Impacts

Analysis of the potential cumulative effects of a proposed action and its alternatives is a requirement of NEPA. Cumulative effects are those combined effects on the quality of the human environment that result from the incremental impact of the proposed action when added to other past, present, and reasonably foreseeable future actions, regardless of what Federal or non-Federal agency or person undertakes such other actions (40 CFR 1508.7, 1508.25(a), and 1508.25(c)). Cumulative impacts can result from individually minor, but collectively significant actions taking place over a period of time. The concept behind cumulative effects analysis is to capture the total effects of many actions over time that would be missed by evaluating each action individually. At the same time, the CEQ guidelines recognize that it is not practical to analyze the cumulative effects of an action on the universe, but to focus on those effects that are truly meaningful.

The cumulative effects of crab fishing under the Crab Rationalization Program are analyzed in Section 4.9 of the Crab EIS, including the interactive effects of any past, present, and reasonable foreseeable future external actions. That analysis is incorporated by reference. The Crab EIS concludes that for majority of the components of the environment analyzed, the cumulative effects of the Program are insignificant based on the best available scientific information. For some environmental components analyzed, the Crab EIS determined the cumulative effects were unknown, because of a lack of sufficient information on the cumulative condition or the inability to predict effects of external future actions. The cumulative effects analysis in the Crab EIS is detailed and broad enough to encompass the likely cumulative effects of fishing under the Crab Rationalization Program. No new significant information is available that would change these determinations in the Crab EIS. This action will not result in additional impacts beyond those considered in the Crab EIS and is not anticipated to change any of the cumulative effects conclusions. As previously discussed, the alternatives are only expected to impact the BSAI crab stocks and fisheries.

No reasonably foreseeable future actions were determined to have a continuing, additive and meaningful relationship to the direct and indirect effects of the alternatives.

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Appendix A. Simulation Models

A.1 Notations used in the equations

a = a parameter in auxiliary models,
b = a parameter in auxiliary models,
B_t = mature male biomass corresponding to a fishing mortality F in year t,
B_0 = mature male biomass corresponding to a fishing mortality F = 0,
B = a general term used for mature male biomass,
B_{MSY} = mature male biomass at the MSY producing level,
c = a parameter in auxiliary models,
c_t = retained catch of legal-sized male in year t,
d = a parameter in auxiliary models,
et = average time elapsed between the mid-molting date (i.e., start of a biological year) and start date of a fishing period as a fraction of a year,
F_{MSY} = instantaneous fishing mortality that will produce MSY at the MSY-producing biomass,
F_T = instantaneous bycatch fishing mortality by the trawl fishery, a fixed value of 0.01 was used,
F_t = instantaneous fishing mortality in year t,
$F_{x\%}$ = instantaneous fishing mortality that results in x% equilibrium spawning potential ratio,
h = steepness parameter of a stock-recruitment curve,
hm = proportion of discarded males and females that died due to capture and release to sea,
$HM^s_{i,t}$ = instantaneous handling mortality of sex *s*, size-class i, and year t,
$immat\,N^s_{i,k,t}$ = new-shell immature abundance of sex *s*, size-class i, age k, and year t,
$immat\,O^s_{i,k,t}$ = old-shell immature abundance of sex *s*, size-class i, age k, and year t,
$immolt^s_i$ = immature crab molt probability of sex *s* and size-class i,
k = age in years,
L = likelihood function,
L_c = minimum legal size,
L^s_i = mean size of crabs of sex *s* in a size-class i,
M = instantaneous natural mortality,
mat^s_i = maturity probability of sex *s* and size-class i,
$matN^s_{i,k,t}$ = new-shell mature abundance of sex *s*, size-class i, age k, and year t,
$matO^s_{i,k,t}$ = old-shell mature abundance of sex *s*, size-class i, age k, and year t,
$mmolt^s_i$ = mature crab molt probability of sex *s* and size-class i,
MSY = maximum sustainable yield,
n = total number of size intervals available in a cohort for P i, j estimation,
$N^s_{i,k,t}$ = new-shell stock abundance in number of sex *s*, size-class i, age k, and year t,
$O^s_{i,k,t}$ = old-shell stock abundance of sex s, size-class i, age k, and year t,
P^{s*}_i = probability of recruits of sex s falling into size-class i,
$P^s_{i,j}$ = probability of crabs of sex s in a size-class i growing into a size-class j,
R = a general term used for total number of recruits,
R_0 = number of recruits at F = 0,
$R_{0,t}$ = number of recruits at age 0, and year t,

R_{max} = maximum number of recruits,
$s_i^{'}$ = trawl bycatch selectivity for size-class i,
s_i = pot fishery retained/discard selectivity for size-class i,
S = a general term used for spawning biomass,
S-R = stock – recruitment,
W_i^s = mean weight of crabs of sex *s* in a size-class i,
y_t = retained yield of legal-sized male in year t,
x = a random variable representing the annual growth increment,
$Z_{i,t}^s$ = instantaneous total mortality of sex s, size-class i, and year t,
τ_i = mid size of a providing size-class i for $P_{i,j}^s$ estimation,
ε_t = overall recruitment error,
σ_ε = standard deviation of overall recruitment error,
e_t = interannual variability of recruitment error
σ_e = standard deviation of the interannual variability of recruitment error,
ρ = temporal correlation parameter,
δ = duration of average fishing period as a fraction of a year (handling and fishing mortalities occur during this time period),
ϕ, ω = growth increment model parameters,
α_r , β_r = recruitment distribution model parameters, and
$\kappa, \eta, \gamma, \theta$ = parameters in the stock-recruitment models.

A.2 Model equations for Bristol Bay red king and Tanner crabs

An age-sex-size-based model was used in all simulations.

The following assumptions were made to simplify the derivation in the analyses:

a) M is constant;

b) Timing of events: molting and mating of primiparous females (first time spawners) on 15 February, molting of males on 1 April; and molting and mating of multiparous females (previously spawned spawners) on 1 May;

c) Initial recruits to simulation models have a 1:1 sex ratio.

The population dynamics model:

The abundance of different stages and shell conditions of crabs of sex *s* (in number) and age k (last age is plus group) growing from smaller size classes i into a larger size class j at the start of year t+1 is,

when k = 0, $\text{immat}N_{j,0,t+1}^s = (R_{0,t} / 2) \times P_j^{s*}$ (B.1)

($R_{0,t}$ is first set to R_{max} to build the age structure; thereafter, it is set to an $R_{0,t}$ value generated by the S-R model.)

when $1 \le k <$ maximum age,

$$matN^{s}_{j,k,t+1} = \sum_{i=1}^{j} \begin{matrix}[(matN^{s}_{i,k-1,t} + matO^{s}_{i,k-1,t})\ mmolt^{s}_{i}\ P^{s}_{i,j} + \\ (immatN^{s}_{i,k-1,t} + immatO^{s}_{i,k-1,t})\ immolt^{s}_{i}\ mat^{s}_{j}\ P^{s}_{i,j}\end{matrix}]\, e^{-Z^{s}_{i,t}}$$

(B.2)

where $Z^{s}_{i,t} = M + F_T\, s'_i + (F_t\, s_i + HM^{s}_{i,t})\, \delta$ for males and $Z^{s}_{i,t} = M + F_T\, s'_i + HM^{s}_{i,t}\, \delta$ for females. F_t is determined by the MSY or target control rule.

$$matO^{s}_{j,k,t+1} = \sum_{i=1}^{j} [(matN^{s}_{i,k-1,t} + matO^{s}_{i,k-1,t})(1 - mmolt^{s}_{i})]\, e^{-Z^{s}_{i,t}} \quad (B.3)$$

$$immatN^{s}_{j,k,t+1} = \sum_{i=1}^{j} [(immatN^{s}_{i,k-1,t} + immatO^{s}_{i,k-1,t})\ immolt^{s}_{i}\,(1 - mat^{s}_{j}) P^{s}_{i,j}]\, e^{-Z^{s}_{i,t}} \quad (B.4)$$

$$immatO^{s}_{j,k,t+1} = \sum_{i=1}^{j} [(immatN^{s}_{i,k-1,t} + immatO^{s}_{i,k-1,t})(1 - immolt^{s}_{i})]\, e^{-Z^{s}_{i,t}} \quad (B.5)$$

The size specific abundances in numbers are converted to biomasses by multiplying them by size specific weights. Total mature male biomass (B) for S-R is calculated by projecting the abundances from molting time (April 1) to February 15.

The total mature male biomass-per-recruit is calculated as

B/R = mature male biomass/ number of male recruits (B.6)

Stochastic S-R models and steepness parameter

$$R_{0,t} = \frac{B_t}{\kappa + \eta B_t} e^{\varepsilon_t - \sigma^2_{\varepsilon}/2} \quad \text{(Beverton-Holt, 1957)}$$

The η parameter in the S-R model was re-parameterized in terms of R_{max} for fitting purpose,

$$R_{0,t} = \frac{B_t}{\kappa + B_t / R_{max}} e^{\varepsilon_t - \sigma^2_{\varepsilon}/2} \tag{B.7}$$

$$R_{0,t} = \gamma\, B_t\, e^{-\theta B_t} e^{\varepsilon_t - \sigma^2_{\varepsilon}/2} \quad \text{(Ricker, 1954)}$$

The θ parameter in the S-R model was re-parameterized in terms of R_{max} for fitting purpose,

$$R_{0,t} = \gamma\, B_t\, e^{-(\gamma \exp(-1) / R_{max})\, B_t}\, e^{\varepsilon_t - \sigma^2_{\varepsilon}/2} \tag{B.8}$$

where,

$\varepsilon_t = \rho * \varepsilon_{t-1} + e_t$ and $e_t \sim N(0, \sigma^2_e)$
(ρ is the autocorrelation)

Note: For $F_{x\%}$ estimation by the equilibrium method, the recruitment random errors were set to zero.

The S-R parameters of the two stock-recruitment models (B.7 and B.8) can be re-parameterized in terms of steepness parameter, *h*, and virgin spawning biomass-per-recruit (B_0/R_0) as:

$$\kappa = \frac{(1-h)}{4\,h} \times (B_0 / R_0) \qquad \text{(Beverton-Holt)}$$

$$\gamma = \frac{(5h)^{5/4}}{B_0 / R_0} \qquad \text{(Ricker)}$$

Where *h* is defined as:

$$h\, R_0 = f(0.2\, B_0) \tag{B.9}$$

and f () is a stock-recruitment function.

Note: We used independent estimates of R_{max} based on observed recruitment data to estimate η and θ in the original Beverton-Holt and Ricker S-R models for stochastic simulations.

For Akaike and Bayes information criteria statistics, maximum log likelihood values are needed (see Chapter 3). The likelihood (L) equations assuming log normal errors in S-R models are,

$$L = \prod \frac{1}{R_{0\,t}\ \sigma_\varepsilon \sqrt{2\pi}}\ e^{-\frac{[(\ln(R_{0,t}) - \ln(\hat{R}_{0,t})\ ]^2}{2\ \sigma_\varepsilon^2}} \qquad \text{(B.10)}$$

Where,

$$\ln(R_{0,t}) = \ln(\gamma) + \ln(B_t) - \gamma\ (e^{-1} / R_{\max})\ B_t - \sigma_\varepsilon^2\ /\ 2 + \varepsilon_t \quad \text{for the Ricker S-R model, and}$$

$$\ln(R_{0,t}) = \ln(B_t) - \ln(\kappa + B_t\ /\ R_{\max}) - \sigma_\varepsilon^2\ /\ 2 + \varepsilon_t \quad \text{for the Beverton-Holt S-R model.}$$

Retained catch:

$$c_t = \sum_{j = L_c, k} (N^s_{j,k,t} + O^s_{j,k,t})(\frac{F_t s_j}{Z^s_{j,t}})\ e^{-(M + F_T s'_j)\,et}(1 - e^{-Z^s_{j,t}\delta}) \qquad \text{(B.11)}$$

$$y_t = \sum_{j = L_c, k} (N^s_{j,k,t} + O^s_{j,k,t})(\frac{F_t s_j}{(Z^s_{j,t})})\,e^{-(M + F_T s'_j)\,et}(1 - e^{-Z^s_{j,t}\delta})\ W^s_j \qquad \text{(B.12)}$$

Total catch:

Discard catch was computed using the same equations (B.11 and B.12) replacing F s_j in the numerator by $HM^s_{i,t}$ (i.e., size specific handling mortality). Trawl bycatch was estimated similarly replacing F s_j by F_T s'_j. Retained, discard, and trawl bycatch were summed up to get the total catch.

Auxiliary Models:

1. The instantaneous handling mortality for sex *s* and size j, $HM^s_{j,t}$, is defined as a function of F_t with discard selectivity s_j, ignoring M and trawl and other bycatch mortality as follows:

$$1 - e^{-HM^s_{j,t}\,\delta} = hm\,(1 - e^{-F_t\ s_j\,\delta}) \qquad \text{(B.13)}$$

Where s_j = discard selectivity.

2. The molt probability for sex s and a given size class j is described by the function:

$$mmolt_j^s = 1 - \frac{1}{1 + e^{-a\,(j-b)}} \qquad \text{(if red king crab males)}$$

$$mmolt_j^s = 1 \qquad \text{(if immature snow and Tanner crabs)}$$

$$mmolt_j^s = 1 \qquad \text{(if red king crab females)} \qquad \text{(B.14)}$$

$$mmolt_j^s = 0 \qquad \text{(if mature snow and Tanner crabs)}$$

The maturity probability, retained selectivity, female discard selectivity, and trawl bycatch selectivity for a given size are described by the logistic function.

The male discard selectivity for a given size j is described by the double logistic function:

$$s_j = \frac{1}{1 + e^{-a\,(j-b)}} \frac{1}{1 + e^{c\,(j-d)}} \qquad \text{(B.15)}$$

3. The expected proportion of molting crabs of sex s ($P_{i,j}^s$) growing from size class i to size class j during a year is described by the gamma distribution as follows:

$$P_{i,j}^s = \frac{\int_{j_1-\tau_i}^{j_2-\tau_i} gamma(x / \phi_i, \omega) dx}{\sum_{j=1}^{n} \int_{j_1-\tau_i}^{j_2-\tau_i} gamma(x / \phi_i, \omega) dx} \qquad \text{(B.16)}$$

where

$$gamma(x / \phi_i, \omega) = \frac{x^{\phi_i - 1} e^{-\frac{x}{\omega}}}{\omega^{\phi_i} \Gamma(\phi_i)}$$

and where x is the growth increment per molt, ϕ_i is the expected growth increment of size interval i divided by the shape parameter ω, j_1 and j_2 are lower and upper limits of the receiving size interval j, τ_i is the mid-point of the contributing size interval i, and n is the total number of receiving size intervals. The summation in the denominator is a normalizing factor for the discrete gamma function.

The expected proportion of recruits of sex s falling in size class i (P_i^{s*}) is described by similar gamma distribution as follows:

$$P_i^{s*} = \frac{\int_{i_1}^{i_2} gamma(x/\alpha_r,\beta_r)dx}{\sum_{i=1}^{n}\int_{i_1}^{i_2} gamma(x/\alpha_r,\beta_r)dx} \qquad \text{(B.17)}$$

where x is the size, α_r and β_r are parameters, i_1 and i_2 are lower and upper limits of the receiving size interval i, and n is the total number of receiving size intervals.

4. Standard size-weight relationship ($W_j^s = a\ L_J^{S\,b}$) was used to determine weight (W_j^s) by size (L_j^s).

A.3 Model equations for Bering Sea snow crab

Model equations were the same as for red king and Tanner crab except that fishery selectivity curves for discard and retained catch were estimated from the stock assessment model for each assumed mortality of discarded catch. Retained catch and discarded catch were estimated as in equations B.11 and B.12 above with the appropriate fishery selectivities. The complete set of parameter values from the stock assessment model with the assumed mortality of discarded crab was used in the simulation projections using the same discard mortality.

Appendix B. Base parameters of red king crab for simulations.

CL=carapace length. Molt probability, growth matrix, recruit proportion in each length bin, retained and discards selectivity values were directly used from the length-based model outputs.

Parameter	Male	Female	Remarks
Size range (mm CL)	65-200	65-165	
Instantaneous M	0.18	0.18	Based on 26-year longevity with 1% survival at maximum age
Pot fishery handling mortality rate (hm)	0.1, 0.2[a], 0.3	0.1, 0.2[a], 0.3	[a]Kruse et al. 2000; Model estimate of discard selectivity with M=0.18 using 1985-2006 data
Trawl fishery bycatch death proportion	0.8	0.8	Model estimate of trawl selectivity with M=0.18 using 1985-2006 data
Mean fishing period (yr)	0.2534	0.2534	October 15 – January 15 fishing
Lapsed time (yr)	0.5425	0.5425	Molt time (Apr 1) to start of fishery (Oct 15)
Growth increment: a, b	17.542, -0.016	16.7, -0.098	Zheng (unpublished data)
Maturity Probability: a, b	0.5, 120.0	0.287, 89.0	Estimates from Otto's unpublished data
Molt Probability: a, b	[a] Model output	100% molt[b]	[a]Model estimates with M=0.18 using 1985-2006 data; [b]Zheng et al.1995a
Recruit distribution	Model output	Model output	Model estimates with M=0.18 using 1985-2004 data
Pot selectivity	Retained; Discard	Discard	Model estimates with M=0.18 using 1985-2004 data
Weight length model: a, b	0.000361, 3.16[a]	0.022863, 2.23382[b]	[a]Balsiger 1974; [b] Brad Stevens, personal communication (unpublished)

Appendix C. Base parameters of Bristol Bay Tanner crab for simulations.

CW=carapace width

Parameter	Male	Female	Remarks
Size range (mm CW)	70-170	70-170	
Instantaneous M	0.23	0.29	Based on 20-year and 16-year longevity with 1% survival at maximum age
Pot fishery handling mortality rate (hm)	0.20	0.20	Applicable to sub-legal
Instantaneous bycatch mortality in the trawl fishery	0.02	0.02	Applicable to all sizes, Siddeek 2002
Mean fishing period (yr)	0.3356	0.3356	October 15 – arbitrary cut off fishing date, February 14
Lapsed time (yr)	0.5425	0.5425	Molt time (Apr 1) to start of fishery (Oct 15)
Growth increment: a, b	15.75, 0.07	25.6, -0.1337	Zheng and Kruse 1999
Maturity Probability: a, b	0.07754, 130.854	0.126, 83.51	Zheng, unpublished
Molt Probability:			
Immature	100% molt	100% molt	
Mature	0%	0%	
Recruit Distribution	mean 82.5 mm, β_r = 1.023	mean 80.7 mm, β_r = 0.955	Recruit proportion Gamma distribution, β_r from Zheng and Kruse 1999
Pot Selectivity:	new-shell, old-shell	Combined new- & old-shell	Size-specific selectivity values from Zheng and Kruse 1999
Weight-carapace width model: a, b	0.00019, 3.09894	0.003661, 2.563912	Somerton 1981; Brad Stevens, personal communication (unpublished)

Male Maturity Probabilities for Tanner Crab

In many majid (true) crabs, it has been hypothesized that the maturity molt is the last or terminal molt (Hartnoll 1963). Maturity is often assessed with morphometric data. For males, morphometrically mature crabs are distinguished from morphometrically immature crabs by an increase in chela height for a given CW (Somerton 1980; Conan and Comeau 1986). For females, a prominent increase in the width of the abdomen indicates sexual maturity (Somerton 1981). It is commonly accepted that female Tanner and snow crabs undergo a terminal molt at maturity.

The terminal molt assumption for male snow crab has been well accepted for Atlantic stocks (e.g., Conan and Comeau 1986; Jamieson et al., 1988; Saint-Marie et al. 1995). Although evidence exists that some tagged mature male snow crab molted in Conception Bay, Newfoundland (Dawe et al. 1991), molting rates were probably very low and the terminal molt assumption was practically accepted (Earl Dawe, Department of Fisheries and Oceans, St. John's, Newfoundland, Canada, pers. comm.).

For Tanner crab in Alaska, some studies support terminal molt for males (Tamone et al. 2005), and data from some other studies contradict it (Donaldson and Johnson 1988; Paul and Paul 1995). Because of Tamone's study, terminal molt for male Tanner crab is accepted for this analysis. However, this analysis also attempts to reconcile the survey data with the terminal molt assumption in stock assessments and harvest strategy evaluation.

Tanner crab chela height data have been collected during the NMFS EBS trawl survey since 1990. These data can be used to estimate male maturity probability. Table C-1 shows proportions of immature males within newshell crab from 1990 to 1997 based on the chela height data. If maturity probability is equal to 1 minus proportion of immature males within newshell crab, then only a very small proportion of males can grow to legal size of 138 mm or larger. It is difficult to explain where the legal males come from during the 1970s, late 1980s and early 1990s for EBS Tanner crab. However, these maturity probabilities can be used to explain the survey data during the early and mid 1980s and after 1995.

The consequence for this approach is that a large amount of mature males are not available for fishing and that estimated F_{MSY} is extremely high. Considering these problems with terminal molt and the real data, the analyst conducted two analyses, called option 1 and option 2. Option 1 used the chela height data from 1990 to 1993 (high proportions of immature males) and assumed all immature oldshell males as immature newshell males to estimate maturity probabilities for male Tanner crab. Estimated F_{MSY} from option 1 is still very high, and these probabilities may still be difficult to explain where legal males come from.

For option 2, the analyst ignored the chela height data and assumed that the average of three levels of estimated molting probabilities for newshell males from 1975 to 1994 (Zheng et al. 1998) as maturity probabilities because molting probabilities for oldshell crab were estimated to be close to zero in the model. Molting probabilities during the 1970s and late 1980s were estimated to be higher than those during the other years (Zheng et al. 1998). Option 2 was used as a base scenario for simulation studies to estimate F_{MSY}. Options 1 and 2 are compared with estimated proportions of maturity by Dr. Otto of Kodiak Lab of Alaska Fisheries Science Center from data in the early 1990s, which are used for the current overfishing definitions, in Table C-2. The estimated proportions of maturity by Dr. Otto includes crabs of all shell condition and should be higher than maturity probabilities for a given size. The fraction of new shell crab which are mature in the survey data should be an estimate of the probability of new shell crab maturing with the terminal molt. However the survey estimates are affected by errors in shell condition as a proxy for shell age and the reliability of chela height measurements to determine maturity.

Table C-1 Proportions of immature males within newshell Tanner crab from 1990 to 1997

Year/Width	90	91	92	93	94	95	96	97
95.5	0.84	0.85	0.68	0.47	0.16	0.54	0.76	0.67
100.5	0.81	0.88	0.77	0.82	0.31	0.40	0.65	0.74
105.5	0.63	0.75	0.69	0.64	0.89	0.37	0.29	0.78
110.5	0.55	0.83	0.52	0.80	0.38	0.23	0.37	0.50
115.5	0.50	0.75	0.67	0.76	0.08	0.11	0.34	0.39
120.5	0.33	0.56	0.39	0.69	0.18	0.17	0.00	0.14
125.5	0.31	0.52	0.35	0.70	0.18	0.00	0.00	0.00
130.5	0.30	0.34	0.17	0.44	0.03	0.00	0.00	0.00
135.5	0.41	0.15	0.59	0.34	0.23	0.00	0.00	0.00
140.5	0.13	0.04	0.25	0.00	0.00	0.00	0.00	0.00
145.5	0.10	0.02	0.00	0.09	0.00	0.00	0.00	0.00
150.5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
155.5	0.00	0.03	0.00	0.00	0.00	0.00	0.00	0.00
160.5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
165.5	0.00	0.04	0.00	0.00	0.00	0.00	0.00	0.00

If male terminal molt at maturity assumption is correct, then one has to question the chela height and shell condition data. Indeed, crabs were not randomly sampled for chela height measurement. Old-shell crabs tend to be sampled more than new-shell crab. However, separating new-shell and old-shell crab, as shown in Table C-2, can overcome this sampling bias. Shell conditions can be a problem. If a high proportion of old-shell crab were misclassified as new-shell, the estimated maturity probability could be higher than the true values because higher proportions of old-shell crab than those of new-shell crab are mature. However, unlike snow crab, old-shell Tanner crabs were abundant in the survey data (Table C-3) Indeed, in some years there were hardly any new-shell male crab >110 mm. So it is difficult to completely blame shell aging errors for this problem.

The current stock assessment model for Bristol Bay Tanner crab does not separate immature and mature males (Zheng et al. 1998). Based on the survey data, the molting probability declines sharply in the model after males become old-shell (about 0 to 10%). In the future development of spatial model for EBSTanner crab, maturity probabilities for male crab will need to be closely examined.

Table C-2 Estimated maturity probabilities (options 1 and 2) and estimate proportions of mature males at size (Otto) for eastern Bering Sea Tanner crab

Width	Option 1	Option 2	Otto
95.5	0.12	0.06	0.527
100.5	0.17	0.08	0.588
105.5	0.23	0.12	0.647
110.5	0.30	0.17	0.701
115.5	0.39	0.24	0.750
120.5	0.49	0.31	0.794
125.5	0.59	0.40	0.832
130.5	0.68	0.49	0.863
135.5	0.76	0.59	0.890
140.5	0.82	0.67	0.912
145.5	0.87	0.75	0.930
150.5	0.91	0.82	0.945
155.5	0.94	0.87	0.956
160.5	0.96	0.91	0.966
165.5	0.97	0.94	0.973

Table C-3 Proportions of old-shell male crab for eastern Bering Sea Tanner crab from the NMFS EBS trawl survey

Year/Width	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**
95.5	0.19	0.26	0.33	0.41	0.62	0.71	0.39	0.23
100.5	0.17	0.29	0.22	0.54	0.79	0.88	0.38	0.23
105.5	0.23	0.25	0.30	0.53	0.68	0.84	0.65	0.36
110.5	0.39	0.34	0.27	0.47	0.65	0.90	0.86	0.46
115.5	0.31	0.36	0.32	0.48	0.73	0.93	0.94	0.54
120.5	0.33	0.35	0.33	0.50	0.73	0.97	0.98	0.65
125.5	0.37	0.36	0.30	0.42	0.84	0.97	0.98	0.73
130.5	0.32	0.36	0.41	0.48	0.79	0.96	1.00	0.89
135.5	0.31	0.46	0.45	0.54	0.79	0.96	1.00	0.91
140.5	0.24	0.36	0.30	0.39	0.72	0.92	0.99	0.97
145.5	0.16	0.30	0.21	0.34	0.52	0.87	0.98	1.00
150.5	0.13	0.28	0.13	0.18	0.31	0.87	0.94	0.92
155.5	0.09	0.30	0.12	0.06	0.33	0.86	0.93	1.00
160.5	0.05	0.27	0.27	0.14	0.22	0.84	1.00	1.00
165.5	0.04	0.16	0.28	0.07	0.11	0.79	0.89	1.00

Appendix D. Base parameters of snow crab for simulations.

Parameters for Bering Sea snow crab simulations. Fishery selectivity curves are for the 50% discard mortality model. CW=carapace width

Parameter	Male			Female
Size range (mm CW)	25-140			25-140
Natural Mortality	0.23			0.29
Trawl fishery bycatch discard mortality	0.8			0.8
Time lapsed from survey to fishery	0.625			0.625
Growth increment a,b (postmolt CW = a + b* premolt CW	a = 8.436, b = 1.128			a = 5.1, b = 1.07
Beta parameter for gamma growth distribution	0.75			0.75
Molting probability(terminal molt males and females)	Immature 100%, mature 0%			Immature 100%, mature 0%
Recruit distribution (parameters of the gamma distribution)	Alpha = 12.0, beta = 1.5			Alpha = 12.0, beta = 1.5
Directed fishery selectivity				
Retention curve* (slope, 50%)		Slope	50%	
	New	0.261666	95.76024	
	Old	0.297873	94.84013	
Total (slope, 50%)	New	0.194253	101.6297	
	Old	0.149547	118.2826	
Weight – carapace width a,b Wt = a * CW ^{b}	a=0.00000023 b=3.12948			Immature females a=0.00000253 b=2.56472 Mature females a=0.000675 b=2.943352

Harrington

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